

Instrumentation Learning Objectives

Learning Objectives - First Half

Session 1: Course Overview and Introduction to Instrumentation

1. List the attendance requirements for Process Instrumentation I.
2. List the homework requirements for Process Instrumentation I.
3. List the class participation requirements for Process Instrumentation I.
4. List the evaluation requirements (quizzes and tests) for Process Instrumentation I.
5. List the lab requirements for Process Instrumentation I.
6. Discuss the evolution and importance of process instrumentation to the petrochemical and refining industry.
7. Define terms associated with instrumentation:
 - local
 - remote
 - indicating
 - recording
 - pneumatic
 - electronic
 - process variables
 - controlling
 - analog
 - digital
 - control loop
 - differential (delta Δ).
8. Describe the major process variables controlled in the Process Industry:
 - flow
 - pressure
 - temperature
 - level
 - analytical
 - others.
9. 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 flow when the differential pressure increases/decreases?
- How do variable changes affect accurate measurement?

Session 2: Process Variables, Elements and Instruments - Pressure

1. Define terms associated with pressure and pressure instruments:
 - differential pressure (Δ)
 - $P = F/A$ (formula used to calculate pressure)
 - pressure measurement scales
 - § PSIG
 - § PSIA
 - § bars
 - § Inches H₂O
 - § Inches Hg
 - § atmospheres
2. Identify the three components that affect the force exerted by molecules:
 - speed
 - number of molecules
 - mass.
3. Identify common types of pressure-sensing/measuring instruments used in the process industry:
 - gauges (internals)
 - differential pressure cells
 - manometers
 - strain gauge.
4. Describe the purpose and operation of pressure-sensing/measuring instruments used in a lab or industrial setting.
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. H₂O)

Session 3: Process Variables, Elements and Instruments – Temperature; Test Review

1. Define terms associated temperature and temperature instruments:
 - thermowell
 - differential (delta)
 - temperature scales
 - § Fahrenheit
 - § Celsius/Centigrade
 - § Rankin
 - § Kelvin.
2. Describe the effect heat energy has on the movement of molecules.
3. Identify the following for Celsius and Fahrenheit:
 - boiling/freezing points for H₂O
 - minimum/maximum water temperature at sea level.
4. Identify common types of temperature-sensing/measurement devices used in the process industry:
 - resistance temperature detector (RTD)
 - thermometer
 - thermocouple
 - temperature gauge
 - bimetallic strip.
5. Describe the purpose and operation of various temperature-sensing/measurement devices used in the process industry.
6. Given a standard calculator and conversion formulas, complete Fahrenheit and Celsius conversions.

Session 4: Test #1; 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. Identify the most common types of level-sensing/measuring devices used in the process industry:
 - gauge/sightglass (reflex or clear glass)
 - differential pressure cells
 - floats
 - displacer
 - bubblers
 - nuclear devices
 - ultrasonic devices
 - tape/ball.
 3. Describe the purpose and operation of various types of level-sensing/measuring devices.
 4. Discuss hydrostatic head pressure and reference pressure in relation to level measurement.
 5. Describe the relationship between temperature and level control as it relates to the density of liquid.
 6. Describe the relationship between temperature and level control as it relates to the volume of a liquid.

Session 5: Process Variables, Elements and Instruments – Flow

1. Define terms associated with flow and flow instruments:
 - fluids (gases and liquids)
 - positive displacement flow measurement
 - laminar
 - turbulent
 - direct and indirect flow.
2. Identify the most common types of flow-sensing/measuring devices used in the process industry:
 - orifice plate
 - venturi tube
 - flow nozzle
 - pitot tube
 - annubar tube

- rotometers
 - magmeter
 - turbine meters
 - mass flow meter
 - others.
3. Describe the purpose and operation of flow-sensing/measurement devices used in process industry.
 4. Explain the difference between total volume flow and flow rate.

Session 6: Process Variables, Elements and Instruments –Analytical

1. Define terms associated with analytical instruments:
 - pH (acid/base) and ORP
 - conductivity
 - Optical Measurements
 - Chromatography
 - Combustion
2. Identify the most common types of analytical devices used in the process industry:
 - mass spectrometer/gas chromatograph
 - ORP (oxidation reduction potential)/ pH meter
 - conductivity meter
 - Hunter color analyzer
 - optical analyzers
 - § turbidity analyzer/meter
 - § opacity analyzer/meter
 - total carbon analyzer
 - spectrophotometers
 - § UV/VIS
 - § infrared.
3. Describe the purpose of analytical devices used in process industry.
4. Discuss how analytical instrumentation affects the role of the process technician and how the process technician affects the operation of the analytical instrumentation.

Session 7: Miscellaneous Measuring Devices; Test Review

1. Define terms associated with miscellaneous measuring devices:

- load cells
 - density
 - mass vs. weight
 - vibration
 - rotational speed.
2. Identify common types of miscellaneous measuring devices:
 - vibration measurement
 - load cells
 - proximity switches (pickups for speed)
 - others.

Session 8: Test #2; Introduction to Control Loops (Simple Loop Theory)

1. Describe process control:
 - variables
 - measuring means (primary element/transmitter)
 - controller (setpoint)
 - final control element (valve or louvers)
2. Explain the function of a control loop.
3. Identify the components of a control loop:
 - sensing
 - measuring
 - comparing
 - controlling
 - transducer (converter)
4. Describe the differences between “open” and “closed” control loops.
5. Explain signal transmission:
 - pneumatic
 - electronic
 - digital
 - mechanical.

Session 9: Control Loops: Primary Sensors, Transmitters, and Transducers

1. Describe the relationship between the measuring instruments (pressure, temperature, level, and flow) and 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.
4. Discuss differential pressure in relation to the process input to the transmitter.
5. Given a process control scheme, explain how a control loop functions.
6. Describe the function of a current to pneumatic transducer (signal converter).
7. Describe the relationship between a 3 psig to 15 psig air signal and a 4 ma to 20 ma electric signal.

Session 10: Control Loops: Controllers

1. Define terms associated with controllers:
 - direct acting
 - reverse acting
 - setpoint
 - auto/manual switch
 - local/remote switch
 - proportional band/gain
 - integral/reset
 - derivative/rate
 - tuning.
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 Setpoint (RSP) controller.
3. Provide an application requiring the following devices:
 - local controller
 - remote controller
 - split range controller
 - ratio controller.
 - Cascade controller.
4. Define “bumpless” transfer of auto to manual/manual to auto control.

5. Describe the process for switching from auto control to manual control on a local controller.
6. Describe the process for switching from manual control to automatic control on a local pneumatic controller without bumping the process.
7. Given a drawing or actual local pneumatic controller, read the chart and state the high and low range values.
8. Demonstrate various control skills, such as:
 - make setpoint adjustments on a local controller
 - operate a local controller in manual mode
 - make setpoint adjustments on a remote pneumatic controller
 - switch from manual to automatic control on a remote pneumatic controller without bumping the process.
9. Given a simulator or actual device, identify if a control loop is in control or out of control and identify the information used to make the decision.

Session 11: Control Valves and Final Control Elements; Test Review

1. 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.
2. Given a drawing or actual device, identify the main components of a control valve.
 - body
 - bonnet
 - disc
 - actuator
 - stem
 - seat
 - spring
 - valve positioner
 - handjack.
3. Explain the purpose and operation of the following:
 - control valves
 - § three-way valve
 - § globe valves

- § butterfly valves
 - valve positioner
 - manual operation (handjack)
 - transducer (converter).
- 4. 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 – starts or stops 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 why the action of a valve actuator may not correspond with the action of the valve.
- 8. Compare and contrast a spring and diaphragm actuator to a cylinder actuator.
- 9. Describe a valve positioner and explain three of its uses.
- 10. Explain the function of each of the three gauges located on a pneumatic valve positioner.
- 11. Given a pressure indication for each of the three gauges on a valve positioner, predict what the control valve movement will be.
- 12. Describe two ways a controller's output signal can be reversed at the valve so the valve's action is opposite of the controller output signal.
- 13. Describe a control scheme that utilizes reversing a controller's output signal at the valve.
- 14. Explain how reversing a controller's output signal at the valve affects the valve's fail safe position upon loss of air.
- 15. Describe operating scenarios in which fail open, fail closed, and fail last positions are desirable.
- 16. Given a drawing or actual device, identify and describe and following:
 - current to pneumatic transducer
 - indications of a sticking control valve.

Session 12: Test #3; Symbology; Process Diagrams – Part 1

1. Describe the types of petrochemical and refining industry drawings that contain instrumentation.
2. Describe the lettering and numbering standards based on ISA instrumentation symbols.
3. Describe how to determine the instrument type from the symbol information.
4. Describe the standards for line symbols.
5. Using a legend, correctly identify instrumentation on a drawing.

Session 13: Process Diagrams – Part 2

1. Compare and contrast P&IDs and PFDs.
2. Given a PFD and P&ID and a legend, locate and identify the following components:
 - field-mounted instruments
 - board-mounted instruments
 - DCS mounted instruments
 - diaphragm actuated valves
 - piston actuated valves
 - motor operated valves
 - control valve
 - three-way valve
 - transducers
 - equipment
 - indicator
 - recorders
 - blind controllers
 - indicating controllers
 - recording controllers
 - instrument air supply/signals
 - electronic signals
 - capillary tubing
 - process piping
 - line markings
 - revision block
 - continuation arrows

- title block
 - “clouds” (revision/abandon-in-place)
 - “notes”
 - reference block
 - variables (measured and manipulated).
 - control loops
3. Given a P&ID, trace a control loop.

Session 14: Instrumentation Sketching

1. Given a P&ID, explain the relationship of one piece of instrumentation to another.
2. Given a drawing that has major system equipment add control loops:
 - flow
 - level
 - temperature
 - pressure.
3. Sketch instrumentation control loops on available trainer resources.

Session 15: Instrumentation Troubleshooting

1. Explain that different facilities have different practices related to process technicians troubleshooting process instruments.
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 hand tools related to process troubleshooting.
5. Discuss safety and environmental issues related to troubleshooting process instruments.
6. Describe the purpose of instrumentation calibration.
7. Explain the methods used for determining if a sensing/measuring device is malfunctioning:
 - remote vs. local indication
 - importance of communication between the board technician and the outside process technician when troubleshooting a control loop problem.

Session 16: Test #3

No new objectives are presented.

Learning Objectives - Second Half

Session 1: Course Introduction and Instrumentation Review

1. List the attendance requirements for Process Instrumentation II.
2. List the homework requirements for Process Instrumentation II.
3. List the class participation requirements for Process Instrumentation II.
4. List the evaluation requirements (quizzes and tests) for Process Instrumentation II.
5. List the lab requirements for Process Instrumentation II.
6. Recall the purpose of instrumentation in the petrochemical and refining industry.
7. Recall the types of instrumentation used in the petrochemical and refining industry to monitor and control the process:
 - indicators
 - transmitters/transducers
 - controllers
 - final control elements
 - control loops.

Session 2: Regulators, Switches, Relays and Annunciator Systems

1. Define the following terms associated with regulators:
 - back pressure regulator (self-actuated)
 - pressure reducing regulator
2. Given a drawing, picture, or actual device, identify and describe pressure regulators.
3. Given a Process Flow Diagram and/or P&ID, locate and identify pressure regulators used in process control.
4. Given an instrument air pressure regulator, perform the following tasks:
 - blow down regulator to check for condensate or oil
 - set specific pressure for operating final control element.
5. Define the function of a switch:
 - energizes alarms, interlocks, safety systems, equipment, or other devices when a process condition meets a preset value
 - It may be operated by hand, actuated by a mechanical signal, actuated by a process or electrical signal.

6. Define the following terms associated with switches used in process control:
 - autostart switch
 - vibration switch
 - proximity
 - limit
 - on/off/auto
 - vibration
 - process variable
 - bypass.
7. Describe three common uses for switches in process control:
 - alarms
 - shutdown
 - autostart.
8. Given a drawing, picture, or actual device, identify and describe basic switch devices.
9. Given a PFD or P&ID and a legend, locate and identify switches used in process control.
10. Explain how relays are used in the process industry:
 - maintains signal
 - used in redundant systems.
11. Given a ladder diagram and a legend, locate a relay.
12. Define terms associated with enunciator systems:
 - first out (first shutdown conditions)
 - acknowledge/reset/test modes.
13. Explain the purpose of enunciator systems.

Session 3: Signal Transmission and Conversion; Test Review

1. Recall the purpose and operation of transmitters.
2. Describe methods for protecting integrity and reliability of signal transmission:
 - heat tracing
 - shielding
 - insulation
 - materials of construction
 - other safety concerns.
3. Recall types of common transmissions:
 - mechanical

- pneumatic
 - electrical
 - digital.
4. Recall purpose and operation of signal converter equipment.
 5. Describe how wet leg instrument lines are “zeroed out.”
 6. Describe the effect on a primary sensing element that uses a wet-leg/sealing liquid when the density of the sealing liquid changes.
 7. Discuss methods used to ensure a dry-leg remains dry.
 8. Perform conversion calculations:
 - square root to linear signal
 - milliamp to psi
 - psi to milliamp
 - millivolts to psi
 - psi to millivolts
 - analog to digital.

Session 4: Test #1; Controllers – Part 1

1. Define the following terms associated with tuning in process control and controllers:
 - tuning
 - proportional (gain) / proportional band
 - integral (reset)
 - derivative (rate) / preact
 - offset
 - hunting
2. Define the following terms associated with process controllers:
 - process equilibrium (material balance)
 - load change
 - indirect controller action
 - on/off (narrow band proportional) control
 - feed forward control scheme
 - feedback control scheme
 - wind up
3. Define the following terms associated with process instrumentation:
 - trend
 - dead time / lag time

- flatline
 - over range
 - spanning
4. Given a drawing, picture or actual trend, distinguish between effects of proportional, integral, and derivative control.

Session 5: Controllers – Part 2

1. Explain the importance of monitoring controller output signals to final control elements within a process:
 - off, auto-control, maintain signal
2. Given a control loop or simulation of a control loop, tune the loop.

Session 6: Control Schemes

1. Define terms associated with control schemes:
 - override controllers
2. Identify and describe types of control schemes:
 - on/off
 - lead/lag
 - feedback
 - feed forward.
3. Describe a control scheme that allows the following modes:
 - local manual control
 - local automatic control
 - remote manual control
 - remote automatic control
 - cascading of the remote automatic control.
4. Match appropriate control schemes to a process.
5. Given a process scenario, design an appropriate process control scheme.

Session 7: Advanced Control Schemes – Part 1

1. Define terms associated with advanced control schemes.
 - master/slave – subordinate

- cascade/remote set point (RSP)
 - ratio
 - split range
 - multivariable input.
2. Explain the purpose of a cascaded/Remote Set Point (RSP) control scheme.
 3. Explain the function of a ratio (fractional) control scheme.

Session 8: Advanced Control Schemes – Part 2; Test Review

1. List different applications of advanced control schemes.
 - cascade/remote set point (RSP)
 - ratio
 - split range
 - multivariable input.
2. List steps required to change instrument controllers without bumping the process:
 - cascade/remote set point (RSP)
 - ratio
 - split range
 - multivariable input.

Session 9: Test #2; Introduction to Digital Control

1. Explain the purpose of digital control.
2. In general terms, describe the difference between analog and digital controllers.
3. Define the following terms associated with process control schemes:
 - analog
 - discreet controllers
 - DCS
 - PLC
 - input
 - output
 - A to D
 - D to A
 - converter
 - multiplexer
 - demultiplexer.
4. In general terms, describe how a digital controller transmits an output signal to an

analog final control element.

5. In general terms, describe how an analog controller transmits to a digital controller.

Session 10: Programmable Logic Control

1. Define terms associated with Programmable Logic Control (PLC):
 - ladder logic diagram.
2. Explain the purpose of PLCs:
 - sequential control
 - on/off
 - ESD systems
 - integral to DCS system
 - can be stand alone.
3. Explain how “ladder logic” applies to programmable logic control.

Session 11: Distributed Control Systems (DCS)

1. Explain the purpose of a DCS.
2. In general terms, describe the operation of a DCS.
3. Explain the function of a multiplexer/demultiplexer.
4. Explain advantages of a DCS over an analog control system:
 - more precise
 - faster
 - cost
 - more trending operation
 - one location/space
5. Explain why process bumps associated with analog controllers are not a concern with digital controllers.
6. Given a DCS diagram, identify the major components.

Session 12: Instrumentation Power Supply; Test Review

1. Define terms associated with instrumentation power supply:
 - automatic transfer switches
 - battery and charger

- inverter
 - emergency generator
2. Explain the purpose of uninterruptible power supply (UPS) systems.
 3. Given a diagram, identify components in a UPS system:
 - refer to Timtene Unit Operating Manual, pg. 52.

Session 13: Test #3; Emergency Shutdown Systems (ESD), Interlocks, and Protective Devices – Part 1

1. Define the following terms associated with emergency shutdown systems, interlocks, and alarms:
 - Start-up permissives
 - Defeat (bypass)
 - high alarm
 - high high alarm/shutdown
 - low alarm
 - low low alarm/shutdown
 - deviation alarm
 - permissive
 - vibration alarm/shutdown
 - interlock
 - emergency shutdown (ESD)
 - gas detector alarm (including auto-activation of deluge system)
 - redundancy
 - voting logic.
2. Given a drawing, picture, or actual device, identify and describe basic shutdown devices.
3. Recall the use of Programmable Logic Controllers in ESD systems.
4. Given a PFD and/or P&ID and a legend, locate and identify emergency shutdown devices.
5. Given a basic description of a process and a P&ID of its ESD system, describe what a specific ESD is designed to protect.
6. Discuss how redundancy devices are used to prevent nuisance shutdowns.

Session 14: Emergency Shutdown Systems (ESD), Interlocks, and Protective Devices – Part 2

1. Describe common uses for interlocks:
 - lube oil/seal oil systems
 - heater electric eye
 - breaker switch.
2. Compare and contrast ESD systems and interlocks:
 - interlocks prevent a startup
 - ESD system shuts down equipment or systems.
3. Explain methods for resetting ESD systems.
4. Explain methods for testing ESD systems.
5. Discuss different safety policies regarding the bypassing of ESD instruments or devices.

Session 15: Instrumentation Malfunctions; Test Review

1. Recall the methods used for determining if a sensing/measuring device is malfunctioning:
 - remote vs. local indication.
2. Describe the failure modes of the following:
 - temperature elements
 - thermocouples
 - RTDs
 - level floats
 - flow elements
 - pressure elements
 - analytical elements
3. Explain how a control loop will respond to typical malfunctions in the following:
 - primary sensing elements
 - transmitters
 - controllers
 - final control elements.

Session 16: Test #4

No new objectives are presented.

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