Process Instrumentation

<table>
<tr><th>TOPIC</th><th>OBJECTIVES</th></tr>
<tr><td>Introduction to Instrumentation</td><td>
1. Discuss the evolution and importance of process instrumentation to the process industries.
2. Explain the importance of monitoring process variables.
3. Discuss the operator’s leadership role, in relation to safety, when monitoring process variables.
4. Explain the importance of process instrumentation to a process technician:
• Eyes and ears of the process technician
• Tool for monitoring and troubleshooting process control
• Effective communications with instrument technician for troubleshooting and repairs
5. Define terms associated with instrumentation:
• local
• remote
• indicating
• recording
• pneumatic
• electronic
• process variables
• controlling
• analog
• digital
○ DCS (Distributive Control Systems)
○ PLC (Programmable Logic Control)
• control loop
• differential (delta Δ)
• split range
6. Describe the major process variables controlled in the process industries and define their units of measurement:
• Flow (gallons per minute, pounds per minute, pounds per hour, barrels per hour, etc.)
• Pressure (psig, psia)
• Temperature (Fahrenheit, Celsius)
• Level (percent, inches of water column, interface)
• Analytical (ppm, percentage, ratio, pH, etc.)
• Other (vibration, variable speed control, proximity switches, amp-meter, etc.)
7. Explain the relationship between common process variables:
• What happens to the pressure in a closed container when temperature increases/decreases?
• What happens to the temperature in a closed container when pressure increases/decreases?
• What happens to vessel bottom pressure when height of liquid increases/decreases?
• What happens to boiling point of a material when pressure increases/decreases?
• What happens to the volume of a material when temperature increases/decreases?
• What happens to the density of a material when temperature increases/decreases?
• What happens to the differential pressure when the flow increases/decreases?
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TOPIC	OBJECTIVES
Process Variables, Elements and Instruments - Pressure	1. Define units of measurement associated with pressure and pressure instruments: • PSIG (pounds per square inch gauge) • PSIA (pounds per square inch atmospheric) • bars • Inches H_2O • Inches Hg (mercury) • mm Hg Abs • Inches Hg Vac • atmospheres 2. Discuss the formula used to calculate pressure and identify the three components that affect the force exerted by molecules: • Speed (temperature) • number of molecules • mass (liquid) 3. Identify common types of pressure-sensing/measuring instruments used in the process industries: • gauges • differential pressure cells • manometers • strain gauge 4. Describe the purpose and operation of pressure-sensing/measuring instruments used in industrial settings. 5. Given a standard calculator and conversion formulas convert between the following pressure scales: • pounds per square inch gauge (psig) and pounds per square inch absolute (psia) • inches of mercury (in. Hg) and inches of water (in. H_2O) • psi (pounds per square inch) and inches of water column

Topic	Objectives

Process Variables,
 	
Elements and Instruments – Temperature
	1. Define units of measure associated with temperature and temperature instruments:
	• differential (delta)
	• temperature scales
	  ○ Fahrenheit
	  ○ Celsius/Centigrade
	2. Describe the effect heat energy has on the movement of molecules.
	3. Identify common types of temperature-sensing/measurement devices used in the process industries:
	• resistance temperature detector (RTD)
	• thermometer
	• thermocouple temperature gauge
	• bimetallic strip
	4. Describe the purpose and operation of various temperature sensing/measurement devices used in the process industries.
	5. Given a standard calculator and conversion formulas, complete Fahrenheit and Celsius conversion

Process Variables, Elements and Instruments - Level	1. Define terms associated with level and level instruments: • ullage (outage) • innage • interface level • direct/indirect measurement • meniscus 2. Identify common types, purposes, and operation of level-sensing/measuring devices used in the process industries: • gauge/sight-glass (reflex or clear glass) • differential pressure cells • floats • displacer • bubblers • nuclear devices • ultrasonic devices • tape/ball • radar 3. Discuss hydrostatic head pressure in relation to level measurement. 4. Describe the level control as it relates to the temperature, density, and volume of liquid.

TOPIC	OBJECTIVES
Process Variables, Elements and Instruments – Flow	1. Define terms associated with flow and flow measuring instruments: • fluids (gases and liquids) • metered displacement • laminar • turbulent • differential pressure • weight/mass measurement 2. Identify the most common types of flow-sensing and measuring devices used in the process industries and their purposes and operation: • orifice plate • venturi tube • flow nozzle • pitot tube • multiport pitot tube (Annubar) • rotameters • magmeter • turbine meters • mass flow meter (Coriolis) • vortex meter • ultrasonic meter • others 3. Describe the purpose and operation of flow-sensing/measurement devices used in process industries. 4. Explain the difference between total volume flow and flow rate. 5. Explain the difference between mass flow and volume flow.

TOPIC	OBJECTIVES
Process Variables, Elements and Instruments – Analytical	1. Define terms associated with analytical instruments: • pH (acid/base) and ORP (oxidation reduction potential) • conductivity • Optical Measurements • Chromatography • Combustion • TOC (total organic carbon) 2. Identify the most common types of analytical devices used in the process industries: • gas/liquid chromatograph • ORP (oxidation reduction potential)/ pH meter • conductivity meter • Color analyzers • optical analyzers • turbidity analyzer/meter • opacity analyzer/meter • TOC (total organic carbon) analyzer • spectrophotometers a. UV (ultraviolet)/VIS (visible) b. IR (Infrared) • O_2 analyzer • LEL (lower explosive limits) 3. Explain the purpose of analytical devices used in process industries. 4. Explain how analytical data affects the role of the process technician. 5. Review the difference between online versus laboratory analysis.

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Miscellaneous Measuring Devices	1. Define terms associated with miscellaneous measuring devices: • load cells • density • vibration • rotational speed • amperage • decibels 2. Identify common types of miscellaneous measuring devices: • Vibration meter • load cells • proximity sensors (pickups for speed) • Amp meters. • decibel meters, etc.
Introduction to Control Loops (Simple Loop Theory)	1. Explain the function of a control loop. 2. Describe process control loop elements: • Process Variables (PV) • measuring means (primary element/transmitter) • controller (set point) • final control element (valve or louvers) 3. Explain signal transmission: • Pneumatic • Electronic • analog • Discrete • Digital • mechanical 4. Classify the functions of a control scheme: • Sensing • Measuring • comparing • transducing (converting) • controlling 5. Review the differences between "open" and "closed" control loops. 6. Explain the purpose of instrument air systems.

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	7. Describe the various types of instrument air systems: • Instrument air • Nitrogen • Process gases
Control Loops: Controllers	1. Explain the terms associated with controllers: • direct acting • reverse acting • set point • auto/manual switch • local/remote switch • tuning ○ proportional band/gain ○ integral/reset ○ derivative/rate 2. Given a drawing or actual device, identify and explain the operation of the following: • local controller • remote controller • split-range controller • ratio controller • Cascade/Remote Set Point (RSP) controller 3. Identify an application which would require the following devices: • local controller • remote controller • split range controller • ratio controller • Cascade controller 4. Explain "bumpless" transfer of auto to manual control. 5. Explain the "bumpless" transfer of manual to auto control. 6. Explain the process for switching from auto control to manual control on a local controller. 7. Explain the process for switching from manual control to automatic control on a local controller. 8. Demonstrate various control skills, such as: • make set point adjustments on a local controller • operate a local controller in manual mode • make set point adjustments on a remote controller • switch from manual to automatic control on a remote controller without bumping the process

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<tr><td>Control Loops: Primary Sensors, Transmitters, and Transducers</td><td>1. Explain the function of measuring instruments (pressure, temperature, level, and flow) and review their role in the overall control loop process.
2. Explain the purpose and operation of the transmitter (D/P Cell) in a control loop.
3. Compare and contrast the transmitter input and output signals (communication).
4. Discuss differential pressure cell (D/P) in relation to the transmitter signal.
5. Explain the function of a transducer (signal converter):
• I (current) to P (pneumatic)
• P (pneumatic) to I (current)
6. Compare and contrast the relationship between air (3 psig to 15 psig) and electric signals (4 ma to 20 ma).
7. Given an example of a process control scheme, demonstrate how a control loop functions.</td></tr>
<tr><td>Switches, Relays, Alarms</td><td>1. Explain the purpose and function of a switch.
2. Explain the purpose and function of a relay.
3. Explain the purpose and function of an alarm.
4. Review placement and use of a switch within a control loop (open and closed).
5. Review the placement and use of a relay within a control loop (open and closed) and in a process unit.
6. Review the placement and use of an alarm within a control loop (open and closed) and in a process unit.
7. Identify switches, relays, and alarms on a Piping & Instrumentation Diagram.</td></tr>
<tr><td>Instrument Air Systems</td><td>1. Discuss potential causes of instrument air failure:
• Compressor shuts down
• Wet/dew point (dryers)
• Plugging (scale, rust)
• Backup air failure
• Regulator failure
• Incorrect manifold alignment
2. Discuss corrective actions for each of the following scenarios:
• Compressor shut down
• Wet (dew point)
• Plugging
• Backup air failure
• Regulator failure
• Incorrect manifold alignment</td></tr>
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<tr><td>Control Valves and Final Control Elements</td><td>1. Explain the purpose and operation of the following:
• control valves
○ three-way valve
○ gate valve
○ globe valve (needle valve)
○ butterfly valve</td></tr>
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	2. Explain the purpose and operation of the following: • valve positioner • manual operation (hand-jack) • transducer (converter) 3. Define terms associated with valves and other final control elements: • “air to close” (fail open) • “air to open” (fail closed) • fail last/in-place/as is • double-acting diaphragm valve actuator • double-acting piston valve actuator • solenoid • variable speed motor 4. Given a drawing or actual device, identify the main components of a control valve: • Body • Bonnet • Disc • Actuator • Stem • Seat • Spring • Valve positioner • Hand-jack 5. Illustrate three types of final control elements and provide an application for each type: • control valve – manipulates a process flow (liquid/gas) in response to a control signal • damper/louver – manipulates an air flow to control draft setting or temperature setting • motor – start, stop or variable speed in response to a control signal 6. Explain the role of the final control element as it relates to the process and the control loop. 7. Given a drawing or actual instrument, identify and describe the operation of the following: • instrument air regulator • louver, damper, final control element • variable speed motor used as a final control element 8. Review reasons why the action of a valve actuator may not correspond with the action of the valve: • Calibration

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	• Valve stroke • Direct versus indirect action • Incorrect air supply pressure / contamination • Sticking valve • Transducer operation 9. Review actions for troubleshooting the items in number 7. 10. Compare and contrast a spring and diaphragm actuator to a cylinder actuator. 11. Explain the purpose of a valve positioner and describe its operation. 12. Review the function of each of the three gauges located on a pneumatic valve positioner: • Air supply • Signal • Output signal to actuator 13. Given a signal pressure from an I/P determine what the valve position should be for the following: • Fail open • Fail closed
Interlocks and Safety Features	1. Explain the purpose of interlocks: • Safety • Process 2. Review the purpose of safety features: • Interlocks and valve actions • ESD (Emergency Shutdown Devices) • Limit switches (proximity, permissive) • Redundant instrumentation • Fail safe position • Overspeed 3. Discuss potential consequences for bypassing or ignoring any of the safety features listed above.
Symbology; Process Diagrams – Part 1	1. Review the types of drawings that contain instrumentation that an operator might use. 2. Explain the lettering and numbering standards based on ISA (Instrumentation Society of Automation) instrumentation symbols. (Legend) 3. Demonstrate how to determine the instrument type from the symbol information. 4. Draw the standards for instrument line symbols: • Electrical • Pneumatic • Digital 5. Using a legend, correctly identify instrumentation on a drawing.

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Process Diagrams – Part 2	1. Compare and contrast P&IDs and PFDs. 2. Given a PFD, trace process flows on the drawing and/or in the field locating major equipment. 3. Given a P&ID with a legend, locate and identify the components:
Instrumentation Sketching	1. Given a P&ID, with a control loop, explain the relationship of one piece of instrumentation to another. 2. Given a process flow diagram of a major system, illustrate/draw control loops for the following variables: • Flow • Level • Temperature • Pressure 3. Using training resources (process simulator, training unit, etc.) sketch instrumentation control loops.
Monitoring Process Variables	1. Given a P&ID identify key process variables that should be monitored.
Instrumentation Troubleshooting	1. Review the extent of an operator's role when troubleshooting problems with process instruments (i.e., identify and not repair, which may vary between sites). 2. Discuss hazards and consequences of deviation for operating outside normal control range of process variables. 3. Identify typical malfunctions found in primary sensing elements and transmitters. 4. Explain the importance of process knowledge in troubleshooting. 5. Illustrate the proper use of equipment related to process troubleshooting. 6. Discuss safety and environmental issues related to troubleshooting process instruments. 7. Describe the symptoms of incorrect instrument calibration: • Variation between local sight glass and level transmitter • Variation between local pressure gauge and pressure transmitter • Inconsistency among instruments • How do process changes affect accurate measurement? o Flow rate o Density/specific gravity (composition) o Temperature o Pressure 8. Given a scenario, demonstrate proactive action for correcting an abnormal process variable. 9. Given a simulator or actual device, determine whether a control loop is in or out of control and identify the information used to make the decision.