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June 2003

DOE STANDARD

INSTRUMENTATION AND CONTROL FUNCTIONAL AREA QUALIFICATION STANDARD

DOE Defense Nuclear Facilities Technical Personnel

U.S. Department of Energy
Washington, D.C. 20585

AREA TRNG

APPROVAL

The Federal Technical Capability Panel consists of senior Department of Energy managers responsible for overseeing the Federal Technical Capability Program. This Panel is responsible for reviewing and approving the Qualification Standard for Department-wide application. Approval of this Qualification Standard by the Federal Technical Capability Panel is indicated by signature below.

Roy J. Schepens
Chairman
Federal Technical Capability Panel

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ACKNOWLEDGMENT

The Savannah River Operations Office is the Sponsor for the Instrumentation and Control Functional Area Qualification Standard. The Sponsor is responsible for coordinating the development and/or review of the Functional Area Qualification Standard by subject matter experts to ensure that the technical content of the standard is accurate and adequate for Department-wide application for those involved in Instrumentation and Control. The Sponsor, in coordination with the Federal Technical Capability Panel, is also responsible for ensuring that the Functional Area Qualification Standard is maintained current.

The following subject matter expert (SME) participated in the original development and review of the revised qualification standard:

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FUNCTIONAL AREA

Instrumentation and Control

PURPOSE

The Department's Federal Technical Capability Program Policy, issued by the Secretary in December 1998, commits the Department to continuously strive for technical excellence. The Technical Qualification Program, along with the supporting technical Functional Area Qualification Standards, complements the personnel processes that support the Department's drive for technical excellence. In support of this goal, the competency requirements defined in the technical Functional Area Qualification Standards should be aligned with and integrated into the recruitment and staffing processes for technical positions. The technical Functional Area Qualification Standards should form, in part, the primary basis for developing vacancy announcements, qualification requirements, crediting plans, interviewing questions, and other criteria associated with the recruitment, selection, and internal placement of technical personnel. Office of Personnel Management minimum qualification standards will be greatly enhanced by application of appropriate materials from the technical Functional Area Qualification Standards.

The technical Functional Area Qualification Standards are not intended to replace the U.S. Office of Personnel Management's (OPM) Qualifications Standards nor other Departmental personnel standards, rules, plans, or processes. The primary purpose of the Technical Qualification Program is to ensure that employees have the requisite technical competency to support the mission of the Department. The Technical Qualification Program forms the basis for the development and assignment of DOE personnel responsible for ensuring the safe operation of defense nuclear facilities.

APPLICABILITY

The Instrumentation and Control Functional Area Qualification Standard establishes common functional area competency requirements for Department of Energy Instrumentation and Control personnel who provide assistance, direction, guidance, oversight, or evaluation of contractor technical activities impacting the safe operation of defense nuclear facilities. The technical Functional Area Qualification Standard has been developed as a tool to assist DOE Program and Field offices in the development and implementation of the Technical Qualification Program in their organization. Satisfactory and documented attainment of the competency requirements contained in this technical Functional Area Qualification Standard, or similar Standards, ensures that Instrumentation and Control personnel possess the requisite competence to fulfill their functional area duties and responsibilities. Office/Facility-Specific Qualification Standards supplement this technical Functional Area Qualification Standard and establish unique operational competency requirements at the Headquarters or Field element, site, or facility level.

IMPLEMENTATION

This technical Functional Area Qualification Standard identifies the technical and associated competency requirements for Instrumentation and Control personnel. Although there are other competency requirements associated with the positions held by Instrumentation and Control personnel, this Functional Area Qualification Standard is limited to identifying the specific technical competencies. The competency statements define the expected knowledge and/or skill that an individual must meet. Each of the competency statements is further explained by a listing of supporting knowledge and/or skill statements. **The supporting knowledge and/or skills provide guidance on the level of expectation and rigor to meet the intent of the competency.**

The competencies identify a familiarity level, a working level, or an expert level of knowledge; or they require the individual to demonstrate the ability to perform a task or activity. These levels are defined as follows:

Familiarity level is defined as basic knowledge of or exposure to the subject or process adequate to discuss the subject or process with individuals of greater knowledge.

Working level is defined as the knowledge required to monitor and assess operations/activities, to apply standards of acceptable performance, and to reference appropriate materials and/or expert advice as required to ensure the safety of Departmental activities.

Expert level is defined as a comprehensive, intensive knowledge of the subject or process sufficient to provide advice in the absence of procedural guidance.

Demonstrate the ability is defined as the actual performance of a task or activity in accordance with policy, procedures, guidelines, and/or accepted industry or Department practices.

Headquarters and Field elements shall establish a program and process to ensure that Instrumentation and Control personnel possess the competencies required of their position. That includes the competencies identified in this technical Functional Area Qualification Standard or a similar Standard developed by the organization. Documentation of the completion of the requirements of the Standard shall be included in the employee's training and qualification record.

Equivalencies may be granted for individual competencies based upon an objective evaluation with corresponding evidence of the employee's prior advanced education, experience, certification, and/or training. Equivalencies should be used sparingly and then with the utmost rigor and scrutiny to maintain the spirit and intent of the Technical Qualification Program. The supporting knowledge and/or skill statements for the individual competencies should be considered before granting equivalency for a competency. Prior experience within the last five years or training that had some form of examination process may be evaluated and documented to demonstrate equivalency to the specified competencies. Completion of a professional certification such as a Professional Engineering license related directly to the functional area may be evaluated and documented to demonstrate equivalency for many of the competencies in a functional area, with the exception of DOE-specific processes and requirements. Satisfactory completion of graduate level college courses that relate directly to specific competencies may be considered equivalent.

Training shall be provided to employees in the Technical Qualification Program to those who do not meet the competencies contained in the technical Functional Area Qualification Standard. Departmental training will be based upon appropriate supporting knowledge and/or skill statements similar to the ones listed for each of the competency statements. Headquarters and Field elements should use the supporting knowledge and/or skill statements as a basis for evaluating the content of any training courses used to provide individuals with the requisite knowledge and/or skill required to meet the technical Functional Area Qualification Standard competency statements.

EVALUATION REQUIREMENTS

Attainment of the individual competencies listed in this technical Functional Area Qualification Standard should be evaluated and documented by a qualifying official or the immediate supervisor (if technically qualified) using one or a combination of the following methods:

- Satisfactory completion of a written examination
- Satisfactory completion of an oral evaluation
- Satisfactory accomplishment of an observed task or activity directly related to a competency
- Documented evaluation of equivalencies

Field Element Managers shall qualify candidates as possessing technical knowledge of the complete set of disciplines and competencies contained in this Functional Area Qualification Standard. Each final qualification should be tailored to place emphasis on competencies of primary interest to the individual sites and/or specific facilities. Final qualification under this Functional Area Qualification Standard should be performed using one or a combination of the following methods:

- Satisfactory completion of a comprehensive written examination. The minimum passing grade should be 80%.
- Satisfactory completion of an oral examination by a qualified Senior Technical Safety Manager (STSM) or a qualification board of technically qualified personnel to include at least one qualified STSM.
- Satisfactory completion of a walkthrough of a facility with a qualifying official for the purpose of verifying a candidate's knowledge and practical skills of selected key elements, including safety systems, structures, components, and system operating principles of the systems associated with a specific technical area.

For oral examinations and walkthroughs, qualifying officials or board members should ask critical questions intended to integrate identified learning objectives during qualification. Field Element Managers or designees should develop formal guidance for oral examinations and walkthroughs that includes: the standards for qualification; the use of technical advisors by a board; the questioning procedures or protocol; pass/fail criteria; the board deliberation and voting authorization procedures; and the documentation process. A board or qualifying official may conduct the oral interview as a group or individually. The board should document explicitly any questions and answers that result in an oral examination failure. Field Element Managers or their designees may require the candidates who fail a written or oral examination to complete a special study program designed to strengthen weaknesses revealed in the examination. Field Element Managers or their designees may direct candidate reexaminations to verify the effectiveness of actions taken to correct weak areas.

CONTINUING EDUCATION, TRAINING AND PROFICIENCY

Instrumentation and Control personnel shall participate in continuing education and training as necessary to improve their performance and proficiency and ensure that they stay up-to-date on changing technology and new requirements. This may include courses and/or training provided by:

- Department of Energy
- Other government agencies
- Outside vendors
- Educational institutions

A description of suggested learning proficiency activities, and the requirements for the continuing education and training program for Instrumentation and Control personnel are included in Appendix A of this document.

DUTIES AND RESPONSIBILITIES

The following are the typical duties and responsibilities expected of DOE nuclear facility technical personnel assigned to the Instrumentation and Control Functional Area:

A. Review the management and technical oversight of the design, construction, and modification process.

B. Serve as a subject matter expert and technical resource for instrumentation and control systems.

C. Inspect and evaluate instrumentation and control systems for safe and efficient operation, maintenance, and testing.

D. Participate in accident investigation and problem-solving activities.

E. Review and participate (as appropriate) in the development, review, and coordination of Department of Energy Orders, standards, and guidance documents.

F. Evaluate Contractor compliance with relevant Department of Energy Orders, standards, and codes.

G. Review and assess authorization basis documentation.

H. Evaluate instrumentation and control system conformity to authorization basis documentation and other design basis documents.

I. Audit facility instrumentation and control systems and components for consistency between physical configuration, plant documentation, and design requirements.

J. Participate in department and industry best-practices working groups.

Position-specific duties and responsibilities for Instrumentation and Control personnel are contained in their Office/Facility-Specific Qualification Standard or Position Description.

BACKGROUND AND EXPERIENCE

The U. S. Office of Personnel Management's Qualification Standards Handbook establishes minimum education, training, experience, or other relevant requirements applicable to a particular occupational series/grade level, as well as alternatives to meeting specified requirements.

The preferred education and experience for instrumentation and control personnel is:

1. Education:

   Bachelor of Science degree in Electrical Engineering or a technical or scientific field; or meet the alternative requirements specified in the Qualification Standards Handbook.

2. Experience:

   Industry, military, Federal, state or other directly related background that has provided specialized experience in instrumentation and control system engineering. Specialized experience may be demonstrated through possession of the competencies outlined in the Standard.

REQUIRED TECHNICAL COMPETENCIES

Each of the competency statements defines the level of expected knowledge and/or skill that an individual must possess to meet the intent of this Technical Qualification Standard. **The supporting knowledge and/or skill statements further describe the intent of the competency statements but are not requirements.**

Note: When regulations or Department of Energy directives or other industry standards are referenced in the Qualification Standard, the most recent revision should be used.

1. Instrumentation and control personnel shall demonstrate a working level knowledge of fundamental electrical theory.

Supporting Knowledge and/or Skills

a. Define and discuss the following terms:

- Voltage
- Current
- Power
- Conductor
- Insulator
- Inductance
- Capacitance
- Impedance
- Electromagnetic force
- Electromagnetic field
- Frequency
- Wavelength

b. Discuss Ohm's Law.

c. Discuss Kirchoff's Law.

d. Discuss the relationships in electrical circuits between voltage, current, resistance, impedance, and power.

e. Discuss the function of the following components in an electrical circuit:

- Resistor
- Capacitor
- Inductor
- Diode
- Rectifier
- Transformer
- Relay
- Contact
- Fuse
- Time delay relay
- Overcurrent relay
- Undervoltage relay
- Switches
- Silicon controlled rectifiers
- underfrequency relay

2. Instrumentation and control personnel shall demonstrate a working level knowledge of the following basic electrical equipment:

- Batteries
- Motors and generators
- Transformers
- Backup power supplies
- Electrical switchgear and transmission equipment

Supporting Knowledge and/or Skills

a. Discuss the basic principle by which the following components produce current:

- Battery
- Direct Current generator
- Alternating Current generator
- Thermocouple
- solar panel
- Fuel cell

b. Discuss the various types of batteries used in electronic components. Include in the discussion the following elements of battery operation:

- Method by which a direct current (DC) is produced
- specific gravity
- Current capacity
- Amp-hour capacity
- Voltage applications
- Charge and discharge characteristics
- Battery life expectancy
- Materials used in the battery construction
- Battery physical characteristics, i.e., size, weight
- Environmental requirements for safe battery operation and disposal
- Specific component applications
- electrolyte precautions

c. Describe the relationship between voltage and current-carrying capacity for series-connected versus parallel-connected batteries.

d. Discuss the basic operation of alternating current and direct current (AC) (DC) generators. Include in the discussion the following elements of generator operation:

- Electromagnetic force
- Counter electromagnetic force
- Generator speed vs. frequency relationship
- Frequency control
- Generator field strength vs. output voltage relationship
- Field excitation
- Generator voltage regulation
- Generator protection circuitry and relaying

e. Discuss the basic operation of the various types of alternating current and direct current motors. Include in the discussion the following elements of motor operation as applicable to alternating current or direct current motors:

- Electromagnetic force
- Counter electromagnetic force
- Starting current vs. running current
- Starting torque slip
- Current vs. load characteristics
- Variable speed operation
- Speed control
- Motor controller circuitry
- Applications of different types of motors

f. Discuss the purposes of a transformer.

g. Discuss the basic operation of the various types of transformers. Include in the discussion the following elements of transformer operation and design:

- Theory of operation
- Magnetic coupling
- Voltage/current relationships between primary and secondary windings
- Purposes of a transformer
- Step up vs. step down transformer design
- Multiple secondary windings
- Transformer tap changers
- Transformer ratings
- Transformer cooling requirements
- Current transformers vs. potential transformers

h. Discuss the application of specific transformer designs to the following types of electrical/electronic circuitry:

- Instrumentation power
- Voltage sensing circuits
- Current sensing circuits
- Control circuitry power
- Circuits requiring fault isolation protection

i. Discuss application of the following as backup power supplies:

- UPS inverters
- Diesel generators
- Motor generators
- Auto transfer switches

j. Identify and discuss the operation of the different types of electrical switchgear.

k. Identify and discuss the operation of the different types of circuit breakers.

3. Instrumentation and control personnel shall demonstrate a working level knowledge of the characteristics and applications of electrical components used in instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Discuss the various methods through which a supply voltage is converted and/or reduced for use in an electronic circuit.

b. Given a schematic diagram of a typical instrumentation and control circuit, identify each of the following electrical components in the circuit and discuss its function, parameters, and rating as applicable:

- Resistors
- Capacitors
- Relays
- Contacts
- Fuses
- Switches
- Diodes
- Power supplies
- Solenoids
- Indicating lights

c. Discuss the application of the various types of circuit breakers and fuses used in the power supplies to instrumentation and control circuits. Include in this discussion the circuit requirements for the sizing, ratings, and characteristics of these power-interrupting devices.

d. Describe how different types of relays are used in instrumentation and control circuits to accomplish the following functions. Include in the discussion the relay characteristics required for each application.

- Logic control
- Signal isolation
- Electrical protection
- Electrical switching
- Time delays
- Alarm annunciation
- Indication actuation

e. Describe the methods and devices used in instrumentation and control circuits to provide for protection against electrical transients.

f. Identify and discuss the use of electrical test equipment used to troubleshoot and analyze instrumentation and control circuit performance.

g. Describe the requirements for electrical safety class systems.

h. Discuss the factors to be considered when selecting electrical components for use in instrumentation and control circuits. Include in the discussion any consideration that must be given to the environment in which the circuit is required to perform its design function.

i. Discuss the effects of electromagnetic interference and electrostatic discharge on the performance of components in a typical instrumentation and control circuit.

j. Discuss the design requirements for I&C system grounds.

4. Instrumentation and control personnel shall demonstrate a working level knowledge of temperature detection circuitry and components used in instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Discuss the basic functions of temperature detectors.

b. Describe the construction of a basic Resistance Temperature Detector (RTD).

c. Explain how Resistance Temperature Detector resistance varies with changes in sensed temperature.

d. Explain how an Resistance Temperature Detector provides an output representative of the measured temperature.

e. Describe the construction of a basic thermocouple including the materials used.

f. Explain how a thermocouple provides an output representative of the measured temperature.

g. Describe the environmental conditions that can affect the accuracy and reliability of temperature detection instrumentation.

h. Given a diagram of a basic temperature instrumentation detection and control system, describe the function of the following components:

- Resistance Temperature Detector (RTD)
- Bridge circuit
- Direct current-Alternating current converter
- Amplifier
- Balancing motor/mechanical linkage

i. Describe the temperature instrument indications for the following faults:

- Short circuit
- Open circuit

j. Explain the methods of bridge circuit compensation for changes in ambient temperature.

5. Instrumentation and control personnel shall demonstrate a working level knowledge of pressure detection circuitry and components used in instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Discuss the basic functions of pressure detectors.

b. Explain how a bellows pressure detector produces an output signal representative of the measured pressure.

c. Explain how a bourdon tube pressure detector produces an output signal representative of the measured pressure.

d. Explain how a strain gauge pressure transducer produces an output signal representative of the measured pressure.

e. Describe the environmental concerns that can affect the accuracy and reliability of pressure detection instrumentation.

f. Given a diagram of a basic pressure detection device, describe the function of the following components:

- Sensing element
- Transducer
- Pressure detection circuitry
- Pressure indication

g. Discuss the failure modes of the various types of pressure indication instruments.

6. Instrumentation and control personnel shall demonstrate a working level knowledge of level detection circuitry and components used in instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Identify the principle of operation of the following types of level instrumentation:

- Gauge glass
- Ball float
- Chain float
- Magnetic bond
- Conductivity probe
- Differential pressure
- Sonic probes
- Capacitance probes
- Bubblers
- radar level sensors

b. Explain the process of density compensation in level detection systems.

c. Given a basic diagram of a differential pressure detector level instrument, discuss the functions of the following:

- Differential pressure (D/P) transmitter
- Amplifier
- Indication

d. Describe the operation and applications of the following types of differential pressure detector level instruments:

- Open tank differential pressure transmitter

- Closed tank, dry reference leg
- Closed tank, wet reference leg

e. Describe the environmental concerns that can affect the accuracy and reliability of level detection instrumentation.

f. Discuss the failure modes of the various types of level indication instruments.

7. Instrumentation and control personnel shall demonstrate a working level knowledge of flow detection circuitry and components used in instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Describe the basic construction and theory of operation of the following types of head flow detectors:

- Orifice plates
- Venturi tube
- Dall flow tube
- Pitot tube
- Rotameter
- Nutating disk
- Electromagnetic flow meter
- Ultrasonic flow detector

b. Describe density compensation of a steam flow instrument. Include a discussion of the reason for density compensation and the parameters used.

c. Given a basic diagram of a typical flow detection device, discuss the functions of the following:

- Differential pressure (D/P) transmitter
- Extractor
- Indication

d. Describe the environmental concerns that can affect the accuracy and reliability of flow sensing instrumentation.

e. Discuss the failure modes of the various types of flow indication instruments.

8. Instrumentation and control personnel shall demonstrate a working level knowledge of position indication circuitry and components used in instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Describe the basic construction and theory of operation of synchro position indicators.

b. Describe the basic construction and theory of operation of the following variable output position indicators:

- Potentiometers
- Linear variable differential transformers (LVDT)

c. Describe the basic construction and theory of operation of the following switch position indicators:

- Limit switches
- Reed switches

d. Given a basic diagram of a position indicator, discuss the functions of the following:

- Detection device
- Indicator and control circuit

e. Describe the environmental concerns that can affect the accuracy and reliability of position indication instrumentation.

f. Discuss the failure modes of the various types of position indication instruments.

g. Discuss the functions and operation of position indication switches in motor operated valves.

h. Describe the methods used to test and adjust the position indication switches in motor operated valves.

9. Instrumentation and control personnel shall demonstrate a working level knowledge of radiation detection equipment.

Supporting Knowledge and/or Skills

a. Describe the operation of a proportional counter. Include the following elements in this discussion:

- Radiation detection
- Quenching
- Voltage variations

b. Describe the operation of an ionization chamber. Include the following elements in this discussion:

- Radiation detection
- Quenching
- Gamma sensitivity reduction

c. Given a basic diagram of a proportional counter circuit, discuss the functions of the following:

- Proportional counter
- Preamplifier/amplifier
- Single channel analyzer/discriminator
- Scaler
- Timer

d. Describe how a compensated ion chamber compensates for gamma radiation.

e. Describe the operation of an electroscope ionization chamber.

f. Describe the operation of a Geiger-Müller (G-M) detector. Include the following elements in this discussion:

- Radiation detection
- Quenching
- Positive ion sheath

g. Describe the operation of a scintillation counter. Include the following elements in this discussion:

- Radiation detection
- Three classes of phosphors
- Photomultiplier tube operation

h. Describe the operation of a gamma spectrometer. Include the following elements in this discussion:

- Type of detector used
- Multichannel analyzer operation

i. Describe how the following detect neutrons:

- Self-powered neutron detector
- Wide range fission chamber
- Flux wire

10. Instrumentation and control personnel shall demonstrate a working level knowledge of nuclear instrumentation.

Supporting Knowledge and/or Skills

a. Define the following terms:

- Signal-to-noise ratio
- Discriminator
- Analog
- Logarithm
- Period
- Decades per minute (DPM)
- Scalar

b. Describe the operation of the detectors used in each of the following nuclear instrument applications:

- Source range
- Intermediate range
- Power range

c. Given a basic diagram of a typical source range instrument, discuss the functions of the following components:

- Linear amplifier
- Discriminator
- Pulse integrator
- Log count rate amplifier
- Differentiator

d. Given a basic diagram of a typical intermediate range instrument, discuss the functions of the following components:

- Log amplifier
- Differentiator
- Reactor protection interface

e. Discuss the reason gamma compensation is not required in the power range.

f. Given a basic diagram of a typical power range instrument, discuss the functions of the following components:

- Linear amplifier
- Reactor protection interface

g. Discuss the failure modes of fission chambers, ion chambers, and proportional counters.

h. Discuss the various Non-Destructive Assay (NDA) instruments (e.g., gamma counters, Neutron Multiplicity Counters, etc.) available for measuring isotopic content, fissile material content, activity concentration for Materials Accountability of special nuclear materials and/or nuclear waste.

11. Instrumentation and control personnel shall demonstrate a working level knowledge of refractometers (as applicable to their facilities):

Supporting Knowledge and/or Skills

a. Discuss the use of refractometers in various facility applications.
b. Discuss how the refractive index of a solution varies with the density of the solution.
c. Discuss critical angle of refraction and how fully reflected light rays and partially reflected light rays form an image to derive the measurement.

12. Instrumentation and control personnel shall demonstrate a working level knowledge of sensor characteristics and instrument loop signal types.

a. Define and discuss the following sensor characteristics:

- Range
- Response Time
- Accuracy
- Precision
- Sensitivity
- Dead-band

b. Discuss the following signal types used in instrumentation loops:

- pneumatic (3-15 pounds)
- electrical (4-20 milliamps)
- electrical (1-5 Volts)

13. Instrumentation and control personnel shall demonstrate a working level knowledge of process control systems.

Supporting Knowledge and/or Skills

a. Define and discuss the following process control terms:

- Control system
- Control system input
- Control system output
- Open loop system
- Closed loop system
- Feedback
- Controlled variable
- Manipulated variable

b. Given a diagram of a process control system, describe its operation including the function of the following basic components:

- Controller
- Controlled device
- Feedback elements and signal
- Setpoint/reference signal
- Actuating signal
- Manipulated variable

c. Discuss the factors in a process control system that contribute to process control time lags.

d. Discuss stability in a process control system. Include in the discussion an explanation of converging and diverging oscillations and hunting.

e. Discuss the following process control system characteristics and terms:

- Reset control
- Rate control
- Proportional band
- Offset
- Span
- Deviation
- Cascading

f. Describe the operation of the following types of automatic control systems:

- Two-position control system
- Proportional control system
- Integral control system

- Proportional plus reset control system
- Proportional plus reset plus rate control system

g. Discuss the function and operation of the following components of a typical control station:

- Setpoint indicator
- Setpoint adjustment
- Deviation indicator
- Output meter
- Manual-automatic transfer switch
- Manual output adjust knob

h. Describe the operation of a self-balancing control station.

i. Describe the operation of the following types of actuators:

- Pneumatic
- Hydraulic
- Solenoid
- Electric motor

j. Discuss controller tuning.

13. Instrumentation and control personnel shall demonstrate a working level knowledge of the characteristics and applications of pneumatic/hydraulic components used in instrumentation and control systems.

Supporting Knowledge and/or Skills

a Describe the operation of a basic pneumatic transmitter.

b. Given a diagram of a typical pneumatic control circuit, describe the operation of the control system and explain the function of its components.

c. Explain the term "live zero" as it applies to pneumatic control circuits.

d. Discuss the function and application of the following types of signal converters:

- I/P converter
- P/I converter

e. Describe the operation of a pneumatic actuator used in the following applications:

- Air operated open/close valve
- Air operated throttle valve
- Air operated damper

f. Describe the operation of an electrohydraulic control system.

14. Instrumentation and control personnel shall demonstrate a working level knowledge of the characteristics and applications of electronic components used in instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Describe the operation and application of the following components found in instrumentation and control circuits:

- Summer
- Root extractor
- Gate
- Integrator
- Multiplier
- Proportional device

b. Discuss the uses and applications for microprocessors in an instrumentation and control system.

c. Discuss each of the following terms including their application to instrumentation and control systems.

- Computer memory (Random Access Memory (RAM)/Read-Only Memory (ROM)
- Discreet logic
- Discreet semiconductors
- Analog integrated circuits
- Comparitor circuits
- Combinatorial logics
- Signal conditioning

15. Instrumentation and control personnel shall demonstrate a working level knowledge of systems integration to achieve performance, effectiveness, and cost objectives.

Supporting Knowledge and/or Skills

a. Given a design package for an instrumentation and control system, evaluate its application within an integrated system for the following criteria:

- Instruments and controls meet the general human factors criteria and considerations for safe and efficient system operation.
- Instruments and controls perform within the parameters required for safe and efficient system operation.
- Instrument and control response times are adequate for safe and efficient system operation.
- Instruments and controls are physically configured for safe and efficient maintenance.
- Instruments and controls meet the general design criteria for the system in which they are to be used.

b. Given a proposed application of an instrumentation and control system to an integrated system, evaluate the performance of the integrated system to determine that instrument and control performance requirements will be met.

c. Discuss the problems presented to instrumentation and control systems under various system applications.

16. Instrumentation and control personnel shall demonstrate a working level knowledge of basic thermodynamic concepts and theories used in the design and operation of process control systems.

Supporting Knowledge and/or Skills

a. Define the following terms:

- Specific volume
- Density
- Specific gravity
- Mass
- Weight

b. Describe the thermodynamic properties of temperature and pressure.

c. Compare and contrast the Fahrenheit, Celsius, Kelvin, and Rankine temperature scales, and discuss the concept of "absolute zero."

d. Describe the relationship between absolute pressure, gauge pressure, and vacuum.

e. Define the following and describe their relationship:

- Energy
- Potential energy
- Kinetic energy
- Work
- Heat

f. Describe the following types of thermodynamic systems:

- Isolated system
- Open system
- Closed system

g. Discuss the application of Bernoulli's principle to a process control system.

17. Instrumentation and control personnel shall demonstrate a familiarity level knowledge of basic heat transfer and fluid flow concepts and theories.

Supporting Knowledge and/or Skills

a. Explain the following terms:

- Static head
- Velocity head
- Friction head
- Head loss

b. Describe the relationship between pressure and flow in a process system.

c. Using the ideal gas law, discuss the relationship between pressure, temperature, and volume.

d. Describe the effects of pressure and temperature changes on confined fluids.

e. Describe how the density of a fluid varies with temperature.

f. Describe the relationship between the pressure in a fluid column and the density and depth of the fluid.

g. Define the terms "mass flow rate" and "volumetric flow rate".

h. Describe the phenomenon of water hammer, pressure spike, and steam hammer.

18. Instrumentation and control personnel shall demonstrate a familiarity level knowledge of mechanical engineering, theories, principles, and techniques.

Supporting Knowledge and/or Skills

a. Describe the basic construction and operation of the following types of valves used in a process system:

- Gate valve
- Globe valve
- Flow control valve
- Butterfly valve
- Diaphragm valves
- Check valve
- Relief and safety valves

b. Discuss how valve operation controlled by a process control system can cause water hammer or pressure spiking if the system is not designed properly.

c. Describe the basic operation and pressure/flow characteristics of the following types of pumps:

- Centrifugal pump
- Positive displacement pump

d. Describe the basic design and operation of a compressed air system used to supply instrument air, including a discussion of the function of the following components:

- Compressor
- Moisture separator
- Intercooler
- After cooler
- Receiver
- Air dryer

e. Describe the function and operation of vibration monitoring equipment used to monitor large motors, pumps, and compressors.

f. Describe the basic operation of pressure regulating valves and flow control valves in a process system.

g. Describe the basic theory of operation of a heat exchanger used in a process system.

h. Describe the various methods and characteristics of heat transfer that may occur in a process system.

i. Describe the basic design and operation of a typical heating, ventilation, and air conditioning (HVAC) system including a discussion of the control system used to maintain habitability.

j. Given a process and instrumentation diagram and the technical specifications for a process system, describe the purpose of the system and the major flowpaths.

k. Given a process and instrumentation diagram and the technical specifications for a process system, describe the function of each of the major components of the system

19. Instrumentation and control personnel shall demonstrate a familiarity level knowledge of the geoseismic/civil engineering theories, principles, and techniques that apply to instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Discuss the seismic design constraints imposed on instrumentation and control systems important to safety.

b. Describe the function and operation of instrumentation systems used to measure and annunciate seismic events at defense nuclear facilities.

c. Discuss the effects of vibration on instrumentation and control system performance and reliability, including the methods used to mitigate those effects.

d. Discuss the general factors that affect the seismic qualification of a system, component, or structure.

20. Instrumentation and control personnel shall demonstrate a familiarity level knowledge of the chemical engineering theories, principles, and techniques that apply to instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Discuss the design elements that must be considered when applying instrumentation and control systems for use with chemical processes.

b. Discuss the application of instrumentation and control system components used to measure and control level, flow, temperature, and pressure in chemical process systems that contain corrosive chemicals.

21. Instrumentation and control personnel shall demonstrate the ability to read and interpret electrical diagrams including:

- **One-line diagrams**
- **Schematics**
- **Logic diagrams**
- **Printed wiring board diagrams**

Supporting Knowledge and/or Skills

a. Given an electrical diagram, identify electrical component symbology.

b. Given a logic diagram for a control circuit, identify and describe the effects of an action taken.

c. Identify the symbols used on logic diagrams to represent the components.

d. Explain the operation of the three types of time delay devices.

e. Identify the symbols used to denote a logical "1" (or high) and a logical "0" (or low) as used in logic diagrams.

f. Given a logic diagram and appropriate information, determine the output of each component and the logic circuit.

g. Given a one-line diagram, identify power sources and loads.

h. Given a one-line diagram or schematic diagram, analyze the effects of a component failure in a system.

i. Given a construction diagram, identify the power supplies.

j. Discuss the origin and purpose of "as-built" drawings.

k. Describe printed wiring board fabrication and assembly.

22. Instrumentation and control personnel shall demonstrate the ability to read and interpret mechanical diagrams associated with instrumentation and control systems including:

- Construction drawings
- As-built drawings
- Piping and Instrumentation Diagrams (P&ID)
- Assembly drawings

Supporting Knowledge and/or Skills

a. Identify the symbols used for:

- Types of valves
- Types of valve operators
- Types of instrumentation
- Types of instrument signal controllers and modifiers

- Types of system components (pumps, etc.)
- Types and sizes of piping

b. Identify the symbols used to denote the location of instruments, indicators, and controllers.

c. Identify how valve conditions are depicted.

d. Determine the system flowpath for a given valve lineup.

23. Instrumentation and control personnel shall demonstrate the ability to read and interpret engineering fabrication, construction, and architectural drawings associated with instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Given the above drawings, read and interpret the following symbology:

- Basic dimensional and tolerance
- Basic fabrication
- Basic construction
- Basic architectural

b. Given a drawing and a completed product, compare the product against the specifications on the drawing.

24. Instrumentation and control personnel shall demonstrate a working level knowledge of the various uses of computers and digital devices used in instrumentation and control systems.

Supporting Knowledge and/or Skills

a. Discuss analog to digital (A/D) and Digital to Analog (D/A) converters.

b. Discuss Programmable Logic Controllers (PLC) and Distributed Control Systems (DCS) including use, operation, program control, etc.

c. Discuss digital I&C scan rates.

25. Instrumentation and control personnel shall demonstrate a working level knowledge of analytical equipment used to measure process chemistry.

Supporting Knowledge and/or Skills

a. List the types of instrumentation used to measure the following process chemistry parameters:

- Conductivity
- pH
- Total dissolved solids
- Silica
- Turbidity
- Chlorine
- Moisture/humidity

- hydrogen
- oxygen

b. Explain how each of the following process chemistry parameters is measured and converted to a usable signal for alarm, indication, and control:

- Conductivity
- pH
- Total dissolved solids
- Silica
- Turbidity
- Chlorine
- Moisture/humidity
- hydrogen
- oxygen

c. Describe the environmental concerns that can affect the accuracy and reliability of analytical equipment used to measure process chemistry.

d. Discuss the failure modes of the various types of analytical equipment used to measure process chemistry.

e. Describe the methods used to test each of the different types of instruments used to measure process chemistry.

26. Instrumentation and control personnel shall demonstrate a familiarity level knowledge of maintenance management practices related to instrumentation and control activities.

Supporting Knowledge and/or Skills

a. Define each of the following maintenance related terms and explain their relationship to each other.

- Corrective
- Preventive
- Predictive
- Reliability Centered

b. Discuss the importance of maintaining a proper balance of maintenance strategies to optimize cost-effective maintenance that achieves high equipment reliability.

c. Discuss the importance of maintaining a maintenance history and identify typical maintenance performance indicators.

d. Discuss the relationship between maintenance and Conduct of Operations, Qualify Assurance, and Configuration Management.

e. Discuss the requirements for the receipt and inspection of parts, materials, and equipment.

f. Describe the difference between temporary and permanent repairs/work and the requirements and controls in place to prevent inadvertent modifications (consider both the hardware and software control elements of the configuration management program).

g. Describe the mechanisms for feedback of relevant information, such as trend analysis and instrumentation performance/reliability data, to identify necessary program modifications.

h. Review a contractor preventive maintenance activity and describe the preventive maintenance factors to be considered as the activity is planned.

i. Discuss the importance of post-maintenance testing and the elements of an effective post-maintenance testing program.

27. Instrumentation and control personnel shall demonstrate the ability to evaluate the adequacy of local compliance of I&C systems with applicable design criteria (such as ISA 84.01, ISA 67.04.01, IEEE 603-1998, NEC or the Uniform Building Code) used by site/facility.

Supporting Knowledge and/or Skills

a. Discuss the purpose and application of the criteria contained in the applicable I&C design standards.

b. Discuss what constitutes a safety class or safety-significant item as represented by the various I&C design standards.

c. Discuss the application of single failure criteria to instrumentation and control systems.

d. Discuss the environmental qualification criteria for instrumentation and control system equipment.

e. Discuss the requirements for testing capability for instrumentation and control systems as it relates to the applicable design standards.

f. Discuss the criteria for generic human factors engineering considerations in the applicable design standards, as they apply to instrumentation and control systems.

g. Discuss criteria for developing the proper setpoints for interlocks and alarms.

h. Given a design package for an instrumentation and control system for a mechanical, civil, structural, or electrical application, determine the general design criteria requirements for the instrumentation and controls.

28. I&C personnel designated as vital safety systems subject matter experts shall demonstrate an expert level of knowledge on their level of understanding and approach to overseeing contractor activities by using the requirements of DOE Order 420.1, Facility Safety, and the guidance in DOE-STD-1073-93, Guide for Operational Configuration Management Program by performing system assessments addressing the following elements:

Supporting Knowledge and/or Skills

a. Determine that adequate and comprehensive documentation exists for the system design basis and safety basis (e.g., Documented Safety Analysis, Technical Safety Requirements, etc.).

b. Assess the adequacy of the system's ability to perform in accordance with the system design basis and safety basis.

c. Determine how system operability and reliability are supported by the maintenance program and system upgrades/modifications.

d. Determine if the field installation is maintained consistent with the documented design during maintenance and modifications.

e. Confirm that knowledgeable and qualified technical personnel are monitoring, operating and maintaining the safety system in an appropriate manner.

29. Instrumentation and control personnel shall demonstrate a familiarity level knowledge of Department of Energy (DOE) Order 430.1, Life Cycle Asset Management.

Supporting Knowledge and/or Skills

a. Discuss the purpose, scope, and application of DOE Order 430.1. Include in this discussion the key terms, essential elements, and personnel responsibilities and authorities.

b. Discuss the project management terminology for which definitions are provided in DOE Order 430.1.

c. Discuss in detail the roles played by various management levels within the Department as they relate to the project management system.

d. Discuss the purpose of "critical decisions". Include in this discussion the responsible authorities for critical decisions.

e. Describe the process by which projects are designated.

f. Describe the phases of a typical project.

g. Explain the purpose and use of a project execution plan.

h. Discuss the role of configuration management as it relates to project management.

i. Discuss the use of safety plans in the management of projects.

j. Discuss the relationship between work breakdown structure (WBS) and cost and schedule.

k. Describe the purpose and use of work packages and/or planning packages.

l. Describe the purpose of schedules, and discuss the use of milestones and activities.

m. Describe the critical path method of scheduling.

n. Explain the concept of a project management baseline and describe the four baselines used in project management.

30. Instrumentation and control personnel shall demonstrate the ability to evaluate the adequacy of local compliance with applicable Instrumentation, Systems, and Automation Society (ISA) Standards related to process control instrumentation and I&C systems (consider entire instrument loops including sensors, transmitters, controllers, final elements):

Supporting Knowledge and/or Skills

a. Discuss the purpose, scope, general content, and application of the ISA Standards.

b. Given a project involving process control instrumentation, identify the proper ISA Standards necessary to effectively evaluate that element of the project.

c. Discuss what constitutes acceptable contractor performance consistent with the requirements of the above standards.

d. Given the design drawings and specifications for a process control system, verify compliance with the appropriate ISA Standards.

31. Instrumentation and control personnel shall demonstrate a familiarity level knowledge of Department of Energy (DOE) Order 414.A, Quality Assurance, as it applies to instrument and control systems.

Supporting Knowledge and/or Skills

a. Describe the types of documents related to instrumentation and control that should be controlled by a document control system.

b. Discuss the requirements for revision and distribution of controlled documents.

c. Discuss the determination of calibration frequency for measuring and test equipment.

d. Describe the effect of using inappropriate calibration standards on test equipment.

e. Discuss the key elements of the procurement process for instrument and control systems as described in the DOE Quality Assurance order.

f. Discuss calibration techniques for various instrument types.

g. Discuss correct actions to be taken for an instrument found out of calibration.

h. Discuss instrument calibration data trending.

i. Discuss the quality assurance measures required for each of the following elements of a project:

- Design control
- Procurement control
- Instructions, procedures, and drawings
- Document control
- Control of purchased material, equipment, and services
- Identification, control, and traceability of materials, parts, and components
- Control of special processes
- Inspection
- Test control
- Calibration and control of test and measurement equipment
- Handling, storage, shipping, and preservation
- Inspection, test, and operating status
- Nonconformity of material, parts, or components
- Corrective action

- Quality assurance records
- Audits

j. Discuss the site organizational roles, responsibilities and authorities for development of process control systems software (i.e., applications software for Programmable Logic Controllers-PLC, Distributed Control Systems-DCS, etc.).

k. Discuss the site requirements and guidance for the software quality assurance process for development of process control systems software.

l. Discuss the techniques the site uses to verify and validate process control systems software.

32. Instrumentation and control personnel shall demonstrate the ability to apply problem analysis techniques necessary to identify problems, determine potential causes of problems, and identify corrective action.

Supporting Knowledge and/or Skills

a. Given event and/or occurrence data, apply problem analysis techniques, identify the problems, and determine how they could have been avoided.

b. Participate in a contractor or Department of Energy (DOE) problem analysis and critique the results.

c. Interpret a fault tree analysis.

33. Instrumentation and control personnel shall demonstrate the ability to perform technical reviews of procedures related to instrumentation and controls.

Supporting Knowledge and/or Skills

a. Given one of the listed documents, review it for the following elements:

- Technical adequacy
- Technical accuracy
- Proper format
- Sufficient level of detail
- Properly defined responsibilities
- Procedural steps are concise and easily understood
- References are accurate and current

b. Given an instrumentation and controls surveillance, test, maintenance, or operating procedure, verify procedural adequacy in the following areas:

- Acceptance criteria is identified and accurate
- Quality control is addressed
- Notification requirements are identified
- Procedural cautions are identified
- Proper equipment and material is identified
- Safety concerns are addressed
- Compliance with Technical Safety Requirements
- Compliance with the Safety Analysis Report

c. Given an instrumentation and controls surveillance, test, maintenance, or operating procedure, perform a safety evaluation to determine that an unidentified safety question is not involved.

APPENDIX A
CONTINUING EDUCATION, TRAINING AND PROFICIENCY OPPORTUNITIES

The following list represents suggested resources for continuing education, training and other opportunities that are available for instrument and control personnel after completion of the competency requirements in this technical Functional Area Qualification Standard. It is extremely important that personnel involved with instrument and control maintain their proficiency through continuing education, training, reading, or other activities such as workshops, seminars, and conferences. The list of suggested activities was developed by the Subject Matter Experts involved in the development of the Functional Area Qualification Standard and is not all-inclusive.

Based on the knowledge and experience of the Subject Matter Experts, it is suggested that [*to be determined*] learning activities per [*to be determined*] are necessary to maintain proficiency in the instrument and control functional area after completion of the competencies in the Standard and other requirements of the Technical Qualification Program.

LIST OF CONTINUING EDUCATION, TRAINING AND OTHER ACTIVITIES

Institute of Electrical and Electronics Engineers, Inc. (IEEE)
3 Park Avenue, 17th Floor
New York, New York 10016-5997
http://www.ieee.org

The Instrumentation, Systems, and Automation Society (ISA)
67 Alexander Drive
PO Box 12277
Research Triangle Park, NC 27709
http://www.isa.org

National Fire Protection Association (NFPA)
(NFPA 70 - National Electrical Code)
1 Batterymarch Park
P.O. Box 9101
Quincy, Massachusetts 02269-9101
http://www.nfpa.org/nec/nechome.asp

AVO International Training Institute
4271 Bronze Way,
Dallas, Texas 75237-1017 USA
http://www.avointl.com/us/training

Electrical Systems Self Study Guide
http://cted.inel.gov/cted/tq_tm_index.html

Electronic Industries Alliance (EIA)
2500 Wilson Blvd.
Arlington, VA 22201
http://www.eia.org

International Electrotechnical Commission (IEC)
IEC Central Office
3, rue de Varembé
P.O. Box 131
CH - 1211 GENEVA 20
Switzerland
http://www.iec.ch

CONCLUDING MATERIAL

Review Activity:

DOE
DP-NNSA
EH
EM
NE
NN-NNSA
SC
FE

Field and Operations Offices
AL
CH
ID
Fernald
NV
OAK
OH
OR
RF
RL
SF
SR
Carlsbad Field Office (CBFO)
Office of River Protection

AREA Offices:
Amarillo Area Office
Argonne Area Office
Brookhaven Area Office
Fermi Area Office
Kirtland Area Office
Los Alamos Area Office
Princeton Area Office
Rocky Flats Area Office
Y-12 Area Office

Preparing Activity:
DOE-EH-53

Project Number:
TRNG-0030