PTAC 1432 – Instrumentation I

TOPIC	OBJECTIVES

Introduction to Instrumentation	1. Discuss the evolution and importance of process instrumentation to the process industries.
	2. 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
	3. Define terms associated with instrumentation:
	• local
	• remote
	• indicating
	• recording
	• pneumatic
	• electronic
	• process variables
	• controlling
	• analog
	• digital
	  o DCS (Distributive Control Systems)
	  o PLC (Programmable Logic Control)
	• control loop
	• differential (delta ∆)
	• split range
	4. 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.)
	5. 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?

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	• What happens to the differential pressure when the flow increases/decreases?
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 H2O • Inches Hg (mercury) • mm Hg Abs • Inches Hg Vac • atmospheres 2. 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. Using a standard calculator and conversion formulas convert between pressure scales such as the following: • pounds per square inch gauge (psig) and pounds per square inch absolute (psia) • inches of mercury (in. Hg) and inches of water (in. H2O) • psi (pounds per square inch) and inches of water column
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

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	• temperature gauge • bimetallic strip 4. Describe the purpose and operation of various temperature sensing/measurement devices used in the process industries. 5. Using a standard calculator and conversion formulas, complete Fahrenheit and Celsius conversions.
Process Variables, Elements and Instruments - Level	1. Define terms associated with level and level instruments: • ullage (outage) • inage • interface level • direct/indirect measurement • meniscus 2. Name the most common types 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. Describe the purpose and operation of various types of level sensing/measuring devices. 4. Discuss hydrostatic head pressure in relation to level measurement. 5. Describe the relationship between temperature and level measurement as it relates to the density of liquid. 6. Describe the relationship between temperature and level measurement as it relates to the volume of a liquid.
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 measurement 2. Name the most common types of flow-sensing/measuring devices used in the process industries: • orifice plate

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venturi tube
flow nozzle
pitot tube
annubar tube
rotometers
magmeter
turbine meters
mass flow meter (Corioliss)
vortex meter
ultra-sonic
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
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<tr><td>Process Variables, Elements and Instruments – Analytical</td><td>
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. Describe the purpose of analytical devices used in process industries.
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	4. Discuss how analytical data affects the role of the process technician. 5. Explain the difference between on-line versus laboratory analysis.
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. Describe process control: • Process Variables (PV) • measuring means (primary element/transmitter) • controller (set point) • final control element (valve or louvers) 2. Explain the function of a control loop. 3. Identify the functions of a control scheme: • Sensing • Measuring • comparing • transducing-(converting) • controlling 4. Describe the differences between “open” and “closed” control loops. 5. Explain signal transmission: • Pneumatic • Electronic • Analog • Discreet • Digital • mechanical

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Control Loops: Controllers	1. Define 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 describe the operation of the following: • local controller • remote controller • split-range controller • ratio controller • Cascade/Remote Set Point (RSP) controller 3. Describe an application which would require the following devices: • local controller • remote controller • split range controller • ratio controller • Cascade controller 4. Define “bumpless” transfer of auto to manual-control. 5. Define the “bumpless” transfer of manual to auto control. 6. Describe the process for switching from auto control to manual control on a local controller. 7. Describe 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 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.

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Control Loops: Primary Sensors, Transmitters, and Transducers	1. Describe the function of measuring instruments (pressure, temperature, level, and flow) and explain their role in the overall control loop process. 2. Describe 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. Describe the function of a transducer (signal converter). • I (current) to P (pneumatic) • P (pneumatic) to I (current) 6. Describe the relationship between air (3 psig to 15 psig) and electric signals (4 ma to 20 ma). 7. Given a process control scheme, explain how a control loop functions.
Instrument Air Systems	1. Describe the purpose of instrument air systems 2. Describe the various types of instrument air systems • Instrument air • Nitrogen • Process gases 3. 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 4. Discuss corrective actions for each of the following scenarios: • Compressor shut down • Wet (dew point) • Plugging • Backup air failure • Regulator failure • Incorrect manifold alignment
Control Valves and Final Control Elements	1. Explain the purpose and operation of the following: • control valves ○ three-way valve ○ gate valve ○ globe valve (needle valve) ○ butterfly valve

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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. Describe 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 5. Describe the role of the final control element as it relates to the process and the control loop. 6. 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 7. Explain reasons why the action of a valve actuator may not correspond with the action of the valve. • Calibration • Valve stroke • Direct verses indirect action • Incorrect air supply pressure / contamination • Sticking valve

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	• Transducer operation 8. Describe actions for troubleshooting the above. 9. Compare and contrast a spring and diaphragm actuator to a cylinder actuator. 10. Describe the purpose of a valve positioner and explain its operation. 11. Explain the function of each of the three gauges located on a pneumatic valve positioner. • Air supply • Signal • Output signal to actuator 12. 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. Describe the purpose of interlocks. • Safety • Process 2. Describe the purpose of safety features. • Interlocks and valve actions • ESD (Emergency Shutdown Devices) • Limit switches (proximity, permissive) • Redundant instrumentation • Fail safe position • Over speed 3. Discuss potential consequences for bypassing or ignoring any of the safety features listed above.
Symbology; Process Diagrams – Part 1	1. Describe the types of drawings that contain instrumentation that an operator might use. 2. Describe the lettering and numbering standards based on ISA (Instrumentation Society of Automation) instrumentation symbols. 3. Describe how to determine the instrument type from the symbol information. 4. Describe the standards for instrument line symbols. • Electrical • Pneumatic • Digital 5. Using a legend, correctly identify instrumentation on a drawing.
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:

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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, add control loops: • Flow • Level • Temperature • Pressure 3. Using training resources (process simulator, training unit, etc.) sketch instrumentation control loops.
Monitoring Process Variables	1. Explain the importance of monitoring process variables. 2. Discuss the operator's leadership role, in relation to safety, when monitoring process variables. 3. Given a P&ID identify key process variables that should be monitored. 4. Discuss hazards and consequences of deviation for operating outside normal control range of process variables. 5. Given a scenario, explain proactive action for correcting an abnormal process variable.
Instrumentation Troubleshooting	1. Explain the extent of an operators role when troubleshooting problems with process instruments (i.e., identify and not repair, which may vary between sites). 2. Identify typical malfunctions found in primary sensing elements and transmitters. 3. Explain the importance of process knowledge in troubleshooting. 4. Explain the proper use of equipment related to process troubleshooting. 5. Discuss safety and environmental issues related to troubleshooting process instruments. 6. 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? ○ Flow rate ○ Density/specific gravity (composition) ○ Temperature ○ Pressure