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DOE-STD-1161-2003
June 2003

DOE STANDARD

MECHANICAL SYSTEMS FUNCTIONAL AREA QUALIFICATION STANDARD

DOE Defense Nuclear Facilities Technical Personnel

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

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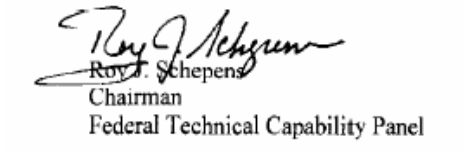
APPROVAL

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 Mechanical Systems 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 mechanical systems. 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 experts (SMEs) participated in the development and/or review of this qualification standard:

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FUNCTIONAL AREA

Mechanical Systems

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 qualifications 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 Mechanical Systems Functional Area Qualification Standard establishes common functional area competency requirements for Department of Energy mechanical systems 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, ensures mechanical systems 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 competency requirements for mechanical systems personnel. Although there are other competency requirements associated with the positions held by mechanical systems 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 skill statements are not requirements and do not necessarily have to be fulfilled 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 mechanical systems 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 5 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 that 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

Mechanical systems 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 mechanical systems personnel are included in Appendix A of this document.

DUTIES AND RESPONSIBILITIES

The following are the typical duties and responsibilities that are expected of DOE defense nuclear facility technical personnel assigned to the mechanical systems functional area:

A. Assess the management and technical oversight of design, construction, modification processes, and decontamination/decommissioning associated with the mechanical systems functional area.

B. Assess the effectiveness of contracting mechanisms (cost plus award fee, cost plus fixed fee, etc.) and contractor performance evaluations.

C. Serve as a subject matter expert and technical resource for mechanical systems personnel training and other technical matters.

D. Evaluate DOE facility and program mechanical systems for safe efficient operation, maintenance, and testing, including emergency systems.

E. Participate in establishing and/or reviewing Department of Energy (DOE) orders related to mechanical system practices and requirements.

F. Evaluate contractor compliance with relevant DOE Orders, standards, codes, and Management and Operating (M&O) contractor operating procedures, etc.

G. Critically analyze system design basis documentation and related safety documentation.

H. Verify the application of quality assurance, configuration management, and safety requirements to mechanical systems.

Position-specific duties and responsibilities for mechanical systems 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 mechanical systems personnel is:

1. Education:

   Bachelor of Science degree in Mechanical Engineering from an accredited institution or meet the alternative requirements specified in the Qualification Standards Handbook for the GS-0800, Professional Engineering Series

2. Experience:

   Industry, facility, operations, or other related experience and/or a Professional Engineer license that has provided a background in mechanical engineering. Specialized experience can be demonstrated through possession of the competencies outlined in this 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. Mechanical systems personnel shall demonstrate a working level knowledge of steady-state heat transfer.

Supporting Knowledge and/or Skills

a. Define:

- Conduction
- Convection
- Radiation
- Thermal conductivity
- Convectivity
- Emissivity

b. Discuss Fourier's law.

c. Describe the factors that contribute to the co-efficient of thermal conductivity.

d. Calculate the heat flux for one-dimensional, steady-state heat transfer through the following:

- Composite wall
- Series wall
- Parallel wall

e. Using data, calculate total heat transfer and local heat flux in a laminar flow system.

f. Using data, calculate the log mean temperature difference for heat exchangers.

2. Mechanical systems personnel shall demonstrate a working level knowledge of the construction and operation of heat exchangers.

Supporting Knowledge and/or Skills

a. Describe the principle of operation for the following types of heat exchangers:

- Shell and tube
- Fin and tube
- Cooling tower

b. Define the following terms as they apply to heat exchangers:

- Tube sheet
- Tell-tale drain
- Parallel flow
- Counter flow
- Cross flow

c. Using a cutaway drawing of the following types of heat exchangers, show the flow paths of the cooling medium and the medium to be cooled:

- Parallel flow
- Counter flow
- Cross flow

d. Explain the principle of operation of a forced-draft cooling tower.

e. Explain the principle of operation of a natural-draft (parabolic) cooling tower.

3. Mechanical systems personnel shall demonstrate a working level knowledge of thermodynamics.

Supporting Knowledge and/or Skills

a. Define the following:

- Compression
- Isothermic
- Isentropic
- Adiabatic

b. Discuss entropy and enthalpy as they relate to mechanical systems.

c. Define and discuss the following:

- Carnot cycle
- Rankine cycle
- Vapor-refrigeration cycle
- Otto cycle
- Gas standard cycle

d. Read and interpret a Mollier diagram.

e. Using data from a steady-state system, calculate the following:

- Entropy change
- Enthalpy change
- Pressure
- Temperature

4. Mechanical systems personnel shall demonstrate a working level knowledge of the theory and operation of air conditioning and refrigeration (AC&R) systems.

Supporting Knowledge and/or Skills

a. Define the following terms as they apply to air conditioning and refrigeration systems:

- Latent heat of vaporization
- Latent heat of fusion
- Refrigerant
- Vaporization point
- Air and non-condensable gases

b. Using a one-line diagram of the basic refrigeration cycle, discuss the theory of operation of refrigeration systems.

c. Discuss the function of the following components of a typical refrigeration system:

- Compressor
- Condenser
- Thermal expansion valve
- Evaporator coils
- Receiver

d. Discuss refrigerant leak detection.

e. Discuss the general hazards involved in handling refrigerants.

5. Mechanical systems personnel shall demonstrate a working level knowledge of the basic construction, operation, and theory of ventilation systems.

Supporting Knowledge and/or Skills

a. Using a one-line diagram of a heating, ventilation, and air conditioning system, identify the following components and discuss their purpose:

- Blowers
- Fans
- Dampers
- Chillers
- Filters
- Heat exchangers
- Scrubbers
- Hoods
- Pressure sensors

- Air flow indicators

b. Compare and contrast the design, operation, and application of axial-flow and radial-flow fans.

c. Discuss the relationships between the following in ventilation systems:

- Supply ventilation
- Flow
- Exhaust ventilation

d. Describe the purpose of the ventilation system in the following applications:

- Hoods
- Glove boxes
- Hot cells
- Confinement systems

e. Identify and discuss when maintaining a negative ventilation system pressure is desirable.

6. Mechanical systems personnel shall demonstrate a working level knowledge of fluid mechanics.

Supporting Knowledge and/or Skills

a. Define the following:

- Temperature
- Pressure
- Viscosity
- Specific volume
- Specific gravity
- Capillarity
- Cavitation
- Laminar flow
- Turbulent flow
- Uniform flow
- Surface tension

b. Describe the bulk modulus of elasticity and compressibility.

c. Describe the effects characterized by Pascal's law of fluid pressure.

d. Explain the equation of continuity as it applies to fluid flow.

e. Discuss the Reynold's number and how it is used.

f. Discuss pressurized and non-pressurized flow.

g. Discuss Bernoulli's equation as it applies to steady-state flow rate calculations.

h. Discuss the ideal gas law as it applies to pressure, volume, and temperature relationships.

7. Mechanical systems personnel shall demonstrate the ability to calculate flow rates in fluid systems.

Supporting Knowledge and/or Skills

a. For non-compressible fluids, calculate flow rates using the following methods:

- Volume flow rate
- Mass flow rate
- Steady-State continuity equation
- Bernoulli's equation
- Darcy's formula

b. Discuss the limitations of the above methods.

8. Mechanical systems personnel shall demonstrate working level knowledge of general piping systems.

Supporting Knowledge and/or Skills

a. Define the following terms as they relate to piping systems:

- Pipe schedule
- Water hammer
- Hydrostatic test pressure
- Laminar flow
- Turbulent flow

b. Discuss the potential hazards to personnel and equipment associated with water hammer.

c. Identify and discuss the typical causes of water hammer in piping systems.

d. Discuss the purpose of seismic restraints (whip restraints or snubbers) in piping systems.

e. Describe the principle of operation for the various methods of measuring piping system parameters (e.g., pressure, temperature, flow) to include:

- Resistance Temperature Detector (RTD)
- Differential pressure detector
- Pitot tube
- Thermocouple
- Bourdon tube pressure gauge
- Duplex pressure gauge
- Manometer
- Mechanical flow meters

f. Identify and discuss different methods of pipe joining (threaded, butt weld, socket weld, seal weld, etc.)

g. Discuss the purpose and types of freeze protection measures used in piping systems.

9. Mechanical systems personnel shall demonstrate a working level knowledge of the general construction, operation, and theory of valves.

Supporting Knowledge and/or Skills

a. Define the following terms as they relate to valves:

- Disc
- Seat
- Throttle
- Actuator
- Bridgewall mark
- Packing

b. Using a drawing of a valve, identify which of the following general types of valve it is and, describe its normal design application in a piping system:

- Gate
- Globe
- Ball
- Check
- Butterfly
- Regulating/reducing

c. Discuss why the design of a globe valve enables it to throttle fluids efficiently.

d. Using a diagram of a globe valve body showing the bridgewall mark, identify how the valve must be oriented in the system related to flow.

e. Discuss why gate valves, ball valves, and butterfly valves should never be used to throttle flow.

f. Discuss how cavitation occurs in valves and state any harmful effects that can result from cavitation.

g. Describe the construction and principle of operation for the following types of valve actuators:

- Manual
- Electric
- Solenoid
- Pneumatic
- Hydraulic

h. Describe the principles of operation and applications for modulating and pressure reducing valves.

10. Mechanical systems personnel shall demonstrate a working level knowledge of safety and relief devices.

Supporting Knowledge and/or Skills

a. Define the following terms as they pertain to safety and relief valves:

- Set point
- Accumulation
- Blowdown
- Weep
- Pilot-actuated
- Gagging device

b. Compare and contrast the purpose and operation of safety and relief valves.

c. Discuss how blowdown and accumulation are controlled in safety and relief valves.

d. Using a cutaway drawing of a safety valve, identify the main components to include:

- Seat
- Disc
- Blowdown ring
- Main spring
- Set-point adjustment mechanism

e. Discuss the methods used to test relief valves.

f. Discuss the application of Rupture Discs.

11. Mechanical systems personnel shall demonstrate a working level knowledge of pump theory and operation.

Supporting Knowledge and/or Skills

a. Define the following terms as they relate to pumps:

- Head
- Net positive suction head
- Cavitation
- Shut-off head
- Run-out
- Centrifugal pump
- Positive displacement pump

b. Describe the general principle of operation for centrifugal pumps.

c. Describe the general principle of operation for positive displacement pumps.

d. Using a cutaway drawing of a centrifugal pump, identify the following components and discuss their purpose:

- Impeller
- Packing or mechanical seal

- Volute
- Lantern ring
- Wearing rings (impeller and/or casing)

e. Discuss Bernoulli's Law as it applies to the design and operation of centrifugal pumps.

f. Discuss why centrifugal pumps should normally be started against a shut-off head and the hazards associated with continuously running against a shut-off head.

g. Compare and contrast the principle of operation and typical pumped medium of the following types of positive displacement pumps:

- Reciprocating
- Rotary-screw
- Vane-axial

h. State the dangers to personnel and equipment associated with starting a positive displacement pump against a shut-off head. Discuss the importance and methods of providing over pressurization protection for positive displacement pumps.

i. Using the following list of system and/or pumped medium characteristics, identify which type of pump (e.g., centrifugal, reciprocating positive displacement, rotary-screw positive displacement) is best suited for the application.

- Slurries
- Fluids with high viscosities
- Low volume, high head
- Low head, high volume
- Water
- Oil

j. Discuss the concept of pump cavitation and describe its harmful effects.

12. Mechanical systems personnel shall demonstrate a working level knowledge of strainers and filters.

Supporting Knowledge and/or Skills

a. Compare and contrast the design, operating characteristics, and applications of filters and strainers.

b. Describe the following types of strainers and filters, including an example of typical use for each:

- Electrostatic filters
- Cartridge filters
- Precoated filters
- Bucket strainers
- Deep-bed filters
- High Efficiency Particulate Air (HEPA) filters
- Duplex strainers

c. Discuss the principle application of high efficiency particulate filters and the general content of DOE-STD-3020-97.

d. Identify and describe the hazards associated with high efficiency particulate filters, including any fire safety concerns.

13. Mechanical systems personnel shall demonstrate a working level knowledge of the basic components, operations, and theory of hydraulic systems.

Supporting Knowledge and/or Skills

a. Define the following terms and discuss their relationship in hydraulic systems:

- Force
- Work
- Pressure
- Reservoir
- Accumulator
- Actuator

b. Describe the basic operation of a hydraulic system.

c. Discuss how energy in a hydraulic system is converted to work.

d. Discuss the purpose and basic construction of a hydraulic reservoir.

e. Discuss the purpose and basic construction of a hydraulic accumulator.

f. Identify and discuss the hazards associated with hydraulic systems and their components.

14. Mechanical systems personnel shall demonstrate a working level knowledge of the components, operation, and theory of pneumatic systems.

Supporting Knowledge and/or Skills

a. Define the following terms and discuss their relationship:

- Dew point
- Dehydrator
- Dew point indicator
- Actuator

b. Describe the basic operation of a pneumatic system.
c. Discuss how energy in a pneumatic system is converted to work.

d. Discuss the hazardous relationship between high pressure air and oil.

e. Identify and discuss the general hazards associated with pneumatic systems and their components and the overpressurization of these systems.

f. Discuss the hazards associated with portable gases such as cylinders of oxygen, nitrogen, etc.

g. Using a Piping and Instrumentation Diagram (P&ID) of a typical facility instrument air system, identify the main components to include:

- Compressor
- Dehydrator
- Receivers
- Relief valve
- Filters

h. Using a cutaway diagram of a typical multi-stage air compressor, identify its main components and discuss their purpose and function to include:
- Prime mover
- High pressure (HP) stage(s)
- Low pressure (LP) stage(s)
- HP and LP suction and discharge valves
- Intercooler
- Aftercooler
- Cooling medium flow path(s)
- Lubrication system/pump

i. State the purpose of an air compressor unloader and discuss its basic operation.

j. Compare and contrast the principle of operation for centrifugal and reciprocating compressors.

15. Mechanical systems personnel shall demonstrate a working level knowledge of a typical diesel engine including support systems.

Supporting Knowledge and/or Skills

a. Differentiate between two-stroke and four-stroke (two-cycle and four-cycle) engines.

b. Discuss the ignition principle in a diesel engine.

c. Discuss the purpose and principle of operation of a diesel engine injector.

d. Discuss the purpose of the following diesel engine support systems:

- Cooling water
- Lubrication
- Fuel oil
- Scavenging air
- Starting systems

e. Using a cutaway drawing of a typical diesel engine, identify and discuss the purpose of the major parts, including:

- Pistons

- Connecting rods
- Crank shaft
- Injectors
- Main bearings
- Cylinder liners
- Cooling water jackets

16. Mechanical system personnel shall demonstrate a working level knowledge of the principles of lubrication.

Supporting Knowledge and/or Skills

a. Define:

- Viscosity
- National Lubricating Grease Institute (NLGI) grease grades

b. Identify and discuss various types of lubricants and their potential corrosion concerns to components and systems to include:

- Oil
- Water
- Solids/powders
- Gaseous
- Grease

c. Discuss the importance of viscosity.

d. Using component vendor data, determine the proper class of lubricant for the component.

e. Discuss the hazards to equipment associated with mixing different types of oils and greases.

f. Discuss the use and importance of filters and filtration in lubricating systems.

g. Discuss the principle of operation of moisture separators.

17. Mechanical systems personnel shall demonstrate a familiarity level knowledge of chemistry fundamentals in the areas of corrosion and water treatment.

Supporting Knowledge and/or Skills

a. Explain the process of general corrosion of iron and steel when exposed to water.

b. Discuss the two conditions that can cause galvanic corrosion.

c. Discuss the following types of specialized corrosion:

- Pitting corrosion
- Stress corrosion cracking
- Crevice corrosion

d. Explain the ion exchange process.

18. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the concepts, theories, and principles of basic material science.

Supporting Knowledge and/or Skills

a. State the five types of bonding that occur in materials and their characteristics.

b. Compare and contrast the properties, characteristics and applications of stainless steel to those of carbon steel.

c. Discuss the following terms:

- Compressibility
- Shear stress
- Tensile stress
- Compressive stress
- Strain
- Proportional limit
- Plastic deformation
- Permanent deformation

d. Using the stress-strain curves for ductile and brittle material, identify the following points on a stress-strain curve:

- Proportional limit
- Ultimate strength
- Yield point
- Fracture point

e. Discuss the following terms:

- Strength
- Malleability
- Ductility
- Toughness
- Yield strength
- Hardness
- Ultimate tensile strength

f. Describe the adverse effects of welding on metal including the types of stress.

g. Discuss the phenomenon of thermal shock.

h. Discuss the following terms and discuss their relationship to material failure:

- Ductile fracture
- Brittle fracture
- Nil-ductility transition (NDT) temperature

i. Explain fatigue failure and work hardening with respect to material failure.

j. Discuss the affects of radiation on the structural integrity of metals.

19. Mechanical systems personnel shall demonstrate a working level knowledge concerning the selection of appropriate components and materials in support of a mechanical system design or modification.

Supporting Knowledge and/or Skills

a. Differentiate between nuclear-grade and non-nuclear-grade materials.

b. Discuss how the following material properties affect performance in different applications:

- Corrosion Resistance
- Weight
- Erosion Resistance
- Strength
- Cost
- Reactivity
- Composition/alloy
- Ductility
- Brittleness
- Weldability
- Machinability

c. Identify and discuss the various methods of verifying the properties of selected materials, including:

- Brinell hardness test
- Rockwell hardness test
- V-notch test
- Drop-weight test
- Tension Test
- Fatigue Test
- Creep Test
- Corrosion Test

d. Discuss the importance of traceability in nuclear system components.

20. Mechanical system personnel shall demonstrate a working level knowledge of the principles of machine element design.

Supporting Knowledge and/or Skills

a. Discuss and demonstrate the principles of use and design for the following mechanisms.

- Brakes
- Clutches
- Belt and Chain drives

- Gear Trains
- Packings and Seals

21. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the various computer applications used in mechanical systems engineering.

Supporting Knowledge and/or Skills

a. Discuss the application of computer-aided design (CAD) as it relates to mechanical system design.

b. Describe the use of computers in the monitoring and control of mechanical systems.

22. Mechanical systems personnel shall demonstrate a working level knowledge of mechanical diagrams, including:

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

Supporting Knowledge and/or Skills

a. Using an engineering print, read and interpret the information contained in the title block, the notes and legend, the revision block, and the drawing grid.

b. Identify the symbols used in piping and instrumentation diagrams for:

- Types of valves
- Types of valve operators
- Types of educators and ejectors
- Basic types of instrumentation
- Types of instrument signal controllers and modifiers
- Types of system components (pumps, etc.)
- Types of lines

c. Identify the symbols used in piping and instrumentation diagrams to denote the location of instruments, indicators, and controllers.

d. Identify how valve conditions are depicted.

e. Determine system flowpath(s) for a given valve lineup.
f. Discuss the origin and purpose of "as-built drawings."

23. Mechanical systems personnel shall demonstrate a familiarity level knowledge of reading and interpreting electrical diagrams and schematics.

Supporting Knowledge and/or Skills

a. Identify the symbols and/or codes used on engineering electrical drawings.

b. Using a simple schematic and initial conditions, identify the power sources and/or loads and their status.

c. Using an electronic block diagram, print, or schematic, identify the basic component symbols.

d. Using a relay ladder, explain the logic ties.

24. Mechanical systems personnel shall demonstrate a familiarity level knowledge of reading and interpreting electrical logic diagrams.

Supporting Knowledge and/or Skills

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

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

c. Using a basic logic diagram and appropriate information, determine the output of each component and the logic circuit.

25. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the principles and concepts of natural phenomena hazards and their effect on mechanical systems.

Supporting Knowledge and/or Skills

a. Discuss the potential impact on mechanical systems at defense nuclear facilities from the following natural hazards:

- Flooding
- Wind
- Tornado
- Earthquake and/or other seismic events
- Fire
- Lightning

b. Briefly describe the safety measures and design features commonly used as safeguards against natural hazards.

26. Mechanical systems personnel shall demonstrate a working level knowledge of requirements of Department of Energy (DOE) Order 420.1, Facility Safety and the associated guidance of DOE G 420.1-1, Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria Guide for Use With DOE O 420.1, Facility Safety.

Supporting Knowledge and/or Skills

a. Discuss the general design requirements of Section 4.1.1, Nuclear Safety.

b. Discuss the general requirements of Section 4.4, Natural Phenomena Hazards Mitigation.

c. Discuss the scope and general content of the Guide with respect to the above areas.

27. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the following Department of Energy (DOE) Standards related to natural phenomena hazards:

- DOE-STD-1020-94, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities
- DOE-STD-1021-93, Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components
- DOE-STD-1022-94, Natural Phenomena Hazards Site Characterization Criteria

Supporting Knowledge and/or Skills

a. Describe the purpose, scope, and application of the requirements detailed in the listed standards.

b. Discuss the graded approach process that Department line management uses to determine an appropriate level of coverage by mechanical systems personnel. Include in this discussion the factors that may influence the level of coverage

28. Mechanical systems personnel shall demonstrate a working level knowledge of the safety and health fundamentals of mechanical systems and/or components.

Supporting Knowledge and/or Skills

a. Discuss the hazards associated with the use of corrosives (acids and alkalies).

b. Describe the general safety precautions necessary for the handling, storage, and disposal of corrosives.

c. Discuss the general safety precautions regarding toxic compounds.

d. Describe the criteria used to determine if a compound is a health hazard and discuss the ways toxic compounds may enter the body.

e. Discuss the general safety precautions regarding the use, handling, and storage of compressed gases, including hydrogen, oxygen, and nitrogen.

f. Explain the difference between a flammable material and a combustible material.

g. Describe the general safety precautions regarding the use, handling, and storage of flammable and combustible materials.

h. Identify and discuss elements of a mechanical safety program, including the following:

- Protective equipment
- Lockout and tagout
- Stored energy
- Component labeling

29. Mechanical systems personnel shall demonstrate a working level knowledge of the following engineering design principles:

- Value engineering
- Systems engineering
- Life cycle cost
- Maintainability

Supporting Knowledge and/or Skills

a. Define:

- Value engineering
- Systems engineering
- Life cycle cost
- Maintainability

b. Describe how the principles of value engineering can be applied to mechanical systems projects.

c. Explain how life cycle costs are determined for a mechanical system and how those costs can be used.

d. Explain Systems Engineering principles and benefits.

e. Describe why maintainability must be considered in mechanical system design.

30. Mechanical maintenance personnel shall demonstrate a familiarity level knowledge of maintenance management practices related to mechanical systems.

Supporting Knowledge and/or Skills

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

- Corrective
- Planned
- Preventive
- Reliability Centered
- Predictive

b. Describe the elements of an effective work control program and the documentation used to control maintenance.

c. Discuss the importance of maintaining a proper balance of preventive and corrective maintenance.

d. Define the term "life limiting component" and discuss its impact on facility operation.

e. Identify typical maintenance performance indicators, and discuss their importance.

f. Discuss the relationship between maintenance and conduct of Operations, Quality Assurance, and Configuration Management.

h. Discuss the purpose of Reliability, Availability, Maintainability and Inspectability (RAMI) analyses in the establishment of maintenance requirements.

31. Mechanical systems personnel shall demonstrate a familiarity level knowledge of Department of Energy (DOE) maintenance management requirements as defined in DOE Order 433.1, Maintenance Management Program for DOE Nuclear Facilities.

Supporting Knowledge and/or Skills

a. Explain the Department of Energy's role in the oversight of contractor maintenance operations.

b. Identify the key elements of a contractor maintenance plan required by DOE Order 433.1, Maintenance Management Program for DOE Nuclear Facilities.

c. Describe configuration control and its relationship to the maintenance work control process and the maintenance history file.

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

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

32. Mechanical systems personnel shall demonstrate a working level knowledge of Department of Energy (DOE) Standard DOE-STD-1073-93, Guide for Operational Configuration Management Program.

Supporting Knowledge and/or Skills

a. Describe the purpose and objectives of the Operational Configuration Management Program.

b. Demonstrate an understanding and the ability on how to provide oversight on the following areas:

- Adequate and comprehensive documentation exists for the system design basis and safety basis (e.g., Safety Analysis Report, Technical Specifications, Operational Safety Requirements/Technical Safety Requirements, etc.)
- The adequacy of the system’s ability to perform through the full spectrum of operations.
- Maintaining system operability and reliability through an adequate maintenance and upgrade program.
- Maintaining configuration management during maintenance and modifications.
- Knowledgeable and qualified technical personnel (system engineers, operators, and maintenance personnel) are monitoring, operating, and maintaining safety systems properly.
- Adequate resources are budgeted and allotted to ensure the viability of the above.

33. Mechanical systems personnel shall demonstrate a working level knowledge of problem analysis principles and the ability to apply techniques necessary to identify problems, determine potential causes of problems, and identify corrective action(s).

Supporting Knowledge and/or Skills

a. Describe and explain the application of problem analysis techniques including the following:

- Root Cause Analysis
- Causal Factor Analysis
- Change Analysis
- Barrier Analysis
- Management Oversight Risk Tree (MORT) Analysis

b. Describe and explain the application of the following root cause analysis processes in the performance of occurrence investigations:

- Event and causal factors charting
- Root cause coding
- Recommendation generation

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

d. Participate in at least one contractor or Department of Energy problem analysis and critique the results.

e. Using data, interpret a fault tree analysis.

34. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the Department of Energy/facility contract provisions necessary to provide oversight of a contractor's performance.

Supporting Knowledge and/or Skills

a. Describe the role of mechanical systems personnel in contractor oversight.

b. Compare and contrast the following:

- The Department of Energy's expectations of a Management and Operating (M&O) contractor.
- Management and Operating (M&O) contractor's expectations of the Department of Energy

c. Discuss the key elements and features of an effective Department of Energy and Management and Operating (M&O) contractor relationship

35. Mechanical systems personnel shall demonstrate a working level knowledge of assessment techniques (such as the planning and use of observations, interviews, and document

reviews) to assess facility performance, report results, and follow up on actions takes as the result of assessments.

Supporting Knowledge and/or Skills

a. Describe the role of mechanical system personnel in the oversight of Government Owned Contractor Operated facilities.

b. Describe the assessment requirements and limitations associated with mechanical system personnel's interface with contractor employees.

c. Explain the essential elements of a performance-based assessment, including the areas of investigation, fact-finding, and reporting.

d. Explain the essential elements of a performance-based assessment including investigation, fact-finding, and reporting. Include a discussion of the essential elements and processes of the following assessment activities:

- Exit interviews
- Closure process
- Tracking to closure
- Follow-up
- Contractor corrective action implementation

e. Describe the actions to be taken if the contractor challenges the assessment findings and explain how such challenges can be avoided.

36. Mechanical systems personnel shall demonstrate the ability to assess contractor mechanical systems activities independently and make all necessary reports.

Supporting Knowledge and/or Skills

a. Using different sets of performance data, compare and contrast the data to highlight acceptable and unacceptable work performance.

b. Describe the methods by which noncompliance is determined and communicated to contractor and Departmental management.

c. Describe the role of mechanical systems personnel in the contractor performance evaluation process.

d. Participate in the evaluation of a contractor's performance.

e. Conduct an interview representative of one that would be conducted during an occurrence investigation.

f. Develop an assessment report.

g. Participate in formal meetings between Department management and senior contractor management to discuss the results of mechanical systems assessments.

37. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the codes and standards of the American Society of Testing and Materials (ASTM).

Supporting Knowledge and/or Skills

a. Discuss the general scope and subject matter range of the various codes and standards, noting those which provide relevant guidance to activities conducted at DOE defense nuclear facilities.

b. Describe the hierarchy of the mechanical rules, codes, Orders, and standards at defense nuclear facilities and explain where American Society of Testing and Materials standards fall within that hierarchy.

c. Discuss the applicability of the above American Society of Testing and Materials documents to DOE defense nuclear facilities.

38. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the codes and standards of the American Petroleum Institute (API).

Supporting Knowledge and/or Skills

a. Discuss the general scope and subject matter range of the various codes and standards, noting those which provide relevant guidance to activities conducted at DOE defense nuclear facilities.

b. Describe the hierarchy of the mechanical rules, codes, Orders, and standards at defense nuclear facilities and explain where American Petroleum Institute standards fall within that hierarchy.

c. Discuss the applicability of the above American Petroleum Institute document to defense nuclear facilities.

39. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the codes and standards of the American National Standards Institute (ANSI).

Supporting Knowledge and/or Skills

a. Discuss the general scope and subject matter range of the various codes and standards, noting those which provide relevant guidance to activities conducted at DOE defense nuclear facilities.

b. Describe the hierarchy of the mechanical rules, codes, Orders, and standards at defense nuclear facilities and explain where American National Standards Institute standards fall within that hierarchy.

c. Discuss the applicability of the above American National Standards Institute documents to defense nuclear facilities.

40. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the codes and standards of the American Nuclear Society (ANS).

Supporting Knowledge and/or Skills

a. Discuss the general scope and subject matter range of the various codes and standards, noting those which provide relevant guidance to activities conducted at DOE defense nuclear facilities.

b. Describe the hierarchy of the mechanical rules, codes, Orders, and standards at defense nuclear facilities and explain where American Nuclear Society standards fall within that hierarchy.

c. Discuss the applicability of the above American Nuclear Society documents to defense nuclear facilities.

41. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the codes and standards of the American Institute of Steel Construction (AISC).

Supporting Knowledge and/or Skills

a. Discuss the general scope and subject matter range of the various codes and standards, noting those which provide relevant guidance to activities conducted at DOE defense nuclear facilities.

b. Describe the hierarchy of the mechanical rules, codes, Orders, and standards at defense nuclear facilities and explain where American Institute of Steel Construction standards fall within that hierarchy.

c. Discuss the applicability of the above American Institute of Steel Construction documents to defense nuclear facilities.

42. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the codes and standards of the American Society of Mechanical Engineers (ASME).

Supporting Knowledge and/or Skills

a. Discuss the general scope and subject matter range of the various codes and standards, noting those which provide relevant guidance to activities conducted at DOE defense nuclear facilities.

b. Describe the hierarchy of the mechanical rules, codes, Orders, and standards at defense nuclear facilities and explain where American Society of Mechanical Engineers standards fall within that hierarchy.

c. Discuss the applicability of the above American Society of Mechanical Engineers documents to defense nuclear facilities.

43. Mechanical systems personnel shall demonstrate a familiarity level knowledge of the codes and standards of the National Fire Protection Agency (NFPA).

Supporting Knowledge and/or Skills

a. Discuss the general scope and subject matter range of the various codes and standards, noting those which provide relevant guidance to activities conducted at DOE defense nuclear facilities.

b. Describe the hierarchy of the mechanical rules, codes, Orders, and standards at defense nuclear facilities and explain where National Fire Protection Agency standards fall within that hierarchy.

c. Discuss the applicability of the above National Fire Protection Agency documents to defense nuclear facilities.

44. Mechanical systems personnel shall demonstrate a working level knowledge of the codes and standards of American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE).

Supporting Knowledge and/or Skills

a. Discuss the general scope and subject matter range of the various codes and standards, noting those that provide relevant guidance to activities conducted at DOE defense nuclear facilities.

b. Describe the hierarchy of the mechanical rules, codes, Orders, and standards at defense nuclear facilities and explain where ASHRAE standards fall within that hierarchy.

c. Discuss the applicability of the above ASHRAE documents to defense nuclear facilities.

45. Mechanical system personnel shall demonstrate a working level knowledge of the quality control inspection techniques described in NQA-1 and ASME Boiler and Pressure Vessel Code Sections V and IX and the verification of mechanical system integrity to include:

- Ultrasonic test (UT)
- Visual inspection (VI)
- Magnetic particle test (MT)
- Dye-penetrant test (PT)
- Radiographic test (RT)
- Hydrostatic test (HT)
- Load test (LT)

Supporting Knowledge and/or Skills

a. Describe the test methodology for each of the listed inspection techniques, including the expected degree of accuracy.

b. Discuss the advantages and disadvantages of each of the listed inspection techniques.

c. Identify and describe the usual application for each of the listed inspection techniques.

d. For each of the listed inspection techniques, identify and discuss the safety considerations and precautions that must be observed.

e. Identify the special hazards that are associated with radiographic testing and discuss how they are mitigated.

f. Identify the special qualifications needed by technicians performing each of the listed inspection techniques and discuss how those qualifications are achieved.

g. Using system specifications, including a system diagram, determine the key information for a hydrostatic test on that system.

h. Using a work package, determine the appropriate tests needed to ensure proper installation of the mechanical system.

i. Using component information, describe the load tests required prior to lifting that component.

APPENDIX A
CONTINUING EDUCATION, TRAINING AND PROFICIENCY PROGRAM

The following list represents suggested resources for continuing education, training and other opportunities that are available for mechanical systems personnel after completion of the competency requirements in this technical Functional Area Qualification Standard. It is extremely important that personnel involved with mechanical systems maintain their proficiency through continuing education, training, reading, or other activities such as workshops, seminars, and conferences. The list 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 two learning activities per year are necessary to maintain proficiency in the mechanical systems functional area after completion of the competencies in the Standard and other requirements of the Technical Qualification Program.

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100 Barr Harbor Drive
P. O. Box C700
West Conshohocken, Pennsylvania, 19428-2959
http://www.astm.org

American Institute of Chemical Engineers
3 Park Avenue
New York, NY 10016-5991
http://www.aiche.org

American National Standards Institute
1819 L Street, NW
Washington, DC 20036
http://www.ansi.org

Institute of Electrical and Electronics Engineers
345 East 47th Street
New York, NY 10017
http://www.ieee.org

American Institute of Steel Construction
One East Wacker Drive, Suite 3100
Chicago, IL 60601-2001
http://www.aisc.org

American Society of Mechanical Engineers International
Three Park Avenue
New York, NY 10016-5990
http://www.asme.org

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269-9101
http://www.nfpa.org

American Society of Heating, Refrigeration and Air-Conditioning Engineers
1791 Tullie Circle, NE
Atlanta, GA 30329
http://www.ashrae.org

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CONCLUDING MATERIAL

Review Activity:

DOE
DP-NNSA
EH
EM
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NN-NNSA
SC
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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-0029