# April 2021

1. (a) Sketch a section through a bilge injection (emergency bilge) valve. (8)

   (b) Describe how the valve sketched in part (a) is tested. (2)

# April 2021

2. Describe, with the aid of a sketch, the operation of a double acting, piston type positive displacement pump. (10)

# April 2021

3. (a) Sketch a relief valve suitable for use on the air side of a compressor. (7)

   (b) Explain how the valve sketched in part (a) is reset after overhaul. (3)

# April 2021

4. With reference to accumulators in pneumatic control systems:

   (a) state the TWO main purposes; (2)

   (b) explain why EACH of the purposes stated in part (a) are required. (8)

# April 2021

5. With reference to a hydraulic steering gear, describe TWO methods that may be used to prevent the idle pump from motoring. (10)

# April 2021

6. (a) Describe, with the aid of a sketch, a pilgrim nut. (5)

   (b) Explain how the pilgrim nut is used to ensure correct fitting of a keyless propeller. (5)

# April 2021

7. Sketch a shaft coupling of the flexible diaphragm type, labelling the MAIN components. (10)

# April 2021

8. Describe, with the aid of sketches, the fitting of a hydraulically tensioned bolt suitable for main propulsion shaft flanges. (10)

# April 2021

9. With reference to a.c. generators:

(a) explain why they must be synchronised before connecting in parallel; (6)

(b) list TWO devices for ensuring that synchronising is correct; (2)

(c) state how the devices listed in part (b) indicated that synchronising is correct. (2)

# April 2021

10. (a) State THREE devices fitted to the main breakers to protect a.c. generators that are able to run in parallel. (3)

(b) Explain why EACH device stated in part (a) is fitted. (7)

# April 2021

1. (a) Sketch a section through a bilge injection (emergency bilge) valve. (8)

   (b) Describe how the valve sketched in part (a) is tested. (2)

## Bilge Injection Valve Cross-Section and Testing

**(a) Bilge Injection Valve Cross-Section:**

A bilge injection valve allows seawater from a dedicated seawater source (often the main sea chest) to be pumped directly overboard in emergency situations. Here's a breakdown of its key components in a cross-section:

- **Valve Body:** The main housing, typically made of cast iron or steel, designed to withstand seawater pressure.
- **Inlet Port:** The connection point for the seawater supply line.
- **Outlet Port:** The connection point for the discharge line leading overboard.
- **Gate:** A movable disc or wedge-shaped element within the body that controls the flow path. The gate can be actuated by various mechanisms (manual lever, hydraulic piston, solenoid).
- **Seat:** The sealing surface within the body that the gate closes against to prevent seawater flow when the valve is shut.
- **Spindle:** The shaft connected to the gate, used for manual or actuated control of the gate's position.
- **Packing:** Sealing material around the spindle to prevent seawater leakage along the shaft.

**(b) Testing Bilge Injection Valves:**

Regular testing of bilge injection valves is crucial to ensure their functionality in emergencies. Here are some common testing procedures:

- **Operational Check:** This involves manually operating the valve through its full open-close cycle to verify smooth movement and proper closure of the gate against the seat. Listen for leaks and ensure the valve opens and closes completely.
- **Remote Activation Test (if applicable):** For valves with remote actuation (hydraulic, pneumatic, or solenoid), simulate an emergency scenario by activating the remote closing mechanism and verify the valve shuts down promptly. This test confirms the functionality of the entire actuation system.
- **Leakage Test:** With the valve closed, the system is pressurized on the inlet side to identify any leaks around the gate, packing, or body. Pressurized air or water (depending on system design) is used to detect leaks which could compromise the valve's ability to isolate the bilge from seawater in an emergency.
- **Visual Inspection:** The valve body, bonnet (if present), and accessible internal components are visually inspected for signs of wear, corrosion, or damage that could affect the valve's performance.

The specific testing frequency and procedures may vary depending on regulations, industry standards, and the specific application on the ship. Records of these tests are typically maintained for documentation and regulatory compliance purposes.

# April 2021

2. Describe, with the aid of a sketch, the operation of a double acting, piston type positive displacement pump. (10)

## Double-Acting Piston Pump Operation

A double-acting piston pump utilizes a reciprocating piston within a cylinder to create a positive displacement flow of fluid. Here's a breakdown of its operation:

**Components:**

- **Housing:** The main body of the pump, typically made of cast iron or steel for strength.
- **Cylinder:** A cylindrical chamber within the housing where the piston reciprocates.
- **Piston:** A tightly fitting cylindrical plunger that moves back and forth within the cylinder.
- **Piston Rod:** A rod connected to the piston, extending out of the cylinder to connect to the driving mechanism.
- **Inlet Valves:** One-way check valves located at each end of the cylinder, allowing fluid to enter but not flow back. These valves are typically located on the cylinder head and crankcase.
- **Outlet Valves:** One-way check valves located at each end of the cylinder, allowing fluid to exit but not flow back. These valves are typically located on the discharge manifold.
- **Discharge Manifold:** A chamber that collects the pressurized fluid from both sides of the piston and directs it out of the pump.
- **Driving Mechanism:** A crankshaft, connecting rod, or other mechanism that converts rotary motion into reciprocating motion for the piston rod.

**Operation:**

1. **Inlet Stroke:**
    - **Piston Movement:** The driving mechanism pushes the piston rod forward, causing the piston to move towards the opposite end of the cylinder.
    - **Inlet Valve Operation:** The inlet valve on the forward end of the cylinder (crankcase side) opens, allowing fluid to enter the chamber in front of the piston. The inlet valve on the opposite end (cylinder head side) remains closed due to the pressure of the existing fluid in that chamber.
    - **Suction Creation:** The movement of the piston creates a decreasing volume in the front chamber, generating a low-pressure zone. This low pressure draws fluid into the cylinder through the open inlet valve.
2. **Outlet Stroke:**
    - **Piston Movement:** The driving mechanism changes direction, pulling the piston rod back, causing the piston to move towards its original position.
    - **Outlet Valve Operation:** The inlet valve on the forward end of the cylinder closes as the pressure in that chamber increases. The outlet valve on the opposite end (cylinder head side) opens due to the pressure of the trapped fluid behind the piston exceeding the discharge pressure.
    - **Displacement and Discharge:** The movement of the piston back towards its original position reduces the volume in the chamber behind the piston. This pressurizes the

trapped fluid, forcing it to flow through the open outlet valve on the cylinder head side and into the discharge manifold.

3. **Continuous Flow:** The continuous back-and-forth motion of the piston creates a continuous flow of fluid into one side of the cylinder while simultaneously discharging pressurized fluid from the other side. The inlet and outlet valves ensure unidirectional flow during each stroke.

**Key Points:**

- **Double Acting:** The pump utilizes both the forward (inlet) and return (outlet) strokes of the piston to move fluid, resulting in a higher flow rate compared to single-acting piston pumps.
- **Positive Displacement:** The fixed volume between the piston and the cylinder ensures a constant amount of fluid is delivered with each cycle, regardless of the discharge pressure.
- **High-Pressure Capability:** Double-acting piston pumps can achieve high discharge pressures due to the balanced forces acting on the piston.

**Note:** This explanation provides a general overview of double-acting piston pump operation. Specific designs and functionalities may vary depending on the manufacturer and application. Some pumps might utilize different valve configurations or additional components for specific purposes.

2021

## April 2021

3. (a) Sketch a relief valve suitable for use on the air side of a compressor. (7)

   (b) Explain how the valve sketched in part (a) is reset after overhaul. (3)

**(a) Relief Valve for Air Compressor:**

A relief valve suitable for use on the air side of a compressor is typically a **pilot-operated pressure relief valve**. Here's a breakdown of its key features:

- **Function:** This valve automatically opens and releases compressed air when the pressure within the system exceeds a predetermined safe limit. This protects the compressor and downstream equipment from overpressure damage.
- **Components:**
    - **Main Valve:** The main valve assembly directly regulates the flow of compressed air. It opens when the pressure overcomes a spring force or a combination of spring and pilot pressure.
    - **Pilot Valve:** A smaller valve that senses the system pressure and controls the main valve indirectly. It often uses a diaphragm or piston to sense pressure.
    - **Spring:** Provides a pre-set force that opposes the system pressure acting on the main valve.
    - **Adjustment Mechanism:** Allows for setting the desired pressure relief level by adjusting the spring preload or pilot pressure.
- **Operation:** As the system pressure rises, it acts on the pilot valve. When the pressure reaches the set point, the pilot valve opens, relieving pressure from the top of the main valve

piston or diaphragm. The system pressure then overcomes the spring force, pushing the main valve open and releasing compressed air until the pressure falls below the set point. The pilot valve then closes, and the spring reseats the main valve, stopping the flow of air.

**(b) Resetting a Pilot-Operated Relief Valve After Overhaul:**

After the valve is disassembled, cleaned, and inspected during an overhaul, resetting it for proper operation involves the following steps:

1. **Reassemble the Valve:** Carefully reassemble the valve components according to the manufacturer's instructions. Ensure proper alignment of parts and proper tightening of all connections.
2. **Adjust the Spring Preload (Optional):** Some relief valves have an external adjustment mechanism for setting the spring preload, which determines the opening pressure. If the spring preload hasn't been changed during disassembly, it might not require adjustment. Consult the manufacturer's instructions for the specific valve model.
3. **Pilot Pressure Adjustment (Optional):** In some pilot-operated valves, the pilot pressure can be adjusted to influence the opening pressure. This adjustment might be done using an external screw or by adjusting the pilot valve spring tension. Again, consult the manufacturer's instructions for the specific model.
4. **Pressure Testing:** With the valve reinstalled in the system, conduct a pressure test using an external pressure source. Gradually increase the pressure and observe the relief valve operation. It should open at the desired set pressure and close once the pressure falls below the setpoint. This ensures the valve functions correctly after the overhaul.

**Important Note:** The specific steps for resetting a relief valve can vary depending on the manufacturer and model. Always refer to the manufacturer's instructions and service manuals for detailed procedures and safety precautions for your specific valve. It's crucial to ensure the valve is set to the correct pressure relief level for safe operation of the compressed air system.

2021

April 2021

4. With reference to accumulators in pneumatic control systems:

(a) state the TWO main purposes; (2)

(b) explain why EACH of the purposes stated in part (a) are required. (8)

## Accumulators in Pneumatic Control Systems

Accumulators play a vital role in pneumatic control systems by serving two key purposes:

**(a) Two Main Purposes:**

1. **Maintaining System Pressure:** Accumulators act as a reservoir to store compressed air, ensuring consistent pressure during peak demand periods when the compressor cannot keep up.
2. **Smoothing Pressure Fluctuations:** Accumulators help dampen pressure spikes and surges caused by rapid actuator operation or system cycling.

**(b) Importance of Each Purpose:**

1. **Maintaining System Pressure (Prevents Pressure Drops):**
- **Ensures Consistent Operation:** In applications requiring constant pressure for reliable operation (e.g., assembly lines, presses), pressure drops due to high demand can disrupt processes. Accumulators provide a buffer, maintaining pressure for smooth operation even when the compressor cycles on and off.
- **Protects Components:** Sudden pressure drops can stress components like valves and cylinders. Accumulators help mitigate these drops, reducing strain and extending component life.

2. **Smoothing Pressure Fluctuations (Prevents Erratic Behavior):**
- **Improves System Performance:** Pressure spikes caused by rapid actuator movement can lead to erratic system behavior or even damage components. Accumulators absorb these spikes, ensuring smoother operation and precise control.
- **Reduces Noise and Vibration:** Pressure fluctuations can generate noise and vibration. Accumulators dampen these fluctuations, creating a quieter and more stable operating environment.

By fulfilling these functions, accumulators contribute to a more reliable, efficient, and smoother operation of pneumatic control systems.

I 2021

## April 2021

5. With reference to a hydraulic steering gear, describe TWO methods that may be used to prevent the idle pump from motoring. (10)

Here are two methods used to prevent the idle pump from motoring in a hydraulic steering gear system:

**1. Pressure Relief Valve:**

- **Function:** A pressure relief valve is a mechanical safety device installed within the hydraulic circuit. It remains closed when the system pressure is below a preset threshold.
- **Operation:** As the hydraulic pump continuously pressurizes the fluid, the pressure builds up in the system. Once the pressure reaches the relief valve's setting, the valve opens.
- **Preventing Idle Pump Motoring:** When the steering gear is not in operation, and the rudder isn't being moved, the pressure in the system remains low. The pressure relief valve stays closed, allowing fluid to return to the reservoir through the bypass passage within the valve. This prevents the pump from unnecessarily churning fluid and wasting energy.
- **Benefits:** Simple and reliable method, easy to integrate into existing systems.
- **Drawbacks:** May lead to slight pressure fluctuations as the valve opens and closes, potentially affecting steering responsiveness.

**2. Load Sensing Pump:**

- **Function:** A load sensing pump is a more advanced type of hydraulic pump that adjusts its output flow based on the system's actual demand.

- **Operation:** The pump continuously monitors the system pressure through a sensor. When the pressure rises due to a demand for hydraulic power (e.g., moving the rudder), the pump automatically increases its flow rate to meet that demand.
- **Preventing Idle Pump Motoring:** When there's no demand for hydraulic power (rudder not moving), the system pressure remains low. The load sensing pump detects this low pressure and automatically reduces its flow to a minimum, or even stops completely in some designs. This eliminates unnecessary churning of fluid by the pump during idle periods.
- **Benefits:** More efficient operation, reduces energy consumption and heat generation in the system.
- **Drawbacks:** More complex and expensive compared to pressure relief valves. May require additional sensors and control systems.

**Choosing the Right Method:**

The selection between a pressure relief valve and a load sensing pump depends on several factors, including:

- **System Complexity:** For simpler systems, a pressure relief valve might be sufficient.
- **Performance Requirements:** If precise control and energy efficiency are crucial, a load sensing pump could be a better choice.
- **Cost Considerations:** Pressure relief valves are generally less expensive than load sensing pumps.

By implementing one of these methods, the hydraulic system ensures that the pump doesn't waste energy by motoring when the steering gear is not in use.

2021

April 2021

6. (a) Describe, with the aid of a sketch, a pilgrim nut. (5)

   (b) Explain how the pilgrim nut is used to ensure correct fitting of a keyless propeller. (5)

# Pilgrim Nut: Securing Keyless Propellers

**(a) Description of a Pilgrim Nut:**

A pilgrim nut is a specialized nut used in the marine industry for securely attaching keyless propellers, rudders, or other tapered components onto a shaft. It utilizes a hydraulically powered mechanism to achieve a precise and high-force fit.

Here are the key components of a pilgrim nut:

- **Body:** The main housing of the nut that contains the internal mechanism.
- **Screw Threads:** These threads are used to screw the pilgrim nut onto the shaft until it reaches the base of the propeller or fitting.
- **Loading Ring:** This ring sits within the body and is the key component for applying force.
- **Hydraulic Chamber:** This chamber is located behind the loading ring and can be pressurized with hydraulic fluid.

- **Piston (Optional):** Some designs may utilize a piston directly actuated by hydraulic pressure.

**(b) Ensuring Correct Fitting with a Pilgrim Nut:**

Here's how a pilgrim nut is used to ensure a secure and precise fit for a keyless propeller on a tapered shaft:

1. **Preparation:** The propeller and shaft are thoroughly cleaned and inspected for any irregularities.
2. **Positioning:** The pilgrim nut is screwed onto the shaft threads until the loading ring makes contact with the base of the propeller.
3. **Hydraulic Pressure Application:** Hydraulic fluid is pumped into the chamber behind the loading ring. This pressurizes the chamber and creates a force against the loading ring.
4. **Force Transmission:** The pressurized fluid pushes the loading ring outwards. This, in turn, pushes the propeller further up the tapered shaft, achieving a tight and secure fit.
5. **Pressure Monitoring and Advance Measurement:** The hydraulic pressure applied and the actual travel (advance) of the propeller along the taper are carefully monitored and compared to predetermined values. This ensures the propeller reaches the correct position for optimal performance and safety.
6. **Pressure Release and Locking (Optional):** Once the desired pressure and advance are achieved, the hydraulic pressure may be released. In some designs, a locking mechanism might be engaged to prevent the nut from loosening due to vibration or propeller thrust.

**Advantages of Pilgrim Nuts:**

- **High Clamping Force:** Pilgrim nuts provide a very high clamping force, ensuring a secure and reliable fit between the propeller and the shaft.
- **Precise Control:** The use of hydraulic pressure allows for precise control over the force applied and the resulting position of the propeller on the taper.
- **Repeatability:** The use of pressure gauges and predetermined values ensures consistent and repeatable results during propeller installation.
- **Keyless Design:** Eliminates the need for a keyway on the shaft and propeller, simplifying manufacturing and reducing potential stress concentrations.

**Overall, pilgrim nuts play a crucial role in ensuring the safe and reliable operation of propellers on vessels by providing a strong and precise connection between the propeller and the shaft.**

I 2021

April 2021

7. Sketch a shaft coupling of the flexible diaphragm type, labelling the MAIN components. (10)

## Flexible Diaphragm Coupling: Main Components

A flexible diaphragm coupling is a type of shaft coupling that utilizes a thin, elastic diaphragm to transmit torque between two shafts while accommodating some degree of misalignment. Here are the main components of a flexible diaphragm coupling:

**1. Flanges:**

- The coupling consists of two metallic flanges, each securely attached to one of the shafts that need to be connected.
- These flanges typically have machined features like hubs or bores for connecting to the shafts and may have drilled holes for bolting the two halves of the coupling together.

**2. Diaphragm:**

- The core of the coupling is a flexible diaphragm, typically made from high-strength alloy steel.
- This diaphragm is a thin plate, often formed into a specific shape (wavy, corrugated) to provide flexibility while maintaining strength.
- The diaphragm is attached to the outer diameter of one flange and the inner diameter of the other flange.

**3. Fasteners:**

- Bolts and nuts are used to securely fasten the two halves of the coupling together, clamping the diaphragm between the flanges.

**Optional Components:**

- **Sealing elements:** In some designs, sealing elements might be incorporated between the diaphragm and the flanges to prevent lubricant leakage or contamination ingress.
- **Spacer elements:** In some cases, spacer elements might be used between the flanges to adjust the overall length of the coupling or to provide a specific axial separation between the shafts.

**How it Works:**

When the shafts rotate, the torque is transmitted from one flange to the other through the deflection of the diaphragm. The flexible nature of the diaphragm allows it to absorb some degree of misalignment between the shafts, including:

- **Angular misalignment:** This occurs when the shafts are not perfectly aligned along the same axis.
- **Parallel misalignment:** This occurs when the shafts are not perfectly parallel but slightly offset.
- **Axial misalignment:** This occurs when there is a slight axial (end-to-end) movement between the shafts.

**Advantages of Flexible Diaphragm Couplings:**

- Compact design
- Simple construction
- Easy to install and maintain
- Accommodates some misalignment

- Low maintenance requirements

**Disadvantages of Flexible Diaphragm Couplings:**

- Lower torque capacity compared to some other coupling types
- Limited speed capability
- Not suitable for applications with large misalignment

**Applications:**

Flexible diaphragm couplings are commonly used in various industrial applications where a compact, low-maintenance solution is needed to connect shafts and accommodate some degree of misalignment. These applications can include:

- Pumps
- Fans
- Blowers
- Gearboxes
- Conveyors
- Printing machinery

ril 2021

# April 2021

8. Describe, with the aid of sketches, the fitting of a hydraulically tensioned bolt suitable for main propulsion shaft flanges. (10)

Here's a breakdown of the process for fitting a hydraulically tensioned bolt suitable for main propulsion shaft flanges:

**Preparation:**

1. **Lockout/Tagout:** Implement proper lockout/tagout procedures to isolate the shaft and ensure safety before starting the fitting process.
2. **Cleaning:** Thoroughly clean the flange surfaces and the threads of the bolt to remove any dirt, oil, or debris that could affect the tightening process or compromise the joint integrity.
3. **Lubrication:** Apply a thin coat of a lubricant specified by the manufacturer to the threads of the bolt. This reduces friction during tightening and ensures proper bolt load is achieved.

**Bolt Installation:**

1. **Screw the Bolt In:** Manually screw the hydraulically tensioned bolt into the threaded hole in the flange until finger tight. Ensure the bolt engages with the threads properly and isn't cross-threaded.

**Hydraulic Tensioning Process:**

1. **Hydraulic Nut and Pump:** The hydraulically tensioned bolt will have a special nut designed to work with a hydraulic tensioning pump. Attach the hydraulic nut to the bolt on the flange.

2. **Pressure Gauge and Calibration:** Connect the hydraulic pump to the hydraulic nut via a high-pressure hose. The pump will have a pressure gauge to monitor the applied tension. Ensure the pressure gauge is calibrated to ensure accurate readings.
3. **Tensioning Procedure:** Follow the manufacturer's instructions for the specific hydraulic tensioning system. This will typically involve slowly increasing the hydraulic pressure applied to the nut.
4. **Target Load:** As the pressure increases, the bolt stretches, applying a specific tension (load) to the flange joint. The target load will be specified by the manufacturer based on the bolt size, material, and the flange design. This target load is typically achieved at a specific pressure value on the gauge.
5. **Holding the Load:** Once the target pressure/load is reached, the hydraulic pump will typically have a mechanism to hold the pressure, maintaining the tension on the bolt.

**Verification and Completion:**

1. **Verification of Load:** After holding the load for a specified time (as per manufacturer's instructions), some systems might require a verification step to ensure the load hasn't bled off. This might involve checking the pressure gauge again or using a separate load verification tool.
2. **Locking the Nut (Optional):** Depending on the specific design, some hydraulic tensioning systems might incorporate a mechanical locking mechanism on the nut to prevent relaxation of the tension over time.
3. **Repeat for All Bolts:** Following the same procedure, tighten all the remaining hydraulically tensioned bolts around the flange to achieve the specified target load.

**Additional Considerations:**

- **Tightening Sequence:** The manufacturer's instructions might specify a specific tightening sequence for the bolts around the flange to ensure even load distribution.
- **Torque Verification (Optional):** While hydraulic tensioning achieves the desired load on the bolt, in some cases, a final torque verification check using a calibrated torque wrench might be performed for additional assurance.
- **Safety Precautions:** Hydraulic tensioning systems operate at high pressures. Always wear appropriate personal protective equipment (PPE) and follow the manufacturer's safety instructions for the specific equipment being used.

By following these steps and adhering to the manufacturer's recommendations, you can ensure the proper fitting and tensioning of hydraulically tensioned bolts for critical applications like main propulsion shaft flanges. This ensures a secure and reliable connection for optimal performance and safety.

# April 2021

9. With reference to a.c. generators:

   (a) explain why they must be synchronised before connecting in parallel; (6)

   (b) list TWO devices for ensuring that synchronising is correct; (2)

   (c) state how the devices listed in part (b) indicated that synchronising is correct. (2)

## Synchronizing AC Generators for Parallel Operation

**(a) Importance of Synchronization:**

AC generators must be synchronized before connecting them in parallel for several crucial reasons:

- **Frequency Matching:** Generators need to be operating at the same frequency to avoid damaging currents flowing between them. If the frequencies differ, the generators will try to "fight" each other, causing unstable voltage and current fluctuations that can damage the generators and connected equipment.
- **Voltage Matching:** The voltage output of each generator needs to be the same magnitude and in phase to ensure smooth power sharing when connected in parallel. Unequal voltages can lead to circulating currents between the generators, causing inefficiency and potential overheating.
- **Phase Sequence Matching:** Three-phase generators also require matching phase sequences. This ensures that the peaks and troughs of the AC voltage waveforms from each generator coincide, preventing destructive interference within the combined system.

Connecting unsynchronized generators can lead to:

- **Large circulating currents:** These currents can damage windings, bearings, and other components in the generators.
- **Voltage and frequency instability:** This can disrupt power quality and damage connected equipment.
- **Potential equipment failure:** Severe cases of unsynchronized operation can lead to complete generator failure.

**(b) Devices for Ensuring Correct Synchronization:**

Two primary devices are used to ensure proper synchronization before connecting AC generators in parallel:

1. **Synchronizing Lamps (Synch Lamps):** These lamps are connected between corresponding phases of the generators being synchronized. As the voltage and frequency approach synchronization, the lamps will flicker at a decreasing rate. When the lamps reach a steady illumination, it indicates the generators are in phase and ready for paralleling.
2. **Synchroscope:** This is a more advanced instrument that provides a visual representation of the phase difference between the generators. It displays a rotating pointer and a stationary

scale. When the pointer aligns with a specific mark on the scale (typically zero), it signifies that the generators are in phase and ready for paralleling.

**(c) Indications of Correct Synchronization:**

The devices listed in part (b) indicate correct synchronization using the following observations:

- **Synchronizing Lamps:** When the lamps achieve a **steady illumination**, without flickering, it indicates that the voltage and frequency of the generators are matched and in phase.
- **Synchroscope:** When the **rotating pointer on the synchroscope aligns with the designated mark** (usually zero) on the stationary scale, it signifies that the phase difference between the generators is zero, and they are synchronized for paralleling.

By utilizing these devices and observing the proper indications, operators can ensure safe and reliable parallel operation of AC generators.

ril 2021

April 2021

10. (a) State THREE devices fitted to the main breakers to protect a.c. generators that are able to run in parallel. (3)

(b) Explain why EACH device stated in part (a) is fitted. (7)

## (a) Three Devices for Protecting Parallel A.C. Generators:

1. **Overcurrent Protection Device (OCPD):** This can be a circuit breaker or a combination of fuses and relays.
2. **Under-voltage Protection Relay:**
3. **Reverse Power Protection Relay:**

## (b) Explanation for Each Device:

**1. Overcurrent Protection Device (OCPD):**

- **Function:** The OCPD protects the generator from damage caused by excessive current flowing through its windings. This can occur due to internal faults within the generator itself or overloading on the distribution system.
- **Importance in Parallel Operation:** When multiple generators are operating in parallel, a fault in one generator can cause a surge in current through the healthy generators. The OCPD in each parallel generator will trip, isolating the faulty unit and protecting the remaining generators from damage.

**2. Under-voltage Protection Relay:**

- **Function:** This relay monitors the generator's output voltage. If the voltage falls below a preset threshold, the relay trips the generator breaker, disconnecting it from the parallel operation.
- **Importance in Parallel Operation:** A sudden drop in voltage from one generator can disrupt the synchronization and stability of the parallel system. The under-voltage protection relay ensures that a faulty generator with low voltage output is automatically disconnected, preventing it from affecting the entire parallel system.

**3. Reverse Power Protection Relay:**

- **Function:** This relay monitors the direction of power flow in the generator. In a healthy parallel operation, the generator should be supplying power to the distribution system. The reverse power protection relay trips the generator breaker if it detects power flowing back into the generator, indicating a potential problem.
- **Importance in Parallel Operation:** A generator experiencing internal issues or a failed governor might start motoring and drawing power from the system instead of supplying it. The reverse power protection relay detects this abnormal condition and disconnects the faulty generator, preventing it from overloading the other generators in the parallel system.

These three devices work together to ensure the safe and reliable operation of parallel AC generators. They protect individual generators from internal faults and overloading, maintain system stability by preventing issues with voltage and power flow, and ultimately contribute to the overall protection of the entire parallel generation system.