

Probes thermistors sensors

July 2021

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- (a) explain the principle of operation by which it is able to give a temperature measurement; (3)
 - (b) describe how the sensing element is constructed, explaining why it is called a PT100 probe; (4)
 - (c) explain why these probes typically have three or four wires to connect them to the temperature indicating device. (3)

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(a) Temperature Measurement through Resistance:

Think of a PT100 probe as a miniature conductor whose electrical resistance changes precisely with temperature. This principle, known as resistive temperature detection (RTD), forms the core of its operation. Here's how it works:

1. **Platinum Magic:** The sensing element inside the probe is made of pure platinum, chosen for its remarkably linear and predictable relationship between temperature and resistance. As the temperature increases, the platinum atoms vibrate more, disrupting the orderly flow of electrons, thereby increasing the resistance.

2. **Measuring the Change:** An external device connected to the probe measures the resistance of the platinum element. This measured resistance directly corresponds to the temperature within the probe through the platinum's inherent temperature-resistance characteristic.
3. **Conversion to Temperature:** Finally, the measuring device utilizes this resistance value and converts it into a temperature reading using pre-programmed calibration equations specific to Pt100 probes.

This simple yet precise method allows PT100 probes to measure temperatures accurately and reliably across a wide range.

(b) Construction of the Sensing Element: The "PT" in PT100:

The heart of the PT100 probe lies in its sensing element, often a thin coil of pure platinum wire wrapped around a ceramic core. This construction offers several advantages:

- **High Purity:** Pure platinum ensures consistent and predictable temperature-resistance behavior, crucial for accurate measurements.
- **Compactness:** The coiled wire design creates a small and sensitive element, allowing for quick thermal response and versatility in placement.
- **Durability:** The ceramic core provides mechanical support and protects the delicate platinum wire from physical damage.

Now, the "PT" in PT100 stands for "Platinum," and the "100" signifies the nominal resistance of the element at 0°C, which in this case is 100 ohms. This standard naming convention allows for easy identification and interchangeability of these probes.

(c) The Mystery of the Wires: Three or Four?

While two wires might seem sufficient to carry the current and measure the resistance, PT100 probes typically have three or four wires. Here's why:

- **Three-Wire Configuration:** This setup uses three wires, one each for supplying current, measuring voltage across the element, and compensating for lead resistance. The lead resistance can introduce errors, and the third wire effectively cancels it out for accurate temperature readings.
- **Four-Wire Configuration:** This offers enhanced precision, especially for long lead lengths. Four wires are used, two for providing current and two for measuring voltage, completely eliminating the influence of lead resistance on the measurement.

The choice between three and four wires depends on the required accuracy, lead length, and cost considerations. In most cases, three-wire probes offer sufficient accuracy for common applications.

Nov 2022

7. (a) Explain, with the aid of a sketch, the design and operation of a thermocouple. (8)
- (b) State ONE limitation of the thermocouple, stating how this is overcome in practice. (2)
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(a) Thermocouple Design and Operation:

Imagine two dissimilar metals joined at one end, forming a junction. This is the heart of a thermocouple, a simple yet powerful tool for measuring temperature. Here's how it works:

Sketch:

- Hot Junction: The two metals are joined at the tip, placed where you want to measure the temperature. This junction acts as the "sensor."
- Dissimilar Metals: Each metal has its unique "voltage curve," representing its relationship between temperature and electrical potential.
- Temperature Difference: When the hot junction experiences a temperature change, the voltage difference between the two metals at the junction also changes.
- Voltage Measurement: The two metals then lead to a measuring device, which detects this tiny voltage change.
- Calibration and Conversion: Using pre-programmed equations specific to the chosen metal pair, the device converts the voltage change into a temperature reading.

Key Points:

- The choice of metal pair determines the temperature range and sensitivity of the thermocouple.
- Thermocouples are relatively inexpensive and robust, making them widely used in various applications.

(b) Overcoming a Limitation: Reference Junction and Compensation:

Thermocouples have one key limitation: their output depends not only on the hot junction temperature but also on the temperature of the connection point where the two metals meet the measuring device (called the reference junction). Any fluctuations in the reference junction temperature can introduce errors in the measurement.

To overcome this, practical thermocouples employ a reference junction compensation technique:

- Reference Junction Sensor: Another thermocouple or a temperature sensor is placed at the reference junction to monitor its temperature.
- Temperature Correction: The measuring device factors in the reference junction temperature, effectively "subtracting" its influence from the hot junction voltage reading, resulting in an accurate temperature value.

This compensation method allows thermocouples to deliver reliable temperature measurements regardless of fluctuations at the reference junction, making them versatile and dependable tools for various industrial and scientific applications.

Remember, thermocouple technology, despite its simplicity, relies on the precise relationship between temperature and voltage changes in dissimilar metals. Choosing the right metal pair, employing proper reference junction compensation, and utilizing calibration for accuracy are crucial aspects of effectively harnessing the power of thermocouples.

Feb 2023

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.

June 2018

8. With reference to a thermistor:

- state the materials used in their construction, the principle of operation and the reason for their use on vessels; (4)
- state the temperature range over which they are able to operate; (1)
- state, with reasons, FIVE applications where thermistors may be found on board a vessel. (5)

Thermistors: Tiny Titans of Temperature Sensing on Board

(a) Construction, Operation, and Use on Vessels:

Thermistors, those miniature marvels of temperature sensing, find their way onto vessels for several compelling reasons. Let's delve into their construction, operation, and benefits:

Materials:

- **Semiconductor Materials:** Thermistors are made from semiconductor materials like metal oxides, ceramics, or even polymers. These materials exhibit a unique characteristic: their electrical resistance changes significantly with temperature.

Operation:

- **Resistance vs. Temperature:** As the temperature increases, the semiconductor material vibrates more, disrupting the orderly flow of electrons. This results in a dramatic increase in resistance for Negative Temperature Coefficient (NTC) thermistors, the most common type used on vessels.
- **Temperature Measurement:** This change in resistance is accurately measured by an external device, which then converts it into a temperature reading using pre-programmed equations specific to the thermistor material and construction.

Use on Vessels:

- **Fast Response:** Thermistors excel in their rapid response to temperature changes, making them ideal for monitoring engine temperatures, cooling systems, and even bearing lubricants, where quick detection of overheating is crucial.
- **Compactness:** Their tiny size allows for flexible placement in tight spaces onboard.
- **Wide Temperature Range:** Some thermistors offer a broad operating range, making them versatile for various applications.
- **Cost-Effectiveness:** They are relatively inexpensive compared to other temperature sensors.

(b) Temperature Range:

The operational temperature range for thermistors varies depending on the specific material used. Generally, they can operate within a range of:

- **-100°C to +300°C:** This range covers most applications on board a vessel, making them versatile tools.
- **Special Materials:** Some specialized thermistors can reach even higher or lower temperatures.

(c) Applications on Board:

Thermistors find their way into various crucial functions on a vessel, thanks to their unique attributes. Here are five key applications:

1. **Engine Monitoring:** Embedded in engine components like cylinder heads and exhaust manifolds, thermistors provide real-time temperature data, facilitating preventative maintenance and preventing overheating.

2. Overload Protection: In electric motors and transformers, thermistors act as safeguards, tripping circuits when temperatures reach critical levels, protecting against damage.
3. Refrigeration Systems: Monitoring temperatures within freezers and cold storage compartments ensures optimal food preservation and prevents equipment failure.
4. Fire Detection: Placed in strategic locations, thermistors can detect rapid temperature rises, triggering early fire alarms and aiding in swift intervention.
5. Bilge Pump Control: Monitoring bilge water temperature can signal potential engine overheating or fuel leaks, prompting automatic activation of bilge pumps and preventing further damage.

Remember, thermistors are not a one-size-fits-all solution, and choosing the right type and placement depends on the specific application and temperature range required. However, their rapid response, compactness, and versatility make them valuable assets for temperature monitoring and protection on board various vessels.

Nov 2020

7. With reference to capacitance probe sensors:
 - (a) describe, with the aid of a sketch, how a capacitance probe produces an output which can be used to measure the liquid level in a tank. (7)
 - (b) state TWO different uses of this device on a vessel; (2)
 - (c) state ONE disadvantage of this type of probe. (1)

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Demystifying Capacitance Probes: Sensing the Secrets of Your Vessel's Tanks

(a) Capacitance Probe Operation and Sketch:

Imagine a tank filled with liquid, and within it, a slender probe like a metal rod inserted. This is the essence of a capacitance probe sensor, and here's how it works:

Sketch:

- **Electrodes:** The probe itself acts as one electrode, and the tank wall or another immersed conductor serves as the other.
- **Dielectric Constant:** The space between the electrodes is filled with the liquid, which acts as a dielectric material with a specific dielectric constant (epsilon). This constant influences the capacitance formed between the electrodes.
- **Capacitance Change:** As the liquid level rises or falls in the tank, the volume of the dielectric (liquid) changes. This, in turn, affects the overall capacitance between the electrodes.
- **Measuring the Change:** An external device connected to the probe measures this change in capacitance.
- **Level Conversion:** Using pre-programmed equations and calibration data, the device converts the capacitance value into a corresponding liquid level reading.

Key Points:

- The dielectric constant of the liquid significantly impacts the sensor's sensitivity.
- Capacitance probes are contactless, offering non-invasive level measurement.

(b) Applications on a Vessel:

These versatile sensors find multiple uses on board:

1. **Fuel Tank Monitoring:** Accurately tracking fuel levels in tanks is crucial for fuel management and voyage planning. Capacitance probes provide reliable and continuous level readings, ensuring optimal fuel utilization.
2. **Bilge Water Management:** Monitoring bilge water levels is essential for ensuring the vessel's seaworthiness and preventing flooding. Capacitance probes offer accurate level data, triggering alarms or pump activation in case of excessive accumulation.

(c) Disadvantage:

One potential drawback of capacitance probes is their susceptibility to changes in the dielectric constant of the liquid. Materials like oil or seawater with varying conductivities or contaminants can affect the capacitance readings and require careful calibration or compensation techniques for accurate performance.

Remember, capacitance probes offer a valuable tool for liquid level measurement on vessels, but understanding their operating principles and potential limitations is crucial for their effective implementation. Choosing the right probe type and considering the liquid properties are essential for reliable and accurate level monitoring.

March 2021

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Here are five different methods for remotely monitoring the content level of a fuel oil service tank, along with their operating principles:

1. Float Switch System:

- **Principle:** A mechanical float attached to a lever rises and falls with the fuel level in the tank. As the level changes, the lever triggers switches at preset levels, sending electrical signals to a remote indicator or control system.
- **Advantages:** Simple and reliable, cost-effective, suitable for basic level monitoring.
- **Disadvantages:** Limited to discrete level readings, prone to mechanical wear and tear, may not be suitable for high-precision applications.

2. Hydrostatic Pressure Transmitter:

- Principle: A pressure sensor is installed at the bottom of the tank. The pressure exerted by the fuel column on the sensor changes with the liquid level. This pressure is converted to an electrical signal and transmitted to a remote indicator or control system.
- Advantages: Continuous and accurate level monitoring, can be calibrated for high precision, suitable for deep tanks.
- Disadvantages: Requires installation at the bottom of the tank, can be affected by temperature changes in the fuel.

3. Capacitance Probe Sensor:

- Principle: A probe with electrodes is inserted into the tank. The dielectric constant of the space between the electrodes changes as the liquid level rises or falls, affecting the overall capacitance. This change is measured and converted to a level reading.
- Advantages: Contactless measurement, suitable for various liquids, continuous and accurate level monitoring.
- Disadvantages: Sensitive to changes in the liquid properties like conductivity and contaminants, requires careful calibration.

4. Ultrasonic Sensor:

- Principle: An ultrasonic sensor emits sound waves and measures the time it takes for the reflected waves to return from the fuel surface. The time difference correlates to the distance to the liquid level, allowing for level calculation.
- Advantages: Non-invasive, suitable for various tank shapes, can be used in harsh environments.
- Disadvantages: Requires clear line-of-sight to the liquid surface, may be affected by tank geometry and turbulence.

5. Guided Radar Level Transmitter:

- Principle: A metal probe with radar pulses travels up and down the inside of the tank. The reflected pulses from the liquid surface provide information on the distance to the fuel level.
- Advantages: Highly accurate and reliable, suitable for tall or irregularly shaped tanks, unaffected by tank conditions.
- Disadvantages: More expensive than other methods, requires installation of the guiding structure inside the tank.

March 2021

8. (a) Explain, with the aid of a sketch, how the fluid level in a tank can be measured using ultrasound energy. (6)
- (b) State TWO advantages of using ultrasound. (2)
- (c) State TWO limitations of this type of measuring device. (2)

(a) Ultrasonic Level Measurement with a Sketch:

Imagine a sensor mounted above or inside a tank, sending out high-frequency sound waves (ultrasound) towards the fluid surface. Here's how it works:

Sketch:

- **Transducer:** The sensor acts as both a transmitter and receiver of ultrasound waves.
- **Pulse Emission:** The transducer emits a short burst of ultrasonic energy towards the liquid surface.
- **Echo Reflection:** The sound waves are reflected back from the liquid surface, similar to how your voice echoes against a wall.
- **Time Measurement:** The transducer measures the time it takes for the reflected pulse to return.
- **Distance Calculation:** Knowing the speed of sound in the air or tank material, the travel time is converted to the distance (d) travelled by the waves.
- **Level Calculation:** Since the distance (d) represents twice the actual distance to the liquid surface (h), dividing d by 2 gives the desired fluid level.

Key Points:

- The method relies on the precise measurement of the time it takes for the sound waves to travel and return.
- The speed of sound is a crucial factor and might need adjustment based on temperature or tank material.

(b) Advantages of Ultrasonic Sensors:

- **Non-invasive:** No contact with the liquid is required, eliminating risks of contamination or interference.
- **Versatility:** Works with various liquids and tank shapes, offering flexibility in application.

(c) Limitations of Ultrasonic Sensors:

- **Line-of-sight:** Requires a clear path between the sensor and the liquid surface. Obstacles or tank geometry can affect accuracy.
- **Sensitivity to conditions:** Foam, turbulence, or temperature changes in the liquid can impact the reflected sound signal and affect readings.

Remember, ultrasonic level measurement offers a powerful tool for non-invasive and versatile level monitoring. However, understanding its limitations and ensuring suitable conditions for accurate operation is crucial for effective liquid level management.

June 2022

8. Describe, with the aid of a sketch, a method of measuring and remotely indicating EACH of the following:

(a) temperature; (4)

(b) rate of flow. (6)

(a) Temperature Measurement and Remote Indication (Sketch):

Imagine a probe inserted into the object or environment you want to monitor. Let's call it a thermocouple, made of two dissimilar metals joined at the tip. Here's how it works:

Sketch:

- Hot Junction: The tip of the thermocouple experiences the temperature you want to measure.
- Dissimilar Metals: Each metal in the thermocouple has a unique relationship between temperature and voltage.
- Voltage Difference: When the hot junction experiences a temperature change, the voltage difference between the two metals at the junction also changes.
- Connecting Wires: Two or four wires connect the thermocouple to a measuring device.
- Measuring Device: This device detects the voltage change and converts it into a temperature reading based on pre-programmed equations specific to the chosen metal pair.
- Remote Indicator: The temperature reading is then displayed on a remote panel or transmitted wirelessly for monitoring.

Key Points:

- Thermocouples are simple, robust, and widely used for temperature measurement.
- The choice of metal pair influences the temperature range and sensitivity of the thermocouple.

(b) Flow Rate Measurement and Remote Indication (Sketch):

Now, imagine a device installed in a pipe carrying the fluid you want to measure. Let's call it a magnetic flow meter. Here's how it works:

Sketch:

- Magnetic Field: The meter generates a magnetic field across the flowing liquid within the pipe.
- Moving Conductors: The moving fluid particles act as conductors within the magnetic field.
- Induced Voltage: The interaction between the moving conductors and the magnetic field induces a voltage proportional to the flow velocity.
- Electrodes: Sensors within the meter pick up this induced voltage.
- Flow Calculation: The electronic unit within the meter converts the voltage to a flow rate value based on the pipe cross-section and calibration factors.
- Remote Indicator: The flow rate reading is then displayed on a remote panel or transmitted wirelessly for monitoring.

- Magnetic flow meters are non-invasive and accurate for measuring flow rates.
- They work with various conductive fluids and are not affected by pressure or temperature changes.

Remember, these are just two examples, and various other technologies can be used for temperature and flow rate measurement and remote indication. Choosing the right method depends on factors like accuracy requirements, fluid properties, budget, and environmental conditions.

March 2022

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Nov 2020

8. Describe, with the aid of a sketch, how a floatation device can produce an output signal that can be used to control the liquid level in a tank. (10)

Here's an example of a floatation device that produces an output signal for remotely controlling the liquid level in a tank, along with a sketch:

Device: Magnetic Float Level Switch with Integrated Transmitter

Sketch:

1. Tank: Depicts the storage tank containing the liquid being monitored.
2. Float: A hollow, buoyant cylinder (shown in red) floats atop the liquid surface.
3. Guide Rod: A vertical rod attached to the tank's top guides the float movement vertically.
4. Magnet: A permanent magnet is mounted inside the float, facing downwards.
5. Reed Switch: One or more reed switches (magnetically sensitive switches) are positioned alongside the guide rod at predetermined levels within the tank.
6. Wiring: Each reed switch connects to a dedicated wire running to the control unit.

Operation:

- As the liquid level rises, the float moves up along the guide rod.
- The magnet inside the float triggers the reed switch positioned at the corresponding level as it passes by.
- The activated reed switch completes the circuit for its associated wire, sending an electrical signal to the control unit.
- The control unit interprets the signal based on which reed switch was activated, indicating the liquid level reaching that specific point.

- Depending on the system configuration, the control unit can then activate pumps, valves, or other devices to maintain the desired liquid level in the tank.

Benefits:

- Non-invasive: No contact with the liquid, minimizing contamination or maintenance needs.
- Reliable: Simple and robust design with minimal moving parts.
- Customizable: Multiple reed switches can be used to create multi-level control.

Limitations:

- Accuracy: Limited to discrete level readings at the positions of the reed switches.
- Sensitivity: May not be suitable for highly precise level control requirements.

Alternative Options:

- Float Switch with Mechanical Lever: Instead of reed switches, the lever attached to the float can directly activate switches or valves mechanically.
- Hydrostatic Pressure Transmitter: Measures the pressure exerted by the liquid column, providing a continuous and more accurate level reading.

Choosing the right type of floatation device depends on factors like desired level control precision, system complexity, and cost considerations.

March 2022

9. (a) Describe, with the aid of a sketch, the principle and operation of a potentiometer. (6)
- (b) Explain how a potentiometer can be used to measure rotary movement. (4)

a) Principle and Operation of a Potentiometer:

Imagine a simple device with three terminals: a knob you can turn, and two connections. This is the essence of a potentiometer, a versatile resistor whose resistance changes smoothly as you rotate the knob. Let's delve into its principle and operation with the help of a sketch:

Sketch:

- Resistive Element: A long strip of conducting material (often nichrome or wire) acts as the heart of the potentiometer.
- Wiper Contact: A sliding contact (wiper) travels along the resistive element when you turn the knob.
- Terminals: Three terminals connect to the potentiometer:
 - A: Connects to one end of the resistive element.
 - B: Connects to the other end of the resistive element.

- C: Connects to the wiper contact.

Operation:

1. **Voltage Source:** Apply a voltage across terminals A and B.
2. **Voltage Division:** As the wiper moves along the resistive element, the distance between it and terminals A and B changes. This creates a variable voltage divider, where the voltage drops across the portion of the element between A and C, and across the remaining portion between C and B.
3. **Output Voltage:** The voltage at terminal C (the output voltage) varies proportionally to the wiper position. When the wiper is closer to A, the output voltage is lower, and vice versa.

Key Points:

- The relationship between wiper position and output voltage is typically linear.
- Potentiometers can be used as variable resistors, voltage dividers, and sensors for rotary movement.

(b) Using a Potentiometer to Measure Rotary Movement:

This unique property of variable resistance makes the potentiometer a useful tool for measuring rotary movement. Here's how:

- **Attach the Potentiometer:** Mount the potentiometer to a fixed point and connect its shaft to the object whose rotation you want to measure.
- **Calibrate the System:** Define the full range of movement by setting zero and maximum output voltage values corresponding to the object's full range of rotation.
- **Measure Voltage:** As the object rotates, the potentiometer's shaft turns, changing the wiper position and, consequently, the output voltage.
- **Convert to Angle:** By measuring the output voltage and comparing it to the pre-defined calibration values, you can calculate the corresponding angle of rotation.

Applications:

This method has various applications, including:

- **Joystick control:** Measuring the tilt of a joystick in two axes for control in video games or robotics.
- **Steering wheel sensors:** Monitoring the angle of a car's steering wheel for accurate control.
- **Robot joint position sensors:** Tracking the rotation of robot joints for precise movement.

Remember, potentiometers offer a simple and reliable way to convert rotary movement into an electrical signal for measurement and control purposes. Understanding their principle and operation unlocks their versatility in various applications.

June 2019

7. With reference to strain gauges:
- (a) describe, with the aid of a sketch, the principle and operation of a simple strain gauge, stating the formula used to determine its change in properties; (5)
 - (b) explain how the device is connected into an electrical circuit to accurately measure pressure; (3)
 - (c) state TWO practical applications in a vessel. (2)

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Unmasking the Mystery of Strain Gauges: Sensing Forces on Your Vessel

(a) Principle and Operation of a Simple Strain Gauge:

Imagine a thin, metallic wire or foil bonded to the surface of an object that experiences stress (force per unit area). This is the essence of a simple strain gauge, a sensor that translates mechanical deformation into a change in electrical properties. Let's explore its principle and operation with the help of a sketch:

Sketch:

1. Object Under Stress: The object experiencing force or pressure (shown in blue) can be anything from a vessel's hull to a bearing in its engine.
2. Gauge Element: The thin metallic wire or foil (green) is tightly bonded to the object's surface.
3. Stress Application: When the object undergoes stress, it stretches or compresses, affecting the gauge element.
4. Resistance Change: This deformation changes the length and cross-sectional area of the gauge element, ultimately altering its electrical resistance.
5. Output Signal: This change in resistance is measured by an external circuit, providing an electrical signal proportional to the applied stress.

Formula for Change in Resistance:

The relative change in resistance ($\Delta R/R$) of a strain gauge can be estimated using the equation:

$$\Delta R/R = GF * \epsilon$$

where:

- $\Delta R/R$ is the relative change in resistance.
- G is the gauge factor, a material-specific constant relating resistance change to strain.
- ϵ is the strain experienced by the gauge element (change in length divided by original length).

(b) Connecting the Strain Gauge for Pressure Measurement:

While strain gauges directly measure strain, converting it to pressure requires proper circuit configuration. Here's a simple method:

1. **Wheatstone Bridge:** Connect the strain gauge as one arm of a Wheatstone bridge circuit, alongside three fixed resistors.
2. **Voltage Source:** Apply a constant voltage across the bridge.
3. **Balanced Bridge:** Initially, with no stress on the gauge, the bridge is balanced, and no current flows through the output.
4. **Stress Application:** As the object experiences pressure, the gauge's resistance changes, unbalancing the bridge and causing a current to flow through the output.
5. **Pressure Measurement:** The magnitude of the output current is proportional to the applied pressure and can be calibrated to provide accurate pressure readings.

(c) Applications in a Vessel:

Strain gauges find various practical uses on vessels:

1. **Hull Stress Monitoring:** Gauges placed on critical hull sections measure pressure variations and deformations, identifying potential structural issues before they become critical.
2. **Engine Monitoring:** Gauges on engine components like bearings and cylinders track mechanical forces, allowing for predictive maintenance and preventing failures.

Remember, strain gauges offer sensitive and versatile sensors for detecting pressure and stress changes in various onboard applications. Understanding their operation and proper circuit integration is crucial for reliable and accurate measurements that contribute to the safety and performance of your vessel.

Nov 2021

8. (a) Explain the term *failsafe* in a control system, stating TWO examples where this term is applied. (4)
- (b) Explain the term *failset* in a control system, stating TWO examples where this term is applied. (4)
- (c) State what is meant by a 4:3 control valve. (2)

Terms and Valves in Control Systems: Navigating Safeguards and Operations

(a) Failsafe:

- Explanation: In a control system, a failsafe mechanism ensures the system transitions to a safe state whenever a component failure or unexpected event occurs. It prioritizes safety over normal operation, preventing potential harm or damage.

Examples:

1. Emergency brakes: In a train control system, the brakes automatically engage if the driver loses control or a sensor detects excessive speed, ensuring passenger safety regardless of human error or equipment malfunction.
2. Pressure relief valves: In a chemical reactor, a pressure relief valve automatically opens if pressure builds beyond a safe limit, preventing explosions or container ruptures.

(b) Failset:

- Explanation: Unlike failsafe, failset prioritizes maintaining the system's current or predetermined state even if a component fails. This can be advantageous in situations where a sudden shift to a safe state could be detrimental.

Examples:

1. Aircraft auto-pilot: The auto-pilot may hold the current flight path and altitude even if a sensor malfunctions, allowing time for crew intervention and safe manual control.
2. Nuclear reactor control rods: Failset mechanisms may ensure control rods remain inserted in the reactor core in case of sensor or actuator failure, preventing an uncontrolled chain reaction.

Important Note: Choosing between failsafe and failset depends on the specific system, potential risks, and consequences of failure. Both approaches have their roles, and careful consideration is necessary to ensure optimal safety and control.

(c) 4:3 Control Valve:

- Explanation: This refers to a specific type of control valve characterized by a flow characteristic where a 40% opening of the valve allows 30% of the total flow to pass through. This means the valve has a progressive flow response, slowly increasing flow with increasing opening.

Applications:

- Precise flow control: In situations where fine adjustments are crucial, like chemical dosing or temperature regulation, a 4:3 valve provides better control over small flow changes compared to linear valves.
- Anti-cavitation: The gradual flow increase reduces fluid pressure changes near the valve seat, minimizing cavitation and noise generation, making it suitable for high-pressure applications.

Remember, understanding the terminology and characteristics of control system elements like failsafe, failset, and 4:3 valves is crucial for ensuring safe and efficient operation in various industrial and maritime applications.

June 2019

9. State a type of transducer or measuring device suitable for measuring EACH of the following parameters:
- (a) accurate remote reading of a diesel engine exhaust temperature; (1)
 - (b) accurate remote reading of the twist of a propeller shaft; (1)
 - (c) accurate and remote position of a diesel engine governor or fuel rack; (1)
 - (d) the speed of a ship's main propeller shaft in RPM; (1)
 - (e) remote reading of a ship's intermediate shaft bearing temperature; (1)
 - (f) remote reading of lubricating oil pressure in a diesel engine; (1)
 - (g) flow rate of a water maker; (1)
 - (h) simple local pressure reading of ships fire-main; (1)
 - (i) the position of the steering gear or rudder; (1)
 - (j) local reading of jacket cooling water temperature. (1)

Here are suitable transducer or measuring devices for each parameter:

(a) Accurate remote reading of a diesel engine exhaust temperature:

- Thermocouple with remote transmitter: Offers high accuracy and remote signal transmission via cable or wirelessly.

(b) Accurate remote reading of the twist of a propeller shaft:

- Strain gauge: Mounted on the shaft, it detects deformations caused by twisting and conveys a proportional electrical signal for remote measurement.

(c) Accurate and remote position of a diesel engine governor or fuel rack:

- Linear potentiometer: Attached to the moving element, it provides a voltage proportional to position, allowing remote monitoring.

(d) Speed of a ship's main propeller shaft in RPM:

- Shaft encoder: Mounted on the shaft, it counts rotations and transmits the data for RPM calculation and remote display.

(e) Remote reading of a ship's intermediate shaft bearing temperature:

- Resistance temperature detector (RTD): Provides accurate remote temperature readings even in harsh environments.

(f) Remote reading of lubricating oil pressure in a diesel engine:

- Pressure transducer: Installed in the oil line, it converts pressure to an electrical signal for remote monitoring.

(g) Flow rate of a water maker:

- Electromagnetic flow meter: Non-invasive and accurate for measuring water flow without obstructing the pipe.

(h) Simple local pressure reading of ships fire-main:

- Pressure gauge: Provides a direct local reading of pressure in the fire-main system.

(i) Position of the steering gear or rudder:

- Potentiometer or rotary encoder: Similar to (c), these track the rudder's rotational angle for remote indication or steering control.

(j) Local reading of jacket cooling water temperature:

- Liquid crystal thermometer (LCD thermometer): Provides a simple and cost-effective local temperature reading.

Remember, the choice of the most suitable device depends on factors like desired accuracy, remote vs. local monitoring needs, budget, and environmental considerations. Consult with specialists and consider specific requirements for optimal selection and implementation.

Feb 2023

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.