Lesson Plans for Module 12402-16

Instrument Calibration and Configuration

Module 12402-16 introduces the important topic of instrument calibration. It presents the principles of calibration and describes the calibration of traditional pneumatic and analog electronic transmitters. It also covers smart instruments, with their significantly different calibration tools and procedures. Transducers and various types of valve positioners are examined, and their calibration procedures introduced.

Objectives

Learning Objective 1

- Define the calibration process and describe the five-point method of calibration.
  a. Define the calibration process.
  b. Describe the five-point method of calibration and the related documentation requirements.

Learning Objective 2

- Describe pneumatic and analog calibration equipment and basic calibration procedures.
  a. Describe pneumatic calibration equipment and basic calibration procedures.
  b. Describe analog calibration equipment and basic calibration procedures.

Learning Objective 3

- Identify and describe smart transmitters and their calibration process.
  a. Describe various communication protocols and devices used for communication.
  b. Explain how to calibrate HART® devices.

Learning Objective 4

- Explain how to calibrate transducers and control valve positioners.
  a. Explain how to calibrate transducers.
  b. Explain how to calibrate pneumatic, electro-pneumatic, and smart control valve positioners.

Performance Tasks

Performance Task 1 (Learning Objective 2)

- Calibrate a pneumatic pressure transmitter using the proper equipment and complete the appropriate documentation.

Performance Task 2 (Learning Objective 2)

- Calibrate a 4–20 mA pressure transmitter using the proper calibration equipment and complete the appropriate documentation.

Performance Task 3 (Learning Objective 2)

- Calibrate a 4–20 mA temperature transmitter using the proper calibration equipment and complete the appropriate documentation.

Performance Task 4 (Learning Objective 3)

- Calibrate a smart transmitter using a HART® communicator and complete the appropriate documentation.

Performance Task 5 (Learning Objective 4)

- Calibrate a transducer and complete the appropriate documentation.

Performance Task 6 (Learning Objective 4)

- Calibrate the following valve positioners and complete the appropriate documentation:
  – Pneumatic positioner
  – Electro-pneumatic positioner
  – Smart positioner (digital valve controller)

Teaching Time: 50.0 hours

(Twenty 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

Safety Considerations

This module requires that the trainees work with potentially energized electrical and pneumatic equipment. Safety must be emphasized at all times. The trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

Classroom Equipment and Materials

Whiteboard
Markers
Pencils and paper
Instrumentation Level Four PowerPoint® Presentation
DVD player or a computer with a DVD drive
LCD projector and screen
Computer with internet access
Review Questions answer key
Copies of the module examination (for paper-based exams) and Performance Profile Sheets
Scientific calculators (*optional*)
Multifunction calibrator
Pneumatic calibrator
Pressure transmitters (various technologies)
Temperature transmitters (various technologies)
Smart communicator
Transducer
Valve positioner
Appropriate cabling and tubing for calibrators

Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE to include the following:
- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Pneumatic calibrator (or multifunction calibrator with pneumatic kit)
Multifunction calibrator
Pneumatic pressure transmitter
Analog electronic pressure transmitter
Analog electronic temperature transmitter
Smart transmitter
Smart communicator
Pneumatic positioner
Electro-pneumatic positioner
Smart positioner
Appropriate cables and tubing for calibrators
Appropriate hand tools
Calibration documentation forms

Additional Resources

This module presents thorough resources for task training. The following reference materials are recommended for further study.

Measurement and Control Basics, Thomas A. Hughes. Fifth Edition. 2014. Research Triangle Park, NC: International Society of Automation.

Maintenance and Calibration of HART® Field Instrumentation (PDF), R. Pirret. Fluke Corporation, Everett, WA, USA. Accessed at www.plantservices.com.

The following websites offer resources for products and training:

Crystal Engineering Corporation, **www.crystalengineering.com**

Emerson Process Management, **www.emersonprocess.com**

Fluke Corporation, **www.fluke.com**

GE, Measurement & Control, **www.gemeasurement.com**

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Instructors are also encouraged to locate additional audiovisual aids available on the internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

Session Outline for 12402-16

Instrument Calibration and Configuration

The Lesson Plan for this module is divided into twenty 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

Session One

Session One introduces the calibration process and its associated terminology. The five-point method of calibration is summarized. Calibration documentation is introduced. This session covers Sections 1.0.0 through 1.2.0.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the general concepts behind calibration.
3. Define *calibration* and explain why it must be done routinely.
4. Introduce the concepts and terminology associated with calibration.
5. Summarize the calibration process and its associated documentation.
6. Explain how to perform a five-point calibration.

Session Two

Session Two examines pneumatic transmitter technology and the way in which it's calibrated. Tools and techniques are summarized. Analog electronic transmitters are then examined and their calibration techniques are explained. This session covers Sections 2.0.0 through 2.2.7.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to review the purpose and operation of transmitters.
3. Describe pneumatic transmitters and introduce the terminology associated with them.
4. List the tools used to calibrate pneumatic transmitters.
5. Summarize the procedures used to calibrate pneumatic devices.
6. Describe analog electronic transmitters and introduce the terminology associated with them.
7. List the tools used to calibrate pneumatic transmitters.
8. Summarize the procedures used to calibrate pneumatic devices.

Session Three

Session Three shifts focus to the newer smart instrumentation and its calibration procedures. The HART protocol is examined. Communicators are introduced. Finally, the internals of a HART device are summarized and their roles in calibration explained. This session covers Sections 3.0.0 through 3.2.6.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the trainees to the tools used to calibrate smart devices.
3. Introduce the HART protocol and summarize its features.
4. Discuss the tools used to calibrate smart devices.
5. Provide an overview of the internal sections of a smart device.
6. Summarize the proper calibration procedure for smart devices.

Session Four

Session Four examines transducers and valve positioners. Transducer types are summarized. Valve positioners are explained. Different underlying technologies are examined. Calibration procedures are briefly summarized. This session covers Sections 4.0.0 through 4.2.2.

1. Show the Session Four PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the trainees to valve positioners.
3. Describe transducers and list the different types.
4. Explain the purpose of a valve positioner.
5. List the valve positioner technologies.
6. Summarize the procedures used to calibrate transducers and positioners.

SESSIONS FIVE THROUGH NINETEEN

Sessions Five through Nineteen are laboratory sessions devoted to the practice and completion of Performance Tasks 1 through 6.

1. Note that no PowerPoint® presentations are associated with these laboratory sessions.
2. Demonstrate how to calibrate a pneumatic pressure transmitter using the proper equipment and complete the appropriate documentation.
3. Demonstrate how to calibrate a 4–20 mA pressure transmitter using the proper calibration equipment and complete the appropriate documentation.
4. Demonstrate how to calibrate a 4–20 mA temperature transmitter using the proper calibration equipment and complete the appropriate documentation.
5. Demonstrate how to calibrate a smart transmitter using a HART communicator and complete the appropriate documentation.
6. Demonstrate how to calibrate a transducer and complete the appropriate documentation.
7. Demonstrate how to calibrate the following valve positioners and complete the appropriate documentation:
   - Pneumatic positioner
   - Electro-pneumatic positioner
   - Smart positioner (digital valve controller)
8. Have the trainees practice and/or complete the requirements of Performance Tasks 1 through 6 in these hands-on sessions.

SESSION TWENTY

Session Twenty is a review and testing session. Have the trainees complete the Module Review. Alternatively, these questions may be assigned as homework at the end of Session Nineteen. Go over the Module Review in class prior to the examination and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor. The results for examinations administered through the Testing Management System are recorded automatically in the NCCER Registry System.

Materials Checklist for 12402-16, Instrument Calibration and Configuration

Equipment and Materials					
Personal protective equipment:		Scientific calculators (*optional*)		Pneumatic calibrator (or multifunction calibrator with pneumatic kit)	
Safety glasses		Multifunction calibrator		Multifunction calibrator	
Work gloves		Pneumatic calibrator		Pneumatic pressure transmitter	
Proper footwear as designated by the instructor or training facility provider		Pressure transmitters (various technologies)		Analog electronic pressure transmitter	
Hearing protection as designated by the instructor or training facility provider		Temperature transmitters (various technologies)		Analog electronic temperature transmitter	
Hard hat as designated by the instructor or training facility provider		Smart communicator		Smart transmitter	
Whiteboard/chalkboard		Transducer		Smart communicator	
Markers/chalk		Valve positioner		Pneumatic positioner	
Pencils and paper		Appropriate cabling and tubing for calibrators		Electro-pneumatic positioner	
Instrumentation Level Four PowerPoint® Presentation Slides				Smart positioner	
DVD player or a computer with a DVD drive				Appropriate cables and tubing for calibrators	
LCD projector and screen				Appropriate hand tools	
Computer with internet access				Calibration documentation forms	
Module Review answer key					
Copies of the module examination (for paper-based exams) and Performance Profile Sheets					

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

Lesson Plans for Module 12410-16

Proving, Commissioning, and Troubleshooting a Loop

Module 12410-16 introduces the multiple steps involved in bringing a process control loop online with live process. These steps include checking the loop, proving and calibrating it, and finally commissioning. Since problems are very likely at each step, troubleshooting is discussed in some detail with the goal of getting the loop ready for hand off to the next responsible party in the chain.

Objectives

Learning Objective 1

- Describe how to inspect loop components and perform continuity checks prior to proving the loop.
  a. Describe how to visually inspect various loop components.
  b. Describe how to conduct loop continuity tests on electrical and pneumatic devices.

Learning Objective 2

- Describe how to prove and calibrate a loop.
  a. Describe how to prove a loop.
  b. Describe how to calibrate a loop.

Learning Objective 3

- Describe how to commission a new loop.
  a. Describe the documents associated with commissioning.
  b. Describe the commissioning process.

Learning Objective 4

- Identify the fundamental steps in loop trouble-shooting and describe the troubleshooting process.
  a. Identify the fundamental steps in loop troubleshooting.
  b. Describe the loop troubleshooting process for oscillating loops.

Performance Tasks

Performance Task 1
(Learning Objective 1)

- Perform a continuity check on an electrical system and document the findings.

Performance Task 2
(Learning Objective 1)

- Perform a continuity check on a pneumatic system and document the findings.

Performance Task 3
(Learning Objective 2)

- Prove a loop and document its completion.

Performance Task 4
(Learning Objective 3)

- Commission a loop.

Performance Task 5
(Learning Objective 4)

- Troubleshoot a newly installed control loop.

Performance Task 6
(Learning Objective 4)

- Troubleshoot an oscillating process.

Teaching Time: 17.5 hours

(Seven 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

Safety Considerations

This module requires that the trainees work with potentially energized electrical and pneumatic equipment. Safety must be emphasized at all times. The trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

Classroom Equipment and Materials

Whiteboard
Markers
Pencils and paper
Instrumentation Level Four PowerPoint® Presentation
DVD player or a computer with a DVD drive
LCD projector and screen
Computer with internet access
Review Questions answer key
Copies of the module examination (for paper-based exams) and Performance Profile Sheets
Multifunction process calibrator
Simple continuity test meter
Pneumatic calibrator
Hand pump (if pneumatic calibrator does not include a pressure source)
Smart communicator
Appropriate cabling and tubing for test equipment

Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE to include the following:
- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Multifunction process calibrator (or simple continuity test meter)
Pneumatic calibrator (or multifunction calibrator with pneumatic kit)
Hand pump (if pneumatic calibrator does not include a pressure source)
Appropriate cables and tubing for test equipment
Appropriate hand tools
Electrical process control loop
Pneumatic process control loop
Loop documentation package

Additional Resources

This module presents thorough resources for task training. The following reference material is recommended for further study.

Instrumentation for Process Measurement and Control, Norman A. Anderson. Third Edition. 1997. Boca Raton, FL: CRC Press.

Maintenance and Calibration of HART® Field Instrumentation (PDF), Richard Pirret. Fluke Corporation, Everett, WA, USA. Accessed at **www.plantservices.com**.

The following websites offer resources for products and training:

Amtek Calibration, **www.crystalengineering.net**

Emerson Process Management, **www.emersonprocess.com**

Extech Instruments, **www.extech.com**

Fluke Corporation, **www.fluke.com**

GE Digital Solutions, **www.gemeasurement.com**

Omega Engineering, **www.omega.com**

WIKA Instrument, LP, **www.wika.us**

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Instructors are also encouraged to locate additional audiovisual aids available on the internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

Session Outline for 12410-16

Proving, Commissioning, and Troubleshooting a Loop

The Lesson Plan for this module is divided into seven 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

Session One

Session One introduces the process of loop checking. Visual loop inspection is covered as an initial step. Loop continuity checks are then addressed. These include both electrical and pneumatic loop checks. The tools involved in each type of test are examined. This session covers Sections 1.0.0 through 1.2.3.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to introduce a test device commonly used to check and prove an electrical process control loop.
3. Define *loop checking* and explain why it must be done after a loop has been assembled.
4. Discuss visual loop checking as the means by which obvious problems are identified.
5. Define *continuity checking* and explain the kinds of problems it identifies.
6. Summarize the tools and techniques used to continuity test both electrical and pneumatic loops.

Session Two

Session Two examines the process of proving a loop to confirm its basic operational status. Process simulation and appropriate test equipment are introduced. Basic calibration concepts are addressed. The instrument asset management system is introduced as a modern way of handling loop information in a centralized database. Loop commissioning is then introduced as the final stage prior to handing off the loop to the next person in the chain. The documentation associated with this step is examined. This session covers Sections 2.0.0 through 3.2.0.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to familiarize the trainees with a multifunction process calibrator.
3. Define *loop proving* and explain its role in preliminary testing of a control loop.
4. Discuss the tools used to simulate the process and assess the loop's performance.
5. Summarize the tests used to assess programmable components and alarm/interlock systems.
6. Briefly examine calibration and the role that it plays in the proving process.
7. Introduce asset management as a modern way to centralize information about loops.
8. Discuss loop commissioning and its purposes.
9. Summarize the documents that must be assembled as a part of commissioning.
10. List the steps involved in commissioning.

Proving, Commissioning, and Troubleshooting a Loop

Session Three

Session Three deals with the important but complex task of troubleshooting. In each stage of the process that leads up to handoff, problems may arise. Trainees are shown how to work through a problem systematically in order to identify its causes. Test procedures and repairs are addressed. Finally, troubleshooting an oscillating process is examined. This session covers Sections 4.0.0 through 4.2.7.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to get the trainees thinking about the troubleshooting process.
3. Summarize the key strategies of troubleshooting.
4. Discuss methods for identifying a problem's cause and the components associated with the problem.
5. Introduce the idea of being systematic and logical in working through a troubleshooting problem.
6. Address the repair process that follows troubleshooting.
7. Explain how to handle an oscillating process, a very common problem in control loops.

Sessions Four through Six

Sessions Four through Six are laboratory sessions devoted to the practice and completion of Performance Tasks 1 through 6.

1. Note that no PowerPoint® presentations are associated with these laboratory sessions.
2. Demonstrate how to perform a continuity check on an electrical system and document the findings.
3. Demonstrate how to perform a continuity check on a pneumatic system and document the findings.
4. Demonstrate how to prove a loop and document its completion.
5. Demonstrate how to commission a loop.
6. Demonstrate how to troubleshoot a newly installed control loop.
7. Demonstrate how to troubleshoot an oscillating process.
8. The trainees practice and/or complete the requirements of Performance Tasks 1 through 6 in these hands-on sessions.

Session Seven

Session Seven is a review and testing session. Have the trainees complete the Module Review. Alternatively, these questions may be assigned as homework at the end of Session Six. Go over the Module Review in class prior to the examination and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor. The results for examinations administered through the Testing Management System are recorded automatically in the NCCER Registry System.

Materials Checklist for Module 12410-16, Proving, Commissioning, and Troubleshooting a Loop

Equipment and Materials					
Personal protective equipment:		Multifunction process calibrator		Multifunction process calibrator (or simple continuity test meter)	
Safety glasses		Simple continuity test meter		Pneumatic calibrator (or multifunction calibrator with pneumatic kit)	
Work gloves		Pneumatic calibrator		Hand pump (if pneumatic calibrator does not include a pressure source)	
Proper footwear as designated by the instructor or training facility provider		Hand pump (if pneumatic calibrator does not include a pressure source)		Appropriate cables and tubing for test equipment	
Hearing protection as designated by the instructor or training facility provider		Smart communicator		Appropriate hand tools	
Hard hat as designated by the instructor or training facility provider		Appropriate cabling and tubing for test equipment		Electrical process control loop	
Whiteboard/chalkboard				Pneumatic process control loop	
Markers/chalk				Loop documentation package	
Pencils and paper					
Instrumentation Level Four PowerPoint® Presentation Slides					
DVD player or a computer with a DVD drive					
LCD projector and screen					
Computer with internet access					
Module Review answer key					
Copies of the module examination (for paper-based exams) and Performance Profile Sheets					

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

Lesson Plans for Module 12405-16

Tuning Loops

Module 12405-16 introduces the process of tuning a working control loop to maintain optimal stability and performance. All controllers require some tweaking for best results. PID controllers, in particular, must be adjusted to achieve the best balance between stability and responsiveness. This module explores the different tuning methods along with their associated equations and procedures.

Objectives

Learning Objective 1

- Describe the function of tuning and basic proportional control concepts.
  a. Describe the importance and function of loop tuning.
  b. Describe basic proportional control and define terms relevant to tuning.

Learning Objective 2

- State the basic equations needed for loop tuning and describe various loop tuning processes.
  a. State the basic equations needed for loop tuning.
  b. Describe open loop tuning processes.
  c. Describe closed loop tuning processes.
  d. Describe a visual loop tuning process.

Performance Tasks

Performance Task 1
(Learning Objective 2)

- Perform open loop tuning.

Performance Task 2
(Learning Objective 2)

- Perform closed loop tuning.

Performance Task 3
(Learning Objective 2)

- Perform visual loop tuning.

Teaching Time: 15 hours

(Six 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

Safety Considerations

This module requires that the trainees work with potentially energized electrical and pneumatic equipment. Safety must be emphasized at all times. The trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

Classroom Equipment and Materials

Whiteboard
Markers
Pencils and paper
Instrumentation Level Four PowerPoint® Presentation
DVD player or a computer with a DVD drive
LCD projector and screen
Computer with Internet access
Review Questions answer key
Copies of the module examination (for paper-based exams) and Performance Profile Sheets
Process controller
Chart recorder (paper or digital)
Appropriate cabling and tubing for test equipment
Scientific calculators

Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE to include the following:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Process control loop
Chart recorder (paper or digital)
Appropriate cables and tubing for test equipment
Appropriate hand tools
Calculator

Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

Good Tuning: A Pocket Guide, G. K. McMillan. Second Edition. 2005. Research Triangle Park, NC: International Society of Automation.

The International Society of Automation, **www.isa.org**

Instructors are also encouraged to locate additional audiovisual aids available on the internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

Session Outline for 12405-16

Tuning Loops

The Lesson Plan for this module is divided into six 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

Session One

Session One introduces the process of loop tuning, a task that happens once a loop is up and running. Tuning terminology is introduced, controller types are reviewed, and the desired loop behavior is addressed. Process types are compared and contrasted. This session covers Sections 1.0.0 through 1.2.5.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the concept of tuning.
3. Explain the reason that controllers must be tuned for best performance.
4. Outline the key concepts associated with loop stability and behavior.
5. Review P, PI, and PID controllers, focusing on their key characteristics and applications.
6. Define the terms associated with loop tuning.
7. Introduce process types and their key qualities and differences.

Session Two

Session Two examines different methods of tuning process control loops. Basic equations used to calculate key parameters are surveyed. Examples to illustrate the equations are introduced. This session covers Sections 2.0.0 through 2.1.8.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to review the two process categories.
3. Introduce the loop tuning equations and the terminology associated with them.
4. Work through the example calculations associated with each equation.

Session Three

Session Three explores the three tuning methods. The trainees are exposed to open loop, closed loop, and visual tuning methods. Example problems are included. This session covers Sections 2.2.0 through 2.4.3.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the trainees to the features of a modern controller.
3. Introduce the open loop tuning method, summarizing the general concepts behind it.
4. Describe the time constant tuning method, working through its calculations.
5. Describe the reaction rate tuning method, working through its calculations.
6. Introduce the closed loop tuning method, summarizing the general concepts behind it.
7. Describe the ultimate period tuning method, working through its calculations.
8. Describe the dampened oscillation tuning method, working through its calculations.
9. Describe visual loop tuning and list some of the situations that it can be used to improve.

Tuning Loops

Sessions Four and Five

Sessions Four and Five are laboratory sessions devoted to the practice and completion of Performance Tasks 1 through 3.

1. Note that no PowerPoint® presentations are associated with these laboratory sessions.
2. Demonstrate how to perform open loop tuning.
3. Demonstrate how to perform closed loop tuning.
4. Demonstrate how to perform visual loop tuning.
5. Have trainees practice and/or complete the requirements of Performance Tasks 1 through 3 in these hands-on sessions.

Session Six

Session Six is a review and testing session. Have the trainees complete the Module Review. Alternatively, these questions may be assigned as homework at the end of Session Five. Go over the Module Review in class prior to the examination and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor. The results for examinations administered through the Testing Management System are recorded automatically in the NCCER Registry System.

Materials Checklist for Module 12405-16, Tuning Loops

Equipment and Materials					
Personal protective equipment:		Process controller		Process control loop	
Safety glasses		Chart recorder (paper or digital)		Chart recorder (paper or digital)	
Work gloves		Appropriate cabling and tubing for test equipment		Appropriate cables and tubing for test equipment	
Proper footwear as designated by the instructor or training facility provider		Scientific calculators		Appropriate hand tools	
Hearing protection as designated by the instructor or training facility provider				Calculator	
Hard hat as designated by the instructor or training facility provider					
Whiteboard/chalkboard					
Markers/chalk					
Pencils and paper					
Instrumentation Level Four PowerPoint® Presentation Slides					
DVD player or a computer with a DVD drive					
LCD projector and screen					
Computer with Internet access					
Module Review answer key					
Copies of the module examination (for paper-based exams) and Performance Profile Sheets					

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

Lesson Plans for Module 12401-16

Digital Logic Circuits

Module 12401-16 introduces the key concepts of digital technology, which underlies many aspects of modern instrumentation. Digital information representation and logic families will be examined. Trainees will study gates, combination logic, memory circuits, arithmetic circuits, and decoders. They will also explore the number systems commonly associated with digital electronics and see how they are applied in arithmetic and counting circuits.

Objectives

Learning Objective 1

- Identify and describe the basic concepts and elements of digital logic circuits.
  a. Define digital logic technology and terminology.
  b. Identify and describe AND, OR, XOR, and NOT gates.
  c. Identify and describe NAND, NOR, and XNOR gates.
  d. Describe combination logic and its purposes.

Learning Objective 2

- Identify and describe memory elements and their function in digital circuits.
  a. Identify and describe the basic flip-flop design.
  b. Explain the operation of clocked logic and clocked flip-flops.
  c. Describe the function of various types of registers.

Learning Objective 3

- Describe counters and their function in digital circuits.
  a. Describe the numbering systems related to digital circuits.
  b. Describe the function of binary counters.
  c. Describe the function of other types of counters.

Learning Objective 4

- Describe the function of arithmetic elements and decoders.
  a. Describe the function of basic arithmetic elements.
  b. Describe the function of decoders.

Performance Task

Performance Task 1

(Learning Objective 1)

- Create the truth table that describes the behavior of an instructor-supplied schematic.

Teaching Time: 15.0 hours

(Six 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

Prerequisites

Core Curriculum, *Instrumentation Level One*, *Instrumentation Level Two, and Instrumentation Level Three*.

Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

Safety Considerations

Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

Classroom Equipment and Materials

Whiteboard

Markers

Pencils and paper

Instrumentation Level Four PowerPoint® Presentation

DVD player or a computer with a DVD drive

LCD projector and screen

Computer with internet access

Review Questions answer key

Copies of the module examination (for paper-based exams) and Performance Profile Sheets

Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE to include the following:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Combination logic circuit schematics

Blank truth table

Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

Digital Fundamentals, Thomas L. Floyd. Eleventh Edition. 2015. Upper Saddle River, NJ: Prentice Hall.

Instructors are also encouraged to locate additional audiovisual aids available on the internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

Session Outline for 12401-16

Digital Logic Circuits

The Lesson Plan for this module is divided into six 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

Session One

Session One introduces digital logic technology. Digital information representation is summarized and logic families are introduced. Compatibility among families is examined and the criteria for compatibility is addressed. Gates, the building blocks of all digital circuits, are introduced along with the concept of the truth table as a way of describing gate function. This session covers Sections 1.0.0 through 1.2.4.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get trainees engaged and to introduce digital technology.
3. Summarize digital information representation.
4. Introduce the concept of logic families and compatibility factors.
5. Discuss the concepts of digital gates, schematic symbols, and truth tables.
6. Introduce the AND, OR, XOR, and NOT gates.

Session Two

Session Two introduces several additional gate types. It also examines the ways in which gates can be combined to produce the more sophisticated circuits known as combination logic. Truth tables as a means of documenting and describing combination logic circuits are examined. Finally, this session includes a laboratory activity designed to fulfill Performance Task 1. This session covers Sections 1.3.0 through 1.4.4.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to reveal the need for truth tables as a means of describing circuit behavior.
3. Introduce NAND, NOR, XNOR, and buffer gates.
4. Explain the ways in which gates can be combined into combination logic circuits.
5. Demonstrate how to use a truth table to document and describe the behavior of a combination logic circuit.
6. Have trainees practice and/or complete the requirements of Performance Task 1.

Session Three

Session Three introduces digital memory circuits starting with the flip-flop and working up to the register. Key flip-flop concepts are explained. RS, D, and JK types are examined. The clock signal as a means of synchronizing circuits is introduced along with timing diagrams. Finally, flip-flops are combined to produce larger storage devices such as registers. This session covers Sections 2.0.0 through 2.3.2.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to help the trainees see the need for digital circuits that can store information.
3. Introduce the need for digital memory circuits as an essential adjunct to combination logic.
4. Describe the construction of an RS flip-flop and discuss its operation.
5. Explain the idea of clocked logic and the role that the clock signal plays in synchronizing circuits.
6. Expand the RS flip-flop's functionality into the D and JK flip-flops.
7. Address the ways in which flip-flops can be combined into larger memory devices, such as registers.

SESSION FOUR

Session Four explains the number systems commonly used in digital electronics. Decimal, binary, and hexadecimal numbers are compared and their roles explored. Binary counters made from flip-flops are examined and their variants introduced. This session covers Sections 3.0.0 through 3.3.2.

1. Show the Session Four PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the trainees to binary numbers.
3. Explain the basic ideas of numbering systems and introduce binary numbers. Compare binary to decimal.
4. Introduce hexadecimal numbers and compare them to binary and decimal.
5. Describe basic binary counters and examine the way in which they work and count.
6. Summarize some of the common variations on the basic binary counter.

SESSION FIVE

Session Five introduces the concept of digital circuit arithmetic. Binary and decimal addition are compared and their similarities stressed. The simple adder circuit is examined. Larger adders made from many simple adders extend this idea. Finally, decoder circuits are briefly studied as a means of converting digital information into different forms. This session covers Sections 4.0.0 through 4.2.2.

2. Use the Kickoff Activity to encourage the trainees to think actively about what they are doing when adding two numbers.
3. Summarize the key principles of addition, emphasizing carrying between columns.
4. Compare binary and decimal addition, stressing the similarities.
5. Introduce the simple adder circuit and explain its operation.
6. Demonstrate how simple adders can be combined to create larger adders.
7. Explain the role of the decoder circuit and provide a few basic examples.

SESSION SIX

Session Six is a review and testing session. Have the trainees complete the Module Review. Alternatively, these questions may be assigned as homework at the end of Session Five. Go over the Module Review in class prior to the examination and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor. The results for examinations administered through the Testing Management System are recorded automatically in the NCCER Registry System.

Materials Checklist for Module 12401-16, Digital Logic Circuits

Equipment and Materials					
Personal protective equipment:		Combination logic circuit schematics		Blank truth tables	
Safety glasses					
Work gloves					
Proper footwear as designated by the instructor or training facility provider					
Hearing protection as designated by the instructor or training facility provider					
Hard hat as designated by the instructor or training facility provider					
Whiteboard/chalkboard					
Markers/chalk					
Pencils and paper					
Instrumentation Level Four PowerPoint® Presentation Slides					
DVD player or a computer with a DVD drive					
LCD projector and screen					
Computer with internet access					
Module Review answer key					
Copies of the module examination (for paper-based exams) and Performance Profile Sheets					

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

Lesson Plans for Module 12406-16

Programmable Logic Controllers

Module 12406-16 introduces programmable logic controllers (PLCs), a common control device found in many different industries. The trainees will learn what makes up a PLC and how PLCs compare to older hardwired systems. The numbering systems commonly used with PLCs are presented, and the different hardware components that make up the system are described. PLC programming is explained and information on ladder diagram (LD) programming is provided.

Objectives

Learning Objective 1

- Define and describe PLCs and compare them to hardwired systems.
  a. Define and describe basic PLCs and systems.
  b. Compare hardwired systems to PLC systems.

Learning Objective 2

- Describe the various number systems that correspond with the digital operation of PLCs.
  a. Describe the binary number system.
  b. Describe the hexadecimal number system.
  c. Define and describe binary coding.

Learning Objective 3

- Describe and explain the function of various PLC hardware components.
  a. Describe typical power supplies.
  b. Describe and explain the operation of processors.
  c. Describe and explain the operation of I/O and communications modules.

Learning Objective 4

- Describe PLC programming concepts.
  a. Identify various programming languages used to program PLCs.
  b. Explain how ladder diagramming is used and identify the six related categories of instructions.
  c. State typical guidelines for PLC programming and installation.

Performance Tasks

Performance Task 1

(Learning Objectives 1 and 3)

- Given an instructor-provided PLC diagram, identify the basic components in a PLC system.

Performance Task 2

(Learning Objective 4)

- Given an instructor-provided ladder diagram program, point out commonly used symbols and their meaning.

Performance Task 3

(Learning Objective 4)

- Implement a simple logic circuit using an instructor-provided PLC platform or simulator.

Teaching Time: 12.5 hours

(Five 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

Safety Considerations

This module requires that the trainees work with potentially energized equipment. Safety must be emphasized at all times. The trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

Classroom Equipment and Materials

Whiteboard

Markers

Pencils and paper

Instrumentation Level Four PowerPoint® Presentation

DVD player or a computer with a DVD drive

LCD projector and screen

Computer with internet access

Review Questions answer key

Copies of the module examination (for paper-based exams) and Performance Profile Sheets

PLC processor

PLC modules of various types

PLC equipment rack

Computer running a PLC development system

PLC simulator (alternative to PLC development system)

Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE to include the following if this laboratory is not conducted in a regular classroom:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

PLC system diagrams

PLC LD program diagrams

PLC systems (or PLC simulators)

PLC development systems for PLC (or simulator)

Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

Programmable Controllers, Thomas A. Hughes. Fourth Edition. 2004. Research Triangle Park, NC: International Society of Automation.

Programmable Logic Controllers, W. Bolton. Sixth Edition. 2015. Oxford, UK: Newnes/Elsvier.

The following websites offer resources for products and training:

Rockwell Automation, Inc., **ab.rockwellautomation.com**

AutomationDirect, **www.automationdirect.com**

Instructors are also encouraged to locate additional audiovisual aids available on the internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

Session Outline for 12406-16

Programmable Logic Controllers

The Lesson Plan for this module is divided into five 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

Session One

Session One introduces programmable logic controllers. The basic pieces of a PLC system are introduced and PLC sizes and capabilities are discussed. PLCs are then compared to traditional hardwired control systems. A detailed explanation of the numbering and encoding schemes commonly used with PLCs (binary, hexadecimal, ASCII, BCD, and Gray code) is provided. This session covers Sections 1.0.0 through 2.3.3.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get the trainees engaged and to introduce PLC technology.
3. Describe the different parts of a PLC system.
4. Introduce the idea of different sized PLCs for applications ranging from the very simple to the very complex.
5. Compare and contrast hardwired control systems to PLCs.
6. Introduce the binary and hexadecimal numbering systems, and explain how to perform conversions between bases.
7. Introduce encoding schemes, using ASCII, BCD, and Gray code as examples.

Session Two

Session Two examines the key parts of a PLC system in more detail. PLC power supplies, processors, communications modules, and I/O modules are discussed. The PLC memory map is introduced. The PLC's scan cycle is connected to the topics of I/O and program logic. Finally, module addressing is briefly explained. This session covers Sections 3.0.0 through 3.3.7.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to give the trainees hands-on contact with the hardware that makes up a PLC system.
3. Review the key components that make up a PLC system.
4. Introduce power supplies and explain their grounding requirements.
5. Discuss PLC processors, focusing upon their power and memory capacity.
6. Describe the PLC memory map and processor scan cycle, relating it to I/O and program logic.
7. Introduce and describe the different types of I/O modules, stressing their applications.
8. Introduce and describe the different types of PLC communications modules. Discuss the roles that they play in PLC communications with other devices.
9. Briefly examine module addressing, using a popular approach as an example.

SESSION THREE

Session Three shifts the focus to software, introducing the different programming systems commonly used with PLCs. The five standard programming languages are summarized, compared, and contrasted. Ladder diagram (LD), the oldest and most popular of the five, is examined in greater detail to familiarize trainees with the key ideas of this form of programming. Development systems are examined, and PLC installation procedures are presented. This session covers Sections 4.0.0 through 4.3.4.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the steps involved in planning a PLC program.
3. Discuss the purpose of PLC programming and introduce the five standard programming languages.
4. Compare and contrast the five standard programming languages, focusing on how they differ in their approaches to reaching the same goal.
5. Describe development tools, including PLC simulators.
6. Introduce LD programming concepts, summarizing the six categories of program instructions.
7. Examine the key ideas of program design.
8. Provide an overview of PLC installation, wiring, and checkout.

SESSION FOUR

Session Four is a laboratory session devoted to the practice and completion of Performance Tasks 1, 2, and 3.

1. Note that no PowerPoint® presentations are associated with this laboratory session.
2. Demonstrate how to identify the basic components in a PLC system.
3. Demonstrate how to interpret the meaning of the symbols in LD programs.
4. Demonstrate how to implement a simple logic circuit using a PLC development system or simulator.
5. Have the trainees practice and/or complete the requirements of Performance Tasks 1, 2, and 3 in this hands-on session.

SESSION FIVE

Session Five is a review and testing session. Have the trainees complete the Module Review. Alternatively, these questions may be assigned as homework at the end of Session Four. Go over the Module Review in class prior to the examination and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor. The results for examinations administered through the Testing Management System are recorded automatically in the NCCER Registry System.

Materials Checklist for Module 12406-16, Programmable Logic Controllers

Equipment and Materials					
Personal protective equipment:		PLC system diagrams		PLC systems (or PLC simulators)	
Safety glasses		PLC LD program diagrams		PLC development systems for PLC (or simulator)	
Work gloves					
Proper footwear as designated by the instructor or training facility provider					
Hearing protection as designated by the instructor or training facility provider					
Hard hat as designated by the instructor or training facility provider					
Whiteboard/chalkboard					
Markers/chalk					
Pencils and paper					
Instrumentation Level Four PowerPoint® Presentation Slides					
DVD player or a computer with a DVD drive					
LCD projector and screen					
Computer with internet access					
Module Review answer key					
Copies of the module examination (for paper-based exams) and Performance Profile Sheets					
PLC processor					
PLC modules of various types					
PLC equipment rack					
Computer running a PLC development system					
PLC simulator (alternative to PLC development system)					

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

Lesson Plans for Module 12407-16

Distributed Control Systems

Module 12407-16 introduces distributed control systems (DCSs), one of several techniques used to control industrial processes. Trainees will learn what makes up a DCS and how it differs from other control technologies such as PLCs and SCADA. The different hardware components that form the complete system are defined and described. Information on the maintenance, calibration, and troubleshooting of DCSs is provided. DCS security, an increasingly important topic, is also addressed.

Objectives

Learning Objective 1

- Define a distributed control system and describe its evolution and relationship to other kinds of control systems.
  a. Define a distributed control system.
  b. Describe the evolution of DCS technology.
  c. Compare a DCS to other types of control systems.

Learning Objective 2

- Identify and describe components and systems related to DCSs.
  a. Describe the hardware components of a typical DCS.
  b. Describe servers and workstations used with DCSs.
  c. Describe DCS fieldbuses, networks, and communications protocols.
  d. Describe human-machine interfaces used with DCSs.

Learning Objective 3

- Describe common considerations for the maintenance of DCS technology.
  a. Describe various considerations for preventive and/or periodic instrument maintenance.
  b. Describe considerations and approaches to the calibration and repair of instrumentation.
  c. Explain the importance of expertise in the servicing of instrumentation and how information can be obtained.
  d. Identify security issues associated with a DCS and explain how they can be addressed.

Performance Task

Performance Task 1

(Learning Objectives 1 and 2)

- Develop a diagram of the basic system architecture of a DCS, including the components and information flow.

Teaching Time: 15.0 hours

(Six 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

Prerequisites

Core Curriculum, *Instrumentation Level One*, *Instrumentation Level Two, and Instrumentation Level Three*.

Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

Safety Considerations

Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

Classroom Equipment and Materials

Whiteboard

Markers

Pencils and paper

Instrumentation Level Four PowerPoint® Presentation

DVD player or a computer with a DVD drive

LCD projector and screen

Computer with internet access

Review Questions answer key

Copies of the module examination (for paper-based exams) and Performance Profile Sheets

DCS controller

HMI/MMIs (several types preferred)

Example fieldbus cables and other related hardware

Example network hardware (switches, routers, cables, etc.)

Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE to include the following if this laboratory is not conducted in a regular classroom:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

Example DCS system diagrams

Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

The following websites offer resources for products and training:

- ABB, a global leader in power and automation technologies, **www.abb.com**
- Emerson Process Management, **www.emersonprocess.com**
- Fieldbus Foundation, **www.fieldbus.org**
- Honeywell International, **www.honeywellprocess.com**
- Profibus, the world leaders in industrial networking, **www.profibus.com**

Instructors are also encouraged to locate additional audiovisual aids available on the internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

Session Outline for 12407-16

Distributed Control Systems

The Lesson Plan for this module is divided into six 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

Session One

Session One introduces the concept of distributed control. The components of a typical DCS are introduced and a review of DCS history and development is presented. PLCs and SCADA are compared and contrasted to DCSs, with the similarities emphasized. This session covers Sections 1.0.0 through 1.3.3.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to get the trainees engaged and to introduce the DCS concept.
3. Discuss the idea of distributed rather than centralized control.
4. Introduce the five classes of components that make up a DCS.
5. Provide an overview of DCS evolution, focusing on how DCSs have changed in the last few decades.
6. Compare and contrast DCSs to other control technologies such as PLCs and SCADA.
7. Introduce safety instrumented systems (SIS) and explain how they fit into a DCS environment.

Session Two

Session Two explores the hardware that makes up a DCS. Field devices and controllers are examined and contrasted to a PLC-based control system. Controller I/O and embedded software are described. Redundancy as a means of greater reliability is introduced. Servers and workstations are defined, and their place in the DCS examined in some detail. Different types of servers and workstations are compared. This session covers Sections 2.0.0 through 2.2.8.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the trainees to typical DCS hardware.
3. Define *field devices* and discuss their levels of intelligence.
4. Introduce controllers, their characteristics, I/O, and embedded software.
5. Discuss the importance of redundancy in critical processes.
6. Define *server* and *workstation* and list the different types and roles.
7. Examine the role that operating systems play in servers and workstations.

Session Three

Session Three continues the overview of DCS hardware by examining the communications system, a crucial component that unites all of the distributed components of the system. Basic networking concepts are introduced. Various types of fieldbuses and high-level networks are surveyed. Information on HMIs and how they function is presented. A review of the many different types of displays, alerts, information screens, and alarms is also provided. This session covers Sections 2.3.0 through 2.4.9.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the trainees to Modbus, a typical example of a fieldbus.
3. Introduce DCS communication, stressing that it is essential to the foundational idea of a DCS.
4. Summarize basic networking concepts, including the layered method of modeling a network.
5. Define *fieldbuses*, list their qualities, and review the most popular types.
6. Introduce high-level networks and compare them to fieldbuses.
7. Define *HMI* and summarize the different types.
8. Discuss the different types of graphics, screens, alarms, and other displays that are available on HMIs.

SESSION FOUR

Session Four focuses on the issues involved with maintaining the DCS and keeping it secure. Information on maintenance, calibration, troubleshooting, and other related topics is presented. DCS security, a vital topic, is examined. DCS vulnerability is discussed, and methods used to resolve these issues are explored. This session covers Sections 3.0.0 through 3.4.3.

1. Show the Session Four PowerPoint® presentation.
2. Use the Kickoff Activity to illustrate the hazards posed by malware to control systems.
3. Explain the need for maintenance, particularly preventative maintenance.
4. Discuss calibration and repair techniques, emphasizing troubleshooting and the locations of likely failure.
5. List the best ways for trainees to gain expertise in DCS maintenance.
6. Introduce the topic of DCS security and its growing importance in an increasingly insecure world.
7. Discuss the nature of DCS attacks and the ways in which they attempt to penetrate the system from within and from without.
8. Discuss methods that can be used to prevent or thwart DCS attacks.

SESSION FIVE

Session Five is a laboratory session devoted to the practice and completion of Performance Task 1.

1. Note that no PowerPoint® presentations are associated with this laboratory session.
2. Demonstrate how to develop a diagram of the basic system architecture of a DCS.
3. Have the trainees practice and/or complete the requirements of Performance Task 1 in this hands-on session.

SESSION SIX

Session Six is a review and testing session. Have the trainees complete the Module Review. Alternatively, these questions may be assigned as homework at the end of Session Five. Go over the Module Review in class prior to the examination and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor. The results for examinations administered through the Testing Management System are recorded automatically in the NCCER Registry System.

Materials Checklist for Module 12407-16, Distributed Control Systems

Equipment and Materials					
Personal protective equipment:		Example DCS system diagrams			
Safety glasses					
Work gloves					
Proper footwear as designated by the instructor or training facility provider					
Hearing protection as designated by the instructor or training facility provider					
Hard hat as designated by the instructor or training facility provider					
Whiteboard/chalkboard					
Markers/chalk					
Pencils and paper					
Instrumentation Level Four PowerPoint® Presentation Slides					
DVD player or a computer with a DVD drive					
LCD projector and screen					
Computer with internet access					
Module Review answer key					
Copies of the module examination (for paper-based exams) and Performance Profile Sheets					
DCS controller					
HMI/MMIs (several types preferred)					
Example fieldbus cables and other related hardware					
Example network hardware (switches, routers, cables, etc.)					

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.

Lesson Plans for Module 12409-16

Analyzers and Monitors

Module 12409-16 introduces the many different types of analytical instruments commonly used in industry. The module begins with a brief overview of the chemistry concepts needed to understand the operation of these instruments. Concepts such as atoms, elements, compounds and chemical bonding are introduced, followed by an explanation of solutions and concentration. Acids, bases, salts, and pH are defined and explained. Analytical instruments are categorized by general function, introduced individually, and described in detail.

Objectives

Learning Objective 1

- Describe basic chemistry concepts and identify key characteristics of compounds and solutions.
  a. Identify and describe basic properties of elements and compounds.
  b. Define and describe chemical bonding and reactivity.
  c. Define and describe solutions and concentration.
  d. Define and describe acids, bases, pH, and salts.

Learning Objective 2

- Define the physical properties of density, specific gravity, viscosity, and turbidity, and identify methods used to analyze them.
  a. Define the properties of density and specific gravity and identify methods used to analyze them.
  b. Define the property of viscosity and identify methods used to analyze it.
  c. Define the property of turbidity and identify methods used to analyze it.

Learning Objective 3

- Define the properties of flash point, pH, conductivity, and oxidation-reduction potential, and identify methods used to analyze them.
  a. Define the property of flash point and identify methods used to analyze it.
  b. Define the property of pH and identify methods used to analyze it.
  c. Define the property of conductivity and identify methods used to analyze it.
  d. Define the property of oxidation-reduction potential and identify methods used to analyze it.

Learning Objective 4

- Identify methods used to analyze air and determine its content of O_2, CO, CO_2, H_2S, and THC.
  a. Identify methods used to analyze air and determine its content of oxygen (O_2).
  b. Identify methods used to analyze air and determine its content of carbon monoxide (CO).
  c. Identify methods used to analyze air and determine its content of carbon dioxide (CO_2).
  d. Identify methods used to analyze air and determine its content of hydrogen sulfide (H_2S).
  e. Identify methods used to analyze air and determine its content of total hydrocarbons (THC).

Learning Objective 5

- Define the properties of particulate count, chemical composition, infrared radiation, and UV light absorption, and identify methods used to analyze them.
  a. Define the property of particulate count and identify methods used to analyze it.
  b. Define the property of chemical composition and identify methods used to analyze it.
  c. Define the property of infrared radiation and identify methods used to analyze it.
  d. Define the property of UV light absorption and identify methods used to analyze it.

Performance Task

Performance Task 1

(Learning Objective 3)

- Determine the pH of a given solution and propose the proper adjustment.

Teaching Time: 40.0 hours

(Sixteen 2.5-Hour Sessions)

Session time may be adjusted to accommodate your class size, schedule, and teaching style.

Prerequisites

Core Curriculum, Instrumentation Level One, Instrumentation Level Two, and Instrumentation Level Three.

Before You Begin

As you prepare for each session, allow sufficient time to review the course objectives, content, visual aids, including the PowerPoint® presentation, and these lesson plans, and to gather the required equipment and materials. Consider the time required for demonstrations, laboratories, field trips, and testing.

Using your access code, download the module exams and Performance Profile Sheets from **www.nccerirc.com**. The passing score for submission into NCCER's Registry is 70% or above for the module exam; performance testing is graded pass or fail.

Safety Considerations

Safety must be emphasized at all times. Trainees should be carefully observed to ensure that they wear the proper PPE, follow safe practices, and give due respect to unseen hazards. Any deficiencies must be corrected to ensure future trainee safety. All practice sessions and Performance Tasks must be completed under your direct supervision.

Classroom Equipment and Materials

- Whiteboard
- Markers
- Pencils and paper
- *Instrumentation Level Four* PowerPoint® Presentation
- DVD player or a computer with a DVD drive
- LCD projector and screen
- Computer with internet access
- Review Questions answer key
- Copies of the module examination (for paper-based exams) and Performance Profile Sheets
- Large periodic table
- Hydrometer
- Falling ball viscometer
- Water samples of varying turbidity
- pH meter and probe
- Conductivity meter
- Handheld gas analyzer (CO or H_2S)
- Handheld IR imager or IR thermometer

Equipment and Materials for Laboratories and Performance Testing

Appropriate PPE to include the following:

- Safety glasses
- Work gloves
- Proper footwear as designated by the instructor or training facility provider
- Hearing protection as designated by the instructor or training facility provider
- Hard hat as designated by the instructor or training facility provider

- pH meter and probe
- Solution with known pH

Additional Resources

This module presents thorough resources for task training. The following resource material is suggested for further study.

Basic Chemistry, Karen C. Timberlake and William Timberlake. Fourth Edition. 2013. Upper Saddle River, NJ: Prentice-Hall.

Chemistry: Concepts and Problems: A Self-Teaching Guide, Clifford C. Houk and Richard Post. Second Edition. 1996. New York, NY: John Wiley & Sons, Inc.

Industrial Pressure, Level, and Density Measurement, Donald R. Gillum. Second Edition. 2008. Research Triangle Park, NC: The International Society of Automation.

Instrument Engineers Handbook, Volume 1: Process Measurement and Analysis, Béla G. Lipták (editor). Fourth Edition. 2003. Boca Raton, FL: CRC Press.

Instrumentation Reference Book, Walt Boyes (editor). Fourth Edition. 2009. Oxford, UK: Butterworth-Heinemann.

Measurement and Instrumentation Principles, Alan S. Morris. Third Edition. 2001. Oxford, UK: Butterworth-Heinemann.

The Condensed Handbook of Measurement and Control, N.E. Battikha. Third Edition, 2006. Research Triangle Park, NC: The International Society of Automation.

The International Society of Automation, **www.isa.org**

Instructors are also encouraged to locate additional audiovisual aids available on the internet, make personal videos, and take still pictures related to the subject matter and add them to the PowerPoint® presentations throughout the program.

Session Outline for 12409-16

Analyzers and Monitors

The Lesson Plan for this module is divided into sixteen 2.5-hour sessions.
This time includes 10 minutes for administrative tasks and a 10-minute break per session.

Session One

Session One introduces the basic concepts of matter in this foundational chemistry session. Atoms and atomic structure are reviewed, and elements, the periodic table, and compounds are discussed. This session covers Sections 1.0.0 through 1.1.3.

1. Show the Session One PowerPoint® presentation.
2. Use the Kickoff Activity to find out how much chemistry background the trainees have and how comfortable they are with the subject.
3. Introduce the basic building blocks of matter, including the atom and subatomic particles.
4. Define *elements* and explain how they are described and quantified.
5. Summarize the purpose and characteristics of the periodic table.
6. Define *compounds* and explain how they are constructed.

Session Two

Session Two introduces the basics of chemical reactions and bonding. Chemical bond types are summarized. Atomic mass concepts are introduced and calculations involving atomic masses are examined. This session covers Sections 1.2.0 through 1.2.2.

1. Show the Session Two PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the idea of chemical bonding.
3. Define *chemical reaction*.
4. Explain the role of the valence shell in chemical bonding.
5. Define and explain the mechanics of ionic, covalent, and metallic bonding.
6. Discuss atomic mass.
7. Introduce the mole and relate it to the quantity of matter and to mass.
8. Perform calculations involving atomic mass.

Session Three

Session Three introduces solutions and the concept of concentration. Trainees will learn to calculate concentration for a particular combination of solvent and solute. Acids and bases are introduced, as is the role that ions play in these substances. Finally, pH is introduced along with the concept of neutralization and salt formation. This session covers Sections 1.3.0 through 1.4.4.

1. Show the Session Three PowerPoint® presentation.
2. Use the Kickoff Activity to get the trainees thinking about acids and bases.
3. Explain the process of forming solutions.
4. Define *concentration* and explain its unit.
5. Perform calculations involving solutions and concentration.
6. Describe ions and the processes of dissociation and ionization.
7. Define *acid* and *base* and explain how they are classified.
8. Explain the pH scale and compare it to the pOH scale.
9. Describe neutralization and the formation of salts.

Session Four

Session Four introduces process analyzers. Physical properties are compared to chemical ones. Density and specific gravity are introduced, along with the instruments that measure them. This session covers Sections 2.0.0 through 2.1.5.

1. Show the Session Four PowerPoint® presentation.
2. Use the Kickoff Activity to get the trainees thinking about density and its role in the reason that some objects float and others sink.
3. Introduce process analyzers and their need for calibration.

4. Explain what a physical property is compared to a chemical one.
5. Define *density* and explain how it is calculated.
6. Compare specific gravity to density, stressing the similarity.
7. Perform density calculations.
8. Explore density-measuring instruments.

SESSION FIVE

Session Five introduces the physical property of viscosity. Various instruments that measure it are introduced. Fluid types are discussed. This session covers Sections 2.2.0 through 2.2.1.

1. Show the Session Five PowerPoint® presentation.
2. Use the Kickoff Activity to introduce Newtonian and non-Newtonian fluids.
3. Introduce the concept of viscosity.
4. Mention the role that temperature plays in viscosity changes.
5. List and describe the three types of viscometers.
6. Define Newtonian and non-Newtonian fluids.

SESSION SIX

Session Six introduces the physical property of turbidity. Different types of turbidity analyzers are described and their operation explained. This session covers Sections 2.3.0 through 2.3.4.

1. Show the Session Six PowerPoint® presentation.
2. Use the Kickoff Activity to get the trainees thinking about turbidity and the reason that it needs to be assessed.
3. Introduce the concept of turbidity.
4. Describe a Jackson turbidimeter to provide an overview of the way that turbidity is measured.
5. Describe modern turbidimeters and explain their operation.

SESSION SEVEN

Session Seven introduces chemical properties. Flash point is defined and the different methods for determining it are explored. The concept of pH is revisited and instruments used to measure pH are introduced. Information on probe types and their care is provided. This session covers Sections 3.0.0 through 3.2.4.

1. Show the Session Seven PowerPoint® presentation.
2. Use the Kickoff Activity to demonstrate how a flash point tester works.
3. Contrast a chemical property to a physical one.
4. Define *flash point* and list the different methods used to establish it.
5. Discuss the different standards that govern flash point determination.
6. Review pH and the pH scale.
7. Describe pH-measuring instruments.
8. Discuss the different types of pH probes and electrodes, including their care and calibration.

SESSION EIGHT

Session Eight is a laboratory session devoted to the practice and completion of Performance Task 1.

1. Note that no PowerPoint® presentations are associated with this laboratory session.
2. Demonstrate how to determine the pH of a given solution and propose the proper adjustment.
3. Have the trainees practice and/or complete the requirements of Performance Task 1 in this hands-on session.

Analyzers and Monitors

Session Nine

Session Nine introduces conductivity and describes the chemical processes that govern it. Conductivity-measuring instruments are introduced and described. Oxidation-reduction potential is defined. ORP-measuring instruments are introduced and described. This session covers Sections 3.3.0 through 3.4.3.

1. Show the Session Nine PowerPoint® presentation.
2. Use the Kickoff Activity to introduce oxidation and reduction.
3. Define *conductivity* and describe the chemical processes that govern it.
4. Introduce the units of conductivity.
5. Describe conductivity-measuring instruments and explain the issues that surround their use.
6. Define *oxidation-reduction potential*.
7. Describe ORP-measuring instruments and explain the issues that surround their use.

Session Ten

Session Ten introduces gas analyzers and explains their importance in industry. Oxygen analyzers are examined and their various underlying technologies examined. Carbon monoxide detectors are introduced and their importance in personnel safety discussed. This session covers Sections 4.0.0 through 4.2.0.

1. Show the Session Ten PowerPoint® presentation.
2. Use the Kickoff Activity to encourage the trainees to develop an awareness of carbon monoxide and its dangers.
3. Introduce gas analyzers and explain how and why they are used in industry.
4. Introduce oxygen analyzers and describe the different types.
5. Introduce carbon monoxide analyzers and explain the hazards that CO poses to personnel.
6. Describe carbon monoxide detectors.

Session Eleven

Session Eleven introduces several additional gas analyzers. Carbon dioxide and hydrogen sulfide are introduced and the analyzers that detect them are examined. Total hydrocarbon content is introduced and analyzers that assess it are described. This session covers Sections 4.3.0 through 4.5.1.

1. Show the Session Eleven PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the trainees to portable gas analyzers.
3. Describe carbon dioxide and its uses in industry.
4. Discuss carbon dioxide detectors and describe their various applications.
5. Introduce hydrogen sulfide and summarize the hazards associated with it.
6. Introduce and explain the function of various H_2S detectors.
7. Define *total hydrocarbon content* and explain how it is measured.

Session Twelve

Session Twelve introduces a miscellaneous collection of analyzers. Particulate analysis is addressed. Methods of determining particulate count for clean rooms are examined. This session covers Sections 5.0.0 through 5.1.2.

1. Show the Session Twelve PowerPoint® presentation.
2. Use the Kickoff Activity to introduce the trainees to clean rooms and the need for particle counting.
3. Summarize the remaining analyzers that will be examined.
4. Introduce particulate count and explain why it's important in a number of industries.
5. Describe the different methods used for determining particulate count.

SESSION THIRTEEN

Session Thirteen introduces chemical composition analyzers. Gas chromatography is discussed and the different forms of chromatographs are compared. This session covers Sections 5.2.0 through 5.2.1.

1. Show the Session Thirteen PowerPoint® presentation.
2. Use the Kickoff Activity to get the trainees thinking about how a complex mixture can be analyzed.
3. Discuss the reasons for chemical composition analysis.
4. Introduce gas chromatography as a powerful method for determining chemical composition.
5. Describe the basic operation of a gas chromatograph.
6. Examine the different types of columns and their qualities.

SESSION FOURTEEN

Session Fourteen introduces instruments that measure infrared radiation. IR thermography is summarized and various applications examined. Different types of IR-sensing instruments are considered. IR spectrometry as means of chemical analysis is introduced. This session covers Sections 5.3.0 through 5.3.4.

1. Show the Session Fourteen PowerPoint® presentation.
2. Use the Kickoff Activity to introduce IR thermography.
3. Describe the basic ideas behind infrared measurements.
4. Examine the factors that influence and affect infrared imaging.
5. Survey the uses of infrared thermography.
6. Describe the key ideas and components behind an IR spectrometer.

SESSION FIFTEEN

Session Fifteen introduces instruments that measure ultraviolet radiation. Explain that UV's differences from IR make it a useful tool in certain situations. UV analysis is introduced as a niche method that is useful in a limited number of circumstances. Different types and applications of UV analysis are examined. This session covers Sections 5.4.0 through 5.4.5.

1. Show the Session Fifteen PowerPoint® presentation.
2. Use the Kickoff Activity to review the characteristics of UV light.
3. Introduce UV analysis and compare it to IR.
4. Point out that UV is more specialized and limited as a method of analysis.
5. Examine UV analyzers and explore their uses.
6. Examine UV flame detectors.

SESSION SIXTEEN

Session Sixteen is a review and testing session. Have the trainees complete the Module Review. Alternatively, these questions may be assigned as homework at the end of Session Fifteen. Go over the Module Review in class prior to the examination and answer any questions that the trainees may have.

1. Have trainees complete the module exam. Any outstanding performance testing must be completed during this session as well.
2. Record the testing results on the Registration of Training Modules form and submit the form to your Training Program Sponsor. The results for examinations administered through the Testing Management System are recorded automatically in the NCCER Registry System.

Materials Checklist for Module 12409-16, Analyzers and Monitors

Equipment and Materials					
Personal protective equipment:		Large periodic table		pH meter and probe	
Safety glasses		Hydrometer		Solution with known pH	
Work gloves		Falling ball viscometer			
Proper footwear as designated by the instructor or training facility provider		Water samples of varying turbidity			
Hearing protection as designated by the instructor or training facility provider		Conductivity meter			
Hard hat as designated by the instructor or training facility provider		Handheld gas analyzer (CO or H_2S)			
Whiteboard/chalkboard		Handheld IR imager or IR thermometer			
Markers/chalk					
Pencils and paper					
Instrumentation Level Four PowerPoint® Presentation Slides					
DVD player or a computer with a DVD drive					
LCD projector and screen					
Computer with internet access					
Module Review answer key					
Copies of the module examination (for paper-based exams) and Performance Profile Sheets					

To the extent possible, and as required for performance testing, provide a selection of the tools listed for each session; alternatively, photos may be used to teach tool identification.