SMART AUTOMATION CERTIFICATION ALLIANCE

Certified Industry 4.0 Automation Specialist I
Core Micro-Credential Skill Standards

Abstract

Defines the knowledge, skills, and abilities required to succeed in positions (e.g. controls engineer or maintenance technician) that install, troubleshoot, program, and maintain factory automation in a modern environment that uses Industry 4.0 technologies. Selected micro-credentials also apply to Professional certification.

Version 1.0

Introduction to SACA

The Smart Automation Certification Alliance (SACA) is a non-profit foundation whose mission is to develop and deploy modular Industry 4.0 certifications for a wide range of industries. The vision is to provide highly affordable, accessible certifications that significantly increase the number of individuals who possess the skills represented by these credentials, thereby ensuring that companies have the highly skilled workers they need, and individuals are prepared to be successful in a "connected enterprise" world.

Industry-Driven Quality

SACA certifications are industry-driven, developed by industry for industry. They use a rigorous process that starts with the development of truly international skill standards, developed and endorsed by leading experts in Industry 4.0 technology throughout the world. Certifications examinations are created based on these standards, pilot-tested and statistically analyzed to ensure quality. Each certification includes a proctored hands-on evaluation and an online test to ensure that candidates for certification can "do" as well as "know." SACA uses an annual standards and examination review process for all certifications to ensure that the certifications continue to remain highly up-to-date.

Preparing Students

No specific training program, curriculum, or equipment is required to prepare individuals for certification. The SACA certifications only evaluate the skills and knowledge of the individual, regardless of the method used to obtain them.

Institutions interested in preparing individuals for the certifications should reach out to major training providers for information on courses and equipment aligned with the SACA standards.

Certifying Individuals

Individuals can receive certifications through authorized SACA certification centers. SACA ensures these certification centers maintain high standards with proctored exams, certified evaluators, and approved equipment for consistent hands-on evaluation.

Certification Structure

SACA certifications use a modular structure to enable them to fit into wide range of individual needs and industries and educational environments. The three SACA certification categories include:

- Associate
- Specialist
- Professional

Industry 4.0 Systems Occupational Certifications

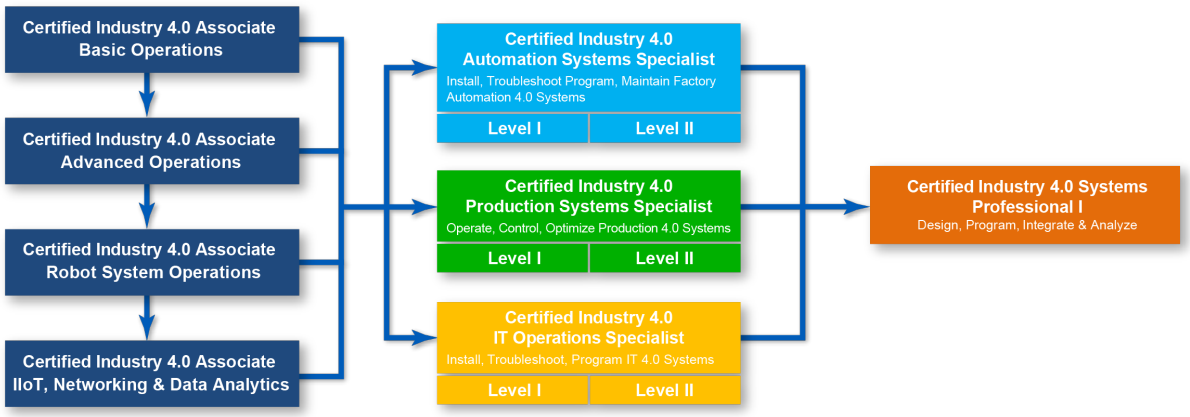

Figure 1 SACA Industry Certification Structure

Each certification is stackable. Individuals can start with one certification and add other certifications to customize their documented skills. Certifications are occupationally focused so they prepare individuals for specific occupations.

Specialist Certifications

The Specialist certifications include a group of required core micro-credentials that certify an individual as having the common knowledge, skills, and abilities required for Industry 4.0 across a wide range of industry sectors and a series of additional elective micro-credentials that may be required to meet the needs of specific industry sectors.

Each of the micro-credentials is a separate credential with both a hands-on practical assessment and a written (online) knowledge assessment.

When individuals achieve all core Specialist I micro-credentials and a safety-related credential (either OSHA 10-hour or SACA Associate-Basic Operations), they will be fully certified as an Industry 4.0 Specialist level 1.

C-200 Automation Systems Specialist I Credentials

The Automation Systems Specialist I certifications certify that individuals are prepared to succeed in positions (e.g. controls engineer or maintenance technician) that install, troubleshoot, program, and maintain factory automation in a modern environment that uses Industry 4.0 technologies. Selected micro-credentials also apply to Professional certifications.

Core Micro-Credentials

C-201 Electrical Systems 1
C-202 Electric Motor Control Systems 1
C-203 Variable Frequency Drive Systems 1
C-204 Motor Control Troubleshooting 1
C-205 Sensor Logic Systems 1
C-206 Electrical System Installation 1
C-207 Programmable Controller Systems 1
C-208 Programmable Controller Troubleshooting 1
C-209 Pneumatic Systems 1
C-210 Mechanical Power Systems I
C-211 Industry 4.0 Total Productive Maintenance Management
C-212 Ethernet Communications 1
C-213 Smart Sensor and Identification Systems 1
C-214 Smart Factory Systems 1
C-215 Robot System Operations 1
C-216 Robot Systems Integration 1

Elective Micro-Credentials

C-251 Mechanical Power Troubleshooting
C-252 Laser Shaft Alignment
C-253 Electric Motor Troubleshooting
C-254 Pneumatic Troubleshooting 1
C-255 Hydraulic Systems 1
C-256 Hydraulic Maintenance
C-257 Process Control Systems 1
C-258 Process Control Troubleshooting 1
C-259 Rigging Systems 1
C-260 Rigging Systems 2

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Misco Products Corporation

Mount Wachusett Community College

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C-200 Automation Specialist I

Core Micro-Credential Standards

C-201 Electrical Systems 1 Credential

- **Standard 201.1 Apply electrical system safety**
  - Performance Indicators
    - Perform a lockout/tagout
    - Identify electrical hazards
  - Knowledge Indicators
    - Describe how to identify electrical hazards
    - Describe PPE/ safe dress for operating electrical systems
    - Describe how to determine if equipment is properly grounded
    - Describe the basic rules of electrical safety
    - Describe the basic elements of NFPA 70E Arc Flash and live cabinet safety rules
- **Standard 201.2 Connect and operate basic electrical circuits**
  - Performance Indicators
    - Use an AC tester to check a wall outlet power
    - Connect and operate a power supply
    - Connect and operate circuits that use knife, push button, and selector switches
    - Connect and operate circuits that use resistors, buzzers, and lamps.
    - Connect and operate basic series and parallel circuits
  - Knowledge Indicators
    - Define electricity and give an application
    - Describe the two types of electrical current: AC and DC
    - Describe the operation of a circuit tester
    - Describe the basic operation of common input and output devices
    - Define series and parallel circuits
    - Describe the operation of two types of power supplies: AC and DC
    - Describe the operation of N.O. and N.C. switch contacts
- **Standard 201.3 Interpret electrical schematics and diagrams**
  - Performance Indicators
    - Identify the schematic symbols for resistors, transistors, transformers, lamps, motors, solenoids, meters, fuses, and switches
    - Identify series and parallel circuits in a schematic
    - Interpret a basic electrical schematic
  - Knowledge Indicators
    - Describe resistor color codes
    - Describe the function of an electrical schematic

- Explain the difference between a schematic and a wiring diagram

- **Standard 201.4 Use a digital multimeter (DMM) to make electrical measurements**
  - Performance Indicators
    - Use a DMM to measure voltage drops in series and parallel circuits
    - Use a DMM to measure current in series and parallel circuits
    - Use a DMM to measure the resistance of a component
    - Measure the resistance in series and parallel circuits
    - Use a DMM to test wire continuity
  - Knowledge Indicators
    - Define voltage and give its units of measurement
    - Describe the basic operation of a digital multimeter
    - Describe the basic operation of a clamp-on ammeter
    - Describe the voltage characteristics of series and parallel circuits
    - Define current and give its units of measurement
    - Describe current characteristics of series and parallel circuits
    - Define resistance and give its units of measurement
    - Describe the resistance characteristics of series and parallel circuits
    - Describe two methods of measuring continuity
- **Standard 201.5 Analyze basic load circuits**
    - Performance Indicators
    - Calculate voltage, current, and resistance in a series circuit
    - Calculate the total power used in a series circuit
    - Calculate the main line current in a parallel circuit
    - Calculate the total parallel resistance
    - Calculate the total power used in a parallel circuit
  - Knowledge Indicators
    - State Ohm's Law and explain its importance
    - State Kirchhoff's Voltage and Current Laws and explain their importance
    - Define power and give its units of measurement
- **Standard 201.6 Test and replace/reset fuses and circuit breakers**
  - Performance Indicators
    - Test and replace a fuse
    - Test and reset a circuit breaker
  - Knowledge Indicators
    - Describe the function and application of two types of circuit protection
    - Describe the operation of a fuse
    - Describe the operation of two types of circuit breakers
    - Describe how fuses and circuit breakers are rated
- **Standard 201.7 Connect and operate basic reactive components**
  - Performance Indicators
    - Connect and operate a circuit with an inductor
    - Connect and operate a circuit with a capacitor

        - Discharge a capacitor
        - Test a capacitor with a DMM
    - Knowledge Indicators
        - Define electromagnetism and give an application
        - Describe the operation of an inductor and give its schematic symbol
        - Describe the effect of an inductor in an AC and DC circuit and give an application
        - Describe the operation of a capacitor and its schematic symbol
        - Describe the effect of a capacitor in an AC and DC circuit and give an application
        - Describe the functions of 3 types of capacitors
- **Standard 201.8 Analyze basic combination circuits**
    - Performance Indicators
        - Trace the current path in a combination circuit
        - Connect and operate a basic lighting circuit
        - Connect and operate a voltage divider network
        - Connect and operate a rheostat as a load dimmer
        - Design a voltage divider network given parameters
        - Solve a combination circuit
    - Knowledge Indicators
        - Define a series-parallel circuit
        - Describe how to identify series and parallel circuit sections
        - Describe the operation of 3 types of voltage dividers
- **Standard 201.9 Troubleshoot basic series and parallel electrical circuits**
    - Performance Indicators
        - Locate a short circuit in a basic series or parallel circuit
        - Locate an open circuit in a basic series or parallel circuit
    - Knowledge Indicators
        - Explain the effects of short and open circuits
        - Describe how to troubleshoot short and open circuits
        - Describe the basic steps for troubleshooting an open circuit
- **Standard 201.10 Connect and operate single-phase transformer circuits**
    - Performance Indicators
        - Connect and operate a transformer
        - Test a transformer
        - Size a transformer
        - Design a control transformer circuit to provide a given output voltage
    - Knowledge Indicators
        - Describe the operation of a transformer
        - Describe the function of a control transformer
        - Describe the function/ application of a secondary tap on a transformer
- **Standard 201.11 Analyze Inductive Circuits**
    - Performance Indicators

- Calculate the total load on an AC inductive circuit
- Calculate the total inductance in series and parallel circuits
- Calculate the current load on a transformer
- Calculate the secondary coil voltage of a transformer

- Knowledge Indicators
  - Describe how to calculate total series inductance and inductive reactance
  - Describe how to calculate total parallel inductance and inductive reactance

- **Standard 201.12 Analyze Capacitive Circuits**
  - Performance Indicators
    - Calculate the total load on an AC capacitive circuit
    - Calculate the time to charge and discharge a capacitor
    - Calculate the total capacitance in series and parallel circuits
  - Knowledge Indicators
    - Describe how to calculate total series capacitance and capacitive reactance
    - Describe how to calculate total parallel capacitance and capacitive reactance

C-202 Electric Motor Control Systems 1 Credential

- **Standard 202.1 Apply approved safety practices for electric motor control systems**
  - Performance Indicators:
    - Perform a lockout/tagout
    - Identify and correct electrical hazards
  - Knowledge Indicators:
    - Describe electrical and electric motor hazards
    - Describe PPE/ safe dress for operating or troubleshooting motor control systems
    - Describe the purpose of the lockout/tagout system used in industry
    - Describe how to determine if equipment is properly grounded
    - Describe the basic rules of electrical safety
- **Standard 202.2 Interpret Ladder logic Schematics**
  - Performance Indicators:
    - Identify the symbols for transformers, lamps, motors, solenoids, meters, fuses, coils, contacts, limit switches, float switches, pressure switches, magnetic motor starters, manual motor starters, and pushbutton switches, and selector switches
  - Knowledge Indicators:
    - Interpret ladder diagram of a control circuit
    - Draw a ladder diagram of a control circuit
    - Describe the function of an electrical ladder diagram

- Describe six rules of drawing a ladder diagram
- Describe the function of electrical control systems
- Describe the operation of a separate control and power circuits
- Describe the operation of AND, OR, NOT,NOR, and NAND circuits

- **Standard 202.3 Make proper electrical ground connections**
  - Performance Indicators:
    - Use a multimeter to measure the voltage at a point referenced to ground
    - Install a grounding circuit for an electrical control system
    - Inspect and verify an installed grounding circuit
    - Identify and interpret NEC code for an electrical system
  - Knowledge Indicators:
    - Define a ground
    - Describe the parts of an electrical control system grounding circuit
    - Explain the importance of the equipment ground connection
    - Describe the operation of grounded and ungrounded systems
    - Explain the function of a neutral line
    - Describe the National Electrical Code (NEC) grounding requirements for electrical systems
- **Standard 202.4 Connect and operate a 3-phase motor**
  - Performance Indicators:
    - Connect and operate a dual-voltage three-phase motor for low voltage operation
    - Connect and operate a dual-voltage three-phase motor for high voltage operation
  - Knowledge Indicators:
    - Interpret a motor nameplate
    - Describe the functions of common standards associated with electrical control
    - Describe the basic operation of three-phase power
    - Describe the three-phase voltage systems: Wye and Delta
    - Explain why time-delay fuses are used with motor starting circuits
    - Describe the operation of overcurrent protection devices
    - Define service factor and explain its importance
    - Explain why dual-voltage motors should be run on the highest available voltage
    - Select heaters for a NEMA overload
- **Standard 202.5 Connect and operate a manual motor control circuit**
  - Performance Indicators:
    - Connect and operate a motor control circuit with a manual motor starter
    - Test the operation of a manual motor starter using a multimeter
    - Test the low-voltage protection of a manual starter

- Adjust and test the trip level of a bimetallic overload
- Connect and operate a drum switch to reverse a motor

- Knowledge Indicators:
  - Describe functions of motor control
  - Describe the basic requirements for motor installation
  - Describe types of motor starters
  - Describe the operation and importance of low-voltage protection
  - Describe the function and operation of magnetic and thermal overloads

- **Standard 202.6 Select and install a control transformer**
  - Performance Indicators:
    - Calculate the turns ratio of a transformer
    - Calculate the secondary voltage of a transformer
    - Connect and operate a control transformer
    - Test a control transformer
    - Size a control transformer
  - Knowledge Indicators:
    - Describe the operation of a control transformer and give its schematic symbol
- **Standard 202.7 Connect and operate a basic ladder logic control circuit**
  - Performance Indicators:
    - Connect and operate a basic electrical control circuit with pushbutton switch
    - Connect and operate a basic electrical control circuit with selector switch
    - Connect and operate a control circuit given a ladder diagram
    - Connect and operate a control relay in a memory logic circuit
    - Connect and operate a forward/reverse jog control circuit
  - Knowledge Indicators:
    - Describe the three steps of a control process
    - Describe the functions of the components of a ladder diagram
- **Standard 202.8 Connect and operate a 2/3 wire magnetic motor starter circuit**
  - Performance Indicators:
    - Connect and operate a two-wire motor control circuit
    - Connect and operate a three-wire motor control circuit
    - Design a multiple operator station three-wire control circuit
  - Knowledge Indicators:
    - Describe the operation of a control relay and give an application
    - Describe the operation/construction of 2 types of control relays
    - Describe the operation of a magnetic motor starter
- **Standard 202.9 Connect and operate a reversing motor control circuit**
  - Performance Indicators:

- Connect and operate a reversing magnetic motor starter to reverse a motor
- Connect and operate a reversing motor circuit with mechanical and auxiliary contact interlocking

▪ Knowledge Indicators:

- Describe two methods used to reverse a three-phase motor
- Describe the function of interlocking control
- Describe three interlocking methods used in reversing motor control
- Describe the function of manual and automatic modes
- Describe the operation of two types of motor jogging circuits
- Describe the operation of a hand-off-automatic motor control circuit
- State the NEMA and IEC standards for reversing the rotation of a three-phase motor

○ **Standard 202.10 Connect and operate a hands-off-auto motor control circuit**

▪ Performance Indicators:

- Connect and operate a hand-off-automatic motor control circuit
- Design a hands-off-automatic motor control circuit
- Design a pump control circuit that includes hand-off operation

▪ Knowledge Indicators:

- Describe the function of a hand-off-automatic motor control circuit
- Describe the function of a hand-off automatic circuit

○ **Standard 202.11 Connect and operate automatic input devices**

▪ Performance Indicators:

- Connect and operate a limit switch, pressure switch and a float switch
- Connect and operate a pump control circuit
- Connect and operate a motor control sequence control circuit
- Design a sequence control circuit

▪ Knowledge Indicators:

- Describe the function of a motor control sequence control circuit
- Describe the operation of a limit switch, pressure switch, and float switch

○ **Standard 202.12 Connect and operate basic timer control circuits**

▪ Performance Indicators**:**

- Connect and operate an On-Delay timer circuit
- Design a control circuit to perform an unloaded start of a motor
- Connect and operate an Off-Delay timer circuit
- Design a motor control circuit to perform time-driven sequencing

▪ Knowledge Indicators:

- Describe the function and application of a time-delay relay
- Describe the function of 2 types of timer relays: on-delay and off-delay
- Describe the operation of an On-Delay timer relay and give its schematic symbol
- Describe the operation of an unloaded motor start circuit

- Describe the operation of an Off-Delay timer relay and give its schematic symbol
- Describe the operation of a time-delay relay in a time-driven sequencing

C-203 Variable Frequency Drive Systems 1 Credential

- **Standard 203.1 Use a keypad to operate an AC variable frequency drive (VFD)**
  - Performance Indicators:
    - Verify that keypad input is enabled
    - Use a keypad to manually operate an AC variable frequency drive, including changing speed, direction
    - Perform a manual startup, drive enable, and normal shutdown of an AC VFD
  - Knowledge Indicators:
    - Describe the function of an AC VFD and give an application
    - Describe types of Variable Speed AC Drives
    - Describe the basic operation of an AC VFD
    - Describe the main parts of an AC VFD
    - Describe the keypad menus of an AC VFD
- **Standard 203.2 View and edit basic VFD parameters**
  - Performance Indicators:
    - Set VFD to factory default settings
    - View and edit basic VFD parameters
  - Knowledge Indicators:
    - Define a VFD parameter
    - Describe types of VFD parameters
    - Describe how to interpret a VFD parameter code
- **Standard 203.3 Interpret a PLC program that controls 2/3-wire VFD operation**
  - Performance Indicators:
    - Interpret a PLC program that controls 2-wire VFD operation
    - Interpret a PLC program that controls 3-wire VFD operation
    - Interpret a VFD wiring schematic
  - Knowledge Indicators:
    - Describe the operation 2 and 3-wire AC VFD
    - Describe the wiring connections to an AC VFD
    - Describe the I/O wiring connections to 2/3-wire operation AC VFD
- **Standard 203.4 Operate and monitor a VFD**
  - Performance Indicators:
    - Enter and operate a PLC program that controls 2/3-wire VFD
    - Configure VFD parameters for 2 or 3-wire operation
    - Perform a normal startup and shutdown of a VFD/PLC system
    - Pause a VFD

        - Perform an emergency shutdown of a VFD
    - Knowledge Indicators:
        - Describe the parameters required for 2 or 3-wire VFD operation
        - Describe how VFD systems are paused
        - Describe the operation of an e-stop VFD circuit
- **Standard 203.5 Reset a VFD after an error occurs**
    - Performance Indicators:
        - Interpret a VFD error code
        - Reset and restart a VFD after an error has occurred
    - Knowledge Indicators:
        - Describe types of VFD error codes
- **Standard 203.6 Program and operate a VFD for multi-speed operation**
    - Performance Indicators
        - Program and Operate an AC VFD using programmable preset speeds
        - Program and operate an AC VFD to provide low speed boost
        - Calculate Volts per Hertz Ratio to determine motor speed
        - Program a variable speed AC drive to skip frequencies
    - Knowledge Indicators
        - Describe how frequency affects the speed on an AC induction motor
        - Describe the output characteristics of a variable frequency drive
        - Describe the effect of reflected wave voltage on AC motor operation
        - Describe how to reduce the effects of reflected wave voltage
- **Standard 203.7 Program and operate a VFD for acceleration, deceleration, and braking**
    - Performance Indicators
        - Program and Operate an AC VFD to accelerate a motor to its rated speed
        - Program and Operate an AC VFD to decelerate a motor to a stop
        - Program and Operate an AC VFD to provide S-Curve acceleration
        - Program and Operate an AC VFD to provide DC Injection braking to a motor
    - Knowledge Indicators
        - Describe the operation of AC VFD ramping and how it is used
        - Describe how an AC VFD can accelerate a motor past its rated speed
        - Describe S-Curve acceleration and explain how it is used

C-204 Motor Control Troubleshooting 1 Credential

- **Standard 204.1 Troubleshoot motor control components**
    - Performance Indicators
        - Test motor control circuit components: indicator lamps, manual switches, control relays, motor contactors, and overload relays
        - Test the windings of a 3-phase motor with a digital multimeter

        - Test the windings of a control transformer with a digital multimeter
    - Knowledge Indicators
        - Describe the electric motor faults
        - Describe 3-phase motor starter faults
        - Describe manual switch faults
        - Describe control transformer faults
        - Describe types of in-circuit component tests
- **Standard 204.2 Use a clamp-on ammeter to measure motor current**
    - Performance Indicators
        - Use a clamp-on ammeter to measure AC current draw in a 3-phase circuit
    - Knowledge Indicators
        - Describe the operation of a clamp-on ammeter
- **Standard 204.3 Troubleshoot 2/3-wire motor control circuits**
    - Performance Indicators
        - Troubleshoot a 2-wire motor control system
        - Troubleshoot a 3-wire motor control system
    - Knowledge Indicators
        - Describe a 6-step troubleshooting sequence
        - Describe methods of systems level troubleshooting and give advantages of each
        - Describe methods used to analyze circuit signals
        - Describe how to isolate a bad component using the output-back and half-split troubleshooting methods
        - Describe faults, symptoms, and causes of 2 and 3-wire motor control circuits
- **Standard 204.4 Troubleshoot reversing motor control circuits**
    - Performance Indicators
        - Troubleshoot a reversing motor control circuit
        - Troubleshoot a motor control circuit that has manual and automatic modes
    - Knowledge Indicators
        - Describe faults, symptoms, and causes of reversing motor control circuits
- **Standard 204.5 Troubleshoot motor control circuits with automatic input devices**
    - Performance Indicators
        - Test an automatic input switch
        - Troubleshoot a motor control circuit with automatic input devices
        - Troubleshoot a motor control sequence control circuit
    - Knowledge Indicators
        - Describe how to test an automatic input device with a multimeter
        - Describe automatic input switch faults
        - Describe how to troubleshoot a sequence circuit

- **Standard 204.6 Troubleshoot timer control circuits**
  - Performance Indicators
    - Test a timer relay
    - Troubleshoot an On-Delay timer circuit
    - Troubleshoot an Off-Delay timer circuit
  - Knowledge Indicators
    - Describe the methods used to test a timer relay
- **Standard 204.7 Troubleshoot an AC VFD motor control system**
  - Performance Indicators:
    - Troubleshoot an AC VFD motor control system
    - Use status and diagnostic indicators to troubleshoot a VFD system
  - Knowledge Indicators:
    - Describe types of VFD processor faults
    - Describe a VFD systems troubleshooting process

C-205 Sensor Logic Systems 1 Credential

- **Standard 205.1 Identify and select an electronic sensor for an application**
  - Performance Indicators
    - Select an electronic sensor type for an application
    - Select sensor switch output type, NPN or PNP, for an application
  - Knowledge Indicators
    - Describe applications of electronic sensors
    - Describe the operation of 2 types of transistor(NPN,PNP) used in electronic sensors
    - Define sinking and sourcing signals
    - Describe the limitations of interfacing transistor devices to other control devices
    - Describe the function and application of opto-isolation
- **Standard 205.2 Connect and test an inductive proximity sensor**
  - Performance Indicators
    - Connect an inductive proximity sensor
    - Test an inductive proximity sensor
    - Adjust an inductive proximity sensor for best performance
  - Knowledge Indicators
    - Describe characteristics that affect inductive proximity sensor operation
- **Standard 205.3 Connect and test a capacitive proximity sensor**
  - Performance Indicators
    - Connect a capacitive proximity sensor
    - Test a capacitive proximity sensor
    - Adjust a capacitive proximity sensor for best performance
  - Knowledge Indicators

- Describe characteristics that affect capacitive proximity sensor operation

- **Standard 205.4 Connect and test a magnetic reed switch**
  - Performance Indicators
    - Connect a magnetic reed switch
    - Test a magnetic reed switch
    - Adjust a magnetic reed switch for best performance
  - Knowledge Indicators
    - Describe characteristics that affect magnetic reed switch operation
- **Standard 205.5 Connect and test a hall-effect sensor**
  - Performance Indicators
    - Connect a hall-effect sensor
    - Test a hall-effect sensor
    - Adjust a hall-effect sensor for best performance
  - Knowledge Indicators
    - Describe characteristics that affect hall-effect sensor operation
- **Standard 205.6 Connect and test a photoelectric sensor**
  - Performance Indicators
    - Connect a photoelectric sensor
    - Test a photoelectric sensor
    - Adjust a photoelectric sensor for best performance
  - Knowledge Indicators
    - Describe characteristics that affect photoelectric sensor operation
- **Standard 205.7 Interpret basic electrical control schematics**
  - Performance Indicators:
    - Interpret basic electrical ladder control schematics
  - Knowledge Indicators:
    - Describe the schematic symbols for electrical control circuits
    - Describe the operation of basic control logic
    - Describe basic electrical ladder schematic guidelines
- **Standard 205.8 Connect and test electro-pneumatic power circuits**
  - Performance Indicators
    - Use the manual override of a solenoid-operated pneumatic DCV to jog a cylinder
    - Connect and operate a double-acting cylinder using a 5/2 solenoid-operated pneumatic DCV
  - Knowledge Indicators
    - Describe the function of a power diagram
    - Describe the function of electro-pneumatic controls and give an application
- **Standard 205.9 Connect and test electric-relay sequence control circuits**
  - Performance Indicators:

- Interpret the operation of basic 2-step electric-relay sequence circuit schematic and power diagram
- Connect and operate a motor control start/stop circuit
- Connect and operate a relay-controlled sequence circuit
- Interpret the operation of a relay-controlled sequence circuit diagram

▪ Knowledge Indicators:

- Describe the operation of a seal-in logic circuit
- Describe operation of sequence interlock logic

○ **Standard 205.10 Connect and test relay sequence circuit that uses electronic sensors**

▪ Performance Indicators

- Connect and test an electronic sensor in an electrical relay circuit
- Interpret the operation a relay-controlled sequence circuit diagram that uses an electronic sensor

▪ Knowledge Indicators

- Describe control applications of electronic sensors
- Performance Indicators
- Test electronic sensors in-circuit
- Test relay control components in-circuit
- Troubleshoot relay sequence circuits
- Knowledge Indicators
- Describe symptoms and faults of electronic sensors
- Describe symptoms and faults of relay control components
- Describe methods of troubleshooting relay control sequence circuits

C-206 Electrical System Installation 1 Credential

○ **Standard 206.1 Apply industrial electrical wiring safety procedures**

▪ Performance Indicators

- Identify industrial electrical wiring installation hazards

▪ Knowledge Indicators

- Describe PPE/ safe dress for wiring industrial electrical systems
- Describe types of industrial electrical wiring installation hazards
- Describe types of electrical component and enclosure standards
- Describe NFPA 70 Arc Flash and explain its importance

○ **Standard 206.2 Interpret electrical prints for wiring installation**

▪ Performance Indicators

- Add wire number labels to an electrical print
- Determine wire size, color, and type needed for electrical panel wiring
- Select a circuit protection device for an electrical control system
- Size a safety disconnect switch

▪ Knowledge Indicators

- Describe the function of an electrical print

        - Describe the function of cross-reference symbols and notes on an electrical print
        - Describe types of wire, colors, and sizes for electrical panel wiring
- **Standard 206.3 Install wires and terminal blocks in electrical panels**
    - Performance Indicators
        - Size and install a terminal block in an electrical panel
        - Install control and power device wires in an electrical panel
        - Route wires in an electrical panel
        - Bundle wires in an electrical panel
    - Knowledge Indicators
        - Describe types of terminal blocks and ratings
        - Describe types of electrical panel routing methods
        - Describe types of wire bundling methods
- **Standard 206.4 Install grounding in an electrical panel**
    - Performance Indicators
        - Install a grounding circuit in an electrical control system
        - Inspect and verify an installed grounding circuit
    - Knowledge Indicators
        - Describe the National Electrical Code (NEC) grounding requirements for Electrical Systems
        - Describe the operation/components of an electrical control system grounding circuit
        - Describe methods of connecting ground wires
- **Standard 206.5 Size and install circuit protection for an industrial electrical panel**
    - Performance Indicators
        - Size a circuit protection device for an electrical control system
        - Size a safety disconnect switch
        - Install and test a circuit breaker in an industrial electrical panel
    - Knowledge Indicators
        - Describe the operation of a safety disconnect switch
        - Describe the operation/construction of industrial circuit breakers
- **Standard 206.6 Install wires between electrical panels**
    - Performance Indicators
        - Determine number of wires to run between electrical panels
        - Run wires through conduit between electrical panels
        - Route wires in an electrical panel
    - Knowledge Indicators
        - Describe types of terminal blocks and ratings
        - Describe types of electrical panel routing methods
- **Standard 206.7 Install electrical panel wiring to external control devices**
    - Performance Indicators
        - Connect electrical wires to limit switches and pressure switches

- Connect electrical wires to solenoid-operated pneumatic and hydraulic valves
- Run wiring through junction boxes to external control devices

▪ Knowledge Indicators
- Describe the construction of electrical switch wiring terminations
- Describe the construction of solenoid valve wiring terminations

○ **Standard 206.8 Install electrical panel wiring to electric motors**

▪ Performance Indicators
- Splice and tape motor leads using ring lug connectors
- Run electrical panel wiring to motor safety switches and motors
- Install and test an electrical motor control circuit using an electrical print

▪ Knowledge Indicators
- Describe how motors are connected to electrical panels

C-207 Programmable Controller Systems 1 Credential

○ **Standard 207.1 Start up and shut down a PLC system**

▪ Performance Indicators:
- Power up and perform a normal shutdown of a PLC system
- Identify the parts of a PLC

▪ Knowledge Indicators:
- Describe the basic operation of a programmable controller (PLC)
- Describe the component functions of a PLC
- Describe the operation of the PLC power supply circuit

○ **Standard 207.2 Configure an Ethernet/IP Driver**

▪ Performance Indicators:
- Configure an Ethernet/IP Driver to permit PLC to PC communications

▪ Knowledge Indicators:
- Describe the function of Ethernet/IP driver software

○ **Standard 207.3 Transfer programs between a PLC / PC via point-to-point Ethernet**

▪ Performance Indicators:
- Connect and configure a point-to-point PLC Ethernet network
- Download a PLC project from a PC via point-to-point Ethernet
- Upload a PLC project to a PC via point-to-point Ethernet

▪ Knowledge Indicators:
- Describe the basic operation of a point-to-point Ethernet network
- Describe the Ethernet IP address system for point-to-point
- Describe the basic operation of PLC programming software

○ **Standard 207.4 Transfer programs between a PLC / PC via USB serial**

▪ Performance Indicators:

- Connect and configure a point-to-point PLC serial network
- Download a PLC project from a PC via point-to-point USB serial
- Upload a PLC project to a PC via point-to-point USB serial

- Knowledge Indicators:
  - Describe the basic operation of USB serial communications
  - Describe the USB configuration using PLC programming software

- **Standard 207.5 Operate and monitor a PLC**
  - Performance Indicators:
    - Change PLC operation mode to Run or Program
    - Monitor PLC status using I/O indicators and software
  - Knowledge Indicators:
    - Describe the functions of PLC operation modes
- **Standard 207.6 Connect, configure, and operate an HMI panel with Ethernet**
  - Performance Indicators:
    - Connect and configure HMI panel with Ethernet network
    - Download a project to an HMI panel via an Ethernet network
    - Operate a basic HMI panel project with Ethernet network
  - Knowledge Indicators:
    - Describe the operation of a Human Machine Interface (HMI) panel
    - Describe basic functions of an HMI panel project
- **Standard 207.7 Configure PLC discrete I/O**
  - Performance Indicators:
    - Configure PLC discrete I/O
    - Identify a discrete I/O terminal given a tag
  - Knowledge Indicators:
    - Describe the memory organization of a typical PLC
    - Describe types of discrete PLC I/O modules
    - Describe how discrete I/O devices are interfaced to a PLC
    - Describe the format of PLC instruction and I/O addresses
    - Interpret a tag
- **Standard 207.8 Program and operate a basic PLC logic program**
  - Performance Indicators:
    - Interpret a basic PLC ladder logic program
    - Interpret a basic PLC I/O diagram
    - Interpret a basic PLC power diagram
    - Design and test a basic PLC ladder program
  - Knowledge Indicators:
    - Describe operation of a basic PLC logic instructions: normally-open, normally-closed, output coil, internal coils, timers, and up/down counters
    - Describe the symbolic, absolute discrete I/O address system
- **Standard 207.9 Create a PLC project**
  - Performance Indicators:

- Create a PLC project
- Enter and operate a PLC logic program
- Edit a PLC project

- Knowledge Indicators:
  - Describe the elements of a PLC project

- **Standard 207.10 Program and operate a PLC logic program that uses comparison instructions**
  - Performance Indicators:
    - Interpret a PLC logic program that uses comparison instructions
    - Enter and operate a PLC logic program that uses comparison instructions
    - Interpret the operation a PLC logic program that uses comparison instructions
  - Knowledge Indicators:
    - Describe the operation of PLC comparison instructions
- **Standard 207.11 Program and operate a PLC project that uses math instructions**
  - Performance Indicators:
    - Interpret a PLC logic program that uses basic math instructions: Add, Subtract, Divide, and Multiply
    - Enter and operate a PLC program that uses basic math instructions
    - Interpret a PLC logic program that uses a Compute instruction
    - Enter and operate a PLC program that uses a Compute instruction
    - Design and test a PLC program that uses math instructions
  - Knowledge Indicators:
    - Describe operation and applications of basic PLC math instructions
    - Describe operation and applications of PLC Compute instruction
- **Standard 207.12 Program and operate a PLC motor control sequence program**
  - Performance Indicators:
    - Interpret the operation of PLC motor control sequence program
    - Design and test operation of a PLC motor control sequence program
  - Knowledge Indicators:
    - Describe the operation of a seal-in logic program
    - Describe the operation of a PLC-controlled motor control circuit
    - Describe the operation of a reversing motor control
- **Standard 207.13 Program and operate a basic PLC sequence program**
  - Performance Indicators:
    - Interpret the operation of an event-driven 2-step PLC sequence program
    - Interpret the operation of a time-driven 2-step PLC sequence program
    - Design and test a basic event-driven PLC sequence program
    - Design and test a time-driven PLC sequence program
  - Knowledge Indicators:
    - Describe the operation of an event-driven PLC sequence program

- Describe the operation of a time-driven PLC sequence program

C-208 Programmable Controller Troubleshooting 1 Credential

- **Standard 208.1 Use status and diagnostic indicators to troubleshoot a PLC**
  - Performance Indicators:
    - Use status and diagnostic indicators to troubleshoot a PLC
  - Knowledge Indicators:
    - Describe two levels of troubleshooting and give an application of each
    - Describe types of PLC faults
- **Standard 208.2 Troubleshoot PLC inputs and outputs**
  - Performance Indicators:
    - Force on a PLC output
    - Troubleshoot PLC inputs and outputs
  - Knowledge Indicators:
    - Describe the function/applications of forcing outputs
    - Describe types of input/output module and field device faults
    - Describe methods of troubleshooting inputs and outputs
- **Standard 208.3 Troubleshoot PLC power distribution system**
  - Performance Indicators:
    - Troubleshoot power distribution faults
  - Knowledge Indicators:
    - Describe the operation of a PLC power distribution system
    - Describe types of power distribution faults
    - Describe methods of troubleshooting power distribution faults
- **Standard 208.4 Troubleshoot a PLC processor**
  - Performance Indicators:
    - Troubleshoot a PLC processor
  - Knowledge Indicators:
    - Describe types of processor faults
    - Describe methods of troubleshooting processor faults
- **Standard 208.5 Troubleshoot a PLC system with discrete I/O**
  - Performance Indicators:
    - Troubleshoot a PLC system with discrete I/O
  - Knowledge Indicators:
    - Describe methods of systems troubleshooting
    - Describe a 6-step PLC systems troubleshooting process
- **Standard 208.6 Program and operate a multi-step PLC sequence program**
  - Performance Indicators:
    - Interpret the operation of a multi-step event-driven PLC sequence program
    - Interpret the operation of a multi-step time-driven PLC sequence program

        - Design and test a PLC multi-step PLC sequence program
    - Knowledge Indicators:
        - Describe the operation of a multi-step event-driven and time-driven PLC sequence programs
        - Describes types of PLC documentation: truth table, sequence of operation
        - Describe how to interpret a multi-step PLC sequence program
- **Standard 208.7 Troubleshoot a multi-step PLC sequence program**
    - Performance Indicators:
        - Troubleshoot a multi-step PLC sequence program with event-driven and time-driven steps
    - Knowledge Indicators:
        - Describe how to troubleshoot a PLC sequence programs

C-209 Pneumatic Systems 1 Credential

- **Standard 209.1 Apply pneumatic system safety procedures**
    - Performance Indicators
        - Identify and correct pneumatic system hazards
    - Knowledge Indicators
        - Describe PPE and safe dress for operation of pneumatic systems
        - Describe types of pneumatic system hazards ID potential injuries/hazards
        - Describe pneumatic system safety guidelines
        - Define pneumatics and give applications
- **Standard 209.2 Connect and adjust a pneumatic supply line**
    - Performance Indicators:
        - Connect an air hose that uses quick-connect fittings
        - Operate pneumatic branch line shutoff valve
        - Adjust pressure regulator to specified operating pressure
        - Read a pressure gauge
    - Knowledge Indicators:
        - Describe the operation/construction of a pneumatic regulator
        - Describe the components of a pneumatic branch line
        - Define pneumatic pressure and give SI and US Customary units
        - Compare types of fittings
        - Describe operation/construction of a pressure gauge
- **Standard 209.3 Start up and shut down a reciprocating air compressor**
    - Performance Indicators:
        - Perform startup and normal shutdown of an air compressor
        - Adjust air compressor pressure switch
        - Drain an air compressor
    - Knowledge Indicators:

- Describe how compressed air is generated and its characteristics
- Describe the operation/components of a reciprocating air compressor
- Describe how air compressor flow capacity is measured
- Define absolute and gage units of pressure measurement
- Define the combined gas law and explain its importance

- **Standard 209.4 Interpret pneumatic schematics**
  - Performance Indicators:
    - Interpret a pneumatic schematics in NFPA/ISO symbols
  - Knowledge Indicators:
    - Describe the guidelines for drawing pneumatic schematics
    - Describe the operation/construction of basic pneumatic circuits, directional valves (2/3/5 way; 2-3 position), cylinders (single and double active), motors, and conductors
    - Describe the NFPA/ISO pneumatic component schematic symbols
- **Standard 209.5 Connect and operate basic pneumatic circuits**
  - Performance Indicators:
    - Connect a pneumatic circuit given a schematic
    - Operate a basic pneumatic valve circuit with manual operator
    - Use pneumatic valve manual overrides to test actuators
    - Adjust the stroke length of a pneumatic cylinder
    - Connect and disconnect pneumatic hoses using push-lok fittings
    - Install a subplate-mounted valve
  - Knowledge Indicators:
    - Describe the operation of manual overrides
    - Describe types and sizes of pneumatic conductors and fittings
- **Standard 209.6 Connect and adjust flow control and needle valves**
  - Performance Indicators:
    - Adjust pneumatic actuator speed using a flow control valve
    - Adjust pneumatic actuator speed using a needle valve
    - Connect flow control valves in meter-in and meter-out circuits
    - Connect a needle valve to control pneumatic actuator speed
  - Knowledge Indicators:
    - Describe the operation of a needle valve and flow control valve
    - Describe fluid power speed control circuits (meter-in, out, etc.)
    - Describe the factors that affect pneumatic actuator speed
- **Standard 209.7 Monitor performance of pneumatic system pressure and force**
  - Performance Indicators:
    - Measure ΔP across a pneumatic component
    - Identify factors that affect pneumatic actuator speed and force
  - Knowledge Indicators:
    - Describe types of resistance in a pneumatic system
    - Calculate net force output of a cylinder
    - State Pascal's law and explain its significance in fluid power

        - Define absolute and gage units of pressure measurement
    - **Standard 209.8 Monitor pneumatic system operation**
        - Performance Indicators:
            - Connect and read a rotameter
            - Connect and read a pneumatic pressure gage
            - Read an air temperature gage
        - Knowledge Indicators:
            - Describe SI and US Customary pneumatic flow units
            - Describe the operation of a rotameter
            - State Pascal's law and explain its significance in pneumatics
            - Explain the effect of air temperature in pneumatics
    - **Standard 209.9 Perform basic pneumatic system servicing**
        - Performance Indicators:
            - Drain a pneumatic filter
            - Inspect and refill an air lubricator
            - Adjust air lubricator rate
            - Inspect and replace an air filter element
        - Knowledge Indicators:
            - Describe the operation of an air lubricator
            - Describe the operation of a pneumatic filter

C-210 Mechanical Power Systems I Credential

- **Standard 210.1 Identify mechanical power transmission type and application**
    - Performance Indicators:
        - Identify mechanical power transmission type by sight
        - Identify a mechanical power transmission type for a given an application
    - Knowledge Indicators:
        - Describe methods of coupling a mechanical power transmission system
        - Describe methods of parallel shaft mechanical power transmission
        - Define 3 types of levers
        - Calculate the mechanical advantage of a lever
        - Define torque and give its units of measurement
- **Standard 210.2 Apply mechanical power transmission safety procedures**
    - Performance Indicators
        - Identify and correct mechanical power transmission hazards
        - Isolate stored mechanical power/energy
    - Knowledge Indicators
        - Describe types of mechanical power transmission hazards
        - Describe mechanical power transmission safety guidelines
- **Standard 210.3 Use a dial indicator to measure component dimensions**
    - Performance Indicators:

- Calibrate a dial indicator
- Use a dial indicator to measure part dimension
- Use a dial indicator to measure Runout (TIR)

- Knowledge Indicators:
  - Describe the operation of a dial indicator

- **Standard 210.4 Install and mount a motor**
  - Performance Indicators:
    - Mount and level a motor
    - Interpret motor nameplate data to ensure correct motor
    - Select size and type of motor mounting hardware
    - Correct a motor soft foot
  - Knowledge Indicators:
    - Define a soft foot
    - Describe the importance of motor mounting
- **Standard 210.5 Select and install a shaft key and hub**
  - Performance Indicators:
    - Install a shaft key and attach a hub to a shaft
    - Select and size a key for a keyway
  - Knowledge Indicators:
    - Describe the function/applications of a key and keyway
    - Describe how keys are specified

- **Standard 210.6 Install and adjust pillow block and flange bearings**
  - Performance Indicators:
    - Install and adjust a pillow block bearing
    - Install and adjust a flange bearing
  - Knowledge Indicators:
    - Define types of friction and their effect on machine operation
    - Define handling and storage procedures for pillow block bearings
    - Describe the basic operation/ construction of a pillow block bearing
    - Describe the basic operation/ construction of a flange bearing
- **Standard 210.7 Install and align shaft system with flexible jaw coupling**
  - Performance Indicators:
    - Install and align a flexible jaw coupling
    - Use straight edge and feeler gage shaft alignment method
    - Identify size and type of flexible jaw couplings
- Knowledge Indicators:
    - Describe the basic operation/construction of a flexible jaw couplings
    - Identify types of flexible couplings
- **Standard 210.8 Install and adjust a basic V-belt drive system**
  - Performance Indicators:
    - Install, align, and tension a basic v-belt drive system
    - Identify size and type of v-belt and sheaves

        - Knowledge Indicators:
            - Identify types of belts/sleeves
            - Describe the basic operation/construction of a belt drive
            - Calculate belt drive ratio, output speed, and output torque
    - **Standard 210.9 Install and adjust a basic chain drive system**
        - Performance Indicators:
            - Install, align, and set chain sag of a basic chain drive system
            - Identify size and type of chain and sprocket
        - Knowledge Indicators:
            - Describe the basic operation/construction of a basic chain drive
            - Calculate chain drive sprocket ratio, output speed, and output torque
    - **Standard 210.10 Install and align a gear drive system**
        - Performance Indicators:
            - Install and align a gear drive
            - Identify size and type of spur gears
        - Knowledge Indicators:
            - Describe the basic operation/construction of open and closed gear drives
            - Calculate gear drive sprocket ratio, output speed, and output torque
    - **Standard 210.11 Monitor the performance of mechanical power transmission system**
        - Performance Indicators:
            - Identify factors that affect mechanical power transmission efficiency
        - Knowledge Indicators:
            - Define rotary mechanical power and give units of measurement
            - Define power efficiency
            - Calculate mechanical power given torque and speed
            - Calculate mechanical power transmission efficiency
    - **Standard 210.12 Apply lubrication to mechanical components**
        - Performance Indicators:
            - Grease a bearing using grease gun and Zerk fitting
            - Use machine documentation to identify machine lubrication points, select lubrication and identify schedule
            - Inspect and fill lubrication reservoirs
        - Knowledge Indicators:
            - Describe the basic operation of a grease gun
            - Describe oil and grease specifications
            - Describe the basic operation of automatic lubricators

C-211 Industry 4.0 Total Productive Maintenance Management Credential

- **Standard 211.1 Identify elements of a Total Productive Maintenance (TPM)**
    - Performance Indicators:

        - Identify elements of Total Productive Maintenance
    - Knowledge Indicators:
        - Define Total Productive Maintenance (TPM) and explain its benefits
        - Define autonomous maintenance and explain its benefits
- **Standard 211.2 Optimize overall equipment effectiveness (OEE)**
    - Performance Indicators:
        - Calculate Overall Equipment Effectiveness (OEE)
        - Optimize OEE to meet production requirements
    - Knowledge Indicators:
        - Define Overall Equipment Effectiveness (OEE)
        - Describe methods of eliminating downtime
- **Standard 211.3 Perform planned and unplanned maintenance operations**
    - Performance Indicators:
        - Perform planned maintenance operation
        - Perform unplanned maintenance operation
        - Record information in maintenance records
        - Interpret a maintenance work order
        - Use approved procedures to notify production personnel of maintenance pending and completed
    - Knowledge Indicators:
        - Describe the steps of planned and unplanned maintenance
        - Describe types and criticality of planned and unplanned maintenance
        - Define a maintenance work order and explain its use
- **Standard 211.4 Perform preventive maintenance operations**
    - Performance Indicators:
        - Perform preventive maintenance operations
        - Record information in preventive maintenance records
        - Clean a machine
        - Identify sources and eliminate contamination
    - Knowledge Indicators:
        - Define preventive maintenance
        - Describe how contamination is quantified
        - Describe the requirements for safe machine cleaning
- **Standard 211.5 Identify types of predictive maintenance operations**
    - Performance Indicators:
        - Identify types of predictive maintenance operations
    - Knowledge Indicators:
        - Describe types of predictive maintenance and their applications
        - Describe applications of predictive analytics
- **Standard 211.6 Configure and use a cloud-based maintenance management system**
    - Performance Indicators:
        - Configure and use a cloud-based maintenance management system
        - Configure teams in a cloud-based maintenance management system

- Configure escalation in a cloud-based maintenance management system
- Analyze computer-based maintenance records
- Initiate and respond to cloud-based maintenance notifications

- Knowledge Indicators:
  - Describe the operation of a cloud-based maintenance management system
  - Describe the advantages of features of a cloud-based maintenance management system

- **Standard 211.7 Use systems troubleshooting techniques to locate root cause**
  - Performance Indicators:
    - Use 5 senses, observation, and interview techniques to collect information about a machine malfunction
    - Use 5 whys to identify root causes of a machine malfunction
    - Use maintenance records and other machine documentation to analyze a machine malfunction
    - Use troubleshooting flow charts to isolate a malfunction cause
    - Isolate machine malfunctions to a sub system
    - Use systems troubleshooting methodologies to locate sources of a malfunction
  - Knowledge Indicators:
    - Describe types of systems troubleshooting methodologies
    - Describe how maintenance records can be used to troubleshoot machine problems

C-212 Ethernet Communications 1 Credential

- **Standard 212.1 Connect and test an Ethernet network**
  - Performance Indicators:
    - Connect and test an Ethernet network
- Knowledge Indicators:
  - Describe levels of industrial networks
  - Describe the basic operation of a TCP/IP Ethernet network
  - Describe the basic operation of an Ethernet switch
- **Standard 212.2 Transfer programs via Ethernet network**
  - Performance Indicators:
    - Set robot and PLC Ethernet IP addresses
    - Transfer robot/ PLC programs
  - Knowledge Indicators:
    - Describe the IP address system
- **Standard 212.3 Connect and configure a managed Ethernet network**
  - Performance Indicators:
    - Connect a managed Ethernet network in a star topology

        - Configure a managed Ethernet network with static and dynamic addressing
        - Configure a managed Ethernet network subnet
    - Knowledge Indicators:
        - Describe Ethernet network topologies
        - Describe hardware used in large-scale industrial Ethernet networks
        - Describe the basic operation of an industrial managed Ethernet switch
        - Describe DHCP's automatic assignment of IP addresses
        - Describe the operation of a managed switch subnet
- **Standard 212.4 View Ethernet switch network performance and diagnostics**
    - Performance Indicators:
        - View managed Ethernet switch network performance and diagnostics
    - Knowledge Indicators:
        - Describe types of Ethernet switch diagnostics
        - Describe types of Ethernet switch network performance data
- **Standard 212.5 Configure port security of a managed industrial Ethernet switch**
    - Performance Indicators:
        - Configure levels of port security of a managed industrial Ethernet switch to protect PLCs, HMIs, and robots
    - Knowledge Indicators:
        - Describe components of industrial Ethernet network security
        - Describe the operation of managed Ethernet switch port security

C-213 Smart Sensor and Identification Systems 1 Credential

- **Standard 213.1 Connect and configure an IO-Link Master**
    - Performance Indicators:
        - Connect an IO-Link Master to Ethernet and IO-Link devices
        - Configure an IO-Link Master in a PLC project
        - Power on an IO-Link Master
        - Interpret IO-Link Master status indicators
        - Download IODD and EDS files for an IO-Link device
    - Knowledge Indicators:
        - Describe the basic operation/applications of an IO-Link Master
        - Describe the basic operation of an IO-Link Master in a PLC project
        - Describe the wiring connections of an IO-Link Master
        - Describe the functions of an IO Device Description (IODD) file and an Electronic Data Sheet (EDS) file
- **Standard 213.2 Connect and operate an IO-Link RFID reader system**
    - Performance Indicators:
        - Connect an RFID reader to an IO-Link Master
        - Power on, adjust, and test an IO-Link RFID reader
        - Interpret RFID reader status indicators

        - Knowledge Indicators:
            - Describe the basic RFID system operation
            - Describe types of RFID tags and their applications
            - Describe the factors that affect RFID operation
    - **Standard 213.3 Interpret and operate a PLC program that uses an IO-Link RFID function block**
        - Performance Indicators:
            - Enter and operate a PLC program that uses an IO-Link RFID function block
            - Interpret the operation of a PLC program that uses an IO-Link RFID reader function block to identify and sort parts
        - Knowledge Indicators:
            - Describe the operation of a PLC function block
            - Describe the operation of an RFID PLC function block
            - Describe the operation of a RFID PLC function block logic
    - **Standard 213.4 Connect and configure an Ethernet-serial interface**
        - Performance Indicators:
            - Connect and configure an Ethernet-Serial interface to a barcode reader and Ethernet network
            - Power on an Ethernet-Serial interface
            - Interpret Ethernet-Serial interface status indicators
        - Knowledge Indicators:
            - Describe the basic operation of an Ethernet-Serial interface
            - Describe Ethernet-Serial interface wiring connections
    - **Standard 213.5 Connect and operate a barcode reader**
        - Performance Indicators:
            - Connect barcode reader to an Ethernet-serial interface
            - Power on, adjust, and test a barcode reader
        - Knowledge Indicators:
            - Describe the basic barcode reader operation
            - Describe the functions of barcode reader status indicators
            - Describe the factors that affect barcode reader operation
    - **Standard 213.6 Interpret and operate a PLC program that uses barcode reader function block**
        - Performance Indicators:
            - Enter and operate a PLC program that uses a barcode reader function block
            - Interpret the operation of a PLC program that uses a barcode reader function block to identify and sort parts
        - Knowledge Indicators:
            - Describe the operation of a barcode reader PLC function block
            - Describe the operation of a barcode reader PLC function block logic

- Describe the basic operation of an Ethernet-Serial interface in a PLC project

- **Standard 213.7 Setup, operate and interpret a PLC program that uses an IO-Link photoelectric sensor**
  - Performance Indicators:
    - Connect, power on, adjust, and test an IO-Link photoelectric sensor
    - Configure an IO-Link photoelectric sensor in a PLC project
    - Interpret the operation of a PLC program that uses an IO-Link photoelectric sensor
    - Design a PLC program that uses an IO-Link photoelectric sensor
  - Knowledge Indicators:
    - Describe the operation of an IO-Link photoelectric sensor
    - Describe IO-Link photoelectric sensor parameters
    - Describe the operation of IO-Link photoelectric sensor tags in a PLC project
- **Standard 213.8 Setup, operate and interpret a PLC program that uses an IO-Link pressure sensor**
  - Performance Indicators:
    - Connect, power on, adjust, and test an IO-Link analog pressure sensor
    - Use analog pressure sensor keypad to view parameters and data
    - Configure an IO-Link analog pressure sensor in a PLC project
    - Interpret the operation of a PLC program that uses an IO-Link analog pressure sensor with function block
    - Design and test a PLC program that uses an IO-Link analog pressure sensor
  - Knowledge Indicators:
    - Describe the operation of an IO-Link analog pressure sensor
    - Describe IO-Link analog pressure sensor parameters
    - Describe the operation of IO-Link analog pressure sensor tags in a PLC project
- **Standard 213.9 Setup, operate and interpret a PLC program that uses an IO-Link smart stack light**
  - Performance Indicators:
    - Connect and power on an IO-Link smart stack light
    - Interpret the operation of a PLC program that uses an IO-Link smart stack light
    - Design and test a PLC program that uses an IO-Link smart stack light
  - Knowledge Indicators:
    - Describe the operation of IO-Link smart stack light
    - Describe the operation of IO-Link smart stack light tags in a PLC project
- **Standard 213.10 Setup, operate and interpret a PLC program that uses an IO-Link ultrasonic sensor**
  - Performance Indicators:

- Connect, power on, adjust, and test an IO-Link ultrasonic sensor
- Configure an IO-Link ultrasonic sensor in a PLC project
- Use ultrasonic sensor keypad to view parameters and data
- Interpret the operation of a PLC program that uses IO-Link ultrasonic sensor Design and test a PLC program that uses an IO-Link ultrasonic sensor

▪ Knowledge Indicators:
- Describe the operation of an IO-Link ultrasonic sensor
- Describe IO-Link ultrasonic sensor parameters
- Describe the operation of IO-Link ultrasonic sensor tags in a PLC project

C-214 Smart Factory Systems 1 Credential

○ **Standard 214.1 Apply smart factory system safety procedures**
▪ Performance Indicators
- Identify and correct smart factory system hazards

▪ Knowledge Indicators
- Define mechatronics, flexible manufacturing, and smart factory
- Describe PPE/safe dress for operation of smart factory systems
- Describe types of smart factory hazards
- Describe smart factory safety guidelines

○ **Standard 214.2 Operate a smart factory**
▪ Performance Indicators:
- Power up a smart factory
- Manually operate actuators to test input and output operation
- Make adjustments to actuators and sensors
- Operate a smart factory in single-step or manual mode
- Operate a smart factory in automatic mode
- Perform a normal shutdown of a smart factory

▪ Knowledge Indicators:
- Describe six automated manufacturing processes
- Describe the role of a modern automated machine operator
- Describe the function of a basic operator panel
- Describe the operation of three categories of stop functions
- Describe guidelines for operation of smart factories

○ **Standard 214.3 Program, adjust, and operate a PLC-controlled automated pick and place system**
▪ Performance Indicators:
- Program and operate a PLC-controlled automated pick and place system
- Adjust vacuum level and vacuum switch setting
- Adjust actuator travel and linear bearings

▪ Knowledge Indicators:

- Describe the operation/construction of vacuum generator and vacuum cup
- Describe the operation/construction of a vacuum switch
- Describe the operation/construction of linear bearings
- Describe the sequence of a PLC-controlled automated pick and place system
- Describe applications for automated pick and place systems

- **Standard 214.4 Program, adjust, and operate a PLC-controlled automated gauging system**
  - Performance Indicators:
    - Program and operate a PLC-controlled automated go/no-go gauging system
    - Test a PLC program that uses an ultrasonic sensor
    - Adjust ultrasonic sensor position and trip points
    - Adjust actuator travel of an electric linear axis
    - Adjust a ball screw drive and clutch
  - Knowledge Indicators:
    - Describe the operation/construction of an ultrasonic sensor
    - Describe the operation/construction of a ball screw drive/clutch
    - Describe the sequence of a PLC-controlled automated go/no-go gauging system
    - Describe applications for automated go/no-go gauging systems
- **Standard 214.5 Program, adjust, and operate a PLC-controlled indexing system**
  - Performance Indicators:
    - Program and operate a PLC-controlled stepper motor indexing system
    - Enter and operate a PLC program that controls a stepper motor index table
    - Adjust a thru-beam fork sensor
  - Knowledge Indicators:
    - Describe the basic operation of a stepper motor/controller
    - Describe the operation of a thru-beam fork sensor
    - Describe the sequence of a stepper motor indexing system
    - Describe applications for stepper motor indexing systems
- **Standard 214.6 Program, adjust, and operate a PLC-controlled sorting and queuing conveyor system**
  - Performance Indicators:
    - Program and operate a PLC-controlled sorting and queuing conveyor system
    - Adjust a flat belt conveyor
  - Knowledge Indicators:
    - Describe the operation of a flat belt conveyor
    - Describe the operation of a solenoid actuator
    - Describe the sequence of a sorting and queuing conveyor system

        - Describe applications for sorting and queuing conveyor systems
    - **Standard 214.7 Program, adjust, and operate a PLC-controlled servo robotic assembly system**
        - Performance Indicators:
            - Program and operate a PLC-controlled robotic assembly system
            - Adjust a screw feeder
        - Knowledge Indicators:
            - Describe the operation of automatic screw feeders
            - Describe the sequence of a PLC-controlled robotic screw assembly system
            - Describe applications for robotic screw assembly system
    - **Standard 214.8 Program and operate a multiple station smart factory that uses discrete I/O and Ethernet handshaking**
        - Performance Indicators:
            - Program and operate a PLC program that uses discrete I/O handshaking to communicate in a multiple station smart factory system
            - Program and operate multiple-station PLC programs with system halt, reset, and stop functions
            - Program and operate a PLC logic program that uses message instructions
            - Program and operate PLC and robot programs that use Ethernet I/O handshaking to communicate in a multiple station smart factory system
        - Knowledge Indicators:
            - Describe the operation of discrete I/O handshaking in a multiple station smart factory system
            - Describe the operation of multiple station smart factory PLC programs with system halt, reset, and stop functions
            - Describe the operation of Ethernet PLC and robot I/O handshaking
            - Describe the operation of PLC message instructions

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- **TOPIC 215.1 ROBOT SYSTEMS CONCEPTS**
    - **Standard 215.1.1 Identify robot type and applications**
        - Performance Indicators:
            - Identify common robot applications
            - Recognize robot types
        - Knowledge Indicators:
            - Define a robot
            - Describe general advantages of a robot
            - Describe types of robots, including collaborative
            - List robot applications and best fit robot type

- **Standard 215.1.2 Identify the components of an articulated servo robot**
  - Performance Indicators:
    - Identify the major parts of a robot
    - Identify the axes of a robot
    - Identify types of end-of-arm tooling
  - Knowledge Indicators:
    - Describe the basic operation of a robot
    - Describe the functions of the parts of a robot
    - Define major and minor axes of an articulated robot
    - Define end-of-arm tooling
- **Standard 215.1.3 Identify types of end-of-arm tooling**
  - Performance Indicators:
    - Identify types of end-of-arm tooling
    - Identify types of grippers
  - Knowledge Indicators:
    - Describe types of end-of-arm tooling
    - Describe the basic operation of curvilinear and parallel grippers
    - Describe the basic operation of 2-point and 3-point grippers
- **Standard 215.1.4 Determine robot work envelope**
  - Performance Indicators:
    - Determine the work envelope of a robot given a specification
  - Knowledge Indicators:
    - Define a work envelope
    - Describe the general work envelope shape of each robot type
    - Describe how work envelopes are specified
    - Describe how EOT affects work envelope

- **TOPIC 215.2 ROBOT SAFETY**
  - **Standard 215.2.1 Identify robot workcell safety features**
    - Performance Indicators:
      - Identify robot safety devices
      - Identify robot safety hazards
    - Knowledge Indicators:
      - Describe types of robot workcell hazards
      - Describe types of robot safety devices
      - Describe collaborative robot safety
      - Describe types of robot workcell safety enhancing devices
      - Describe the elements of a safe robot workcell
  - **Standard 215.2.2 Perform a robot workcell safety inspection**
    - Performance Indicators:
      - Perform a robot workcell safety inspection

- Identify proper dress for robot workcell safety
- Knowledge Indicators:
  - Describe robot workcell inspection hazards

- **Standard 215.2.3 Apply robot safety procedures**
  - Performance Indicators:
    - Apply robot safety procedures during manual operation
    - Apply robot safety procedures during automatic operation
    - Apply robot safety procedures during maintenance operation
  - Knowledge Indicators:
    - Describe automatic operation hazards
    - Describe manual operation hazards
    - Describe maintenance operation hazards

- **TOPIC 215.3 MANUAL ROBOT OPERATION**
  - **Standard 215.3.1 Power up and shut down a robot**
    - Performance Indicators:
      - Perform a cold start robot power up
      - Perform a normal shutdown of a robot
      - Perform an emergency shutdown and reset of a robot
    - Knowledge Indicators:
      - Describe the operation of the operator panel
      - Describe basic power connections to a robot
      - Describe the operation of the emergency stop pushbutton
      - Describe the effect of triggering a robot safety enhancing device
  - **Standard 215.3.2 Use teach pendant to view menus and status indicators**
    - Performance Indicators:
      - Power up a teach pendant
      - Navigate robot teach pendant full and quick menus
      - Interpret teach pendant status indicators
    - Knowledge Indicators:
      - Describe the functions of the teach pendant
      - Describe the functions of teach pendant keys
      - Describe operation of a teach pendant
      - Describe the functions of the robot teach pendant menus
      - Describe the functions of the teach pendant status indicators
  - **Standard 215.3.3 Identify robot model number and version data**
    - Performance Indicators:
      - Locate and interpret model number
      - Use robot teach pendant to view version data
    - Knowledge Indicators:
      - Describe the location of the model number

        - Describe the version identification status screen
- **Standard 215.3.4 Jog an articulated robot in joint mode**
    - Performance Indicators:
        - Jog an articulated robot in joint mode
        - Adjust jog speed
        - Operate a teach pendant deadman switch and reset robot
    - Knowledge Indicators:
        - Describe the basic operation of robot jogging
        - Describe types of robot speed settings
        - Describe the operation of a teach pendant deadman switch
- **Standard 215.3.5 Set and test robot joint travel limits**
    - Performance Indicators:
        - View robot axis software limits
        - Set robot axis software limits
        - Test robot axis software limits and reset robot
        - Check axis zero reference
    - Knowledge Indicators:
        - Describe the operation of robot axis software limits
        - Describe robot operation if an axis encounters a software limit
        - Describe the operation of axis zero reference
        - Define mastering
- **Standard 215.3.6 Identify robot position in each of 5 frames**
    - Performance Indicators:
        - Use a teach pendant to view robot joint axis positions
        - Use a teach pendant to view robot position in 5 frames
    - Knowledge Indicators:
        - Define Cartesian coordinates
        - Define 5 robot frame types
        - Define tool center point
        - Describe the operation of the teach pendant Position screen
- **Standard 215.3.7 Jog an articulated robot using Cartesian coordinates**
    - Performance Indicators:
        - Jog a robot in World mode
        - Jog a robot in Tool mode
        - Jog a robot in User mode
        - Switch between jog modes
    - Knowledge Indicators:
        - Describe the five methods of jogging and their applications
- **Standard 215.3.8 Define a tool frame and user frame**
    - Performance Indicators:

- Define a tool frame using the 3-point method
- Define a user frame using the 3-point method
- Define a jog frame using the 3-point method
- Use direct entry method to define tool, user, and jog frames

- Knowledge Indicators:
  - Describe the function of defining tool, user, and jog frames
  - Describe methods of defining tool, user, and jog frames
  - Describe the operation of the Jog Menu screen

- **TOPIC 215.4 AUTOMATIC ROBOT OPERATION**
  - **Standard 215.4.1 Load a robot program**
    - Performance Indicators:
      - Locate and load a program using a teach pendant
      - Change the default storage device of a robot
      - View a directory of files on a robot file storage device
      - Back up files and programs via Ethernet and memory card
      - Restore programs and files to controller via Ethernet and memory card
    - Knowledge Indicators:
      - Describe robot programs/files storage architecture
      - Describe methods of storing robot programs/files
      -
      - Describe the memory organization of a robot
      - Describe the operation of the backup and restore processes
      - Describe types of robot storage media
  - **Standard 215.4.2 Teach robot motion points and enter program commands**
    - Performance Indicators:
      - Teach robot motion points
      - Select proper tool/user frame for teaching points
      - Record and name robot motion points in position registers
    - Knowledge Indicators:
      - Describe the operation of recording robot points
      - Describe the operation of the position register
  - **Standard 215.4.3 Test a robot program**
    - Performance Indicators:
      - Test robot discrete inputs and outputs
      - Test robot end effector
      - Test a robot program in single-step mode
      - Test a robot program in continuous mode
    - Knowledge Indicators:
      - Describe the basic operation of discrete robot I/O and end effectors

- Describe the operation of robot single step test mode
- Describe the operation of the mode switch
- Describe the operation of robot continuous test mode

- **Standard 215.4.4 Operate a robot in production**
  - Performance Indicators:
    - Operate and monitor a robot in Auto mode
    - Pause a robot in production
    - Perform a robot cycle stop
    - Perform a robot e-stop
  - Knowledge Indicators:
    - Describe the operation of robot Auto mode
    - Describe the operation of robot pause and cycle stop
    - Describe the operation of a robot e-stop
    - Describe the menu screens for monitoring robot operation
    - Define robot position repeatability and explain its importance
    - Describe the effect of payload on robot operation
- **Standard 215.4.5 Recover a robot from basic faults**
  - Performance Indicators:
    - View and interpret active robot alarms
    - View and interpret robot alarm history
    - Recover a robot from basic faults and return to operation
  - Knowledge Indicators:
    - Describe common types of robot errors and faults
    - Describe robot alarm screens

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- **TOPIC 216.1 ROBOT PROGRAMMING**
  - **Standard 216.1.1 Enter and interpret robot program with motion commands**
    - Performance Indicators:
      - Interpret a robot motion command
      - Use a teach pendant to enter a robot motion command
    - Knowledge Indicators:
      - Describe three types of robot motion commands (linear, joint, and circular)
      - Describe the parts of a robot motion command
      - Describe the position configuration settings
      - Describe operation of motion command speed settings
      - Describe types of motion command terminations

- Describe the use of local and global points

- **Standard 216.1.2 Enter and interpret robot program tool and user frame offset commands**
  - Performance Indicators:
    - Interpret a robot program tool offset command
    - Interpret a robot program user frame offset command
    - Use a teach pendant to enter a robot offset command
  - Knowledge Indicators:
    - Describe the operation of the tool offset command
    - Describe the operation of the user frame offset command
- **Standard 216.1.3 Enter and interpret robot program data register commands**
  - Performance Indicators:
    - Interpret a robot program that uses a data register command
    - Use a teach pendant to enter a robot register command
  - Knowledge Indicators:
    - Define a data register
    - Define direct and indirect data register addressing
    - Describe the operation of the arithmetic data register instruction
- **Standard 216.1.4 Enter and interpret robot program branching commands**
  - Performance Indicators:
    - Interpret a robot program that uses unconditional branching
    - Interpret a robot program that uses conditional branching
    - Use a teach pendant to enter a robot branching command
  - Knowledge Indicators:
    - Describe the function of conditional and unconditional branching commands
    - Describe the operation of the JMP and LBL commands
    - Describe the operation of the CALL command
    - Describe the operation of the Register IF command
    - Describe the operation of the Select command
- **Standard 216.1.5 Enter and interpret robot program looping and wait commands**
  - Performance Indicators:
    - Interpret a robot program that uses looping
    - Interpret a robot program that uses a wait command
    - Use a teach pendant to enter a robot looping and wait commands
  - Knowledge Indicators:
    - Describe the function of looping commands
    - Describe the operation of the For…Do loop
    - Describe the operation of the Repeat loop
    - Describe the operation of the While loop

- Describe the operation of the Wait command

- **TOPIC 216.2 ROBOT COMMUNICATIONS**
  - **Standard 216.2.1 Interface and test discrete robot inputs and outputs**
    - Performance Indicators:
      - Interface and test robot digital input with an input sensor
      - Interface and test robot digital output with solenoid
      - Test safety enhancing devices
    - Knowledge Indicators:
      - Describe how input/output devices are wired to a robot
      - Describe the operation of robot I/O forcing
      - Describe how safety enhancing devices are wired to a robot
      - Describe how end effector I/O are wired to a robot
  - **Standard 216.2.2 Interface and test PLC I/O to robot controller**
    - Performance Indicators:
      - Interface and test robot discrete I/O to PLC I/O
      - Interface and test robot to PLC modular I/O
    - Knowledge Indicators:
      - Describe the operation of modular PLC I/O
      - Describe how PLC discrete I/O are wired to robot I/O
  - **Standard 216.2.3 Enter and interpret robot programs that use discrete I/O**
    - Performance Indicators:
      - Interpret robot programs that use discrete I/O
      - Interpret robot programs that use program condition monitoring
      - Use a teach pendant to enter a robot discrete I/O commands
    - Knowledge Indicators:
      - Describe two types of condition monitoring: program and system
  - **Standard 216.2.4 Connect and test robot Ethernet network communications**
    - Performance Indicators:
      - Connect and test a robot to Ethernet network connection
    - Knowledge Indicators:
      - Describe robot Ethernet communications capabilities

  - **TOPIC 216.3 ROBOT APPLICATIONS**
  - **Standard 216.3.1 Enter and test a robot program Macro command**
    - Performance Indicators:
      - Enter and test a Macro command to operate an end effector
      - Enter and test a Macro command to move to a position
    - Knowledge Indicators:
      - Describe the operation of a robot macro
      - Describe the Macro table and Macros screen

- Describe applications of macros
- Describe manual and automatic methods of executing a macro

- **Standard 216.3.2 Develop and test a basic pick and place robot program**
  - Performance Indicators:
    - Develop and test a basic pick and place robot program that picks up parts from a feeder and places them on a conveyor
  - Knowledge Indicators:
    - Describe the sequence of a pick and place operation
    - Describe applications of pick and place robot programs
    - Describe how to plan a motion path for pick and place with robot approach, avoidance and placement points
- **Standard 216.3.3 Develop and test a machine load/unload robot program**
  - Performance Indicators:
    - Develop and test a machine load robot program that picks up parts from a feeder and places in a CNC machine
  - Knowledge Indicators:
    - Describe the sequence of a robot machine load operation
    - Describe applications of machine load robot programs
    - Describe how to plan a motion path for machine loading with robot approach, avoidance and placement points
- **Standard 216.3.4 Develop and test a basic assembly robot program**
  - Performance Indicators:
    - Develop and test a basic assembly robot program that picks up parts from a feeder and assembles parts using press fit
  - Knowledge Indicators:
    - Describe the sequence of a robot mechanical assembly operation
    - Describe applications of mechanical assembly robot programs
    - Describe how to plan a motion path for assembly with robot approach, avoidance and placement points
    - Describe types of assembly feeders: gravity, vibratory, etc.
- **Standard 216.3.5 Develop and test a basic gluing robot program**
  - Performance Indicators:
    - Develop and test a basic gluing robot program that applies a glue line on a part
  - Knowledge Indicators:
    - Describe the sequence of a robot gluing assembly operation
    - Describe applications of gluing assembly robot programs
    - Describe how to plan a motion path for gluing with robot approach and application points
    - Describe types of glue systems and end effectors