National Nuclear Security Administration

Facility Representative

Qualification Standard

Reference Guide

JUNE 2006

Table of Contents

Table of Contents

Table of Contents

PURPOSE

The purpose of this reference guide is to provide a document that contains the information required for a National Nuclear Security Administration (NNSA) technical employee to successfully complete the facility Representative (FR) Functional Area Qualification Standard. In some cases, information essential to meeting the qualification requirements is provided. Some competency statements require extensive knowledge or skill development. Reproducing all the required information for those statements in this document is not practical. In those instances, references are included to guide the candidate to additional resources. Additional reference material is available in the Federal Technical Capability Manual, chapter 3, section 1, Facility Representative Program, available in the Department of Energy (DOE) Directives home page at http://www.directives.doe.gov/.

SCOPE

This reference guide has been developed to address the competency statements in the April 2002 edition of DOE-STD-1151-2002, Facility Representative Functional Area Qualification Standard. Competency statements and supporting knowledge and/or skill statements from the qualification standard are shown in contrasting bold type, while the corresponding information associated with each statement is provided below it. The qualification standard for the STSM contains 48 competency statements.

Every effort has been made to provide the most current information and references available as of June 2006. However, the candidate is advised to verify the applicability of the information provided.

Please direct your questions or comments related to this document to the Leadership and Career Development Department.

GENERAL TECHNICAL

1.1 A Facility representative shall demonstrate a familiarity-level knowledge of principles of steam system operation including theory and component design.

a) Explain the application of the following concepts to steam systems:

- **Enthalpy**
- **Saturation**
- **Superheat**
- **Steam quality**
- **Moisture content**
- **Condensation**
- **Sensible heat**
- **Carryover**
- **Thermal expansion**
- **Thermal contraction**

Enthalpy

Specific enthalpy (h) is defined as $h = u + Pv$, where u is the specific internal energy (Btu/lbm) of the system being studied, P is the pressure of the system (lbf/ft^2), and ν is the specific volume (ft^3/lbm) of the system. Enthalpy is usually used in connection with an open system problem in thermodynamics. Enthalpy is a property of a substance, like pressure, temperature, and volume, but it cannot be measured directly. Normally, the enthalpy of a substance is given with respect to some reference value. For example, the specific enthalpy of water or steam is given using the reference that the specific enthalpy of water is zero at .01°C and normal atmospheric pressure. The fact that the absolute value of specific enthalpy is unknown is not a problem, however, because it is the change in specific enthalpy (Dh) and not the absolute value that is important in practical problems. Steam tables include values of enthalpy as part of the information tabulated.

Saturation

Saturation defines a condition in which a mixture of vapor and liquid can exist together at a given temperature and pressure. The temperature at which vaporization (boiling) starts to occur for a given pressure is called the saturation temperature or boiling point. The pressure at which vaporization (boiling) starts to occur for a given temperature is called the saturation pressure. For water at 212°F, the saturation pressure is 14.7 psia, and for water at 14.7 psia, the saturation temperature is 212°F. For a pure substance, there is a definite relationship between saturation pressure and saturation temperature. The higher the pressure, the higher the saturation temperature will be. The graphical representation of this relationship between temperature and pressure at saturated conditions is called the vapor pressure curve.

Superheat

If a substance exists entirely as vapor at saturation temperature, it is called saturated vapor. Sometimes the term dry saturated vapor is used to emphasize that the quality is 100%. When the vapor is at a temperature greater than the saturation temperature, it is said to exist as superheated vapor. The pressure and temperature of superheated vapor are independent properties, since the temperature may increase while the pressure remains constant. Actually, the substances we call gases are highly superheated vapors.

Steam Quality

Most practical applications using the saturated steam tables involve steam-water mixtures. The key property of such mixtures is steam quality (x), defined as the mass of steam present per unit mass of steam-water mixture, or steam moisture content (y), defined as the mass of water present per unit mass of steam-water mixture. When a substance exists as part liquid and part vapor at saturation conditions, its quality (x) is defined as the ratio of the mass of the vapor to the total mass of both vapor and liquid. Thus, if the mass of the vapor is 0.2 lbm and the mass of the liquid is 0.8 lbm, the quality is 0.2 or 20%. Quality is an intensive property. Quality has meaning when the substance is in a saturated state only, at saturation pressure and temperature.

Moisture Content

The moisture content of a substance is the opposite of its quality. Moisture (M) is defined as the ratio of the mass of the liquid to the total mass of both liquid and vapor. The moisture of the mixture in the previous paragraph would be 0.8 or 80%.

Condensation

If heat is removed at a constant pressure from a saturated vapor, condensation will occur and the vapor will *c*hange phase to liquid.

Sensible Heat

When a substance is heated, its temperature increases, and when it is cooled, its temperature decreases. The heat added to or removed from a substance to produce a change in its temperature is called sensible heat.

Carryover

Carryover refers to the entrainment of water in steam. See the discussions on steam quality and moisture content, above. Too much water entrained in steam can damage downstream components by impingement.

Thermal Expansion

As temperature increases, metal will expand. This expansion has to be accommodated in the design and support of the metal (e.g., expansion joints). Additionally, an increase in temperature will add stress and increase a metal's ductility.

Thermal Contraction

As temperature decreases, metal will contract. This contraction has to be accommodated in the design and support of the metal. Additionally, a decrease in temperature will cause a decrease in ductility and a change from ductile to more brittle behavior. Stress may or may not be relieved.

b) Explain the use of steam tables and the Mollier diagram and demonstrate their use.

Steam tables consist of two sets of tables of the energy transfer properties of water and steam: saturated steam tables and superheated steam tables. Portions of the tables are shown in figure A-2 of appendix A of DOE-HDBK-1012/1-92, Thermodynamics, Heat Transfer, and Fluid Flow, volume 1. Both sets of tables are tabulations of pressure (P), temperature (T), specific volume (n), specific enthalpy (h), and specific entropy (s). The following notation is used in steam tables. Some tables use v for ν (specific volume) because there is little possibility of confusing it with velocity.

T = temperature (°F)
P = pressure (psi)
ν = specific volume (ft^3/lbm)
ν_f = specific volume of saturated liquid (ft^3/lbm)
ν_g = specific volume of saturated vapor (ft^3/lbm)
ν_{fg} = specific volume change of vaporization (ft^3/lbm)
h = specific enthalpy (Btu/lbm)
h_f = specific enthalpy of saturated liquid (Btu/lbm)
h_g = specific enthalpy of saturated vapor (Btu/lbm)
h_{fg} = specific enthalpy change of vaporization (Btu/lbm)
s = specific entropy (Btu/lbm-°R)
s_f = specific entropy of saturated liquid (Btu/lbm-°R)
s_g = specific entropy of saturated vapor (Btu/lbm-°R)
s_{fg} = specific entropy change of vaporization (Btu/lbm-°R)
SH = number of degrees of superheat (°F)

The saturated steam tables give the energy transfer properties of saturated water and saturated steam for temperatures from 32°F to 705.47°F (the critical temperature), and for the corresponding pressure from 0.08849 psi to 3208.2 psi. Normally, the saturated steam tables are divided into two parts: temperature tables, which list the properties according to saturation temperature (T_{sat}); and pressure tables, which list them according to saturation pressure (P_{sat}). Figure A-2 shows a portion of a typical saturated steam temperature table and a portion of a typical saturated steam pressure table. The values of enthalpy and entropy given in these tables are measured relative to the properties of saturated liquid at 32°F. Hence, the enthalpy (h_f) of saturated liquid and the entropy (s_f) of saturated liquid have values of approximately zero at 32°F.

Most practical applications using the saturated steam tables involve steam-water mixtures. The key property of such mixtures is steam quality (x), defined as the mass of steam present per unit mass of steam-water mixture, or steam moisture content (y), defined as the mass of water present per unit mass of steam-water mixture. The following relationships exist between the quality of a liquid-vapor mixture and the specific volumes, enthalpies, or entropies of both phases and of the mixture itself. These relationships are used with the saturated steam tables.

$\nu = x\nu_g + (1 - x)\,\nu_f$
$x = (\nu - \nu_f) / \nu_{fg}$
$h = xh_g + (1 - x)\,h_f$
$x = (h - h_f) / h_{fg}$

$s = xs_g + (1 - x)\, s_f$
$x = (s - s_f) / s_{fg}$

The Mollier diagram, shown in figure A-1 of appendix A of DOE-HDBK-1012/1-92, Thermodynamics, Heat Transfer, and Fluid Flow, volume 1, is a chart on which enthalpy (h) versus entropy (s) is plotted. It is sometimes known as the h-s diagram and has an entirely different shape from the T-s diagrams. The chart contains a series of constant temperature lines, a series of constant pressure lines, a series of constant moisture or quality lines, and a series of constant superheat lines. The Mollier diagram is used only when quality is greater than 50% and for superheated steam.

To solve problems in thermodynamics, information concerning the "state" of the substance studied must be obtained. Usually, two properties (e.g., v, p, T, h, s) of the substance must be known in order to determine the other needed properties. These other properties are usually obtained utilizing either the Mollier diagram (if the substance is steam) or the saturated and superheated steam tables, as shown in the figures A-1 and A-2 of appendix A of DOE-HDBK-1012/1-92, Thermodynamics, Heat Transfer, and Fluid Flow, volume 1.

The following two examples illustrate the use of the Mollier diagram and the steam tables.

Example 1: Use of the Mollier chart

Superheated steam at 700 psia and 680°F is expanded at constant entropy to 140 psia.

What is the change in enthalpy?

Solution:

Use the Mollier Chart. Locate point 1 at the intersection of the 700 psia and the 680°F line. Read h = 1333 Btu/lbm.

Follow the entropy line downward vertically to the 140 psia line and read h = 1178 Btu/lbm.

h = 1178 - 1333 = -155 Btu/lbm Δ

Example 2: Use of Steam Tables

What are the specific volume, enthalpy, and entropy of steam having a quality of 90% at 400 psia?

Solution:

From the steam tables at 400 psia:

$\nu_f = 0.01934$	$\nu_{fg} = 1.14162$	$h_f = 424.2$
$h_{fg} = 780.4$	$s_f = 0.6217$	$s_{fg} = 0.8630$

$\nu = \nu_f + x(\nu_{fg})$
$\nu = 0.01934 + (0.9)(1.14162) = 1.0468 \text{ lbm/ft}^3$

$h = h_f + x(h_{fg})$
$h = 424.2 + (0.90)(780.4) = 1126.56$ Btu/lbm

$s = s_f + x(s_{fg})$
$s = 0.6217 + (0.9)(0.8630) = 1.3984$ Btu/lbm-°R

c) Explain the function/application of the following steam system components and describe how the components contribute to steam system operation:

- **Isolation valves**
- **Isolation valve bypass valves**
- **Vent valves**
- **Drain valves**
- **Safety/relief valves**
- **Flow control valves**
- **Steam trap bypass valves**
- **Expansion joints**
- **Pressure control valves**
- **Moisture separators**
- **Pipe hangers/supports**
- **Mist eliminators**
- **Evaporators**
- **Condensers**
- **Boilers**
- **Reboilers**
- **Steam traps (mechanical, impulse, thermostatic)**

Isolation Valves

Pump isolation valves are sometimes interlocked with the pump. In some applications, these interlocks act to prevent the pump from being started with the valves shut. The pump/valve interlocks can also be used to automatically turn off the pump if one of its isolation valves shuts, or to open a discharge valve at some time interval after the pump starts.

Isolation Valve Bypass Valves

Isolation valve bypass valves are small valves used to bypass isolation valves in order to warm up piping downstream from the isolation valve, and/or to equalize pressure across the isolation valve prior to opening the isolation valve.

Vent Valves

Vent valves are small valves installed in system high points that are used to relieve or prevent the build up of pressure inside pipes or other components (e.g., the shell side of a condenser).

Drain Valves

Drain valves are small valves installed in system low points that are used to drain condensate from pipes and other components (e.g., the low side of condensers or heat exchangers).

Safety/Relief Valves

Safety/relief valves prevent equipment damage by relieving accidental over-pressurization of fluid systems. If a system contains both a relief and a safety valve, the relief valve will open before the safety valve. Relief valves are typically used for incompressible fluids (e.g., water or oil), while safety valves are typically used for compressible fluids (e.g., steam or other gases). Most relief and safety valves open against the force of a compression spring. The pressure set point is adjusted by turning the adjusting nuts on top of the yoke to increase or decrease the spring compression.

The main difference between a relief valve and a safety valve is the extent of opening at the set-point pressure. A relief valve gradually opens as the inlet pressure increases above the set point, only opening as necessary to relieve the over-pressure condition. A safety valve rapidly opens fully as soon as the pressure setting is reached, and stays fully open until the pressure drops below a reset pressure. (The reset pressure is lower than the actuating pressure set point; the difference between the actuating pressure set point and the pressure at which the safety valve resets is called "blow down.")

Flow Control Valves

Flow control valves are valves used to control flow rate in a system by varying (throttling) the amount of fluid flow. They are also used to control the amount of power produced by the cylinders in an air compressor that convert the potential energy of the compressed air into kinetic energy at the output.

Steam Trap Bypass Valves

Steam trap bypass valves are small valves used to bypass steam traps during the early part of a system heat-up when there is excessive condensate in the lines, and to blow down steam traps to reduce the buildup of crud in the traps.

Expansion Joints

Expansion joints are connections between piping sections that allow for thermal expansion and contraction as the piping is heated or cooled.

Pressure Control Valves

Pressure control valves are valves used to control pressure in a system by regulating downstream system or process pressure.

Moisture Separators

Moisture separators utilize centrifugal force to collect moisture and solids at the bottom of the moisture separator. They are installed at the discharge of an after cooler to remove liquid moisture and solids from compressed air, and at the exhaust of a high-pressure turbine stage to remove condensation from the steam, thereby increasing steam quality back to nearly 100%. This steam may be sent to a reheater or directly expanded through a low-pressure turbine stage to the condenser.

Pipe Hangers/Supports

Pipe hangers are used to fix all kinds of pipes including water pipes, down pipes, ventilation pipes, and cable pipes in buildings. Pipe hangers are made of quality steel or stainless steel. Constant support hangers are principally used to support pipes and equipment subjected to vertical movement due to thermal expansion and contraction at locations where transfer of stress to other supports or equipment can be critical. Variable springs are one of the most important devices available to help support pipe because they balance the concentrated gravitational load of a vertical section of pipe while allowing for thermal movement.

Mist Eliminators

Mist eliminators are highly effective for removing liquid entrainment from gas streams providing high efficiency and low pressure drops in scrubbers, cooling towers, gas absorbers, and ventilation systems.

Evaporators

Evaporation is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid. It is thus a thermal separation or concentration process. The evaporation process starts with a liquid product and ends up with a more concentrated, but still liquid and still pumpable concentrate as the main product from the process. Evaporators are also used to convert wastewater or oils to clean water vapor. Evaporators are also the components in the refrigeration system that absorb heat from air to produce a cooling effect. The process is an air-to-air heat exchange.

Condensers

Condensers (and heat exchangers) decrease the enthalpy of the working fluid by removing heat without doing work. In a turbine condenser, water is circulated through tubes and condenses the turbine exhaust steam (i.e., a heat sink). The heat added to the water is eventually rejected to the environment (via a cooling tower, a cooling lake, or the ocean).

Boilers

Boilers are components that increase the enthalpy of the working fluid (usually steam). The term boiler often is used to imply the entire system of components designed to add heat to water and produce saturated or superheated steam.

Reboilers

Reboilers, also called reheaters, are located downstream of moisture separators (or are combined with a moisture separator) and restore the nearly dry steam to a superheated condition. This superheated steam is then expanded through a low-pressure turbine stage to the condenser.

Steam Traps (Mechanical, Impulse, Thermostatic)

A steam trap consists of a valve and a device or arrangement that causes the valve to open and close as necessary to drain the condensate from the lines without allowing the escape of steam. Steam traps are installed at low points in the system or machinery to be drained.

Mechanical steam traps operate on the principle that water (in steam) is heavier and thus can be measured by a float (e.g., ball or bucket float). As the water level rises, a drain is opened and the condensate is released from the trap.

Thermostatic steam traps (e.g., bellows type) are more compact and have fewer moving parts than most mechanical steam traps.

Impulse steam traps pass steam and condensate through a strainer before entering the trap. A circular baffle keeps the entering steam and condensate from impinging on the cylinder or on the disk. The impulse type of steam trap is dependent on the principle that hot water under pressure tends to flash into steam when the pressure is reduced.

1.2 A facility representative shall demonstrate a working-level knowledge of steam system operation including startup, normal and off-normal operation, and shutdown.

a) Describe the following steam system evolutions and associated precautions:

- **Pressurization and warm-up of a cold steam system**
- **Initiation of steam flow in a stagnant, but pressurized steam system**
- **Isolation of a portion of a steam system**
- **Pressurization and warm-up of an isolated portion of a steam system**
- **Isolation and de-pressurization of an in-service steam system**

Pressurization and Warm-Up of a Cold Steam System

When initiating pressurization and warm-up of a cold steam system, the cold start-up system checklist should be completed. This ensures all systems (primary and support) are properly aligned and operable, parameters are in permissible ranges (e.g., water levels, chemistry, temperatures, and pressures), and all technical safety requirements (TSRs) are or will be met before reaching the stage where they are applicable.

Main steam isolation and/or shutoff valves will normally be open (although start up may occur with these valves closed) and the steam lines drained. A vacuum will be drawn on the main condenser, the heat source (e.g., boiler or reactor) will be started up, and the heat-up will commence within allowable parameters (e.g., heat-up rate and differential temperatures and pressures).

Steam line vent and drain valves will be monitored for proper operation. At some point (e.g., above 190°F but below 200°F) the vent valves will be closed and steam traps will be placed in normal operation.

When system pressure increases to a certain level (e.g., 60 psig), steam-driven equipment (e.g., feed pump turbines) warm-up begins. As pressure increases to the next level (e.g., 100 psig), the main turbine will be warmed up and readied for service.

As pressure increases, steam bypass and regulating systems will be tested and placed in service. Feed and condensate pumps will be placed in service.

As the system nears normal operating temperature and pressure, most steam drain valves will be closed or checked closed. Turbine bypass valve operation will be monitored to ensure it maintains the proper main steam pressure, turbine warm-up will be completed, feed water and condenser systems will be checked for normal operation, and then the turbine will be placed in normal operation. All open main steam line drain valves will be closed.

Initiation of Steam Flow in a Stagnant, but Pressurized Steam System

To initiate steam flow in a stagnant, but pressurized steam system, ensure all checklists and alignments are complete, including the vent and drain valves upstream and downstream from the closed steam isolation valve. Open the isolation valve (or isolation valve bypass valve) slowly to reduce the differential pressure across the isolation valve to within limits (e.g., 50 psid) prior to fully opening the isolation valve in order to avoid damaging the valve or causing steam hammer. Monitor downstream temperature and pressure, close or check closed the isolation bypass valve, close or check closed all drain valves, and check all systems for proper operation.

Isolation of a Portion of a Steam System

To isolate a portion of a steam system, check that no technical safety requirements will be violated as a result of the isolation, and then secure equipment related to the portion of the steam system to be isolated. Shut the steam isolation valve and line up the drain valves and steam traps on the isolated portion of the steam system to drain any condensate resulting from cool down of the system. If the system is to be de-pressurized, see below. Line up the isolated system and components per procedures and/or checklists.

Pressurization and Warm-Up of an Isolated Portion of a Steam System

The pressurization and warm-up of an isolated portion of a steam system is similar to the initiation of flow into a pressurized system (above) with the following exceptions. Pressurization and warm-up will be accomplished by opening the isolation valve warm-up or bypass valve (or cracking open the isolation valve if it does not have a warm-up or bypass valve). Pressurization and heat-up rate will be controlled to within limits (e.g., less than 100°F per hour), and vent, drain, and steam trap operations will be closely monitored for proper operation to prevent steam or condensate-induced water hammer.

Isolation and De-Pressurization of an In-Service Steam System

To isolate and depressurize an in-service steam system, isolate the steam system as discussed above. Depressurize the system using steam-driven components connected to the system (e.g., pumps) and/or vent valves. Observe any related pressure and/or temperature cool-down limits (e.g., less than 100°F per hour). Line up the depressurized system and components per procedures and/or checklists.

b) Describe condensation-induced water hammer and its potential impact on steam systems.

Water hammer is a liquid shock wave resulting from the sudden starting or stopping of flow. It is affected by the initial system pressure, the density of the fluid, the speed of sound in the fluid, the elasticity of the fluid and pipe, the change in velocity of the fluid, the diameter and thickness of the pipe, and the valve operating time.

One of the concerns with steam piping is water slugs (i.e., condensation in the steam system) as a result of improper warm up.

Also, moisture in compressed air systems can cause serious damage. Condensed moisture can cause corrosion, water hammer, and freeze damage; therefore, it is important to avoid moisture in compressed air systems. Coolers are used to minimize the problems caused by heat and moisture in compressed air systems.

The shock wave caused by water hammer can be of sufficient magnitude to cause physical damage to piping, equipment, and personnel. Water hammer in pipes has been known to pull pipe supports from their mounts, rupture piping, and cause pipe whip.

c) Describe the expected operator response to, and where possible, how to prevent the following steam system abnormal conditions. Include a discussion of associated hazards:

- **Water hammer during pressurization/warm-up of a cold steam system**
- **Water hammer during initiation of flow in an in-service steam system**
- **Seat leakage of an isolation valve**
- **Steam leakage to atmosphere**
- **Steam header rupture**

Water Hammer during Pressurization/Warm-Up of a Cold Steam System

Flow changes in piping systems should be done slowly as part of good operator practice. To prevent water and steam hammer during pressurization/warm-up of a cold steam system, operators should ensure liquid systems are properly vented and gaseous or steam systems are properly drained during start-up. When possible, initiate pump starts against a closed discharge valve, and open the discharge valve slowly to initiate system flow. If possible, start-up smaller capacity pumps before larger capacity pumps. Use warm-up valves around main stream stop valves whenever possible. If possible, close pump discharge valves before stopping pumps. Periodically verify proper function of moisture traps and air traps during operation.

Water Hammer during Initiation of Flow in an In-Service Steam System

To prevent steam-induced water hammer during initiation of flow in an in-service steam system, open isolation valves (or isolation valve bypass valves) slowly.

Seat Leakage of an Isolation Valve

Seat leakage can cause erosion of the isolation valve’s seat, preventing it from performing its intended function and requiring a shutdown and expensive repairs.

Monitor closed isolation valves for signs of leakage (e.g., noise or excessive condensate flowing through downstream steam traps or drains).

Steam Leakage to Atmosphere

Steam leaks can harm personnel and damage equipment. Operators should check for steam leaks during rounds, and notify operations and maintenance personnel of any leaks found. Adjusting the valve packing stops minor valve leaks. All other types of steam leaks usually require isolation before repair.

Steam Header Rupture

A steam header rupture can harm personnel, damage equipment, and generate significant stresses due to rapid cool-down and depressurization. Operators should immediately ensure that automatic protective equipment has isolated the affected line, or identify and isolate the line manually.

1.3 Personnel shall demonstrate familiarity-level knowledge of basic pneumatic and hydraulic systems in the area of theory.

a) Define the following and discuss their relationship:

- **Force**
- **Pressure**
- **Pneumatic**
- **Hydraulic**

The foundation of modern hydraulic powered systems was established when a scientist named Blaise Pascal discovered that pressure in a fluid acts equally in all directions. This concept is known as Pascal's law. The application of Pascal's law requires the understanding of the relationship between force and pressure.

Force and Pressure

Force may be defined as a push or pull exerted against the total area of a surface. It is expressed in pounds. Pressure is the amount of force on a unit area of the surface. That is, pressure is the force acting upon one square inch of a surface. The relationship between pressure and force is expressed mathematically.

$$F = PA$$

where:
F = force in lbf
P = pressure in lbf/in.^{2} (psi)
A = area in in.^{2}

Pneumatic

The term pneumatic refers to air. Compressed air has numerous uses throughout a facility including the operation of equipment and portable tools. Pneumatic actuators are used to position control valves. They are normally used to control processes requiring quick and accurate response because they do not require a large amount of motive force.

Hydraulic

The term hydraulic refers to liquid. Many machines and processes use a fluid for developing a force to move or hold an object or control an action, and a number of fluids can be used for developing the force. In a hydraulic system, oil, water, or other liquids can be used (oil is the most common). Hydraulic actuators are normally used when a large amount of force is required to operate a valve (e.g., main steam system valves). Although hydraulic actuators come in many designs, piston types are most common.

1.4 Personnel shall demonstrate working-level knowledge of pneumatic and hydraulic systems operations in the following areas.

a) Describe the following pneumatic and hydraulic system evolutions and associated precautions and hazards:
- **Start-up and shutdown**
- **Normal operation**
- **System rupture or leakage**

Start-Up and Shutdown

People often lack respect for the power in compressed air because air is so common and is often viewed as harmless.

Closed valves should be slowly cracked open to allow pressure to equalize prior to opening the valve further. Systems being opened for maintenance should always be depressurized before work begins.

Great care should be taken to keep contaminants from entering air systems. This is especially true for oil. Oil introduced in an air compressor can be compressed to the point where detonation takes place in a similar manner as that which occurs in a diesel engine. This detonation can cause equipment damage and personnel injury.

Normal Operation

At sufficient pressures, compressed air can cause serious damage if handled incorrectly. To minimize the hazards of working with compressed air, all safety precautions should be followed closely.

Small leaks or breaks in the compressed air system can cause minute particles to be blown at extremely high speeds. Always wear safety glasses when working in the vicinity of any compressed air system. Safety goggles are recommended if contact lenses are worn. Compressors can make an exceptional amount of noise while running. The noise of the compressor, in addition to the drain valves lifting, creates enough noise to require hearing protection. The area around compressors should normally be posted as a hearing protection zone. Pressurized air can do the same type of damage as pressurized water. Treat all operations on compressed air systems with the same care taken on liquid systems.

The hazards and precautions for air compressors are applicable to hydraulic systems as well, because most of the hazards are associated with high-pressure conditions. Any use of a pressurized medium can be dangerous. Hydraulic systems carry all the hazards of pressurized systems and special hazards that are related directly to the composition of the fluid used. When using oil as a fluid in a high-pressure hydraulic system, the possibility of fire or an explosion exists. A severe fire hazard is generated when a break in the high-pressure piping occurs and the oil is vaporized into the atmosphere. Extra precautions against fire should be practiced in these areas.

If oil is pressurized by compressed air, an explosive hazard exists if the high-pressure air comes into contact with the oil, because it may create a diesel effect and subsequent explosion. A carefully followed preventive maintenance plan is the best precaution against explosion.

System Rupture or Leakage

Minor leaks should be promptly fixed so they do not lead to larger problems or present a hazard to workers or equipment. Large leaks and system rupture can injure workers and damage equipment, so they must be quickly isolated (either automatically or manually).

1.5 Personnel shall demonstrate familiarity-level knowledge of heat exchanger construction, operations, and theory.

a) Describe the two types of heat exchanger construction.

Heat, like work, is energy in transit. The transfer of energy as heat, however, occurs at the molecular level as a result of a temperature difference. The transfer of heat is usually accomplished by means of a device known as a heat exchanger. Common applications of heat exchangers in the nuclear field include boilers, fan coolers, cooling water heat exchangers, and condensers.

The construction of most heat exchangers falls into one of two categories: tube and shell, or plate.

The most basic and the most common type of heat exchanger construction is the tube and shell heat exchanger. This type of heat exchanger consists of a set of tubes in a container called a shell. The fluid flowing inside the tubes is called the tube side fluid, and the fluid flowing on the outside of the tubes is the shell side fluid. At the ends of the tubes, the tube side fluid is separated from the shell side fluid by the tube sheet(s). The tubes are rolled and press-fitted or welded into the tube sheet to provide a leak tight seal. In systems where the two fluids are at vastly different pressures, the higher pressure fluid is typically directed through the tubes, and the lower pressure fluid is circulated on the shell side. This is due to economy, because the heat exchanger tubes can be made to withstand higher pressures than the shell of the heat exchanger for a much lower cost.

A plate type heat exchanger consists of plates instead of tubes to separate the hot and cold fluids. The hot and cold fluids alternate between each of the plates. Baffles direct the flow of fluid between plates. Because each of the plates has a very large surface area, the plates provide each of the fluids with an extremely large heat transfer area. Therefore, a plate type heat exchanger, as compared to a similarly sized tube and shell heat exchanger, is capable of transferring much more heat. This is due to the larger area the plates provide over tubes. Due to the high heat transfer efficiency of the plates, plate type heat exchangers are usually very small when compared to tube and shell type heat exchangers with the same heat transfer capacity. Plate type heat exchangers are not widely used because of the inability to reliably seal the large gaskets between each of the plates. Because of this problem, plate type heat exchangers have only been used in small, low-pressure applications such as on oil coolers for engines. However, new improvements in gasket design and overall heat exchanger design have allowed some large scale applications of the plate type heat exchanger. As older facilities are upgraded or newly designed facilities are built, large plate type heat exchangers are replacing tube and shell heat exchangers and becoming more common.

b) Describe hot and cold fluid flow in parallel flow, counter flow, and cross flow heat exchangers.

Parallel flow exists when both the tube side fluid and the shell side fluid flow in the same direction. In this case, the two fluids enter the heat exchanger from the same end with a large temperature difference. As the fluids transfer heat, hotter to cooler, the temperatures of the two fluids approach each other. Note that the hottest cold-fluid temperature is always less than the coldest hot-fluid temperature.

Counter flow exists when the two fluids flow in opposite directions. Each of the fluids enters the heat exchanger at opposite ends. Because the cooler fluid exits the counter flow heat exchanger at the end where the hot fluid enters the heat exchanger, the cooler fluid will approach the inlet temperature of the hot fluid. Counter flow heat exchangers are the most efficient of the three types. In contrast to the parallel flow heat exchanger, the counter flow heat exchanger can have the hottest cold-fluid temperature greater than the coldest hot-fluid temperature.

Cross flow exists when one fluid flows perpendicular to the second fluid; that is, one fluid flows through tubes and the second fluid passes around the tubes at 90° angle. Cross flow heat exchangers are usually found in applications where one of the fluids changes state (two-phase flow). An example is a steam system's condenser, in which the steam exiting the turbine enters the condenser shell side, and the cool water flowing in the tubes absorbs the heat from the steam, condensing it into water. Large volumes of vapor may be condensed using this type of heat exchanger flow.

The most common arrangements for flow paths within a heat exchanger are counter flow and parallel flow. Under comparable conditions, more heat is transferred in a counter flow arrangement than in a parallel flow heat exchanger.

The temperature profiles of the two heat exchangers indicate two major disadvantages in the parallel flow design. First, the large temperature difference at the ends causes large thermal stresses. The opposing expansion and contraction of the construction materials due to diverse fluid temperatures can lead to eventual material failure. Second, the temperature of the cold fluid exiting the heat exchanger never exceeds the lowest temperature of the hot fluid. This relationship is a distinct disadvantage if the design purpose is to raise the temperature of the cold fluid.

The design of a parallel flow heat exchanger is advantageous when two fluids are required to be brought to nearly the same temperature. The counter flow heat exchanger has three significant advantages over the parallel flow design. First, the more uniform temperature difference between the two fluids minimizes the thermal stresses throughout the exchanger. Second, the outlet temperature of the cold fluid can approach the highest temperature of the hot fluid (the inlet temperature). Third, the more uniform temperature difference produces a more uniform rate of heat transfer throughout the heat exchanger.

c) Discuss the following heat exchanger applications:

- **Air conditioner evaporator**
- **Preheater**
- **Radiator**
- **Air conditioner condenser**
- **Cooling tower**

Air Conditioner Evaporator

All air conditioning systems contain at least two heat exchangers, usually called the evaporator and the condenser. In either case the refrigerant flows into the heat exchanger and transfers heat, either gaining or releasing it to the cooling medium. Commonly, the cooling medium is air or water. In the case of the condenser, the hot, high-pressure refrigerant gas must be condensed to a sub-cooled liquid.

Preheater

In large steam systems, or in any process requiring high temperatures, the input fluid is usually preheated in stages, instead of trying to heat it in one step from ambient to the final temperature. Preheating in stages increases the plant's efficiency and minimizes thermal shock stress to components, as compared to injecting ambient temperature liquid into a boiler or other device that operates at high temperatures. In the case of a steam system, a portion of the process steam is tapped off and used as a heat source to reheat the feed water in pre-heater stages.

Radiator

Commonly, heat exchangers are thought of as liquid-to-liquid devices only. But a heat exchanger is any device that transfers heat from one fluid to another. Some of a facility's equipment depends on air-to-liquid heat exchangers. The most familiar example of an air-to-liquid heat exchanger is a car radiator. The coolant flowing in the engine picks up heat from the engine block and carries it to the radiator. From the radiator, the hot coolant flows into the tube side of the radiator (heat exchanger). The relatively cool air flowing over the outside of the tubes picks up the heat, reducing the temperature of the coolant. Because air is such a poor conductor of heat, the heat transfer area between the metal of the radiator and the air must be maximized. This is done by using fins on the outside of the tubes. The fins improve the efficiency of a heat exchanger and are commonly found on most liquid-to-air heat exchangers and in some high efficiency liquid-to-liquid heat exchangers.

Air Conditioner Condenser

All air conditioning systems contain at least two heat exchangers, usually called the evaporator and the condenser. In either case, evaporator or condenser, the refrigerant flows into the heat exchanger and transfers heat, either gaining or releasing it to the cooling medium. Commonly, the cooling medium is air or water.

In the case of the condenser, the hot, high-pressure refrigerant gas must be condensed to a sub-cooled liquid. The condenser accomplishes this by cooling the gas and transferring its heat to either air or water. The cooled gas then condenses into a liquid. In the evaporator, the sub-cooled refrigerant flows into the heat exchanger, but the heat flow is reversed, with the relatively cool refrigerant absorbing heat from the hotter air flowing on the outside of the tubes. This cools the air and boils the refrigerant.

Cooling Tower

The typical function of a cooling tower is to cool the water of a steam power plant by air that is brought into direct contact with the water. The water is mixed with vapor that diffuses from the condensate into the air. The formation of the vapor requires a considerable removal of internal energy from the water; the internal energy becomes latent heat of the vapor. Heat and mass exchange are coupled in this process, which is a steady-state process like the heat exchange in the ordinary heat exchanger.

1.6 Personnel shall demonstrate working-level knowledge of heat exchanger systems operations in the following areas.

a) Describe the following heat exchanger system evolutions and associated precautions and hazards:

- **Start-up and shutdown**
- **Normal operation**
- **System rupture or leakage**

Start-Up and Shutdown

Operators should perform a pre-start checklist prior to startup. The heat exchanger design pressures and temperatures should not be exceeded during startup or operation.

Prior to operation, if possible to do so safely, the heat exchanger system should be vented of air (non-condensables) to ensure the performance of the exchanger meets specifications. Venting should only be done if operator and environmental safety requirements can be met. After the shell has been completely filled, close all vents.

If specific instructions or operating procedures are not provided, the fluid stream closest to ambient temperature should be gradually introduced into the heat exchanger first, followed by the second. To avoid thermally shocking the unit, slowly increase flow, instead of providing full flow immediately.

Shutdown should be accomplished in the reverse order of the start-up procedure. Complete drainage of fluids is essential when freezing or accelerated corrosion is possible during the shutdown time period.

Normal Operation

Heat exchangers may have very hot surfaces, so personal injury or damage to equipment may occur. Ensure the area around this equipment is kept clear to prevent damage from occurring.

The bolting on gasketed or packed joints should be checked periodically to ensure the joint is tight.

Periodically verify actual flow rates against design flow rates to avoid subjecting the exchanger to excessive velocities.

Excessive vibration or audible noise from a heat exchanger is abnormal. If this occurs, the cause should be investigated immediately. Verify that operating parameters (flows, pressures, and temperatures) do not exceed design. Additional corrective actions may require removal of the exchanger from service, followed by inspection.

Water hammer, usually caused by quick-closing valves or inadequate condensate removal, can cause vibration or audible noise in a heat exchanger.

System Rupture or Leakage

Heat exchangers may contain fluids at very high pressures. Prior to installing, removing, or maintaining this equipment, ensure that the equipment is isolated from all connecting piping, the equipment is de-pressurized, the contents have been drained, and the equipment is cool.

Abnormal outlet temperatures and pressures are usually the only indication of internal ruptures or leaks. Perform tests for ruptured and/or corroded tubes by applying tube-side test pressure (after removing the coil bundle from the shell). Leaks may also be detected during routine chemical samples.

1.7 Personnel shall demonstrate familiarity-level knowledge of pump construction, operations, and theory.

a) Describe the principles of operation for centrifugal pumps.

Centrifugal pumps basically consist of a stationary pump casing and an impeller mounted on a rotating shaft. The pump casing provides a pressure boundary for the pump, and contains channels to properly direct the suction and discharge flow. The pump casing has suction and discharge penetrations for the main flow path of the pump, and normally has small drain and vent fittings to remove gases trapped in the pump casing or to drain the pump casing for maintenance. The pump casing guides the liquid from the suction connection to the center, or eye, of the impeller. The vanes of the rotating impeller impart a radial and rotary motion to the liquid, forcing it to the outer periphery of the pump casing where it is collected in the outer part of the pump casing called the volute. The volute is a region that expands in cross-sectional area as it wraps around the pump casing. The purpose of the volute is to collect the liquid discharged from the periphery of the impeller at high velocity and gradually cause a reduction in fluid velocity by increasing the flow area. This converts the velocity head to static pressure. The fluid is then discharged from the pump through the discharge connection.

Centrifugal pumps can be classified based on the manner in which fluid flows through the pump. The manner in which fluid flows through the pump is determined by the design of the pump casing and the impeller. The three types of flow through a centrifugal pump are radial flow, axial flow, and mixed flow. In a radial flow pump, the liquid enters at the center of the impeller and is directed out along the impeller blades in a direction at right angles to the pump shaft. In an axial flow pump, the impeller pushes the liquid in a direction parallel to the pump shaft. Axial flow pumps are sometimes called propeller pumps because they operate essentially in the same manner as the propeller of a boat. Mixed flow pumps borrow characteristics from both radial flow and axial flow pumps. As liquid flows through the impeller of a mixed flow pump, the impeller blades push the liquid out and away from the pump shaft and to the pump suction at an angle greater than 90°.

For a given centrifugal pump operating at a constant speed, the flow rate through the pump is dependent upon the differential pressure or head developed by the pump. The lower the pump head, the higher the flow rate.

There are several terms associated with the pump characteristic curve that must be defined. Shutoff head is the maximum head that can be developed by a centrifugal pump operating at a set speed. Pump run out is the maximum flow that can be developed by a centrifugal pump without damaging the pump. Centrifugal pumps must be designed and operated to be protected from the conditions of pump run out or operating at shutoff head.

b) Describe the principles of operations for positive displacement pumps.

A positive displacement pump is one in which a definite volume of liquid is delivered for each cycle of pump operation. This volume is constant regardless of the resistance to flow offered by the system the pump is in, provided the capacity of the power unit driving the pump or the pump component strength limits are not exceeded. The positive displacement pump delivers liquid in separate volumes with no delivery in between, although a pump having several chambers may have an overlapping delivery among individual chambers, which minimizes this effect. The positive displacement pump differs from centrifugal pumps, which deliver a continuous flow for any given pump speed and discharge resistance.

Positive displacement pumps can be grouped into three basic categories based on their design and operation. The three groups are reciprocating pumps, rotary pumps, and diaphragm pumps.

All positive displacement pumps operate on the same basic principle. This principle can be most easily demonstrated by considering a reciprocating positive displacement pump consisting of a single reciprocating piston in a cylinder with a single suction port and a single discharge port. Check valves in the suction and discharge ports allow flow in only one direction. During the suction stroke, the piston moves to the left, causing the check valve in the suction line between the reservoir and the pump cylinder to open and admit water from the reservoir. During the discharge stroke, the piston moves to the right, seating the check valve in the suction line and opening the check valve in the discharge line. The volume of liquid moved by the pump in one cycle (one suction stroke and one discharge stroke) is equal to the change in the liquid volume of the cylinder as the piston moves from its farthest left position to its farthest right position.

c) Define the following terms and explain their relationship:
- **Net Positive Suction Head**
- **Cavitation**

Net Positive Suction Head

To avoid cavitation in centrifugal pumps, the pressure of the fluid at all points within the pump must remain above saturation pressure. The quantity used to determine if the pressure of the liquid being pumped is adequate to avoid cavitation is the net positive suction head (NPSH). The net positive suction head available ($NPSH_A$) is the difference between the pressure at the suction of the pump and the saturation pressure for the liquid being pumped. The net positive suction head required ($NPSH_R$) is the minimum net positive suction head necessary to avoid cavitation. The condition that must exist to avoid cavitation is that the net positive suction head available must be greater than or equal to the net positive suction head required. It is possible to ensure that cavitation is avoided during pump operation by monitoring the net positive suction head of the pump. NPSH for a pump is the difference between the suction pressure and the saturation pressure of the fluid being pumped. NPSH is used to measure how close a fluid is to saturated conditions. The following equation can be used to calculate the net positive suction head available for a pump. The units of NPSH are feet of water.

$$NPSH = P_{suction} - P_{saturation}$$

where:
$P_{suction}$ = suction pressure of the pump
$P_{saturation}$ = saturation pressure for the fluid

By maintaining the available NPSH at a level greater than the NPSH required by the pump manufacturer, cavitation can be avoided.

Cavitation

The flow area at the eye of the pump impeller is usually smaller than either the flow area of the pump suction piping or the flow area through the impeller vanes. When the liquid being pumped enters the eye of a centrifugal pump, the decrease in flow area results in an increase in flow velocity accompanied by a decrease in pressure. The greater the pump flow rate, the greater the pressure drop between the pump suction and the eye of the impeller. If the pressure drop is large enough, or if the temperature is high enough, the pressure drop may be sufficient to cause the liquid to flash to vapor when the local pressure falls below the saturation pressure for the fluid being pumped. Any vapor bubbles formed by the pressure drop at the eye of the impeller are swept along the impeller vanes by the flow of the fluid. When the bubbles enter a region where local pressure is greater than saturation pressure farther out the impeller vane, the vapor bubbles abruptly collapse. This process of the formation and subsequent collapse of vapor bubbles in a pump is called cavitation.

Cavitation in a centrifugal pump has a significant effect on pump performance. Cavitation degrades the performance of a pump, resulting in a fluctuating flow rate and discharge pressure. Cavitation can also be destructive to a pump's internal components. When a pump cavitates, vapor bubbles form in the low-pressure region directly behind the rotating impeller vanes. These vapor bubbles then move toward the oncoming impeller vane, where they collapse and cause a physical shock to the leading edge of the impeller vane. This physical shock creates small pits on the leading edge of the impeller vane. Each individual pit is microscopic in size, but the cumulative effect of millions of these pits formed over a period of hours or days can literally destroy a pump impeller.

Noise is one of the indications that a centrifugal pump is cavitating. A cavitating pump can sound like a can of marbles being shaken. Other indications that can be observed from a remote operating station are fluctuating discharge pressure, flow rate, and pump motor current.

If a centrifugal pump is cavitating, several changes in the system design or operation may be necessary to increase the $NPSH_A$ above the $NPSH_R$ and stop the cavitation. One method for increasing the $NPSH_A$ is to increase the pressure at the suction of the pump. For example, if a pump is taking suction from an enclosed tank, either raising the level of the liquid in the tank or increasing the pressure in the space above the liquid increases suction pressure. It is also possible to increase the $NPSH_A$ by decreasing the temperature of the liquid being pumped. Decreasing the temperature of the liquid decreases the saturation pressure, causing the $NPSH_A$ to increase. Large steam condensers usually sub-cool the condensate to less than the saturation temperature, called condensate depression, to prevent cavitation in the condensate pumps. If the head losses in the pump suction piping can be reduced, the $NPSH_A$ will be increased. Various methods for reducing head losses include increasing the pipe diameter, reducing the number of elbows, valves, and fittings in the pipe, and decreasing the length of the pipe.

It may also be possible to stop cavitation by reducing the $NPSH_R$ for the pump. The $NPSH_R$ is not a constant for a given pump under all conditions, but depends on certain factors. Typically, the $NPSH_R$ of a pump increases significantly as flow rate through the pump increases. Therefore, reducing the flow rate through a pump by throttling a discharge valve decreases $NPSH_R$. $NPSH_R$ is also dependent upon pump speed. The faster the impeller of a pump rotates, the greater the $NPSH_R$ will be. Therefore, if the speed of a variable speed centrifugal pump is reduced, the $NPSH_R$ of the pump decreases. However, since a pump's flow rate is most often dictated by the needs of the system on which it is connected, only limited adjustments can be made without starting additional parallel pumps, if available.

The net positive suction head required to prevent cavitation is determined through testing by the pump manufacturer, and depends upon factors including the type of impeller inlet, impeller design, pump flow rate, impeller rotational speed, and the type of liquid being pumped. The manufacturer typically supplies curves of $NPSH_R$ as a function of pump flow rate for a particular liquid (usually water) in the vendor manual for the pump.

1.8 Personnel shall demonstrate familiarity-level knowledge of valve construction, operations, and theory.

a) Given a drawing of a valve, identify the major component parts.

b) Given a drawing of a valve, identify which of the following type of valve it is:
- **Gate/globe**
- **Relief/safety**
- **Ball**
- **Check**

Elements “a” and “b” are performance-based competencies. The qualifying official will evaluate the completion of these competencies.

c) Describe the construction and principle of operation for the following types of valve actuators:
- **Manual**
- **Electric**
- **Solenoid**
- **Pneumatic**
- **Hydraulic**

Manual

Manual actuators are the most common type of valve actuators. Manual actuators include hand wheels directly attached to the valve stem, and hand wheels attached through gears to provide a mechanical advantage. Manual actuators are capable of placing the valve in any position, but do not permit automatic operation.

Electric

Electric motor actuators consist of reversible electric motors connected to the valve stem through a gear train that reduces rotational speed and increases torque. Electric motors permit manual, semi-automatic, and automatic operation of the valve. The motor is usually a reversible, high-speed type connected through a gear train to reduce the motor speed and thereby increase the torque at the stem. Direction of motor rotation determines direction of disk motion. The electrical actuation can be semi-automatic, as when the motor is started by a control system. A hand wheel, which can be engaged to the gear train, provides for manual operation of the valve. Limit switches are normally provided to stop the motor automatically at full open and full closed valve positions. Limit switches are operated either physically by position of the valve, or torsionally by torque of the motor.

Solenoid

Solenoid actuators have a magnetic slug attached to the valve stem. The force to position the valve comes from the magnetic attraction between the slug on the valve stem and the coil of the electromagnet in the valve actuator.

Pneumatic

Pneumatic actuators use air pressure on either one or both sides of a diaphragm to provide the force to position the valve. Pneumatic actuators are used in throttle valves for open-close positioning where fast action is required. When air pressure closes the valve and spring action opens the valve, the actuator is termed direct-acting. When air pressure opens the valve and spring action closes the valve, the actuator is termed reverse-acting.

Hydraulic

Hydraulic actuators use a pressurized liquid on one or both sides of a piston to provide the force required to position the valve. Hydraulic actuators provide for semi-automatic or automatic positioning of the valve, similar to the pneumatic actuators. These actuators use a piston to convert a signal pressure into valve stem motion. Hydraulic fluid is fed to either side of the piston while the other side is drained or bled. Water or oil is used as the hydraulic fluid. Solenoid valves are typically used for automatic control of the hydraulic fluid to direct either opening or closing of the valve. Manual valves can also be used for controlling the hydraulic fluid, thus providing semi-automatic operation.

d) Describe the four basic types of flow control elements employed in valve design.

There are four basic types of flow control elements employed in valve design:

- Moving a disc or plug into or against an orifice (e.g., a globe or needle type valve)
- Sliding a flat, cylindrical, or spherical surface across an orifice (e.g., gate and plug valves)
- Rotating a disc or ellipse about a shaft extending across the diameter of an orifice (e.g., a butterfly or ball valve)
- Moving a flexible material into the flow passage (e.g., diaphragm and pinch valves)

e) Given the bridge wall markings from a valve be able to explain:

- **The type of valve (gate/globe, ball, check, etc.)**
- **Direction of flow**
- **Application**

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

1.9 Personnel shall demonstrate familiarity-level knowledge of basic air compressor, strainer, and filter construction, operations, and theory.

a) Describe the basic operation of an air compressor.

Air compressors of various designs are used widely throughout Department of Energy (DOE) facilities in numerous applications. Compressed air has numerous uses throughout a facility, including the operation of equipment and portable tools. Three types of designs include reciprocating, rotary, and centrifugal air compressors.

The reciprocating air compressor is the most common design employed today. The reciprocating compressor normally consists of the following elements:

- The compressing element, consisting of air cylinders, heads and pistons, and air inlet and discharge valves

- A system of connecting rods, piston rods, crossheads, and a crankshaft and flywheel for transmitting the power developed by the driving unit to the air cylinder piston
- A self-contained lubricating system for bearings, gears, and cylinder walls, including a reservoir or sump for the lubricating oil, and a pump, or other means of delivering oil to the various parts (On some compressors, a separate force-fed lubricator is installed to supply oil to the compressor cylinders.)
- A regulation or control system designed to maintain the pressure in the discharge line and air receiver (storage tank) within a predetermined range of pressure
- An unloading system, which operates in conjunction with the regulator to reduce or eliminate the load put on the prime mover when starting the unit

Inlet and discharge valves are located in the clearance space and connected through ports in the cylinder head to the inlet and discharge connections.

During the suction stroke, the compressor piston starts its downward stroke and the air under pressure in the clearance space rapidly expands until the pressure falls below that on the opposite side of the inlet valve. This difference in pressure causes the inlet valve to open into the cylinder until the piston reaches the bottom of its stroke. During the compression stroke, the piston starts upward and compression begins and reaches the same pressure as the compressor intake. The spring-loaded inlet valve then closes. As the piston continues upward, air is compressed until the pressure in the cylinder becomes great enough to open the discharge valve against the pressure of the valve springs and the pressure of the discharge line. From this point to the end of the stroke, the air compressed within the cylinder is discharged at practically constant pressure.

The rotary compressor is adaptable to direct drive by induction motors or multicylinder gasoline or diesel engines. The units are compact, relatively inexpensive, and require a minimum of operating attention and maintenance. They occupy a fraction of the space and weight of a reciprocating machine of equivalent capacity. Rotary compressor units are classified into three general groups: slide vane-type, lobe-type, and liquid seal ring-type. Each of these types is discussed in more detail in DOE-STD-1018/2-93, Mechanical Science.

The centrifugal force utilized by the centrifugal compressor is the same force utilized by the centrifugal pump. The air particles enter the eye of the impeller. As the impeller rotates, air is thrown against the casing of the compressor. The air becomes compressed as more and more air is thrown out to the casing by the impeller blades. As the air is pushed along a designated path, the pressure of the air is increased.

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

- **Cartridge filters**
- **Precoated filters**
- **Bucket strainer**
- **Deep-bed filters**
- **HEPA filters**
- **Duplex strainer**

Cartridge Filters

Figure 1 illustrates a typical multi-cartridge filter. The cartridges are cylinders and usually consist of a fiber yarn wound around a perforated metal core. The liquid being filtered is forced through the yarn, which is approximately 1/2 inch thick, and then through the perforations in the metal core to the filter outlet, which can be at either end. A cartridge filter may include several cartridges, the exact number depending on the liquid flow rate that must be handled.

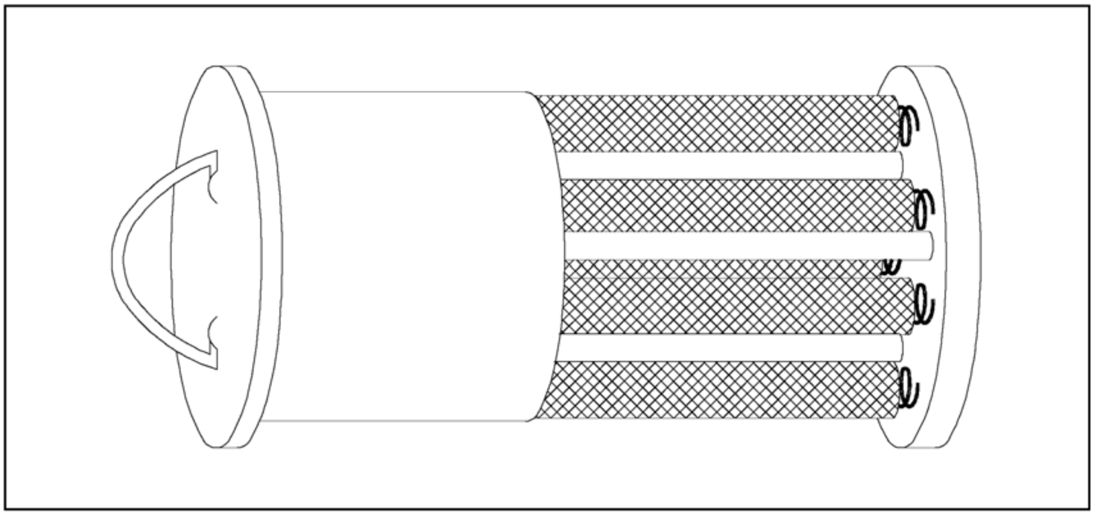


Figure 1. Typical multi-cartridge filter

The type of yarn that is used depends on the application. Some of the fibers commonly used include resin-impregnated wool or cellulose, cotton-viscose, polypropylene, nylon, and glass. In some applications that involve high temperatures or pressures, porous metal cartridges are used. These cartridges are usually made of 316 stainless steel, but inconel, monel, and nickel are also used.

Depending on the fiber or metal that is used, cartridges are available that will filter out all particle matter down to a specified size. For example, a certain cartridge might be designed to remove all particles larger than 10 microns, one micron, or even 0.1 micron.

Another type of cartridge filter is the wafer, or disk filter. In this filter, disks are stacked to form a cartridge and placed down over a central perforated pipe. Each disk is typically 1/8 inch to 1/4 inch thick and made of cellulose or asbestos fibers. Liquid that enters the disk filter moves up around the outside of the stack of disks, is forced between the disks, travels through the perforations in the central pipe, and then leaves the filter. The filtering action takes place as the liquid is forced between the disks. As with the smaller cartridges, if a disk filter is used to filter radioactive water, it may be very radioactive when it is removed and must be handled very carefully. One way to remove a disk filter is by means of a crane, which lifts the filter out of its housing and moves it to a shielded container. The disposal problem is one of the major disadvantages of cartridge and disk-cartridge filters.

Precoated Filters

When a precoated filter is in use, water that enters the filter vessel passes through the filter medium that is deposited on the septums and then leaves through the outlet. Before the filter can be placed into operation, however, the filter medium must be installed; that is, the filter must be precoated.

The first step in precoating the filter is to close the inlet and outlet valves to the filter. The filter medium used is mixed with demineralized water in an external mixing tank to form a slurry, which is pumped through the filter. Some of the filter medium deposits on the septums and is held there by the pressure of water on the outside of the septums. At the beginning of the precoating process, some of the fibers of the filter medium pass through the septums, either because they are smaller than the openings or because they pass through lengthwise. Thus, there is still some filter medium in the water as it leaves the filter, so the slurry is recirculated again and again until the water is clear. Clear water indicates that all of the filter medium is deposited on the septums, and the filter is precoated. Because water pressure holds the filter in place, flow must be maintained through the recirculating loop to keep the medium from falling off. This is called a holding flow. As the inlet and outlet valves are opened for normal usage, called service flow, the holding flow is gradually cut off.

The filtering medium fibers may be finely divided diatomite, perlite, asbestos, or cellulose. Diatomite, the least expensive medium, is used to filter liquid waste that will be discharged from the plant. Cellulose is generally used for processing water that will be returned to a reactor because diatomite can allow silica leaching.

Deep-Bed Filters

Deep-bed filters are usually found only in makeup water systems, where they are used to filter water after it has been treated in a clarifier. They are used to remove organic matter, chlorine, and very fine particulate matter. A deep-bed filter is based on a support screen (decking), which is mounted a few inches above the bottom of the tank. The screen is perforated to allow water to flow through it. A coarse, aggregate layer of crushed rock or large lumps of charcoal is placed on top of the screen, and the deep bed itself (2 to 4 feet of granular anthracite or charcoal) is placed on top of the aggregate. The filter is sized so that there is 1 to 2 feet of "free board" above the deep bed. When the filter is in service, raw water is pumped in through a pipe that feeds a distribution pipe above the deep bed. The water is filtered as it percolates down through the granules. (Charcoal granules will filter out organic matter, chlorine, and fine particulates, while anthracite granules remove only the particulates.) The water collects in the bottom of the tank below the support screen, and leaves the filter through a pipe in the bottom of the filter vessel.

Deep-bed filters, like precoat filters, are cleaned by backwashing. Water is pumped through the distribution piping near the top of the filter. The flow rate of the water is kept high enough to lift the granulated charcoal or anthracite up into the free space. The water washes away the deposits that have accumulated. When the backwash cycle is completed, the flow is stopped, and the granules settle back down into the filter bed. The filter can then be put back into service.

HEPA Filters

A HEPA (High Efficiency Particle Arresting) filter can remove the majority of harmful particles, including mold spores, dust, dust mites, pet dander and other irritating allergens from the air. Along with other methods to reduce allergens, such as frequent dusting, the use of a HEPA filtration system can be a helpful aid in controlling the amount of allergens circulating in the air. HEPA filters can be found in most air purifiers, which are usually small and portable.

Bucket and Duplex Strainers

The bucket strainer is literally a bucket to catch debris. The bucket can be removed for cleaning by loosening the strongback screws, removing the cover, and lifting the bucket out by its handle. It is usually used in systems expected to have larger debris.

Figures 2 and 3 illustrate two additional common types of strainers. Figure 2 shows a typical sump pump suction bucket strainer located in the sump pump suction line between the suction manifold and the pump. Any debris that enters the piping is collected in the strainer basket. The basket can be removed for cleaning by loosening the strongback screws, removing the cover, and lifting the basket out by its handle.

Figure 3 shows a duplex oil strainer commonly used in fuel oil and lubricating oil lines, where it is essential to maintain an uninterrupted flow of oil. The flow may be diverted from one basket to the other, for cleaning purposes.

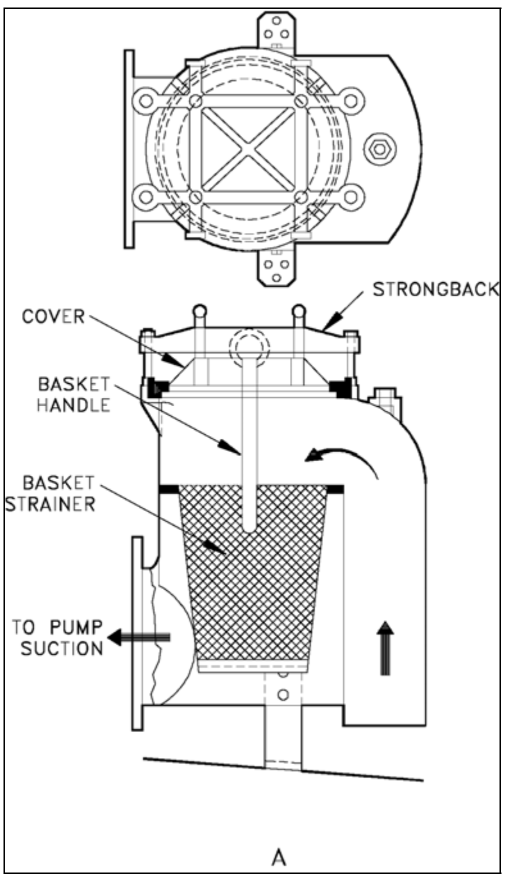


Figure 2. Sump pump suction bucket strainer

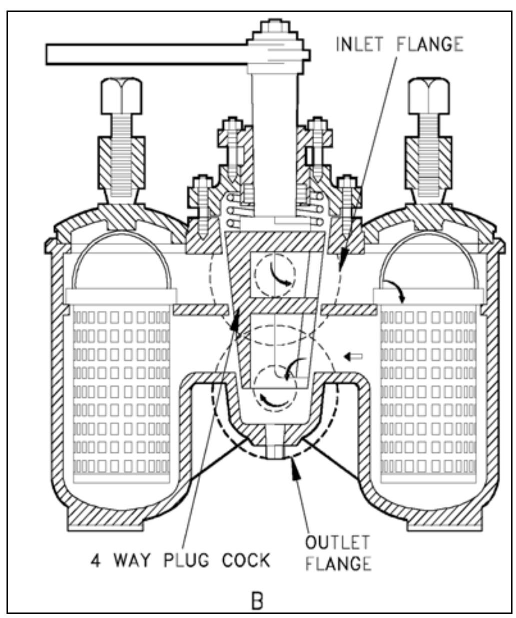


Figure 3. Duplex oil strainer

1.10 Personnel shall demonstrate familiarity-level knowledge of basic heating, ventilation, and air conditioning system construction, operations, and theory.

a) Given a one-line diagram of an HVAC system, identify and discuss the purpose of the following components:

- **Compressors**
- **Blowers**
- **Dampers**
- **Chillers**
- **Filters**
- **Heat exchangers**
- **Scrubbers**
- **Hoods**
- **Glove boxes**
- **Pressure sensors**

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

b) Discuss the relationships between the following in HVAC systems:

- **Supply ventilation**
- **Flow**
- **Exhaust ventilation**

Supply Ventilation

Supply ventilation is air delivered to the conditioned space and used for ventilation, heating, cooling, humidification, or dehumidification.

Flow

Flow is the path that the conditioned air takes coming from the supply air and exiting the space as exhaust air. The flow is the amount of air that enters a given space and subsequently traverses the space.

Exhaust Ventilation

Exhaust ventilation is air that exits a space and is discharged from the ventilation system.

c) Describe the types of refrigerants used in air conditioning systems.

Refrigerants can be air, water, ammonia, carbon monoxide, or fluorocarbon gases such as hydrofluorocarbon (HFC), chlorofluorocarbon (CFC), or hydrochlorofluorocarbon (HCFC).

Freon is a Dupont trade name for any CFC, HCFC, or HFC refrigerant. The name of each includes a number indicating molecular composition (e.g., R-11, R-12, R-22, or R-134). The blend most used in direct-expansion comfort cooling is an HCFC known as R-22, but it will be phased out by 2010 and completely discontinued by 2020. R-11 and R-12 are no longer manufactured in the U.S., so the only source for purchase is the cleaned and purified gas recovered from other air conditioner systems.

d) Discuss the hazards associated with these refrigerants.

Heavier-than-air refrigerants will displace air in a confined space leading to possible oxygen starvation (asphyxiation) for any technician working in the space. Oxygen starvation is the leading cause of death in accidents involving a refrigerant.

Overexposure to refrigerant vapors by inhalation may cause temporary nervous system depression with anesthetic effects such as dizziness, headache, confusion, loss of coordination, and loss of consciousness. Higher exposure to the vapors may cause temporary alteration of the heart's electrical activity with irregular pulse, palpitations, or inadequate circulation, or fatality from gross overexposure. Potential hazards such as room ventilation issues, eye irritation, skin freezing or burning when exposed to escaping refrigerant gas, exposed flame, and residual flux issues associated with brazing operations need to be considered.

e) Describe the purpose of the HVAC system in the following applications:

- **Hoods**
- **Glove boxes**
- **Hot Cells**
- **Confinement systems**

Hoods

Hoods are localized areas designed to prevent fumes and gases from escaping the work area, and usually consist of a workspace with a strong exhaust ventilation system.

Glove Boxes

A glove box is a device used to isolate an area to accommodate working with potentially hazardous substances or materials that need to be free from direct contact with the outside environment for any reason. Most glove boxes are small, tightly enclosed boxes with glass panels for viewing and special airtight gloves that a person on the outside can use to manipulate objects inside. HVAC systems in glove boxes usually maintain a negative pressure relative to the surrounding atmosphere, and flow from areas of low contamination toward areas of higher contamination.

Hot Cells

Hot cells are heavily shielded and environmentally controlled enclosures in which radioactive materials can be handled remotely with manipulators and viewed through shielding windows to limit danger to operating personnel. HVAC systems in hot cells usually maintain a negative pressure relative to the surrounding atmosphere, and flow from areas of low contamination toward areas of higher contamination.

Confinement Systems

Confinement systems may consist of a building, building space, a room, a cell, a glove box, or some other enclosed volume in which air supply and exhaust are controlled and filtered.

f) Discuss the reason for and significance of the following system parameters:

- **Positive vs. Negative system pressure**
- **Differential pressure across filters**
- **Differential pressure across components**

Positive vs. Negative System Pressure

Negative pressure for a system is desirable when that system contains hazardous materials as the negative pressure helps minimize the spread of contaminants in case of an accident. Some facilities require certain systems to be maintained at a negative pressure and make it a safety significant requirement.

A positive pressure system helps prevent or minimize the entry of contamination or contaminants into equipment or a facility from the outside.

Differential Pressure across Filters

As differential pressure across a filter increases, it indicates an increase in the amount of material contained (trapped) in the filters. In radioactive systems, this may lead to increased radiation levels above what is prescribed in the documented safety analysis (DSA).

Differential Pressure across Components

As differential pressure across a component increases, it indicates an increase in the amount of material settling out in that component. In radioactive systems, this may lead to increased radiation levels above what is prescribed in the DSA.

1.11 Personnel shall demonstrate working-level knowledge of heating, ventilation, and air conditioning (HVAC) system operations in the following areas.

a) Describe the following heating, ventilation, and air conditioning system evolutions and associated precautions and hazards:

- **Start-up and shutdown**
- **Normal operation**

Startup and Shutdown

An HVAC system is usually configured to operate in the automatic mode, normally under the control of a centralized energy control system. This system sends a start signal to the HVAC control logic, which in turn puts the local system through its start sequence.

For example, it may start a dehumidifier to maintain reactivation exhaust temperature in the allowed range. Next, supply and relief fans start and the air handling unit is started. Additionally, a condensing unit is enabled to run when outside air temperature goes above a pre-set temperature. Finally, the pneumatic control system is placed in operation.

Normal Operation

Controls are used to automate HVAC functions because the processes tend to be “On-Off” rather than variable. Cooling or heating air is supplied at design rates (e.g., 100%) until the desired temperature is reached. The function of the controls (e.g., thermostats or expansion valves) is usually to sense demand and either actuate or de-actuate.

b) HEPA filter maintenance and testing

HEPA Filter Maintenance and Testing

High efficiency particulate air (HEPA) filters and their integral frames are tested and certified in place. Filter pressure-drop gauges are required as an aid to economical replacement scheduling. Nuclear facilities require dioctylphthlate (DOP) testing, which requires special instruments to produce the DOP aerosol and to detect the amount of DOP penetrating the filters by light scattering. The filter must exhibit a minimum efficiency of 99.97 percent when tested at an aerosol of 0.3 micrometers diameter.

c) Ventilation system balancing

Ventilation System Balancing

HVAC systems (e.g., air or water distribution, vent or fume hoods, and glove boxes) must have provisions to balance the mass flow rates after installation or maintenance to achieve the desired results. This is normally accomplished by balancing static pressures using blast gates (dampers).

1.12 Personnel shall demonstrate familiarity-level knowledge of basic electrical fundamentals in the areas of terminology and theory.

a) Discuss the following terms:

- **Electrostatic force**
- **Electrostatic field**
- **Conductor**
- **Insulator**
- **Resistor**

Electrostatic Force

One of the mysteries of the atom is that the electron and the nucleus attract each other. This attraction is called electrostatic force, the force that holds the electron in orbit. Without this electrostatic force, the electron, which is traveling at high speed, could not stay in its orbit.

Electrostatic Field

A special force acts between charged objects. Forces of this type are the result of an electrostatic field that exists around each charged particle or object. Charged objects repel or attract each other because of the way these fields act together. This force is present with every charged object. When two objects of opposite charge are brought near one another, the electrostatic field is concentrated in the area between them. When two objects of like charge are brought near one another, the lines of force repel each other. The strength of the attraction or of the repulsion force depends upon two factors: (1) the amount of charge on each object, and (2) the distance between the objects. The greater the charge on the objects, the greater the electrostatic field will be. The greater the distance between the objects, the weaker the electrostatic field between them, and vice versa. This leads us to the law of electrostatic attraction, commonly referred to as Coulomb's law of electrostatic charges, which states that the force of electrostatic attraction, or repulsion, is directly proportional to the product of the two charges and inversely proportional to the square of the distance between them.

Conductor

Conductors are materials with electrons that are loosely bound to their atoms, or materials that permit free motion of a large number of electrons. Atoms with only one valence electron, such as copper, silver, and gold, are examples of good conductors. Most metals are good conductors.

Insulator

Insulators, or nonconductors, are materials with electrons that are tightly bound to their atoms and require large amounts of energy to free them from the influence of the nucleus. The atoms of good insulators have their valence shells filled with eight electrons, which means they are more than half filled. Any energy applied to such an atom will be distributed among a relatively large number of electrons. Examples of insulators are rubber, plastics, glass, and dry wood.

Resistor

Resistors are made of materials that conduct electricity, but offer opposition to current flow. These types of materials are also called semiconductors because they are neither good conductors nor good insulators. Semiconductors have more than one or two electrons in their valence shells, but less than seven or eight. Examples of semiconductors are carbon, silicon, germanium, tin, and lead. Each has four valence electrons.

b) Describe the following parameters and discuss their relationship:

- **Voltage**
- **Current**
- **Resistance**
- **Ohm's Law**
- **Power**
- **Inductance**
- **Capacitance**

Voltage

Voltage is described as the pressure or force that causes electrons to move in a conductor. In electrical formulas and equations, you will see voltage symbolized by a capital (E), while on laboratory equipment or schematic diagrams the voltage is often represented by a capital (V).

Current

Electron current, or amperage, is described as the movement of free electrons through a conductor. In electrical formulas, current is symbolized by a capital (I), while in the laboratory or on schematic diagrams, it is common to use a capital (A) to indicate amps or amperage.

Resistance

Resistance is defined as the opposition to current flow. The amount of opposition to current flow produced by a material depends on the amount of available free electrons it contains and the types of obstacles the electrons encounter as they attempt to move through the material.

Resistance is measured in ohms and is represented by the symbol (R) in equations; the shorthand notation is the Greek letter capital omega (Ω). One ohm is defined as that amount of resistance that will limit the current in a conductor to one ampere when the potential difference (voltage) applied to the conductor is one volt. If a voltage is applied to a conductor, current flows. The amount of current flow depends upon the resistance of the conductor. The lower the resistance, the higher the current flow for a given amount of voltage; the higher the resistance, the lower the current flow for a given amount of voltage.

Ohm's Law

Ohm's law defines the relationship between voltage, current, and resistance in an electrical circuit. Ohm's law can be stated in three ways:

Applied voltage equals circuit current times the circuit resistance. This is represented by the equation:

$$E = I \times R$$

Current is equal to the applied voltage divided by the circuit resistance. This is represented by the equation:

$$I = E / R$$

Resistance of a circuit is equal to the applied voltage divided by the circuit current:

$$R \text{ (or } \Omega) = E/I$$

where:
I = current (A)
E = voltage (V)
R = resistance (Ω)

If any two of the component values are known, the third can be calculated.

Power

Electricity is generally used to do some sort of work, such as turning a motor or generating heat. Specifically, power is the rate at which work is done, or the rate at which heat is generated. The unit commonly used to specify electric power is the watt. In equations, you will find power symbolized by the capital letter (P), and watts, the units of measure for power, are symbolized by the capital letter (W). Power is also described as the current (I) in a circuit times the voltage (E) across the circuit.

Inductance

Inductance is defined as the ability of a coil to store energy, induce a voltage in itself, and oppose changes in current flowing through it. The symbol used to indicate inductance in electrical formulas and equations is a capital (L). The unit of measurement is a Henry (H), and one Henry is defined as the amount of inductance that permits one volt to be induced when the current through the coil changes at a rate of one ampere per second. The mathematical representation of the rate of change in current through a coil per unit of time is as follows:

$$\Delta I / \Delta t$$

Capacitance

Capacitance (C), measured in farads, is equal to the amount of charge (Q) that can be stored in a device or capacitor divided by the voltage (E) applied across the device or capacitor plates when the charge was stored. Capacitance is defined as the ability to store an electric charge.

1.13 Personnel shall demonstrate familiarity-level knowledge of basic electrical fundamentals in the area of direct current (DC).

a) Discuss the basic principle by which the following components produce DC:

- **Battery**
- **DC Generator**
- **Thermocouple**

Battery

A battery consists of two or more chemical cells connected in series. The combination of materials within a battery is used for the purpose of converting chemical energy into electrical energy. The chemical cell is composed of two electrodes made of different types of metal or metallic compounds which are immersed in an electrolyte solution. The chemical actions which result are complicated, and they vary with the type of material used in cell construction. Some knowledge of the basic action of a simple cell will be helpful in understanding the operation of a chemical cell in general.

In the cell, electrolyte ionizes to produce positive and negative ions (part A in figure 4). Simultaneously, chemical action causes the atoms within one of the electrodes to ionize.

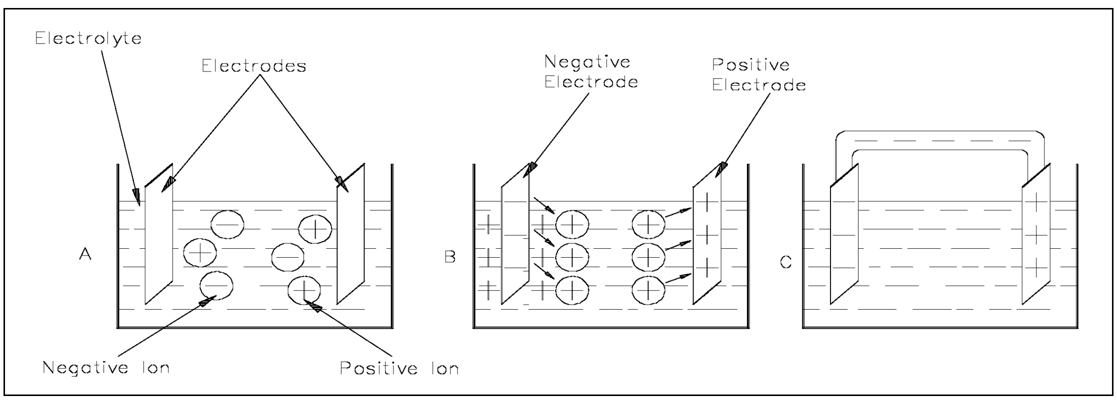


Figure 4. Basic chemical battery

Due to this action, electrons are deposited on the electrode, and positive ions from the electrode pass into the electrolyte solution (part B). This causes a negative charge on the electrode and leaves a positive charge in the area near the electrode (part C).

The positive ions, which were produced by ionization of the electrolyte, are repelled to the other electrode. At this electrode, these ions will combine with the electrons. Because this action causes removal of electrons from the electrode, it becomes positively charged.

DC Generator

A simple DC generator consists of an armature coil with a single turn of wire. The armature coil cuts across the magnetic field to produce a voltage output. As long as a complete path is present, current will flow through the circuit in the direction shown by the arrows in figure 5. In this coil position, commutator segment 1 contacts with brush 1, while commutator segment 2 is in contact with brush 2.

Rotating the armature one-half turn in the clockwise direction causes the contacts between the commutator segments to be reversed. Now segment 1 is contacted by brush 2, and segment 2 is in contact with brush 1.

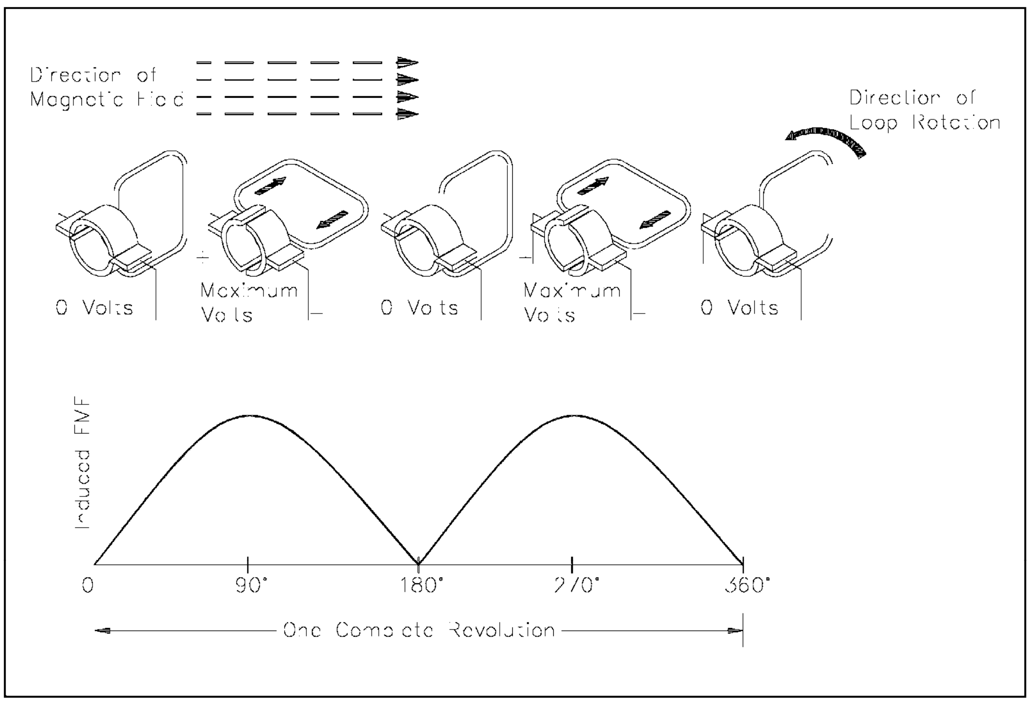


Figure 5. Basic DC generator

Due to this commutator action, that side of the armature coil which is in contact with either of the brushes is always cutting the magnetic field in the same direction. Brushes 1 and 2 have a constant polarity, and pulsating DC is delivered to the load circuit.

Thermocouple

A thermocouple is a device used to convert heat energy into a voltage output. The thermocouple consists of two different types of metal joined at a junction.

As the junction is heated, the electrons in one of the metals gain enough energy to become free electrons. The free electrons will then migrate across the junction and into the other metal. This displacement of electrons produces a voltage across the terminals of the thermocouple. The combinations used in the makeup of a thermocouple include: iron and constantan; copper and constantan; antimony and bismuth; and chromel and alumel. Thermocouples are normally used to measure temperature. The voltage produced causes a current to flow through a meter, which is calibrated to indicate temperature.

b) Discuss the purpose of a rectifier.

The purpose of a rectifier circuit is to convert alternating current (AC) power to DC. Most electrical power generating stations produce alternating current. The major reason for generating AC is that it can be transferred over long distances with fewer losses than DC; however, many of the devices which are used today operate only, or more efficiently, with DC. For example, transistors, electron tubes, and certain electronic control devices require DC for operation. If we are to operate these devices from ordinary AC outlet receptacles, they must be equipped with rectifier units to convert AC to DC. In order to accomplish this conversion, we use diodes in rectifier circuits. The most common type of solid state diode rectifier is made of silicon. The diode acts as a gate, which allows current to pass in one direction and blocks current in the other direction. The polarity of the applied voltage determines if the diode will conduct. The two polarities are known as forward bias and reverse bias.

c) Discuss the following terms:

- **Resistivity**
- **Electric circuit**
- **Series circuit**
- **Parallel circuit**

Resistivity

Resistivity is defined as the measure of the resistance a material imposes on current flow. The resistance of a given length of conductor depends upon the resistivity of that material, the length of the conductor, and the cross-sectional area of the conductor, as shown in the following equation.

$$R = \rho L/A$$

where:
R = resistance of conductor, Ω
ρ = specific resistance or resistivity, cm-Ω/ft
L = length of conductor, ft
A = cross-sectional area of conductor, cm

The resistivity ρ (rho) allows different materials to be compared for resistance, according to their nature, without regard to length or area. The higher the value of ρ, the higher the resistance will be.

Electric Circuit

Each electrical circuit has at least four basic parts: (1) a source of electromotive force, (2) conductors, (3) a load or loads, and (4) some means of control.

Series Circuit

A series circuit is a circuit where there is only one path for current flow. In a series circuit, the current will be the same throughout the circuit. This means that the current flow through R_1 is the same as the current flow through R_2 and R_3 as shown in figure 6.

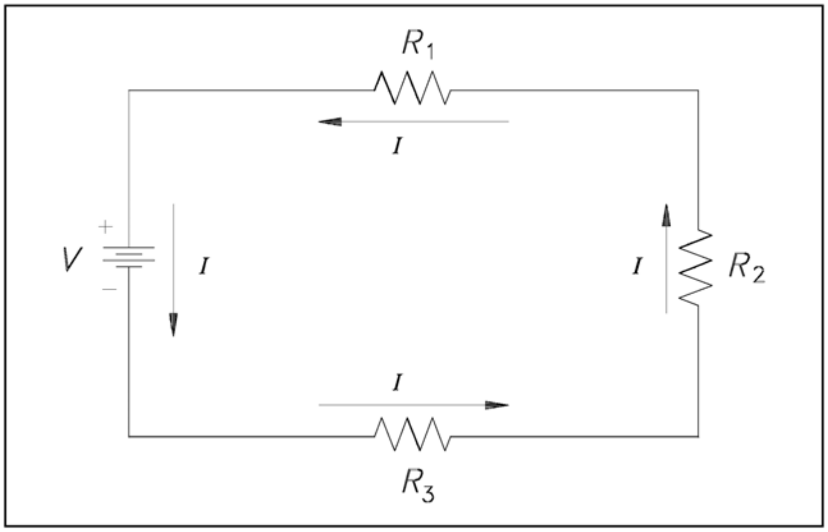


Figure 6. Series circuit

Parallel Circuit

Parallel circuits are those circuits that have two or more components connected across the same voltage source. Resistors R_1, R_2, and R_3 in figure 7are in parallel with each other and the source. Each parallel path is a branch with its own individual current. When the current leaves the source V, part I_1 of I_T will flow through R_1; part I_2 will flow through R_2; and part I_3 will flow through R_3. Current through each branch can be different; however, voltage throughout the circuit will be equal.

$$V = V_1 = V_2 = V_3$$

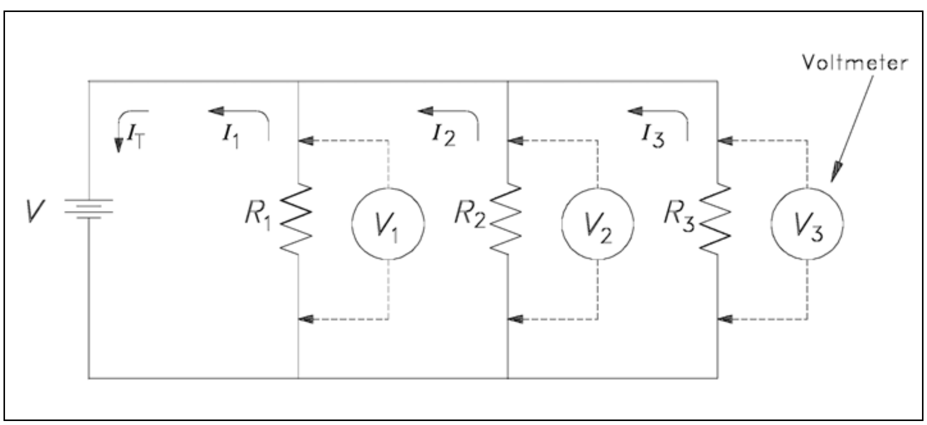


Figure 7. Parallel circuit

d) Discuss the following terms:

- **Battery**
- **Electrode**
- **Electrolyte**
- **Specific-Gravity**
- **Ampere-Hour**

Battery

A *battery* is a group of two or more connected voltaic cells.

Electrode

An electrode is a metallic compound, or metal, which has an abundance of electrons (negative electrode) or an abundance of positive charges (positive electrode).

Electrolyte

An electrolyte is a solution which is capable of conducting an electric current. The electrolyte of a cell may be a liquid or a paste. If the electrolyte is a paste, the cell is referred to as a dry cell; if the electrolyte is a solution, it is called a wet cell.

Specific Gravity

Specific gravity is defined as the ratio comparing the weight of any liquid to the weight of an equal volume of water. The specific gravity of pure water is 1.000. Lead-acid batteries use an electrolyte which contains sulfuric acid. Pure sulfuric acid has a specific gravity of 1.835, since it weighs 1.835 times as much as pure water per unit volume.

Ampere-Hour

An ampere-hour is defined as a current of one ampere flowing for one hour. Ampere-hours are normally used to indicate the amount of energy a storage battery can deliver.

e) Describe in basic terms what happens when a lead-acid battery is charged and discharged.

In a lead-acid battery, two types of lead are acted upon electro-chemically by an electrolytic solution of diluted sulfuric acid (H_2SO_4). The positive plate consists of lead peroxide (PbO_2), and the negative plate is sponge lead (Pb), shown in figure 8.

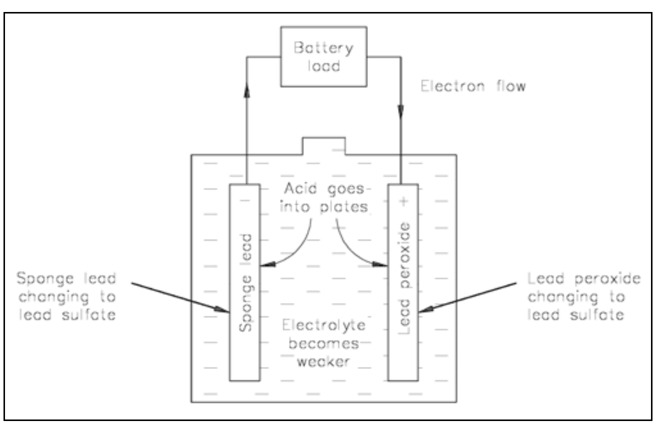


Figure 8. Chemical action during discharge

When a lead-acid battery is discharged, the electrolyte divides into H_2 and SO_4. The H_2 will combine with some of the oxygen that is formed on the positive plate to produce water (H_2O), and thereby reduce the amount of acid in the electrolyte. The sulfate (SO_4) combines with the lead (Pb) of both plates, forming lead sulphate ($PbSO_4$), as shown below.

$$PbO_2 + Pb + 2H_2SO_4 \xrightarrow{\text{discharge}} 2PbSO4 + 2H_2O$$

As a lead-acid battery is charged in the reverse direction, the action described in the discharge is reversed. The lead sulphate ($PbSO_4$) is driven out and back into the electrolyte (H_2SO_4). The return of acid to the electrolyte will reduce the sulphate in the plates and increase the specific gravity. This will continue to happen until all of the acid is driven from the plates and back into the electrolyte. As a lead-acid battery charge nears completion, hydrogen (H_2) gas is liberated at the negative plate, and oxygen (O_2) gas is liberated at the positive plate. This action occurs since the charging current is usually greater than the current necessary to reduce the remaining amount of lead sulfate on the plates. The excess current ionizes the water (H_2O) in the electrolyte.

The decrease in specific gravity on discharge is proportional to the ampere-hours discharged. While charging a lead-acid battery, the rise in specific gravity is not uniform, or proportional, to the amount of ampere-hours charged.

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

Series Cells

When several cells are connected in series, the total voltage output of the battery is equal to the sum of the individual cell voltages. Therefore, four 1.5V cells connected in series provide a total of 6 volts. When cells are connected in series, the positive terminal of one cell is connected to the negative terminal of the next cell. The current flow through a battery connected in series is the same as for one cell.

Parallel Cells

Cells connected in parallel give the battery a greater current capacity. When cells are connected in parallel, all the positive terminals are connected together, and all the negative terminals are connected together. The total voltage output of a battery connected in parallel is the same as that of a single cell. Cells connected in parallel have the same effect as increasing the size of the electrodes and electrolyte in a single cell. The advantage of connecting cells in parallel is that it will increase the current-carrying capability of the battery.

g) Other than lead-acid batteries, list three additional types of batteries.

Primary Cells

Cells that cannot be returned to good condition, or that cannot be recharged after their voltage output has dropped to a value that is not usable, are called primary cells. Dry cells that are used in flashlights and transistor radios (e.g., AA cells, C cells) are examples of primary cells.

Secondary Cells

Cells that can be recharged to nearly their original condition are called secondary cells. The most common example of a secondary, or rechargeable cell, is the lead-acid automobile battery. The advantage of a carbon-zinc battery is that it is durable and very inexpensive to produce.

Other Battery Cells

The alkaline cell has the advantage of an extended life over that of a carbon-zinc cell of the same size. The nickel-cadmium battery has the advantage of being a dry cell that is a true storage battery with a reversible chemical reaction. The edison cell has the advantage of being a lighter and more rugged secondary cell than a lead-acid storage battery. The mercury cell has the advantage of maintaining a fairly constant output under varying load conditions.

h) Describe the hazards associated with lead-acid storage batteries.

Short circuits cause a great reduction in battery capacity. To prevent short circuits in a battery, overcharging and over discharging should be avoided at all costs.

The adverse effect of gassing is that if gassing occurs and the gases are allowed to collect, an explosive mixture of hydrogen and oxygen can be readily produced. To reduce the amount of gassing, charging voltages above 2.30 volts per cell should be minimized.

Whenever the battery is charged, the current flowing through the battery will cause heat to be generated by the electrolysis of water and by I_2R_i power generation. Higher temperatures will give some additional capacity, but they will eventually reduce the life of the battery. Very high temperatures, 125°F and higher, can actually do damage to the battery and cause early failure.

1.14 Personnel shall demonstrate familiarity-level knowledge of basic electrical fundamentals in the area of alternating current (AC).

a) Discuss the basic theory of operation of an AC generator.

The elementary AC generator (figure 8) consists of a conductor, or loop of wire, in a magnetic field that is produced by an electromagnet. The two ends of the loop are connected to slip rings, and they are in contact with two brushes. When the loop rotates, it cuts magnetic lines of force, first in one direction and then in the other.

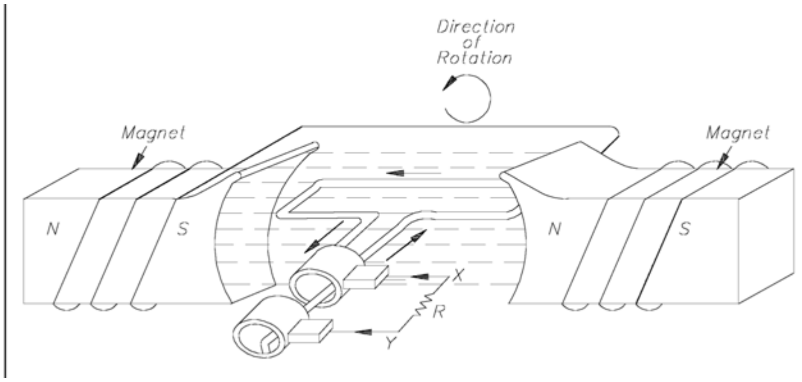


Figure 9. Simple AC generator

At the instant the loop is in the vertical position (0^o), the coil sides are moving parallel to the field and do not cut magnetic lines of force. In this instant, there is no voltage induced in the loop. As the coil rotates in a counter-clockwise direction, the coil sides will cut the magnetic lines of force in opposite directions. The direction of the induced voltages depends on the direction of movement of the coil. The induced voltages add in series, making slip ring X positive (+) and slip ring Y negative (-). The potential across resistor, R, will cause a current to flow from Y to X through the resistor.

This current will increase until it reaches a maximum value when the coil is horizontal to the magnetic lines of force (90^o). The horizontal coil is moving perpendicular to the field and is cutting the greatest number of magnetic lines of force. As the coil continues to turn, the voltage and current induced decrease until they reach zero, where the coil is again in the vertical position (180^o). In the other half revolution, an equal voltage is produced except that the polarity is reversed (270^o, 360^o). The current flow through R is now from X to Y. The periodic reversal of polarity results in the generation of a voltage, as shown in figure 9. The rotation of the coil through 360° results in an AC sine wave output.

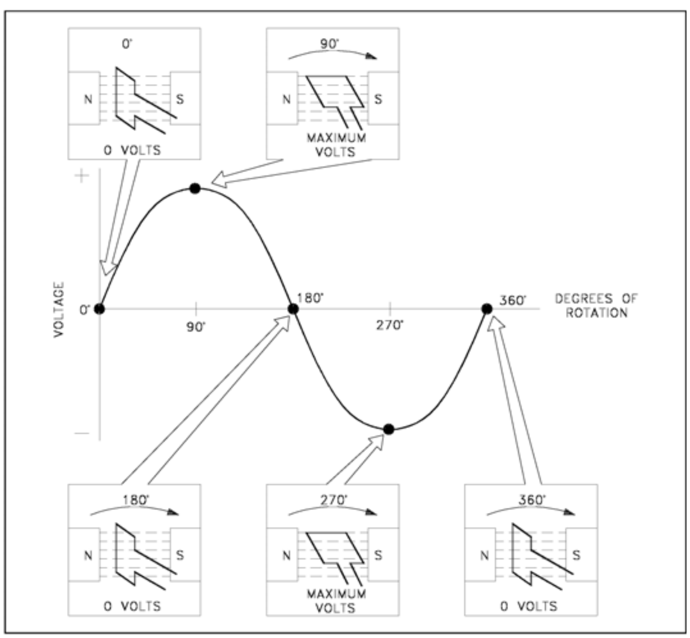


Figure 10. Developing a sine wave voltage

A simple generator consists of a conductor loop turning in a magnetic field, cutting across the magnetic lines of force. The sine wave output is the result of one side of the generator loop cutting lines of force. In the first half turn of rotation, this produces a positive current, and in the second half of rotation, this produces a negative current. This completes one cycle of AC generation.

A simple AC generator consists of

- a strong magnetic field
- conductors that rotate through that magnetic field
- a means by which a continuous connection is provided to the conductors as they are rotating

The strong magnetic field is produced by a current flow through the field coil of the rotor. The field coil in the rotor receives excitation through the use of slip rings and brushes. Two brushes are spring-held in contact with the slip rings to provide the continuous connection between the field coil and the external excitation circuit. The armature is contained within the windings of the stator and is connected to the output. Each time the rotor makes one complete revolution, one complete cycle of AC is developed. A generator has many turns of wire wound into the slots of the rotor.

The magnitude of AC voltage generated by an AC generator is dependent on the field strength and speed of the rotor. Most generators are operated at a constant speed; therefore, the generated voltage depends on field excitation, or strength.

b) Discuss the reasons that three phase power systems are used in industry.

Three-phase power systems are used in industry because

- three-phase circuits weigh less than single-phase circuits of the same power rating;
- they have a wide range of voltages, and can be used for single-phase loads;
- three-phase equipment is smaller in size, weighs less, and is more efficient than single-phase equipment.

c) Discuss the basic theory of operation of an AC motor.

The principle of operation for all AC motors relies on the interaction of a revolving magnetic field created in the stator by AC current, with an opposing magnetic field either induced on the rotor or provided by a separate DC current source. The resulting interaction produces usable torque, which can be coupled to desired loads throughout the facility in a convenient manner.

d) Discuss the purposes of a transformer.

Transformers are constructed so that their characteristics match the application for which they are intended. The differences in construction may involve the size of the windings or the relationship between the primary and secondary windings. Transformer types are also designated by the function the transformer serves in a circuit, such as an isolation transformer.

Distribution Transformer

Distribution transformers are generally used in electrical power distribution and transmission systems. This class of transformer has the highest power, or volt-ampere rating, and the highest continuous voltage rating. The power rating is normally determined by the type of cooling methods the transformer may use. Ampere rating is increased in a distribution transformer by increasing the size of the primary and secondary windings; voltage rating is increased by increasing the voltage rating of the insulation used in making the transformer.

Power Transformer

Power transformers are used in electronic circuits and come in many different types and applications. Electronics or power transformers are sometimes considered to be those with ratings of 300 volt-amperes and below. These transformers normally provide power to the power supply of an electronic device, such as in power amplifiers in audio receivers.

Control Transformer

Control transformers are generally used in electronic circuits that require constant voltage or constant current with a low power or volt-ampere rating. Various filtering devices, such as capacitors, are used to minimize the variations in the output. This results in a more constant voltage or current.

Auto Transformer

The auto transformer is generally used in low power applications where a variable voltage is required. The auto transformer is a special type of power transformer. It consists of only one winding. By tapping or connecting at certain points along the winding, different voltages can be obtained.

Isolation Transformer

Isolation transformers are normally low power transformers used to isolate noise from, or to ground, electronic circuits. Since a transformer cannot pass DC voltage from primary to secondary, any DC voltage (such as noise) cannot be passed, and the transformer acts to isolate this noise.

Instrument Potential Transformer

The instrument potential transformer steps down voltage of a circuit to a low value that can be effectively and safely used for operation of instruments such as ammeters, voltmeters, watt meters, and relays used for various protective purposes.

Instrument Current Transformer

The instrument current transformer steps down the current of a circuit to a lower value, and is used in the same types of equipment as a potential transformer. This is done by constructing the secondary coil, consisting of many turns of wire, around the primary coil, which contains only a few turns of wire. In this manner, measurements of high values of current can be obtained. A current transformer should always be short-circuited when not connected to an external load. Because the magnetic circuit of a current transformer is designed for low magnetizing current when under load, this large increase in magnetizing current will build up a large flux in the magnetic circuit and cause the transformer to act as a step-up transformer, inducing an excessively high voltage in the secondary when under no load.

e) Explain the theory of operation of a transformer.

A transformer works on the principle that energy can be transferred by magnetic induction from one set of coils to another set by means of a varying magnetic flux. The magnetic flux is produced by an AC source. The coil of a transformer that is energized from an AC source is called the primary winding (coil), and the coil that delivers this AC to the load is called the secondary winding (coil).

When alternating voltage is applied to the primary winding, an alternating current will flow that will magnetize the magnetic core, first in one direction and then in the other direction. This alternating flux flowing around the entire length of the magnetic circuit induces a voltage in both the primary and secondary windings. Since both windings are linked by the same flux, the voltage induced per turn of the primary and secondary windings must be of the same value and same direction. This voltage opposes the voltage applied to the primary winding and is called counter-electromotive force.

1.15 Personnel shall demonstrate working-level knowledge of basic electrical fundamentals in the area of electrical distribution systems.

a) Explain the following terms as they apply to electrical distribution systems:

- **Single-line diagram**
- **Diesel power**
- **Neutral grounding**
- **Protective relays**

Single-Line Diagram

When dealing with a large power distribution system, a special type of schematic diagram called an electrical single line is used to show all or part of the system. This type of diagram depicts the major power sources, breakers, loads, and protective devices, thereby providing a useful overall view of the flow of power in a large electrical power distribution system.

On power distribution single lines, even if it is a three-phase system, each load is commonly represented by only a simple circle with a description of the load and its power rating (running power consumption). Unless otherwise stated, the common units are kilowatts (kW). A single, or one-line, diagram of a distribution system is a simple and easy-to-read diagram showing power supplies, loads, and major components in the distribution system.

Diesel Power

Diesel power is power generated by a diesel-driven generator. Diesel-driven generators are the most economical and practical source of standby power.

Neutral Grounding

Neutral grounding in electrical distribution systems helps prevent accidents to personnel and damage to property caused by: fire, in case of lightning; a breakdown between primary and secondary windings of transformers; or accidental contact of high-voltage wires and low-voltage wires. If some point on the circuit is grounded (in this case neutral ground), lightning striking the wires will be conducted into the ground, and breakdown between the primary and secondary windings of a transformer will cause the primary transformer fuses to blow. Another advantage of neutral grounding is that it reduces the amount of insulation required for high-voltage transmission lines.

Protective Relays

Protective relays are designed to cause the prompt removal of any part of a power system that might cause damage or interfere with the effective and continuous operation of the rest of the system. Protective relays are aided in this task by circuit breakers that are capable of disconnecting faulty components or subsystems.

Protective relays can be used for types of protection other than short circuit or over current. The relays can be designed to protect generating equipment and electrical circuits from any undesirable condition, such as under voltage, under frequency, or interlocking system lineups.

There are only two operating principles for protective relays: (1) electromagnetic attraction, and (2) electromagnetic induction. Electromagnetic attraction relays operate by a plunger being drawn up into a solenoid or an armature that is attracted to the poles of an electromagnet. This type of relay can be actuated by either DC or AC systems. Electromagnetic induction relays operate on the induction motor principle whereby torque is developed by induction in a rotor. This type of relay can be used only in AC circuits.

b) Describe the protection provided by fuses and circuit breakers.

A fuse is a device that protects a circuit from an over current condition only. It has a fusible link directly heated and destroyed by the current passing through it. A fuse contains a current-carrying element sized so that the heat generated by the flow of normal current through it does not cause it to melt the element; however, when an over current or short-circuit current flows through the fuse, the fusible link will melt and open the circuit.

The purpose of a circuit breaker is to break the circuit and stop the current flow when the current exceeds a predetermined value without causing damage to the circuit or the circuit breaker. Circuit breakers are commonly used in place of fuses and sometimes eliminate the need for a switch. A circuit breaker differs from a fuse in that it trips to break the circuit and may be reset, while a fuse melts and must be replaced.

A circuit breaker is also used to provide a means for connecting and disconnecting circuits of relatively high capacities without causing damage to them. The three most commonly-used automatic trip features for a circuit breaker are over current, under frequency, and under voltage.

c) Describe the purpose and functions of a motor controller.

Motor controllers range from a simple toggle switch to a complex system using solenoids, relays, and timers. The basic functions of a motor controller are to control and protect the operation of a motor. This includes starting and stopping the motor, and protecting the motor from over current, under voltage, and overheating conditions that would cause damage to the motor. There are two basic categories of motor controllers: the manual controller and the magnetic controller.

1.16 Personnel shall demonstrate working-level knowledge of electrical systems and components in the area of safety.

a) Discuss the hazards associated with operations and maintenance of electrical systems and components.

Battery Fluids and Materials

Hazards	Precautions
Sulfuric acid can cause chemical burns if it comes in contact with the skin or eyes.	▪ Wear protective clothing when working with batteries. ▪ Know where the closest working eyewash and shower are located. ▪ Know how to operate the eyewash and shower.
Hydrogen and oxygen gas produced during the charging process can create a flammable environment.	▪ Ensure battery well ventilation systems are operating as designed. ▪ Observe no smoking/flames requirements. ▪ Use sparkless tools.
Excessive charging of a battery can raise the temperature of the electrolyte, causing splattering.	▪ Observe proper battery charging techniques and rates.
Batteries have large electrical storage and current capacity. Batteries cannot be turned off.	▪ Observe precautions to prevent coming in contact with electrical components of batteries. ▪ Ensure that only qualified personnel operate or perform maintenance on electrical equipment. ▪ Install guards to prevent accidental contact with live conductors. ▪ Ground electrical equipment. ▪ Whenever possible, de-energize equipment prior to working on it. ▪ Consider electrical equipment energized until proven de-energized by qualified personnel.

Transformer Oils

In general, it is best to stay clear of transformers unless work requires you to approach a transformer because transformers can explode under fault conditions. Some old transformers still contain oil containing polychlorinated biphenyls (PCBs), a know carcinogen. Fans on transformers can start without warning, so stay clear of fan blades and rotating equipment.

Cleaning Solvents

Fire and explosions may be caused by

- flammable and combustible cleaning solvents such as methyl ethyl ketone (MEK), mineral spirits, and diesel fuel/oil;
- liquids with high flash points (greater than 100ºF) when applied as a fine mist;
- hydrogen gas generated during cleaning processes.

Epoxies

The following examples represent the most common health problems stemming from epoxy use:

- Contact dermatitis (skin inflammation) is the most common reaction to contact with epoxies. Both epoxy resin and hardener can cause acute contact dermatitis, and discomfort can be severe, but usually disappears after stopping contact with the irritant. Repeated skin contact with resins and hardeners may also cause chronic contact dermatitis, which is usually milder but longer lasting. If left untreated for long periods, it can progress to eczema, a form of dermatitis that can include swelling, blisters, and itching. Partially cured epoxy sanding dust, if allowed to settle on the skin, can also lead to contact dermatitis.
- Allergic dermatitis is a more serious problem, but less than two percent of epoxy users are likely to get it. You are most susceptible if you have been grossly overexposed to epoxy or if you are inherently sensitized or allergic to a component of epoxy.
- Hardener burns are uncommon and mixed epoxy is unlikely to cause burns. By themselves, epoxy hardeners are moderately corrosive. If left in contact with the skin, they can severely irritate it and cause moderate chemical burns. The time it takes for a hardener to cause a chemical burn depends on the area of contact and the hardener concentration. When resin and hardener are mixed, the hardener is diluted and therefore is less corrosive. However, you must never leave it on your skin as it cures rapidly and is difficult to remove.
- Breathing highly concentrated epoxy vapor can irritate the respiratory system and cause sensitization. At room temperature, epoxy vapors are unlikely to be highly concentrated; however, if you are already sensitized to epoxy, exposure to low concentrations of epoxy vapors can trigger an allergic reaction. At warmer temperatures and in unventilated spaces, the epoxy vapor levels increase.

Insulating and Protective Gases

Insulating and protective gases such as sulfur hexafluoride (a gas at normal temperature and pressure) can act as an asphyxiant if inhaled. High concentrations can cause headache, drowsiness, dizziness, excitation, excess salivation, vomiting, and unconsciousness. Lack of oxygen can kill. Frostbite of the lips and mouth may result from contact with the liquid.

b) Describe the general safety precautions for operations and maintenance of electrical systems and components.

Two-Man Rule

The two-man rule is designed as a risk-reducing policy. It requires the physical presence of at least two personnel to perform tasks where an unaccompanied individual would be at an unreasonable risk. For example, the second person is there to ensure that if one person working on an electrical system receives an electrical shock, the second person can disconnect the power or safely remove the person, provide any required first aid, and notify other personnel.

Protective Equipment

Protective equipment is specific to the hazard and work conditions. The most common types of protective equipment are for eye protection (e.g., safety glasses), foot protection (e.g., safety shoes or boots), hearing protection (e.g., ear plugs), and head protection (e.g., hard hat). Work planning involves identification of all hazards associated with the work and selection of the proper personnel protective equipment (PPE) to eliminate or mitigate the hazards. PPE requirements are often posted at all entrances to a work site and/or included in the work authorization document.

Lockout/Tagout

A tagout program includes the placement of a tagout device on an energy-isolating device, in accordance with an established procedure, to indicate that the energy-operating device and the equipment being controlled may not be operated until the tagout device is removed. Similarly, a lockout program includes the placement of a lockout device (e.g., a lock or hasp with a lock in place) on an energy-isolating device in accordance with an established procedure ensuring that the energy-isolating device and the equipment being controlled cannot be operated until the lockout device is removed.

An effective lockout/tagout program is developed by each facility and should include detailed administrative procedures, training of personnel, and uniquely identifiable tags. The program should also exercise appropriate control over lockout/tagout preparation, approval, placement, and removal; provide for adequate documentation; and be consistent with the requirements of 29 CFR 1910, Occupational Safety and Health Standards.

Grounding

See competency 1.15 a. for a discussion of neutral grounding.

Stored Energy

Stored energy is used for backup or emergency power (e.g., batteries or capacitors). It is also used to improve the efficiency and reliability of the electric utility system by reducing the requirements for using reserves to meet peak power demands, making better use of efficient base-load generation, and allowing greater use of intermittent renewable energy technologies. Energy storage technologies include utility battery storage, flywheel storage, super-conducting magnetic energy storage, compressed air energy storage, pumped hydropower, and super-capacitors.

Component Labeling

Information on labels should be consistent with the information found in facility procedures, valve lineup sheets, and piping and instrument diagrams. Abbreviations and nomenclature used should be standardized and should be understood by facility personnel. Labels should

- be permanent, securely attached, and have distinguishable, easy-to-read information.
- list a unique component number. The accompanying component noun name or description and power supply, if applicable, should also be provided.
- be color-coded for unit, system, and/or train designation. If color-coding is used, the colors should be applied consistently and have only one meaning per color or combination.
- be made from materials that are compatible with their particular application. Adhesives used for label attachment should also be verified for compatibility.
- be placed on or as near as practicable to the equipment to be labeled, and oriented in a manner that is easy to read and so that the correct component is easy to identify. For example, labels for switches, indications, and breakers on control or power panels should be placed closer to the identified component than to any other component so that the label clearly identifies the correct component.
- be placed so as not to interfere with equipment operation, and in a way that does not obscure indicators.

c) Discuss the safety precautions specific to batteries.

Short circuits cause a great reduction in battery capacity. To prevent short circuits in a battery, overcharging and over-discharging should be avoided at all costs. The adverse effect of gassing is that if gassing occurs and the gases are allowed to collect, an explosive mixture of hydrogen and oxygen can be readily produced.

To reduce the amount of gassing, charging voltages above 2.30 volts per cell should be minimized. Whenever the battery is charged, the current flowing through the battery will cause heat to be generated by the electrolysis of water and by I_2R_i power generation.

Higher temperatures will give some additional capacity, but they will eventually reduce the life of the battery. Very high temperatures, 125°F and higher, can actually do damage to the battery and cause early failure.

1.17 Personnel shall demonstrate familiarity-level knowledge of process instrumentation principles of operation, purpose, and uses.

a) Explain the reason for measuring temperature, pressure, flow, and fluid level.

Temperature, pressure, flow, and fluid levels are monitored in processes to provide an indication of operating conditions and potential failures. Monitoring provides an indication of failure prior to having equipment damaged or destroyed or before possibly releasing material to the environment. The long-term tracking of operations allows for trend analysis of potential equipment failures.

b) List the three basic functions that temperature, pressure, flow, and fluid level detectors provide.

The hotness or coldness of a piece of plastic, wood, metal, or other material depends on the molecular activity of the material. Kinetic energy is a measure of the activity of the atoms that make up the molecules of any material. Therefore, temperature is a measure of the kinetic energy of the material in question.

Although the temperatures that are monitored vary slightly depending on the details of facility design, temperature detectors are used to provide three basic functions: indication, alarm, and control. The temperatures monitored may normally be displayed in a central location, such as a control room, and may have audible and visual alarms associated with them when specified preset limits are exceeded. These temperatures may have control functions associated with them so that equipment is started or stopped to support a given temperature condition, or so that a protective action occurs.

Although the pressures that are monitored vary slightly depending on the details of facility design, all pressure detectors are used to provide up to three basic functions: indication, alarm, and control. Since the fluid system may operate at both saturation and sub-cooled conditions, accurate pressure indication must be available to maintain proper cooling. Some pressure detectors have audible and visual alarms associated with them when specified preset limits are exceeded. Some pressure detector applications are used as inputs to protective features and control functions.

Liquid level measuring devices are classified into two groups: (a) direct method, and (b) inferred method. An example of the direct method is the dipstick in your car which measures the height of the oil in the oil pan. An example of the inferred method is a pressure gauge at the bottom of a tank which measures the hydrostatic head pressure from the height of the liquid.

c) For the temperature detection devices listed, explain how the instrument provides an output representative of the temperature being measured:

- **Thermocouple (TC)**
- **Resistance temperature detector (RTD)**

Thermocouple (TC)

TCs will cause an electric current to flow in the attached circuit when subjected to changes in temperature. The amount of current that will be produced is dependent on the temperature difference between the measurement and reference junction, the characteristics of the two metals used, and the characteristics of the attached circuit. Heating the measuring junction of the thermocouple produces a voltage which is greater than the voltage across the reference junction. The difference between the two voltages is proportional to the difference in temperature and can be measured on the voltmeter (in millivolts). For ease of operator use, some voltmeters are set up to read out directly in temperature through use of electronic circuitry.

A TC is constructed of two dissimilar wires joined at one end and encased in a metal sheath. The other end of each wire is connected to a meter or measuring circuit. Heating the measuring junction of the TC produces a voltage that is greater than the voltage across the reference junction. The difference between the two voltages is proportional to the difference in temperature and can be measured on a voltmeter.

Resistance Temperature Detector (RTD)

The resistance of an RTD varies directly with temperature:

- As temperature increases, resistance increases.
- As temperature decreases, resistance decreases.

RTDs are constructed using a fine, pure, metallic, spring-like wire surrounded by an insulator and enclosed in a metal sheath. A change in temperature will cause an RTD to heat or cool, producing a proportional change in resistance. The change in resistance is measured by a precision device that is calibrated to give the proper temperature reading.

d) For the pressure detection devices listed, explain how the instrument provides an output representative of the pressure being measured:

- **Bellows type**
- **Bourdon tube type**

Bellows Type

The bellows is a one-piece, collapsible, seamless metallic unit that has deep folds formed from very thin-walled tubing. The diameter of the bellows ranges from 0.5 to 12 in. and may have as many as 24 folds. System pressure is applied to the internal volume of the bellows. As the inlet pressure to the instrument varies, the bellows will expand or contract. The moving end of the bellows is connected to a mechanical linkage assembly. As the bellows and linkage assembly moves, either an electrical signal is generated or a direct pressure indication is provided. The flexibility of a metallic bellows is similar in character to that of a helical, coiled compression spring. Up to the elastic limit of the bellows, the relation between increments of load and deflection is linear. However, this relationship exists only when the bellows is under compression. It is necessary to construct the bellows such that all of the travel occurs on the compression side of the point of equilibrium. Therefore, in practice, the bellows must always be opposed by a spring, and the deflection characteristics will be the resulting force of the spring and bellows.

The following apply to a bellows-type detector:

- System pressure is applied to the internal volume of a bellows and mechanical linkage assembly.
- As pressure changes, the bellows and linkage assembly move to cause an electrical signal to be produced or to cause a gauge pointer to move.

Bourdon Tube Type

The bourdon tube consists of a thin-walled tube that is flattened diametrically on opposite sides to produce a cross-sectional area elliptical in shape, having two long, flat sides and two short, round sides. The tube is bent lengthwise into an arc of a circle of 270 to 300 degrees. Pressure applied to the inside of the tube causes distention of the flat sections and tends to restore its original round cross-section. This change in cross-section causes the tube to straighten slightly.

Since the tube is permanently fastened at one end, the tip of the tube traces a curve that is the result of the change in angular position with respect to the center. Within limits, the movement of the tip of the tube can then be used to position a pointer or to develop an equivalent electrical signal (which is discussed later in the text) to indicate the value of the applied internal pressure.

The following apply to a bourdon tube-type detector:

- System pressure is applied to the inside of a slightly flattened arc-shaped tube. As pressure increases, the tube tends to restore to its original round cross-section. This change in cross-section causes the tube to straighten.
- Since the tube is permanently fastened at one end, the tip of the tube traces a curve that is the result of the change in angular position with respect to the center. The tip movement can then be used to position a pointer or to develop an electrical signal.

e) For the fluid level detection devices listed, explain how the instrument provides an output representative of the level being measured:

- **Gauge-glass type**
- **Conductive probe type**
- **Magnetic bond type**
- **Differential pressure type**
- **Ball float type**

Gauge-Glass Type

In the gauge-glass method of fluid level detection, a transparent tube is attached to the bottom and top of the tank that is monitored (however, a top connection is not needed in a tank open to atmosphere). The height of the liquid in the tube will be equal to the height of water in the tank.

Conductive Probe Type

A conductivity probe consists of one or more level detectors, an operating relay, and a controller. When the liquid makes contact with any of the electrodes, an electric current will flow between the electrode and ground. The current energizes a relay that causes the relay contacts to open or close depending on the state of the process involved. The relay in turn will actuate an alarm, a pump, a control valve, or all three. A typical system has three probes: a low-level probe, a high-level probe, and a high-level alarm probe.

Magnetic Bond Type

The magnetic bond method of fluid level detection was developed to overcome the problems of cages and stuffing boxes. The magnetic bond mechanism consists of a magnetic float which rises and falls with changes in level. The float travels outside of a non-magnetic tube which houses an inner magnet connected to a level indicator. When the float rises and falls, the outer magnet will attract the inner magnet, causing the inner magnet to follow the level within the vessel.

Differential Pressure Type

The differential pressure (DP) detector method of liquid level measurement uses a DP detector connected to the bottom of the tank being monitored. The higher pressure, caused by the fluid in the tank, is compared to a lower reference pressure (usually atmospheric). This comparison takes place in the DP detector.

In an open tank, only the high-pressure (HP) connection to the DP transmitter is used; the low-pressure (LP) side is vented to the atmosphere. Therefore, the pressure differential is the hydrostatic head, or weight, of the liquid in the tank. The maximum level that can be measured by the DP transmitter is determined by the maximum height of liquid above the transmitter; the point where the transmitter is connected to the tank determines the minimum level measured.

Many tanks are totally enclosed to prevent vapors or steam from escaping or to allow pressurizing the contents of the tank. When measuring the level in a tank that is pressurized, or where level can become pressurized by vapor pressure from the liquid, both the high- and low-pressure sides of the DP transmitter must be connected.

The high-pressure connection is connected to the tank at or below the lower range value to be measured, and the low-pressure side is connected to a reference leg that is connected at or above the upper range value to be measured. The reference leg is pressurized by the gas or vapor pressure; no liquid is permitted to remain in the reference leg so that there is no liquid head pressure on the low-pressure side of the transmitter. The high-pressure side is exposed to the hydrostatic head of the liquid plus the gas or vapor pressure exerted on the liquid's surface. Since the gas or vapor pressure is equally applied to the low- and high-pressure sides, the output of the DP transmitter is directly proportional to the hydrostatic head pressure (i.e., the liquid level in the tank).

Ball Float Type

The ball float method of fluid level detection is a direct reading liquid level mechanism. The most practical design for the float is a hollow metal ball or sphere. However, there are no restrictions to the size, shape, or material used. The design consists of a ball float attached to a rod, which in turn is connected to a rotating shaft which indicates level on a calibrated scale. The operation of the ball float is simple. The ball floats on top of the liquid in the tank. If the liquid level changes, the float will follow and will change the position of the pointer attached to the rotating shaft.

f) For the flow detection devices listed, explain how the instrument provides an output representative of the flow being measured:

- **Orifice plate type**
- **Venturi tube type**
- **Pitot tube type**
- **Displacement type**
- **Dall flow tube type**
- **Ultrasonic type**
- **Electromagnetic**

Orifice Plate Type

The orifice plate is the simplest of the flowpath restrictions used in flow detection, as well as the most economical. Orifice plates are flat plates 1/16 to 1/4 inch thick. They are normally mounted between a pair of flanges and are installed in a straight run of smooth pipe to avoid disturbance of flow patterns from fittings and valves. Three kinds of orifice plates are used: concentric, eccentric, and segmental. Flow through a sharp-edged orifice plate is characterized by a change in velocity. As the fluid passes through the orifice, the fluid converges, and the velocity of the fluid increases to a maximum value. At this point, the pressure is at a minimum value. As the fluid diverges to fill the entire pipe area, the velocity decreases back to the original value. The pressure increases to about 60% to 80% of the original input value. The pressure loss is irrecoverable; therefore, the output pressure will always be less than the input pressure. The pressures on both sides of the orifice are measured, resulting in a differential pressure which is proportional to the flow rate.

Venturi Tube Type

The venturi tube is the most accurate flow-sensing element when properly calibrated. The venturi tube has a converging conical inlet, a cylindrical throat, and a diverging recovery cone. It has no projections into the fluid, no sharp corners, and no sudden changes in contour. The inlet section decreases the area of the fluid stream, causing the velocity to increase and the pressure to decrease. The low pressure is measured in the center of the cylindrical throat since the pressure will be at its lowest value, and neither the pressure nor the velocity is changing.

Pitot Tube Type

The pitot tube is another primary flow element used to produce a differential pressure for flow detection. In its simplest form, it consists of a tube with an opening at the end. The small hole in the end is positioned such that it faces the flowing fluid. The velocity of the fluid at the opening of the tube decreases to zero. This provides for the high-pressure input to a differential pressure detector. A pressure tap provides the low-pressure input. In a displacement flow meter, all of the fluid passes through the meter in almost completely isolated quantities. The number of these quantities is counted and indicated in terms of volume or weight units by a register. The most common type of displacement flow meter is the nutating disk, or wobble plate meter. As the fluid flows through the chamber, the disk wobbles, or executes a nutating motion. Since the volume of fluid required to make the disc complete one revolution is known, the total flow through a nutating disc can be calculated by multiplying the number of disc rotations by the known volume of fluid.

Displacement Type

The rotameter is an area flow meter so named because a rotating float is the indicating element. The rotameter consists of a metal float and a conical glass tube, constructed such that the diameter increases with height. When there is no fluid passing through the rotameter, the float rests at the bottom of the tube. As fluid enters the tube, the higher density of the float will cause the float to remain on the bottom, and the space between the float and the tube allows for flow past the float. As flow increases in the tube, the pressure drop increases; when the pressure drop is sufficient, the float will rise to indicate the amount of flow. The higher the flow rate, the greater the drop in pressure, and the higher the pressure drop, the farther up the tube the float will rise. This type of flow meter is usually used to measure low flow rates.

Dall Flow Tube Type

The dall flow tube has a higher ratio of pressure developed to pressure lost than the venturi flow tube. It is more compact and is commonly used in large flow applications. The tube consists of a short, straight inlet section followed by an abrupt decrease in the inside diameter of the tube. This section, called the inlet shoulder, is followed by the converging inlet cone and a diverging exit cone. The two cones are separated by a slot or gap between the two cones. The low pressure is measured at the slotted throat (the area between the two cones). The high pressure is measured at the upstream edge of the inlet shoulder.

Ultrasonic Type

Ultrasonic flow equipment uses the Doppler frequency shift of ultrasonic signals reflected from discontinuities in the fluid stream to obtain flow measurements. These discontinuities can be suspended solids, bubbles, or interfaces generated by turbulent eddies in the flow stream. The sensor is mounted on the outside of the pipe, and an ultrasonic beam from a piezoelectric crystal is transmitted through the pipe wall into the fluid at an angle to the flow stream. A second piezoelectric crystal located in the same sensor detects signals reflected off flow disturbances. Transmitted and reflected signals are compared in an electrical circuit, and the corresponding frequency shift is proportional to the flow velocity.

Electromagnetic Flowmeter

The electromagnetic flowmeter is similar in principle to the generator. The rotor of the generator is replaced by a pipe placed between the poles of a magnet so that the flow of the fluid in the pipe is normal to the magnetic field. As the fluid flows through this magnetic field, an electromotive force is induced in it that will be mutually normal (perpendicular) to both the magnetic field and the motion of the fluid. This electromotive force may be measured with the aid of electrodes attached to the pipe and connected to a galvanometer or an equivalent. For a given magnetic field, the induced voltage will be proportional to the average velocity of the fluid. However, the fluid should have some degree of electrical conductivity.

g) For the position detection devices listed, explain how the detector provides an output representative of the position being represented:

- **Synchronous type**
- **Limit switches**
- **Reed switches**
- **Potentiometer**
- **Linear variable differential transformer (LVDT) types**

Synchronous Type

Remote indication or control may be obtained by the use of self-synchronizing motors, called synchro equipment. Synchro equipment consists of synchro units that electrically govern or follow the position of a mechanical indicator or device. An electrical synchro has two distinct advantages over mechanical indicators: (1) greater accuracy, and (2) simpler routing of remote indication. The transmitter, or synchro generator, consists of a rotor with a single winding and a stator with three windings placed 120 degrees apart. When the mechanical device moves, the mechanically attached rotor moves. The rotor induces a voltage in each of the stator windings based on the rotor's angular position. Since the rotor is attached to the mechanical device, the induced voltage represents the position of the attached mechanical device. The voltage produced by each of the windings is utilized to control the receiving synchro position. The receiver, or synchro motor, is electrically similar to the synchro generator. The synchro receiver uses the voltage generated by each of the synchro generator windings to position the receiver rotor. Since the transmitter and receiver are electrically similar, the angular position of the receiver rotor corresponds to that of the synchro transmitter rotor. When the transmitter's shaft is turned, the synchro receiver's shaft turns such that its electrical position is the same as the transmitter's. What this means is that when the transmitter is turned to electrical zero, the synchro receiver also turns to zero. If the transmitter is disconnected from the synchro receiver and then reconnected, its shaft will turn to correspond to the position of the transmitter shaft.

Limit Switches

A limit switch is a mechanical device which can be used to determine the physical position of equipment. For example, an extension on a valve shaft mechanically trips a limit switch as it moves from open to shut or from shut to open. The limit switch gives ON/OFF output that corresponds to valve position. Normally, limit switches are used to provide full open or full shut indications

Reed Switches

Reed switches are more reliable than limit switches, due to their simplified construction. The switches are constructed of flexible ferrous strips (reeds) and are placed near the intended travel of the valve stem or control rod extension. When using reed switches, the extension used is a permanent magnet. As the magnet approaches the reed switch, the switch shuts. When the magnet moves away, the reed switch opens. This ON/OFF indicator is similar to mechanical limit switches. By using a large number of magnetic reed switches, incremental position can be measured. This technique is sometimes used in monitoring a reactor's control rod position.

Potentiometer

Potentiometer valve position indicators provide an accurate indication of position throughout the travel of a valve or control rod. The extension is physically attached to a variable resistor. As the extension moves up or down, the resistance of the attached circuit changes, changing the amount of current flow in the circuit. The amount of current is proportional to the valve position.

Potentiometer valve position indicators use an extension which is physically attached to a variable resistor. As the extension moves up or down, the resistance of the attached circuit changes, changing the amount of current flow in the circuit.

Linear Variable Differential Transformer (LVDT) Types

An LVDT uses the extension shaft or control rod as a movable core of a transformer. Moving the extension between the primary and secondary windings of a transformer causes the inductance between the two windings to vary, thereby varying the output voltage proportional to the position of the valve or control rod extension.

h) Referring to a basic block diagram of the above detection systems, explain the function of the key elements.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

1.18 Personnel shall demonstrate familiarity-level knowledge of control system principles of operation and uses.

a) Define and discuss the application of each of the following:

- **Control system**
- **Control system input**
- **Control system output**
- **Open-loop control system**
- **Control system feedback**
- **Closed-loop control system**

Control System

A control system is a system of integrated elements whose function is to maintain a process variable at a desired value or within a desired range of values. The control system monitors a process variable or variables, and then causes some action to occur to maintain the desired system parameter. In a central heating unit, the system monitors the temperature of the house using a thermostat. When the temperature of the house drops to a preset value, the furnace turns on, providing a heat source. The temperature of the house increases until a switch in the thermostat causes the furnace to turn off.

Control System Input and Control System Output

Two terms which help define a control system are input and output. Control system input is the stimulus applied to a control system from an external source to produce a specified response from the control system. In the case of the central heating unit, the control system input is the temperature of the house as monitored by the thermostat.

Control system output is the actual response obtained from a control system. In the example above, the temperature dropping to a preset value on the thermostat causes the furnace to turn on, providing heat to raise the temperature of the house. In the case of nuclear facilities, the input and output are defined by the purpose of the control system. Knowledge of the input and output of the control system enables the components of the system to be identified. A control system may have more than one input or output.

Control systems are classified by the control action, which is the quantity responsible for activating the control system to produce the output. The two general classifications are open-loop and closed-loop control systems.

Open-Loop Control System

An open-loop control system is one in which the control action is independent of the output. An example of an open-loop control system is a chemical addition pump with a variable speed control. The feed rate of chemicals that maintain proper chemistry of a system is determined by an operator, who is not part of the control system. If the chemistry of the system changes, the pump cannot respond by adjusting its feed rate (speed) without operator action.

Control System Feedback

Feedback is information in a closed-loop control system about the condition of a process variable. This variable is compared with a desired condition to produce the proper control action on the process. Information is continually fed back to the control circuit in response to control action. In the closed-loop example below, the actual storage tank water level, sensed by the level transmitter, is feedback to the level controller. This feedback is compared with a desired level to produce the required control action that will position the level control as needed to maintain the desired level.

Closed-Loop Control System

A closed-loop control system is one in which control action is dependent on the output. The control system maintains water level in a storage tank. The system performs this task by continuously sensing the level in the tank and adjusting a supply valve to add more or less water to the tank. The desired level is preset by an operator, who is not part of the system.

b) Describe an automatic control system, including the four functions required for an automatic control system to operate.

An automatic control system is a preset closed-loop control system that requires no operator action. This assumes the process remains in the normal range for the control system. An automatic control system has two process variables associated with it: a controlled variable and a manipulated variable.

A controlled variable is the process variable that is maintained at a specified value or within a specified range. In the previous example, the storage tank level is the controlled variable.

A manipulated variable is the process variable that is acted on by the control system to maintain the controlled variable at the specified value or within the specified range. In the previous example, the flow rate of the water supplied to the tank is the manipulated variable.

In any automatic control system, the four basic functions that occur are as follows:

- Measurement
- Comparison
- Computation
- Correction

In the water tank level control system in the example above, the level transmitter measures the level within the tank. The level transmitter sends a signal representing the tank level to the level control device which compares it to a desired tank level. The level control device then computes how far to open the supply valve to correct any difference between actual and desired tank levels.

c) Referring to a basic block diagram of a control system, explain the function of the elements.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

1.19 Personnel shall demonstrate familiarity-level knowledge of chemistry fundamentals in the areas of theory and the periodic table.

a) Describe the four possible states of matter.

The term "states of matter" refers to the physical forms in which matter exists: solid, liquid, gas, and plasma. Solids are characterized as having both a definite shape and a definite volume. In a solid, the forces that keep the molecules or atoms together are strong. Therefore, a solid does not require outside support to maintain its shape.

Liquids have definite volumes but indefinite shapes and are slightly compressible. Liquids take the shape of their containers. The forces that keep a liquid's molecules or atoms together are weaker than in the solids.

Gases are readily compressible and capable of infinite expansion. They have indefinite shape and indefinite volume. Of the three states, gases have the weakest forces holding their molecules or atoms together.

Plasma is a collection of charged particles (as in the atmospheres of stars or in a metal) containing about equal numbers of positive ions and electrons and exhibiting some properties of a gas, but differing from a gas in being a good conductor of electricity and in being affected by a magnetic field.

b) Explain the structure of an atom.

All matter is composed of atoms, existing individually or in combination with each other. An atom is an extremely small electrically neutral particle. It is the smallest unit involved in the chemical change of matter. Atoms can be treated as distinct particles because they behave as such chemically, but atoms themselves are composed of even smaller subparts. Understanding these atomic sub-particles is important in understanding chemistry.

An atom is composed of a positively-charged nucleus orbited by one or more negatively-charged particles called electrons. The nucleus is the core of an atom. It has a positive charge because it usually consists of two particles, the neutron and the proton (hydrogen is the exception with only a proton in the nucleus). The neutrons are electrically neutral, and the protons are electrically positive. A nucleus with one proton has a charge of +1 (or simply 1), and a nucleus with two protons has a +2 charge. Together the neutrons and protons give the nucleus its mass, but the proton alone gives the nucleus its positive charge.

Neutrons and protons are relatively massive and are essentially equal in mass. The particles that orbit the nucleus are electrons. They are very small, with a mass only 1/1835 the mass of a proton or neutron. Each electron is negatively charged, and the charge of one electron is equal in magnitude (but opposite in sign) to the charge of one proton. The number of electrons orbiting a nucleus is exactly equal to the number of protons contained in that nucleus. The equal and opposite charges cancel each other, and the atom as a whole is neutral.

The electrons are bound in the atom by electrostatic attraction. The atom remains neutral unless some external force causes a change in the number of electrons. The diameter of the atom is determined by the range of the electrons in their travels around the nucleus and is approximately 10^{-8}. The diameter of the nucleus is roughly 10,000 times smaller, approximately 10^{-13} to 10^{-12} cm. Because the nucleus is composed of neutrons and protons that are about 1835 times heavier than an electron, the nucleus contains practically all the mass of the atom, but constitutes a very small fraction of the volume. Although electrons are individually very small, the space in which they orbit the nucleus constitutes the largest part of the atomic volume.

c) Discuss the following terms:

- **Element**
- **Molecule**
- **Avogadro's Number**
- **Mole**

Element

An atom is classified chemically by the number of protons in its nucleus. Atoms that have the same number of protons in their nuclei have the same chemical behavior. Atoms that have the same number of protons are grouped together and constitute a chemical element.

Molecule

Molecules are groups or clusters of atoms held together by means of chemical bonding. There are two types of molecules: molecules of an element and molecules of a compound.

A molecule can be formed when a bond attracts two single atoms of an element to one another. Examples of this are hydrogen (H_2), oxygen (O_2), and bromine (Br_2). Most gaseous elements exist as molecules of two atoms.

A compound is formed when a bond holds two atoms of different elements together. The molecule is the primary particle of a chemical compound. Some examples of this type of molecule include hydrogen chloride (HCl), water (H_2O), methane (CH_4), and ammonia (NH_3).

Avogadro's Number

Experimentation has shown that, for any element, a sample containing the atomic weight in grams contains 6.0225 x 1023 atoms; this number is known as Avogadro's number. It represents the number of atoms in X grams of any element, where X is the atomic weight of the element. It permits chemists to predict and use exact amounts of elements needed to cause desired chemical reactions to occur.

Mole

A single atom or a few atoms are rarely encountered. Instead, larger, macroscopic quantities are used to quantify or measure collections of atoms or molecules, such as a glass of water, a gallon of alcohol, or two aspirin. Chemists have introduced a large unit of matter, the mole, to deal with macroscopic samples of matter. One mole represents a definite number of objects, substances, or particles (for example, a mole of atoms, a mole of ions, a mole of molecules, and even, theoretically, a mole of elephants). A mole is defined as the quantity of a pure substance that contains 6.022×10^{23} units (atoms, ions, molecules, or elephants) of that substance. In other words, a mole is Avogadro's number of anything.

For any element, the mass of a mole of that element's atoms is the atomic mass expressed in units of grams. For example, to calculate the mass of a mole of copper atoms, simply express the atomic mass of copper in units of grams. Because the atomic mass of copper is 63.546 amu, a mole of copper has a mass of 63.546 grams. The value for the atomic mass of gold is 196.967 amu. Therefore, a mole of gold has a mass of 196.967 grams. The mass of a mole of atoms is called the gram atomic weight. The mole concept allows the conversion of grams of a substance to moles and vice versa.

d) Given a periodic table, identify and explain the significance of the arrangement of elements to include the following:

- **Periods of the table**
- **Classes of the table**
- **Group characteristics**

Periods of the Table

A table in which elements with similar chemical properties are grouped together is called a periodic table (See figure 11). In this table, elements are arranged in order of increasing atomic number in succeeding rows. Each horizontal row is called a period. Elements with similar chemical properties appear in vertical columns called groups. Each group is designated by a Roman numeral and a capital letter, except the one on the extreme right-hand side, Group 0 (the inert gases). At the bottom of the periodic table are two long rows of elements identified as the lanthanide series and the actinide series. They are separated from the table primarily to keep it from becoming too wide. Also, the elements within each of these two series show similar chemical properties. The number directly below each element is its atomic number, and the number above each element is its atomic weight. In several cases the atomic weights are in parentheses. This indicates that these elements have no stable isotopes; that is, they are radioactive. The value enclosed in parentheses and used for the atomic weight is the atomic mass number of the most stable known isotope, as indicated by the longest half-life.

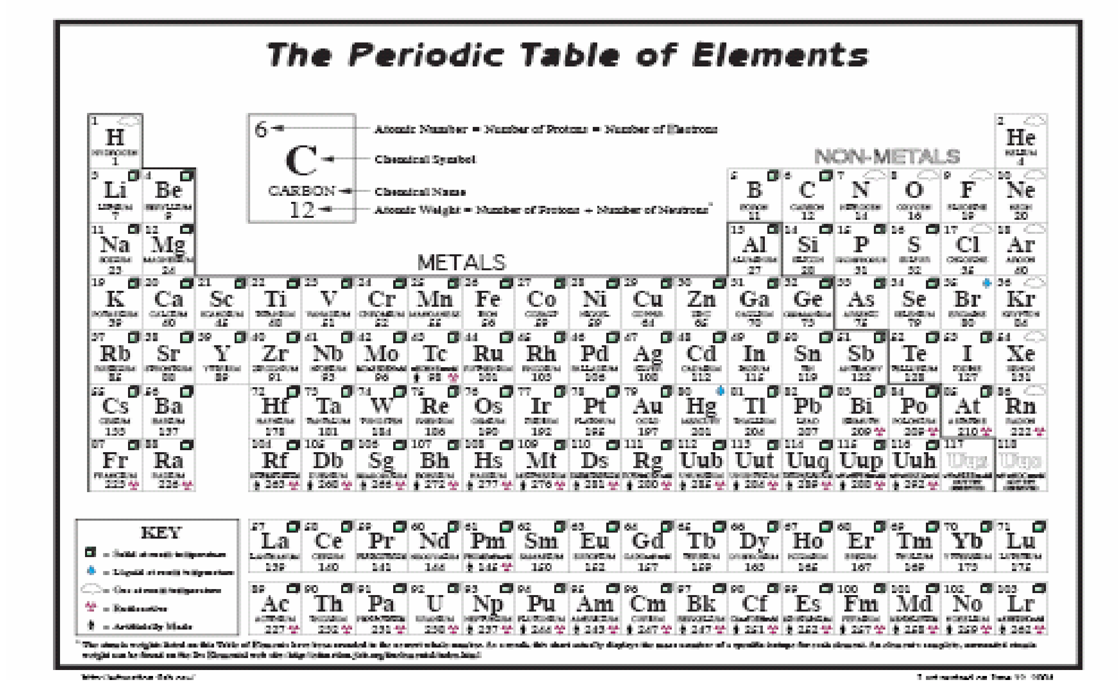


Figure 11. Periodic table of elements

Classes of the Table

There are three broad classes of elements: the metals, the non-metals, and the semi-metals.

Metals. The metals constitute the largest class of elements and are located on the left and toward the center of the periodic table as shown in figure 11. The heavy line running step-wise from boron (B) to astatine (At) generally separates the metals from the rest of the elements (elements in the actinide and lanthanide series are metals). Metals tend to lose electrons to form positive ions rather than to gain electrons and become negative ions.

Metals are divided into the following two categories:

- The light metals, which are soft, have a low density, are very reactive chemically, and are unsatisfactory as structural materials
- The transition metals, which are hard, have a high density, do not react readily, and are useful structural materials

The metals in the first category are located at the far left of the table. The metals in the second category are located in the middle of the table (the B groups).

Nonmetals. The nonmetals occupy the part of the periodic table to the right of the heavy, step-like line. In general, the physical properties of the nonmetals are the opposite of those attributed to metals. Nonmetals are often gases at room temperature. The nonmetals that are solids are not lustrous, are not malleable or ductile, and are poor conductors of heat and electricity. Some nonmetals are very reactive, but the nature of the reactions is different from that of metals. Nonmetals tend to gain electrons to form negative ions rather than to lose electrons to form positive ions. The six elements in Group 0 represent a special subclass of nonmetals. They are all very unreactive gases, so they are called the inert gases.

Semi-Metals. The obvious trend in the periodic table is that from left to right, across any period, the elements change from distinctly metallic to distinctly nonmetallic. This change in character is not sharply defined, but is gradual. Generally, elements well to the left of the heavy diagonal line are metals, and those well to the right are nonmetals. Some of the elements near the line, however, exhibit properties of metals under some conditions and properties of nonmetals under other conditions. These elements are called the semi-metals and include boron (B), silicon (Si), germanium (Ge), arsenic (As), and tellurium (Te). They are usually classified as semi-conductors of electricity and are widely used in electrical components.

Group Characteristics

Each set of elements appearing in the vertical column of a periodic table is called a Group and represents a family of elements that have similar physical and chemical properties. Group IA is the Alkali Family; Group IIA is the Alkaline Earth Family; Group VIA is the Oxygen Family; Group VIIA is the Halogen Family. On the left side of the table are Group IA elements (except hydrogen), which are soft metals that undergo similar chemical reactions. The elements in Group IIA form similar compounds and are much harder than their neighbors in Group IA. There are some exceptions to the generalizations concerning chemical properties and the periodic table. The most accurate observation is that all elements within a particular group have similar physical and chemical properties. This observation is most accurate at the extreme sides of the table. All elements in Group 0 are unreactive gases, and all elements in Group VIIA have similar chemical properties, although there is a gradual change in physical properties. For example, fluorine (F) is a gas while iodine (I) is a solid at room temperature. Groups with a B designation (IB through VIIB) and Group VIII are called transition groups. In this region of the table, exceptions begin to appear. Within any group in this region, all the elements are metals, but their chemical properties may differ. In some cases, an element may be more similar to neighbors within its period than it is to elements in its group. For example, iron (Fe) is more similar to cobalt (Co) and nickel (Ni) than it is to ruthenium (Ru) and osmium (Os). Most of these elements have several charges, and their ions in solution are colored (ions of all other elements are colorless).

The line separating metals from nonmetals cuts across several groups. In this region of the table, the rule of group similarities loses much of its usefulness. In Group IVA, for example, carbon (C) is a nonmetal; silicon (Si) and germanium (Ge) are semi-metals; and tin (Sn) and lead (Pb) are metals.

Chemical activity can also be determined from position in the periodic table. The most active metals are the members of the alkali family, e.g., cesium (Cs) and francium (Fr). The most active nonmetals are the members of the halogen family, e.g., fluorine (F) and chlorine (Cl).

The noble gases in Group 0 are inert. The activity of metals decreases when proceeding to the right in the periodic table; the activity of nonmetals decreases when proceeding to the left. The subdivisions of the periodic table are periods, groups, and classes. The horizontal rows are called periods. The vertical columns are called groups. Elements of the same group share certain physical and chemical characteristics. Examples of the characteristics of several groups are listed below.

- Group 0 contains elements that are unreactive gases.
- Group IA contains elements that are chemically active soft metals.
- Group VIIA contains elements that are chemically active nonmetals.
- Groups IB through VIIB and VIII are called transition groups, and elements found in them display properties of metals.

1.20 Personnel shall demonstrate familiarity-level knowledge of chemistry fundamentals in the areas of chemical bonding and chemical reactions.

a) Discuss the following types of chemical bonds:
- **Ionic**
- **Covalent**
- **Metallic**

Ionic Bond

An ionic bond is formed when one or more electrons are wholly transferred from one element to another, and the elements are held together by the force of attraction due to the opposing charges. An example of ionic bonding is sodium chloride (table salt).

The sodium atom loses the one electron in its outer shell to the chlorine atom, which uses the electron to fill its outer shell. When this occurs, the sodium atom is left with a +1 charge and the chlorine atom a -1 charge. The ionic bond is formed as a result of the attraction of the two oppositely-charged particles. No single negatively-charged ion has a greater tendency to bond to a particular positively-charged ion than to any other ion. Because of this, the positive and negative ions arrange themselves in three dimensions to balance the charges among several ions. In sodium chloride, for example, each chloride ion is surrounded by as many sodium ions as can easily crowd around it, namely six. Similarly, each sodium ion is surrounded by six chloride ions. Therefore, each chloride ion is bonded to the six nearest sodium ions and bonded to a lesser extent to the more distant sodium ions. Accordingly, the ionic bond is a force holding many atoms or ions together rather than a bond between two individual atoms or ions.

Covalent Bonds

A covalent bond is formed when one or more electrons from an atom pair off with one or more electrons from another atom and form overlapping electron shells in which both atoms share the paired electrons. Unlike an ionic bond, a covalent bond holds together specific atoms. Covalent bonding can be single covalent, double covalent, or triple covalent, depending on the number of pairs of electrons shared.

Two double covalent bonds result when carbon dioxide, which consists of one carbon atom and two oxygen atoms, is formed. Four pairs of electrons are shared by the carbon atom, two from each of the two oxygen atoms. A combination of two electrons forms a combination of lower energy than their energy when separated. This energy difference represents the force that binds specific atoms together. When both shared electrons in a covalent bond come from the same atom, the bond is called a coordinate covalent bond. Although both shared electrons come from the same atom, a coordinate covalent bond is a single bond similar in properties to a covalent bond.

Covalent bonds can be either polar or non-polar. When the shared pair of electrons is not shared equally, one end of the bond is positive and the other end is negative. This produces a bond with two poles called a polar covalent bond.

Molecules having polar covalent bonds are called dipolar or polar molecules. Water is an example of a polar molecule. When two atoms of the same element share one or more pairs of electrons (such as H or N), each atom exerts the same attraction for the shared electron pair or pairs. When the electron pairs are distributed or shared equally between the two like atoms, the bond is called a non-polar covalent bond. If all the bonds in a molecule are of this kind, the molecule is called a non-polar covalent molecule.

Metallic Bonds

Another chemical bonding mechanism is the metallic bond. In the metallic bond, an atom achieves a more stable configuration by sharing the electrons in its outer shell with many other atoms. Metallic bonds prevail in elements in which the valence electrons are not tightly bound with the nucleus, namely metals, thus the name metallic bonding. In this type of bond, each atom in a metal crystal contributes all the electrons in its valence shell to all other atoms in the crystal.

Another way of looking at this mechanism is to imagine that the valence electrons are not closely associated with individual atoms, but instead move around amongst the atoms within the crystal. Therefore, the individual atoms can slip over one another, yet remain firmly held together by the electrostatic forces exerted by the electrons. This is why most metals can be hammered into thin sheets (malleable) or drawn into thin wires (ductile). When an electrical potential difference is applied, the electrons move freely between atoms, and a current flows.

b) Explain each of the following as they relate to the basic laws of chemical reactions:

- **The Law of Conservation of Mass**
- **The Law of Definite Proportions**
- **The Law of Multiple Proportions**

The Law of Conservation of Mass

The law of conservation mass states that in a chemical reaction, the total mass of the products equals the total mass of the reactants. Antoine Lavoisier, a French chemist, discovered that when tin reacts with air in a closed vessel, the weight of the vessel and its contents is the same after the reaction as it was before. Scientists later discovered that whenever energy (heat, light, radiation) is liberated during a reaction, a very small change in mass does occur, but this change is insignificant in ordinary chemical reactions.

The Law of Definite Proportions

The law of definite proportions states that no matter how a given chemical compound is prepared, it always contains the same elements in the same proportions by mass. John Dalton, an English physicist, discovered that when various metals are burned or oxidized in air, they always combine in definite proportions by weight.

For example, one part by weight of oxygen always combines with 1.52 parts by weight of magnesium or 37.1 parts by weight of tin. This law results from the fact that a compound is formed by the combination of a definite number of atoms of one element with a definite number of atoms of another.

The Law of Multiple Proportions

The law of multiple proportions states that if two elements combine to form more than one compound, the masses of one of the elements combining with a fixed mass of the other are in a simple ratio to one another. For example, carbon forms two common compounds with oxygen; carbon monoxide and carbon dioxide. With carbon monoxide (CO), 1.33 grams of oxygen are combined with 1 gram of carbon. With carbon dioxide (CO_2), 2.67 grams of oxygen are combined with 1 gram of carbon. Therefore, the masses of oxygen combining with a fixed mass of carbon are in the ratio 2:1.

c) Discuss how elements combine to form chemical compounds.

The number of electrons in the outer (valence) shell determines the relative activity of the element. The arrangement of electrons in the outer shell explains why some elements are chemically very active, some are not very active, and others are inert. In general, the fewer electrons an element must lose, gain, or share to reach a stable shell structure, the more chemically active the element is.

The likelihood of elements forming compounds is strongly influenced by the completion of the valence shell and by the stability of the resulting molecule. The more stable the resulting molecules are, the more likely these molecules are to form. For example, an atom that needs two electrons to completely fill the valence shell would rather react with another atom that must give up two electrons to satisfy its valence.

Atoms are joined or bonded together through this interaction of their electrons. There are several types of chemical bonds that hold atoms together, the most common being ionic, covalent, and metallic.

d) Discuss the following terms:

- **Mixture**
- **Solvent**
- **Solubility**
- **Solute**
- **Solution**
- **Equilibrium**

Mixture

If two substances are placed together in a container, in any ratio, the result is a mixture. When a teaspoon of sugar is added to a glass of water, it will slowly dissolve into the water and disappear from view. As a result, the molecules of sugar are evenly distributed throughout the water and become mixed with the water molecules.

Solvent

All solutions consist of a solvent and one or more solutes. The solvent is the material that dissolves the other substance(s); it is the dissolving medium. In the water-sugar solution, water is the solvent.

Solubility

One factor that determines the degree and/or rate at which a reaction takes place is solubility. Solubility is defined as the maximum amount of a substance that can dissolve in a given amount of solvent at a specific temperature.

Solute

The substances that dissolve in the solution are called solutes. In the water-sugar solution, sugar is the solute.

Solution

Because the sugar and water mixture is uniform throughout, it is said to be homogeneous. A homogeneous mixture of two or more substances is called a solution. The reason solutions are classified as mixtures rather than as compounds is because the composition is not of fixed proportion.

It is not always easy to identify which is the solvent and which is the solute (e.g., a solution of half water and half alcohol).

Equilibrium

A solution is saturated when equilibrium is established between the solute and the solvent at a particular temperature. Equilibrium is the point at which the rates of the forward and reverse reactions are exactly equal for a chemical reaction if the conditions of reaction are constant.

e) With regard to chemical reactions, state Le Chatelier's principle.

The effect of temperature on solubility can be explained on the basis of Le Chatelier's principle. Le Chatelier's principle states that if a stress (for example, heat, pressure, concentration of one reactant) is applied to an equilibrium, the system will adjust, if possible, to minimize the effect of the stress. This principle is of value in predicting how much a system will respond to a change in external conditions.

Consider the case where the solubility process is endothermic (heat added). An increase in temperature puts a stress on the equilibrium condition and causes it to shift to the right. The stress is relieved because the dissolving process consumes some of the heat. Therefore, the solubility (concentration) increases with an increase in temperature.

If the process is exothermic (heat given off), a temperature rise will decrease the solubility by shifting the equilibrium to the left. How much solute is dissolved in a solution is very important when the solution is being made for a specific use. To say there is a little, a lot, or a bit would not be very accurate if a specific concentration is required. There are a few common and accurate methods used to express concentration. These are density, molarity, normality, and parts per million.

f) Discuss the following terms:
- **Density**
- **Molarity**
- **Parts per million (ppm)**

Density

Density is the measure of the mass per unit volume of a material (density = mass/volume). Density is a characteristic of a substance; mass and volume are not. Mass and volume vary with size, but density will remain constant. Temperature will affect the density of a substance, and the temperature at which density for that substance was determined is usually reported along with the density value.

Molarity

A useful way to express exact concentrations of solutions is molarity. Molarity is defined as moles of solute per liter of solution. Molarity is symbolized by the capital letter M. It can be expressed mathematically as follows.

$$\text{molarity (M)} = \frac{\text{moles of solute (n)}}{\text{liters of solution (V)}}$$

Notice that the moles of solute are divided by the liters of solution, and not solvent. One liter of one molar solution will consist of one mole of solute plus enough solvent to make a final volume of one liter.

Parts per Million (ppm)

Another term used to describe the specific concentration of a solution is parts per million, or ppm. The term ppm is defined as the concentration of a solution in units of one part of solute to one million parts solvent. One ppm equals one milligram of solute per liter of solution. Another term, parts per billion (ppb), is defined as one part solute per one billion parts solvent. One ppb is equal to one microgram solute per liter of solution. These two terms are usually used for very dilute solutions.

g) Given an unbalanced chemical equation, explain how to balance the equation.

The number of atoms or molecules of each substance is shown by the coefficients in the equation. Because atoms cannot be created or destroyed in a chemical reaction, a chemical equation must be balanced so that there is exactly the same number of atoms of each element on each side of the equation.

h) Define the following terms:
- **Acid**
- **Base**
- **pOH**
- **Salt**
- **pH**

Acid

Acids are substances that dissociate in water to produce hydrogen (H+). Examples of acids are sulfuric acid (H_2SO_4), vinegar, aspirin, and lemon juice. These substances share the following common properties:

- Acid solutions taste sour (acid means sour in Latin).
- Acids react with many metals to form hydrogen gas.
- Acids turn litmus paper red.
- Acid solutions conduct electricity.
- Acids react with bases to form a salt and water.

Base

Bases are substances that produce hydroxide ions (OH-) in water solutions. Examples of bases are sodium hydroxide (NaOH), household ammonia, most soaps, and lye. The following are four characteristic properties of bases:

- Basic solutions taste bitter and feel slippery to the touch.
- Bases turn litmus paper blue.
- Basic solutions conduct electricity.
- Bases neutralize acids.

pOH

The pOH of a solution is defined as the negative logarithm of the hydroxyl concentration, represented as [OH-] in moles/liter:

- pOH = - log [OH-]
- [OH-] = 10-pOH

Salt

When an acid reacts with a base, two products are formed: water and a salt. A salt is an ionic compound composed of positive ions and negative ions. The ionic bond is what keeps salts in their molecular form.

pH

ph is defined as the negative logarithm of the hydrogen concentration, represented as [H+] in moles/liter:

- pH = - log [H+]
- [H+] = 10-pH

1.21 Personnel shall demonstrate familiarity-level knowledge of chemistry fundamentals in the areas of corrosion and water treatment.

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

Iron goes into solution as Fe^{++} ions. As these ions go into solution, the metal becomes negatively charged (by the electrons left behind) with respect to the electrolyte. A potential difference (voltage) is produced between the electrolyte and the metal. The process in which electrons are given up and positive metal ions are formed is called oxidation. The sites at which the oxidation takes place on the surface of the metal become electrochemical cells made up of micro-electrodes of the two different substances: the metal and the electrolyte. Electrochemical cells and oxidation potentials are very important in understanding most corrosion processes. Examples of electrochemical cells include galvanic cells (cells made up of electrodes of two different substances) and concentration cells (cells containing electrodes of the same substance under different conditions of concentration).

Consider iron in water. If the surface of the iron and the water solution were uniform, iron would go into solution as Fe^{++} ions until the difference in potential between the positively charged solution and the negatively charged metal stopped the iron ions from leaving the surface. In practice, though, impurities and imperfections (for example, oxide coatings) lead to preferential removal of metal from certain parts of the surface, and potential differences arise as in the two-metal system. The corrosion cells, changing as surface and solution differences change, cause general overall corrosion. If the cells do not shift, pitting results. The corrosion of a metal (that is, the chemical transformation that is recognized as destructive to the metal) is the oxidation step of the overall oxidation-reduction process. Oxidation is the process of losing electrons; reduction is the process of gaining electrons. The metal atoms release electrons (are oxidized) and become positive ions. The site at which this occurs is known as the anode.

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

Galvanic corrosion is the corrosion that results when two dissimilar metals with different potentials are placed in electrical contact in an electrolyte. Of all the different types of corrosion, galvanic corrosion corresponds most closely to the electrochemical cells described previously because galvanic corrosion occurs when two electrochemically dissimilar metals are joined together (in electrical contact) in a conducting medium (electrolyte). It may also take place with one metal with heterogeneities (dissimilarities) (for example, impurity inclusions, grains of different sizes, difference in composition of grains, differences in mechanical stress); abnormal levels of pH; and high temperatures. A difference in electrical potential exists between the different metals and serves as the driving force for electrical current flow through the corrodant or electrolyte. This current results in corrosion of one of the metals. The larger the potential difference, the greater the probability of galvanic corrosion.

Galvanic corrosion only causes deterioration of one of the metals. The less resistant, active metal becomes the anodic corrosion site. The stronger, more noble metal is cathodic and protected.

If there were no electrical contact, the two metals would be uniformly attacked by the corrosive medium as if the other metal were absent.

c) Discuss the following types of specialized corrosion:

- **Pitting corrosion**
- **Stress corrosion cracking**
- **Crevice corrosion**

Pitting Corrosion

Pitting corrosion is a form of extremely localized corrosion that leads to the creation of small holes in the metal. The driving power for pitting corrosion is the lack of oxygen around a small area. This area becomes anodic, while the area with an excess of oxygen becomes cathodic.

Stress Corrosion Cracking

Stress corrosion cracking (SCC) is the cracking induced from the combined influence of tensile stress and a corrosive environment. The required tensile stresses may be in the form of directly applied stresses or in the form of residual stresses.

The impact of SCC on a material usually falls between dry cracking and the fatigue threshold of that material. Stress corrosion cracking appears to be relatively independent of general uniform corrosion processes; thus, the extent of general corrosion can be essentially nil and stress cracking can still occur. Most pure metals are immune to this type of attack.

Crevice Corrosion

Crevice corrosion is a localized form of pitting corrosion usually associated with a stagnant solution on the micro-environmental level. Such stagnant microenvironments tend to occur in crevices (shielded areas) such as those formed under gaskets, washers, insulation material, fastener heads, surface deposits, threads, lap joints, and clamps. Crevice corrosion is initiated by changes in local chemistry within the low-flow region of a crevice.

d) Discuss the reasons for removing impurities from water prior to use in nuclear and non-nuclear systems.

There are three general reasons to treat water for its impurities:

- To minimize corrosion, which is enhanced by impurities
- To minimize radiation levels in the reactor facility
- To minimize fouling of heat transfer surfaces

e) Explain the ion exchange process.

Ion exchange is a process used extensively in nuclear facilities to control the purity and pH of water by removing undesirable ions and replacing them with acceptable ones. Specifically, it is the exchange of ions between a solid substance (called a resin) and an aqueous solution (reactor coolant or makeup water). Depending on the identity of the ions that a resin releases to the water, the process may result in purification of water or in control of the concentration of a particular ion in a solution. An ion exchange is the reversible exchange of ions between a liquid and a solid. This process is generally used to remove undesirable ions from a liquid and substitute acceptable ions from the solid (resin).

The devices in which ion exchange occurs are commonly called demineralizers. This name is derived from the term demineralize, which means the process whereby impurities present in the incoming fluid (water) are removed by exchanging impure ions with H+ and OH- ions, resulting in the formation of pure water. H+ and OH- are present on the sites of resin beads contained in the demineralizer tank or column.

1.22 Personnel shall demonstrate working-level knowledge of chemistry fundamentals in the area of safety.

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

The hazards of acids are listed below:

- High concentrations of acids can destroy body tissue. The eyes are especially susceptible to permanent damage, and exposure can result in loss of sight.
- Inhalation of acidic vapors can irritate the respiratory system.
- Ingestion can destroy the stomach and throat lining, and if the concentration is strong enough, ingestion can be fatal.
- Aqueous solutions can become explosive if combined with other chemicals or combustible materials.
- If reacting with metal, hydrogen gas, which is very explosive, may be a byproduct.

The hazards of alkalies are listed below:

- Alkalies are more destructive than the acids.
- Alkali dusts, mists, and sprays can cause irritation of nasal passages, eyes, and the respiratory tract.
- When in contact with the tissue, strong alkalies will cause ulcers, severe burns, and eventual scarring.
- Ingestion of alkalies causes perforations of the mucous membrane and deeper tissues. Death may result if penetration is in vital areas.

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

Handling

The following precautions apply to the handling of corrosives:

- Pouring acids into small containers by hand, except by use of a cradle, is prohibited.
- The safest type of cradle should hold the acid container securely and should return to the upright position by gravity, with the provision for locking when not in use. A slow, steady motion should be used to operate the cradle.
- When pipettes are used to remove small quantities of acids from carboys, drawing acid into the pipette should be by suction bottle and never by mouth.
- When mixing acids and water, always add acid to water. Never add water to acid.
- Plastic carriers should be used to move acids from one location to another.

Storage

The following precautions apply to the storage of corrosives:

- Store large bottles of acids on low shelves or in acid storage cabinets.
- Segregate oxidizing acids from organic acids and flammable and combustible liquids.
- Segregate acids from bases and active metals such as sodium, potassium, and magnesium.
- Use bottle carriers for transporting acid bottles, and have spill-neutralizing agent available in case of acid spills.

Disposal

The following precautions apply to the disposal of corrosives:

- Corrosives should be disposed of in an approved container.
- Never pour corrosives down the drain.
- Always wear proper safety equipment when handling acids.

c) Discuss the general safety precautions regarding toxic compounds.

There are some general precautions that should be universally employed regarding toxic compounds. Proper ventilation, appropriate hygienic practices, housekeeping, protective clothing, and training on safe handling and storage will diminish many of the hazards that exist. Each toxic compound has a material safety data sheet identifying its hazards.

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

The following criteria are used to determine if a compound is a health hazard:

- The toxicity of the materials used
- The physical properties of the compound
- The absorption probabilities of these materials by individuals
- The extent and intensity of exposure to these materials
- The control measures used

The methods by which toxic compounds may enter the body are as follows:

- Ingestion
- Inhalation
- Absorption

In general, industrial poisonings usually result from inhalation, ingestion, and absorption. The inhalation and absorption of toxic agents by the lungs depends on the solubility in body fluids, the diffusion through the lungs, the volume of inhalation, the volume of blood in the lungs, and the concentration gradient of vapors between the inhaled air and the blood.

Ingestion of the toxic agent can occur to some extent; however, there would generally be considerable inhalation of the material where such conditions exist.

Absorption through the skin can occur upon exposure to some toxic agents. Some liquids and vapors are known to pass through the skin in concentrations high enough such that respiratory protection is not adequate. For example, hydrogen cyanide is known to pass through unbroken skin.

Consideration should be given to the type of work clothes being worn. If the clothes become saturated with solvents, they will act as a reservoir to bathe the body continually with the harmful material.

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

Compressed and liquefied gases are widely useful due to properties including high heat output in combustion for some gases, high reactivity in chemical processing with other gases, extremely low temperatures available from some gases, and the economy of handling them all in compact form at high pressure or low temperature. These same properties, however, also represent hazards if the gases are not handled with full knowledge and care.

Practically all gases can act as simple asphyxiants by displacing the oxygen in air. The chief precaution taken against this potential hazard is adequate ventilation of all enclosed areas in which unsafe concentrations may build up. A second precaution is to avoid entering unventilated areas that might contain high concentrations of gas without first putting on a breathing apparatus with a self-contained or hose-line air supply.

A number of gases have characteristic odors that can warn of their presence in air. Others, however, like the atmospheric gases, have no odor or color. For this reason, warning labels are required for compressed and liquefied-gas shipping containers, and similar warning signs are placed at the approaches to areas in which the gases are regularly stored and used.

Some gases can have a toxic effect on the human system, either by inhalation, through high-vapor concentrations, or by liquefied gas coming in contact with the skin or the eyes. Adequate ventilation of enclosed areas serves as the chief precaution against high concentrations of gas. In addition, for unusually toxic gases, automatic devices can be purchased or built to constantly monitor the gas concentration and set off alarms if the concentration approaches a danger point.

Oxygen poses a combustible hazard of a special kind. Although oxygen does not ignite, it lowers the ignition point of flammable substances and greatly accelerates combustion. It should not be allowed closer than 10 feet from any flammable substance, including grease and oil, and should be stored no closer than 10 feet from cylinders or tanks containing flammable gases.

Proper storage and handling of containers avoids many possible incidents. Hazards resulting from the rupture of a cylinder or other vessel containing gas at high pressure are protected against by careful and secure handling of containers at all times. Cylinders should be moved by a hand truck, not dragged or rolled across the floor. Also, when they are upright on a hand truck, floor, or vehicle, they should be chained securely to keep them from falling over. Moreover, cylinders should not be heated to the point at which any part of the outside surface exceeds a temperature of 125°F, and they should never be heated with a torch or other open flame.

f) Discuss the safety precautions for working with cryogenic liquids.

Always handle cryogenic liquids carefully as they can cause frostbite on skin and exposed eye tissue. When spilled, they tend to spread, covering a surface completely and cooling a large area. The vapors emitted by these liquids are also extremely cold and can damage tissues.

Stand clear of boiling or splashing liquid and its vapors. Boiling and splashing occurs when a warm container is charged, or when warm objects are inserted into a liquid.

These operations should always be performed slowly to minimize boiling and splashing. If cold liquid or vapor comes in contact with the skin or eyes, first aid should be given immediately.

Never allow an unprotected part of the body to touch un-insulated pipes or vessels that contain cryogenic fluids because the extremely cold metal will cause the flesh to stick fast to the surface and tear when withdrawn. Touching even nonmetallic materials at low temperatures is dangerous.

Tongs, or a similar device, should be used to withdraw objects immersed in a cryogenic liquid. Materials that are soft and pliable at room temperature become hard and brittle at extremely low temperatures and will break easily.

Workers handling cryogenic liquids should use eye and hand protection to protect against splashing and cold contact burns. Safety glasses are also recommended. If severe spraying or splashing is likely, a face shield or chemical goggles should be worn. Protective gloves should always be worn when anything that comes in contact with cold liquids and their vapors is being handled. Gloves should be loose fitting so that they can be removed quickly if liquids are spilled into them. Trousers should remain outside of boots or work shoes.

g) Explain the difference between a flammable liquid and a combustible liquid.

Flammable liquids are liquids that have a flash point below 100°F and a vapor pressure not exceeding 40 psia at 100°F. Combustible liquids are liquids with flash points at or above 100°F, but below 200°F.

h) Describe the general safety precautions regarding the use, handling, and storage of flammable and combustible liquids.

General safety precautions regarding the use, handling, and storage of flammable and combustible liquids include the following:

- The vapor-air mixture formed from the evaporation of the liquid poses a hazard; therefore, exposures of large liquid surface areas to sources of heat should be avoided or prevented during handling or storage of these liquids.
- The accidental mixture of flammable and combustible liquids should be prevented.
- Fill and discharge lines and openings, as well as control valves associated with flammable and combustible systems, should be identified by labels, color coding, or both to prevent mixing different substances.
- All storage tanks should be clearly labeled with the name of the contents.
- Transfer lines from different types and classes of flammable products should be kept separate, and preferably, different pumps should be provided for individual products.
- When handling quantities of flammable liquids up to five gallons, a portable, approved container should be used. The container should be clearly labeled.
- Smoking, the carrying of strike-anywhere matches, lighters, and other spark-producing devices should not be permitted in a building or area where flammable liquids are stored, handled, or used.

1.23 Personnel shall demonstrate familiarity-level knowledge of basic thermodynamics concepts and theories.

a) Define the following terms:

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

Specific Volume

Specific volume (ν) is the total volume (V) of a substance divided by the total mass (m) of that substance.

Density

Density (ρ) is the total mass (m) of a substance divided by the total volume (V) occupied by that substance. The density (ρ) of a substance is the reciprocal of its specific volume (ν).

Specific Gravity

Specific gravity (S.G.) is a measure of the relative density of a substance as compared to the density of water at a standard temperature. Since the density of a fluid varies with temperature, specific gravities must be determined and specified at particular temperatures.

Mass

The mass (m) of a body is the measure of the amount of material present in that body.

Weight

The weight (wt) of a body is the force exerted by that body when its mass is accelerated in a gravitational field.

b) Describe the thermodynamic properties of temperature and pressure.

Temperature is a measure of the molecular activity of a substance. The greater the movement of molecules, the higher the temperature will be. It is a relative measure of how hot or cold a substance is, and can be used to predict the direction of heat transfer.

Pressure is a measure of the force exerted per unit area on the boundaries of a substance (or system). It is caused by the collisions of the molecules of the substance with the boundaries of the system. As molecules hit the walls, they exert forces that try to push the walls outward. The forces resulting from all of these collisions cause the pressure exerted by a system on its surroundings. Pressure is frequently measured in units of lbf/in^2 (psi).

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

The two temperature scales normally employed for measurement purposes are the Fahrenheit (F) and Celsius (C) scales. These scales are based on a specification of the number of increments between the freezing point and boiling point of water at standard atmospheric pressure. The Celsius scale has 100 units between these points, and the Fahrenheit scale has 180 units. The zero points on the scales are arbitrary.

It is necessary to define an absolute temperature scale having only positive values. The absolute temperature scale that corresponds to the Celsius scale is called the Kelvin (K) scale, and the absolute scale that corresponds to the Fahrenheit scale is called the Rankine (R) scale. The zero points on both absolute scales represent the same physical state. This state is where there is no molecular motion of individual atoms. The relationships between the absolute and relative temperature scales are shown in the following equations:

- R = F + 460 (1-7)
- K = C + 273
- Absolute zero = -460°F or -273°C
- Freezing point of water = 32°F or 0°C
- Boiling point of water = 212°F or 100°C

Conversions between the different scales can be made using the following formulas.

- F = 32 + (9/5)C
- C = (°F - 32)(5/9)
- R = F + 460
- K = C + 273

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

When pressure is measured relative to a perfect vacuum, it is called absolute pressure (psia); when measured relative to atmospheric pressure (14.7 psi), it is called gauge pressure (psig). The latter pressure scale was developed because almost all pressure gauges register zero when open to the atmosphere. Therefore, pressure gauges measure the difference between the pressure of the fluid to which they are connected and that of the surrounding air. If the pressure is below that of the atmosphere, it is designated as a vacuum. A perfect vacuum would correspond to absolute zero pressure. All values of absolute pressure are positive, because a negative value would indicate tension, which is considered impossible in any fluid. Gauge pressures are positive if they are above atmospheric pressure and negative if they are below atmospheric pressure. Figure 12 shows the relationships between absolute, gauge, vacuum, and atmospheric pressures.

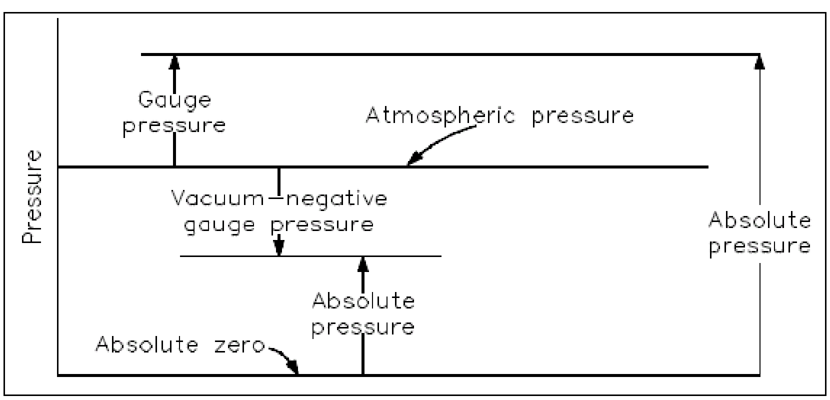


Figure 12. Pressure relationships

Relationships between absolute pressure, gauge pressure, and vacuum can be shown using the following formulas.

- Pabs = Patm + Pgauge
- Pabs = Patm - Pvac

e) Define the following and describe their relationship:

- **Energy**
- **Potential Energy**
- **Kinetic Energy**
- **Work**
- **Heat**

Energy

Energy is defined as the capacity of a system to perform work or produce heat.

Potential Energy

Potential energy (PE) is defined as the energy of position.

Kinetic Energy

Kinetic energy (KE) is the energy of motion.

Work

Work is a form of energy, but it is energy in transit. Work is not a property of a system. Work is a process done by or on a system, but a system contains no work. This distinction between the forms of energy that are properties of a system and the forms of energy that are transferred to and from a system is important to the understanding of energy transfer systems.

Work is defined for mechanical systems as the action of a force on an object through a distance. It equals the product of the force (F) times the displacement (d).

$$W = Fd \quad (1\text{-}15)$$

where:
W = work (ft-lbf)
F = force (lbf)
d = displacement (ft)

In dealing with work in relation to energy transfer systems, it is important to distinguish between work done by the system on its surroundings and work done on the system by its surroundings. Work is done by the system when it is used to turn a turbine and thereby generate electricity in a turbine-generator. Work is done on the system when a pump is used to move the working fluid from one location to another. A positive value for work indicates that work is done by the system on its surroundings; a negative value indicates that work is done on the system by its surroundings.

Heat

Heat, like work, is energy in transit. The transfer of energy as heat, however, occurs at the molecular level as a result of a temperature difference. The symbol Q is used to denote heat. In engineering applications, the unit of heat is the British thermal unit (Btu). Specifically, this is called the 60 degree Btu because it is measured by a one degree temperature change from 59.5 to 60.5°F.

As with work, the amount of heat transferred depends on the path and not simply on the initial and final conditions of the system. Also, as with work, it is important to distinguish between heat added to a system from its surroundings and heat removed from a system to its surroundings. A positive value for heat indicates that heat is added to the system by its surroundings. This is in contrast to work that is positive when energy is transferred from the system and negative when transferred to the system. The symbol q is sometimes used to indicate the heat added to or removed from a system per unit mass. It equals the total heat (Q) added or removed divided by the mass (m). The term specific heat is not used for q since specific heat is used for another parameter. The quantity represented by q is referred to as the heat transferred per unit mass.

$$q = \frac{Q}{m}$$

where:
q = heat transferred per unit mass (Btu/lbm)
Q = heat transferred (Btu)
m = mass (lbm)

Latent heat is the amount of heat added or removed to produce only a phase change.

Sensible heat is the heat added or removed that causes a temperature change.

Heat and work are both transient phenomena. Systems never possess heat or work, but either or both may occur when a system undergoes a change of energy state. Heat and work are boundary phenomena in that both are observed at the boundary of the system. Both represent energy crossing the system boundary.

f) Describe the following types of thermodynamic systems:
- **Isolated system**
- **Open system**
- **Closed system**

Isolated System

An isolated system is one that is not influenced in any way by the surroundings. This means that no energy in the form of heat or work may cross the boundary of the system. In addition, no mass may cross the boundary of the system. A thermodynamic system is defined as a quantity of matter of fixed mass and identity upon which attention is focused for study.

Open System

An open system is one that may have a transfer of both mass and energy with its surroundings.

Closed System

A closed system has no transfer of mass with its surroundings, but may have a transfer of energy (either heat or work) with its surroundings.

g) Describe the following terms concerning thermodynamic processes:

- **Thermodynamic process**
- **Cyclic process**
- **Reversible process**
- **Irreversible process**
- **Adiabatic process**
- **Isentropic process**
- **Throttling process**
- **Polytropic process**

Thermodynamic Process

Whenever one or more of the properties of a system change, a change in the state of the system occurs. The path of the succession of states through which the system passes is called the thermodynamic process. One example of a thermodynamic process is increasing the temperature of a fluid while maintaining a constant pressure. Another example is increasing the pressure of a confined gas while maintaining a constant temperature.

Cyclic Process

When a system in a given initial state goes through a number of different changes in state (going through various processes) and finally returns to its initial values, the system has undergone a cyclic process or cycle. Therefore, at the conclusion of a cycle, all the properties have the same value they had at the beginning. Steam (water) that circulates through a closed cooling loop undergoes a cycle.

Reversible Process

A reversible process for a system is defined as a process that, once having taken place, can be reversed, and in so doing leaves no change in either the system or surroundings. In other words, the system and surroundings are returned to their original condition before the process took place. In reality, there are no truly reversible processes; however, for analysis purposes, one uses the reversible concept to make the analysis simpler, and to determine maximum theoretical efficiencies. Therefore, the reversible process is an appropriate starting point on which to base engineering study and calculation.

Although the reversible process can be approximated, it can never be matched by real processes. One way to make a real process approximate a reversible process is to carry out the process in a series of small or infinitesimal steps. For example, heat transfer may be considered reversible if it occurs due to a small temperature difference between the system and its surroundings. For example, transferring heat across a temperature difference of 0.00001°F appears to be more reversible than transferring heat across a temperature difference of 100°F. Therefore, by cooling or heating the system in a number of very small steps, we can approximate a reversible process. Although not practical for real processes, this method is beneficial for thermodynamic studies since the rate at which processes occur is not important.

Irreversible Process

An irreversible process is a process that cannot return both the system and the surroundings to their original conditions. That is, the system and the surroundings would not return to their original conditions if the process was reversed. For example, an automobile engine does not give back the fuel it took to drive up a hill as it coasts back down the hill. There are many factors that make a process irreversible. Four of the most common causes of irreversibility are friction, unrestrained expansion of a fluid, heat transfer through a finite temperature difference, and mixing of two different substances.

Adiabatic Process

An adiabatic process is one in which there is no heat transfer into or out of the system. The system can be considered to be perfectly insulated.

Isentropic Process

An isentropic process is one in which the entropy of the fluid remains constant. This will be true if the process the system goes through is reversible and adiabatic. An isentropic process can also be called a constant entropy process.

Throttling Process

A throttling process is defined as a process in which there is no change in enthalpy from state one to state two, $h_1 = h_2$; no work is done, W = 0; and the process is adiabatic, Q = 0. To better understand the theory of the ideal throttling process, let's compare what we can observe with the above theoretical assumptions.

An example of a throttling process is an ideal gas flowing through a valve in mid-position. From experience we can observe that: $P_{in} > P_{out}$, $vel_{in} < vel_{out}$ (where P = pressure and vel = velocity). These observations confirm the theory that $h_{in} = h_{out}$. Remember, h = u + Pv (v = specific volume), so if pressure decreases, then specific volume must increase if enthalpy is to remain constant (assuming u is constant). Because mass flow is constant, the change in specific volume is observed as an increase in gas velocity, and this is verified by our observations.

The theory also states W = 0. Our observations again confirm this to be true as clearly no work has been done by the throttling process. Finally, the theory states that an ideal throttling process is adiabatic. This cannot clearly be proven by observation since a real throttling process is not ideal and will have some heat transfer.

Polytropic Process

When a gas undergoes a reversible process in which there is heat transfer, the process frequently takes place in such a manner that a plot of the Log P (pressure) vs. Log V (volume) is a straight line. Or stated in equation form, PV^n = a constant. This type of process is called a polytropic process. An example of a polytropic process is the expansion of the combustion gases in the cylinder of a water-cooled reciprocating engine.

h) Discuss the First Law of Thermodynamics.

The First Law of Thermodynamics states that energy can neither be created nor destroyed, only altered in form. For any system, energy transfer is associated with mass and energy crossing the control boundary, external work and/or heat crossing the boundary, and the change of stored energy within the control volume. The mass flow of fluid is associated with the kinetic, potential, internal, and flow energies that affect the overall energy balance of the system. The exchange of external work and/or heat completes the energy balance.

The First Law of Thermodynamics is referred to as the conservation of energy principle, meaning that energy can neither be created nor destroyed, but rather transformed into various forms as the fluid within the control volume is being studied. The energy balance spoken of here is maintained within the system being studied. The system is a region in space (control volume) through which the fluid passes. The various energies associated with the fluid are then observed as they cross the boundaries of the system and the balance is made.

i) Discuss the Second Law of Thermodynamics.

The Second Law of Thermodynamics states that it is impossible to construct a device that operates in a cycle and produces no effect other than the removal of heat from a body at one temperature and the absorption of an equal quantity of heat by a body at a higher temperature.

With the Second Law of Thermodynamics, the limitations imposed on any process can be studied to determine the maximum possible efficiencies of such a process, and then a comparison can be made between the maximum possible efficiency and the actual efficiency achieved. One of the areas of application of the second law is the study of energy-conversion systems. For example, it is not possible to convert all the energy obtained from a nuclear reactor into electrical energy. There must be losses in the conversion process. The second law can be used to derive an expression for the maximum possible energy conversion efficiency taking those losses into account. Therefore, the second law denies the possibility of completely converting into work all of the heat supplied to a system operating in a cycle, no matter how perfectly designed the system may be. The concept of the second law is best stated using Max Planck's description: It is impossible to construct an engine that will work in a complete cycle and produce no other effect except the raising of a weight and the cooling of a heat reservoir.

The Second Law of Thermodynamics is needed because the First Law of Thermodynamics does not define the energy conversion process completely. The first law is used to relate and to evaluate the various energies involved in a process. However, no information about the direction of the process can be obtained by the application of the first law. Early in the development of the science of thermodynamics, investigators noted that while work could be converted completely into heat, the converse was never true for a cyclic process. Certain natural processes were also observed always to proceed in a certain direction (e.g., heat transfer occurs from a hot to a cold body). The second law was developed as an explanation of these natural phenomena.

1.24 Personnel shall demonstrate familiarity-level knowledge of basic heat transfer and fluid flow concepts and theories.

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

The ideal gas law can be used to determine how the properties of pressure, temperature, and volume will be related during compression processes.

$$Pv = R\ T$$

The ideal gas law is used by engineers working with gases because it is simple to use and approximates real gas behavior. Most physical conditions of gases used by man fit the above description. Perhaps the most common use of gas behavior studied by engineers is that of the compression process using ideal gas approximations. Such a compression process may occur at constant temperature (pV = constant), constant volume, or adiabatic (no heat transfer). Whatever the process, the amount of work that results from it depends on the process, as brought out in the discussion on the First Law of Thermodynamics. The compression process using ideal gas considerations results in work performed on the system and is essentially the area under a P-V curve. As can be seen in figure 13, different amounts of work result from different ideal gas processes, such as constant temperature and constant pressure.

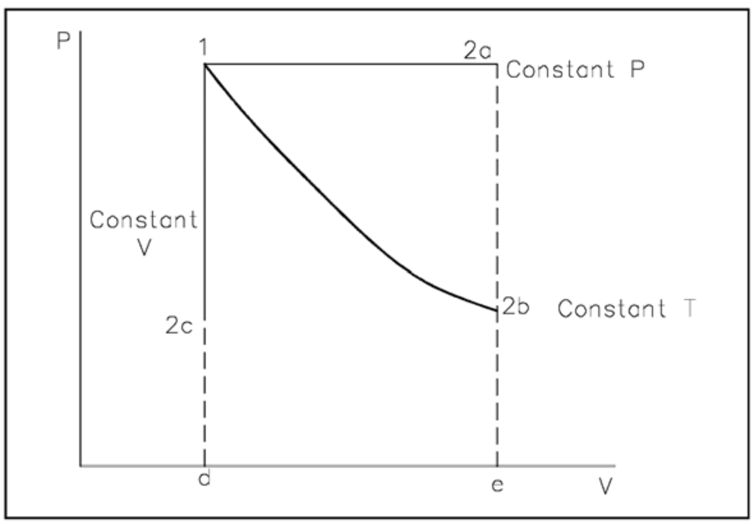


Figure 13. Pressure-volume diagram

b) Describe when a fluid may be considered to be incompressible.

Usually a fluid may be considered incompressible when the velocity of the fluid is greater than one-third of the speed of sound for the fluid, or if the fluid is a liquid. The treatment of a fluid that is considered incompressible is easy because the density is assumed to be constant, giving a simple relationship for the state of the substance. The variation of density of the fluid with changes in pressure is the primary factor considered in deciding whether a fluid is incompressible.

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

The predominant effect of an increase in pressure in a compressible fluid, such as a gas, is an increase in the density of the fluid. An increase in the pressure of an incompressible fluid will not have a significant effect on the density. For example, increasing the pressure of 100°F water from 15 psia to 15,000 psia will only increase the density by approximately 6%. Therefore, in engineering calculations, it is assumed that the density of incompressible fluids remains constant. An increase in temperature will tend to decrease the density of any fluid. If the fluid is confined in a container of fixed volume, the effect of a temperature change will depend on whether the fluid is compressible.

If the fluid is a gas, it will respond to a temperature change in a manner predicted by the ideal gas laws. A 5% increase in absolute temperature will result in a 5% increase in the absolute pressure.

If the fluid is an incompressible liquid in a closed container, an increase in the temperature will have a tremendously greater and potentially catastrophic effect. As the fluid temperature increases, it tries to expand, but expansion is prevented by the walls of the container. Because the fluid is incompressible, this results in a tremendous increase in pressure for a relatively minor temperature change. The change in specific volume for a given change in temperature is not the same at various beginning temperatures. Resultant pressure changes will vary. A useful thumb rule for water is that pressure in a water-solid system will increase about 100 psi for every 1°F increase in temperature.

d) Describe the difference between heat and temperature, and heat and work.

Heat is energy transferred as a result of a temperature difference. Temperature is a measure of the amount of molecular energy contained in a substance. It is a relative measure of how hot or cold a substance is, and can be used to predict the direction of heat transfer.

Work is a transfer of energy resulting from a force acting through a distance. Distinction should also be made between the energy terms heat and work. Both represent energy in transition. Work is the transfer of energy resulting from a force acting through a distance. Heat is energy transferred as the result of a temperature difference. Neither heat nor work is a thermodynamic property of a system. Heat can be transferred into or out of a system, and work can be done on or by a system, but a system cannot contain or store either heat or work. Heat into a system and work out of a system are considered positive quantities.

e) Describe the three modes of heat transfer.

Conduction involves the transfer of heat by the interactions of atoms or molecules of a material through which the heat is being transferred.

Convection involves the transfer of heat by the mixing and motion of macroscopic portions of a fluid.

Radiation, or radiant heat transfer, involves the transfer of heat by electromagnetic radiation that arises due to the temperature of a body.

f) Describe how the density of a fluid varies with temperature.

As the temperature of the fluid increases, the density decreases and the specific volume increases.

g) Define the term buoyancy.

Buoyancy is defined as the tendency of a body to float or rise when submerged in a fluid. We all have had numerous opportunities of observing the buoyant effects of a liquid. When we go swimming, our bodies are held up almost entirely by the water. Wood, ice, and cork float on water. When we lift a rock from a stream bed, it suddenly seems heavier on emerging from the water. Boats rely on this buoyant force to stay afloat. The amount of this buoyant effect was first computed and stated by the Greek philosopher Archimedes. When a body is placed in a fluid, it is buoyed up by a force equal to the weight of the water that it displaces.

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

Pressure can be measured with reference to the force that exists in a column of fluid at a certain height. The most common of these are inches of water, inches of mercury, millimeters of mercury, and microns of mercury. Conversion factors are listed below:
14.7 psia = 408 inches of water
14.7 psia = 29.9 inches of mercury
1 inch of mercury = 25.4 millimeters of mercury
1 millimeter of mercury = 10^3 microns of mercury

i) Define the terms mass flow rate and volumetric flow rate.

Mass Flow Rate

The mass flow rate (m) of a system is a measure of the mass of fluid passing a point in the system per unit time. The mass flow rate is related to the volumetric flow rate as shown in the equation below, where ρ is the density of the fluid and V is the volumetric flow rate.

$$m = \rho V$$

If the volumetric flow rate is in cubic feet per second and the density is in pounds-mass per cubic foot, the above equation results in mass flow rate measured in pounds-mass per second. Other common units for measurement of mass flow rate include kilograms per second and pounds-mass per hour.

Volumetric Flow Rate

The volumetric flow rate (V) of a system is a measure of the volume of fluid passing a point in the system per unit time. The volumetric flow rate can be calculated as the product of the cross-sectional area (A) for flow and the average flow velocity (v).

$$V = Av$$

If area is measured in square feet and velocity in feet per second, the above equation results in volumetric flow rate measured in cubic feet per second. Other common units for volumetric flow rate include gallons per minute, cubic centimeters per second, liters per minute, and gallons per hour.

j) Describe the characteristics and flow velocity profiles of laminar flow and turbulent flow.

All fluid flow is classified into one of two broad categories or regimes. These two flow regimes are laminar flow and turbulent flow. The flow regime, whether laminar or turbulent, is important in the design and operation of any fluid system. The amount of fluid friction, which determines the amount of energy required to maintain the desired flow, depends upon the mode of flow. This is also an important consideration in certain applications that involve heat transfer to the fluid.

Laminar Flow

Laminar flow is also referred to as streamline or viscous flow. These terms are descriptive of the flow because, in laminar flow, (1) layers of water flow over one another at different speeds with virtually no mixing between layers, (2) fluid particles move in definite and observable paths or streamlines, and (3) the flow is characteristic of viscous (thick) fluid or is one in which viscosity of the fluid plays a significant part.

Turbulent Flow

Turbulent flow is characterized by the irregular movement of particles of the fluid. There is no definite frequency as there is in wave motion. The particles travel in irregular paths with no observable pattern and no definite layers.

k) Define the property of viscosity.

Viscosity is a fluid property that measures the resistance of the fluid to deforming due to a shear force. Viscosity is the internal friction of a fluid that makes it resist flowing past a solid surface or other layers of the fluid. Viscosity can also be considered to be a measure of the resistance of a fluid to flowing. Thick oil has a high viscosity; water has a low viscosity.

l) Define the terms head, head loss, and frictional loss, with respect to their use in fluid flow.

Head

The term head is used by engineers in reference to pressure. It is a reference to the height, typically in feet, of a column of water that a given pressure will support. Each of the energies possessed by a fluid can be expressed in terms of head. The elevation head represents the potential energy of a fluid due to its elevation above a reference level. The velocity head represents the kinetic energy of the fluid. It is the height in feet that a flowing fluid would rise in a column if all of its kinetic energy were converted to potential energy. The pressure head represents the flow energy of a column of fluid whose weight is equivalent to the pressure of the fluid. The sum of the elevation head, velocity head, and pressure head of a fluid is called the total head. Thus, Bernoulli's equation states that the total head of the fluid is constant.

Head Loss

Head loss is a measure of the reduction in the total head (sum of elevation head, velocity head, and pressure head) of the fluid as it moves through a fluid system. Head loss is unavoidable in real fluids. It is present because of: the friction between the fluid and the walls of the pipe; the friction between adjacent fluid particles as they move relative to one another; and the turbulence caused whenever the flow is redirected or affected in any way by such components as piping entrances and exits, pumps, valves, flow reducers, and fittings.

Frictional Loss

Frictional loss is that part of the total head loss that occurs as the fluid flows through straight pipes. The head loss for fluid flow is directly proportional to the length of pipe, the square of the fluid velocity, and a term accounting for fluid friction called the friction factor. The head loss is inversely proportional to the diameter of the pipe.

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

Water Hammer

Water hammer is a liquid shock wave resulting from the sudden starting or stopping of flow. It is affected by the initial system pressure, the density of the fluid, the speed of sound in the fluid, the elasticity of the fluid and pipe, the change in velocity of the fluid, the diameter and thickness of the pipe, and the valve operating time.

During the closing of a valve, kinetic energy of the moving fluid is converted into potential energy. The elasticity of the fluid and pipe wall produces a wave of positive pressure back toward the fluid's source. When this wave reaches the source, the mass of fluid will be at rest, but under tremendous pressure. The compressed liquid and stretched pipe walls will now start to release the liquid in the pipe back to the source and return to the static pressure of the source. This release of energy will form another pressure wave back to the valve. When this shockwave reaches the valve, due to the momentum of the fluid, the pipe wall will begin to contract. This contraction is transmitted back to the source, which places the pressure in the piping below that of the static pressure of the source. These pressure waves will travel back and forth several times until the fluid friction dampens the alternating pressure waves to the static pressure of the source. Normally, the entire hammer process takes place in under one second.

The initial shock of suddenly stopped flow can induce transient pressure changes that exceed the static pressure. If the valve is closed slowly, the loss of kinetic energy is gradual. If it is closed quickly, the loss of kinetic energy is very rapid. A shock wave results because of this rapid loss of kinetic energy. The shock wave caused by water hammer can be of sufficient magnitude to cause physical damage to piping, equipment, and personnel. Water hammer in pipes has been known to pull pipe supports from their mounts, rupture piping, and cause pipe whip.

Pressure Spike

A pressure spike is the resulting rapid rise in pressure above static pressure caused by water hammer. The highest pressure spike attained will be at the instant the flow changed and is governed by the following equation:

$$\Delta P = \frac{\rho c \Delta v}{g_c}$$

where:
ΔP = pressure spike
ρ = density of the fluid
c = velocity of the pressure wave
Δv = change in velocity of the fluid
g_c = gravitational constant 32.17

Steam Hammer

Steam hammer is similar to water hammer except it occurs in a steam system. Steam hammer is a gaseous shock wave resulting from the sudden starting or stopping of flow. Steam hammer is not as severe as water hammer for three reasons:

- The compressibility of the steam dampens the shock wave.
- The speed of sound in steam is approximately one third the speed of sound in water.
- The density of steam is approximately 1600 times less than that of water.
- The items of concern that deal with steam piping are thermal shock and water slugs (i.e., condensation in the steam system) as a result of improper warm up.

1.25 Personnel shall demonstrate familiarity-level knowledge of basic material science in the areas of concepts, theories, and principles.

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

The five types of bonding and their characteristics are as follows:

- Ionic bond. In an ionic bond, an atom with one or more electrons is wholly transferred from one element to another, and the elements are held together by the force of attraction due to the opposite polarity of the charge.
- Covalent bond. In a covalent bond, an atom that needs electrons to complete its outer shell shares those electrons with its neighbor.
- Metallic bond. In a metallic bond, the atoms do not share or exchange electrons to bond together. Instead, many electrons (roughly one for each atom) are more or less free to move throughout the metal, so that each electron can interact with many of the fixed atoms.
- Molecular bond. In a molecular bond, when neutral atoms undergo shifting in centers of their charge, they can weakly attract other atoms with displaced charges. This is sometimes called the Van Der Waals bond.
- Hydrogen bond. The hydrogen bond is similar to the molecular bond and occurs due to the ease with which hydrogen atoms displace their charge.

b) Describe the characteristics of the following crystal structures:

- **Body-centered cubic structure**
- **Face-centered cubic structure**
- **Hexagonal close-packed structure**

Body-Centered Cubic Structure

In a body-centered cubic (BCC) arrangement of atoms, the unit cell consists of eight atoms at the corners of a cube and one atom at the body center of the cube.

Face-Centered Cubic Structure

In a face-centered cubic (FCC) arrangement of atoms, the unit cell consists of eight atoms at the corners of a cube and one atom at the center of each of the faces of the cube.

Hexagonal Close-Packed Structure

In a hexagonal close-packed (HCP) arrangement of atoms, the unit cell consists of three layers of atoms. The top and bottom layers contain six atoms at the corners of a hexagon and one atom at the center of each hexagon. The middle layer contains three atoms nestled between the atoms of the top and bottom layers, hence, the name close-packed.

c) Identify and describe the crystalline structure of a metal.

Metals containing BCC structures include ferrite, chromium, vanadium, molybdenum, and tungsten. These metals possess high strength and low ductility. Metals containing FCC structures include austenite, aluminum, copper, lead, silver, gold, nickel, platinum, and thorium. These metals possess low strength and high ductility. Metals containing HCP structures include beryllium, magnesium, zinc, cadmium, cobalt, thallium, and zirconium. HCP metals are not as ductile as FCC metals.

d) Define the following terms:

- **Grain structure**
- **Creep**
- **Polymorphism**
- **Grain boundary**
- **Alloy**
- **Grain**

Grain Structure

Grain structure is the arrangement of grains in a metal, with a grain having a particular crystal structure.

Creep

Creep is the permanent deformation that increases with time under constant load or stress.

Polymorphism

Polymorphism is the property or ability of a metal to exist in two or more crystalline forms depending on temperature and composition. Most metals and metal alloys exhibit this property.

Grain Boundary

Grain boundary is the outside area of grain that separates it from other grains.

Alloy

An alloy is a mixture of two or more materials, at least one of which is a metal. Alloys can have a microstructure consisting of solid solutions, where secondary atoms are introduced as substitutionals or interstitials in a crystal lattice. An alloy might also be a crystal with a metallic compound at each lattice point. In addition, alloys may be composed of secondary crystals imbedded in a primary polycrystalline matrix. This type of alloy is called a composite (although the term composite does not necessarily imply that the component materials are metals).

Grain

Grain is the region of space occupied by a continuous crystal lattice.

e) Describe the three possible alloy microstructures and their two main characteristics as compared to pure metals.

Alloy microstructures include the following:

- Solid solutions, where secondary atoms are introduced as substitutionals or interstitials in a crystal lattice
- Crystal with metallic bonds
- Composites, where secondary crystals are imbedded in a primary polycrystalline matrix

Alloys are usually stronger than pure metals, but alloys generally have lower electrical and thermal conductivities than pure metals.

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

There are nearly 40 standard types of stainless steel and many other specialized types under various trade names. Through the modification of the kinds and quantities of alloying elements, the steel can be adapted to specific applications. Stainless steels are classified as austenitic or ferritic based on their lattice structure. Austenitic stainless steels, including 304 and 316, have a face-centered cubic structure of iron atoms with the carbon in interstitial solid solution. Ferritic stainless steels, including type 405, have a body-centered cubic iron lattice and contain no nickel.

Ferritic steels are easier to weld and fabricate and are less susceptible to stress corrosion cracking than austenitic stainless steels. They have only moderate resistance to other types of chemical attack.

g) Identify the three types of microscopic imperfections found in crystalline structures.

Microscopic imperfections are generally classified as point, line, or interfacial imperfections.

- Point imperfections have atomic dimensions, and are in the size range of individual atoms.
- Line imperfections or dislocations are generally many atoms in length. They can be of the edge type, screw type, or mixed type, depending on lattice distortion. Line imperfections cannot end inside a crystal; they must end at crystal edge or other dislocation, or close back on themselves.
- Interfacial imperfections are larger than line imperfections and occur over a two-dimensional area. Interfacial imperfections exist at free surfaces, domain boundaries, grain boundaries, or inter-phase boundaries.

h) Discuss the following terms:
- **Compressibility**
- **Stress**
- **Shear stress**
- **Tensile stress**
- **Compressive stress**

Compressibility

Compressibility is the ability of a material to react to compressive stress or pressure.

Stress

Stress is an applied force (or system of forces) that tends to strain or deform a body.

Shear Stress

Shear stress exists when two parts of a material tend to slide across each other in any typical plane of shear upon application of force parallel to that plane.

Tensile Stress

Tensile stress is a type of stress in which the two sections of material on either side of a stress plane tend to pull apart or elongate.

Compressive Stress

Compressive stress is the reverse of tensile stress; adjacent parts of the material tend to press against each other through a typical stress plane.

i) Define the following terms:
- **Strain**
- **Proportional limit**
- **Plastic deformation**

Strain

Strain is the proportional dimensional change, or the intensity or degree of distortion, in a material under stress.

Proportional Limit

Proportional limit is the amount of stress just before the point (threshold) at which plastic strain begins to appear, or the stress level and the corresponding value of elastic strain.

Plastic Deformation
Plastic deformation is the dimensional change that does not disappear when the initiating stress is removed.

j) Identify the two common forms of strain and discuss the differences.

Elastic strain is a transitory dimensional change that exists only while the initiating stress is applied and disappears immediately upon removal of the stress.

Plastic strain (plastic deformation) is a dimensional change that does not disappear when the initiating stress is removed.

k) Discuss Hooke's Law.

If a metal is lightly stressed, a temporary deformation takes place, presumably permitted by an elastic displacement of the atoms in the space lattice; removal of the stress results in a gradual return of the metal to its original shape and dimensions. Hooke provided data that showed that in the elastic range of a material, strain is proportional to stress. The elongation of the bar is directly proportional to the tensile force and the length of the bar and inversely proportional to the cross-sectional area and the modulus of elasticity.

l) Discuss what is meant by the terms bulk modulus and fracture point.

The bulk modulus of elasticity is the elastic response to hydrostatic pressure and equilateral tension or the volumetric response to hydrostatic pressure and equilateral tension. It is also the property of a material that determines the elastic response to the application of stress.

Fracture point is the point where the material fractures due to plastic deformation.

m) Given 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**

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

n) Discuss the following terms:
- **Strength**
- **Malleability**
- **Ductility**
- **Toughness**
- **Yield Strength**
- **Hardness**
- **Ultimate Tensile Strength**

Strength

Strength is the ability of a material to resist deformation. An increase in slip will decrease the strength of a material.

Malleability

Malleability is the ability of a metal to exhibit large deformation or plastic response when being subjected to compressive force.

Ductility

Ductility is the ability of a material to deform easily upon the application of a tensile force, or the ability of a material to withstand plastic deformation without rupture. An increase in temperature will increase ductility. Ductility decreases with lower temperatures, cold working, and irradiation. Ductility is desirable in high-temperature and high-pressure applications.

Toughness

Toughness describes how a material reacts under sudden impacts. It is defined as the work required to deform one cubic inch of metal until it fractures.

Yield Strength

Yield strength is the stress at which a predetermined amount of permanent deformation occurs.

Hardness

Hardness is the property of a material that enables it to resist plastic deformation, penetration, indentation, and scratching.

Ultimate Tensile Strength

Ultimate tensile strength is the maximum resistance to fracture.

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

Welding can induce internal stresses that will remain in the material after the welding is completed. In stainless steels, such as type 304, the crystal lattice is face-centered cubic (austenite). During high-temperature welding, some surrounding metal may be elevated to between 500°F and 1000°F. In this temperature region, the austenite is transformed into a body centered cubic lattice structure (bainite). When the metal has cooled, regions surrounding the weld contain some original austenite and some newly formed bainite. A problem arises because the "packing factor" (PF = volume of atoms/volume of unit cell) is not the same for FCC crystals as for BCC crystals; the bainite that has been formed occupies more space than the original austenite lattice. This elongation of the material causes residual compressive and tensile stresses in the material. Welding stresses can be minimized by using heat sink welding, which results in lower metal temperatures, and by annealing.

p) Discuss the phenomenon of thermal shock.

Thermal shock can lead to excessive thermal gradients on materials, which lead to excessive stresses. These stresses can be comprised of tensile stress, which is stress arising from forces acting in opposite directions tending to pull a material apart, and compressive stress, which is stress arising from forces acting in opposite directions tending to push a material together. These stresses, cyclic in nature, can lead to fatigue failure of the materials. Thermal shock is caused by non-uniform heating or cooling of a uniform material, or uniform heating of non-uniform materials. Suppose a body is heated and constrained so that it cannot expand. When the temperature of the material increases, the increased activity of the molecules causes them to press against the constraining boundaries, thus setting up thermal stresses.

q) Discuss the following terms and discuss their relationship to material failure:

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

Ductile Fracture

Metals can fail by ductile or brittle fracture. Metals that can sustain substantial plastic strain or deformation before fracturing exhibit ductile fracture. Usually, a large part of the plastic flow is concentrated near the fracture faces.

Brittle Fracture

Metals that fracture with a relatively small or negligible amount of plastic strain exhibit brittle fracture. Cracks propagate rapidly. Brittle failure results from cleavage (splitting along definite planes). Ductile fracture is better than brittle fracture because ductile fracture occurs over a period of time, where as brittle fracture is fast and can occur (with flaws) at lower stress levels than a ductile fracture.

Nil-Ductility Transition (NDT) Temperature

The NDT temperature, which is the temperature at which a given metal changes from ductile to brittle fracture, is often markedly increased by neutron irradiation. The increase in the NDT temperature is one of the most important effects of irradiation from the standpoint of nuclear power system design.

r) Discuss the phenomenon of brittle fracture.

Brittle fracture is exhibited when metals fracture with a relatively small or negligible amount of plastic strain. Cracks propagate rapidly. Brittle failure results from cleavage (splitting along definite planes). Ductile fracture is better than brittle fracture, because ductile fracture occurs over a period of time, where as brittle fracture is fast, and can occur (with flaws) at lower stress levels than a ductile fracture.

Brittle cleavage fracture is of great concern. Brittle cleavage fracture occurs in materials with a high strain-hardening rate and relatively low cleavage strength or great sensitivity to multi-axial stress.

Many metals that are ductile under some conditions become brittle if the conditions are altered. The effect of temperature on the nature of the fracture is of considerable importance. Many steels exhibit ductile fracture at elevated temperatures and brittle fracture at low temperatures.

s) Explain fatigue failure and work hardening with respect to material failure.

The majority of engineering failures are caused by fatigue. Fatigue failure is defined as the tendency of a material to fracture by means of progressive brittle cracking under repeated alternating or cyclic stresses of an intensity considerably below the normal strength. Although the fracture is of a brittle type, it may take some time to propagate, depending on the intensity and frequency of the stress cycles. Nevertheless, there is very little, if any, warning before failure if the crack is not noticed. The number of cycles required to cause fatigue failure at a particular peak stress is generally quite large, but it decreases as the stress is increased. For some mild steels, cyclical stresses can be continued indefinitely provided the peak stress (sometimes called fatigue strength) is below the endurance limit value.

A good example of fatigue failure is breaking a thin steel rod or wire with your hands after bending it back and forth several times in the same place. Another example is an unbalanced pump impeller resulting in vibrations that can cause fatigue failure.

t) Discuss the affects of the following types of radiation on the structural integrity of metals.

- **Alpha**
- **Beta**
- **Gamma**
- **Fast neutron**
- **Slow neutron**

Beta and gamma radiation produce ionization and excitation of electrons, which does very little damage. Heavier particles, such as protons, α-particles, fast neutrons, slow neutrons, and fission fragments, usually transfer energy through elastic or inelastic collisions to cause radiation damage. These particles in organic material break the chemical bonds, which will change the material's properties.

1.26 Personnel shall demonstrate a working-level knowledge of engineering prints and drawings.

a) Given an engineering print, read and interpret the following information:

- **Title block**
- **Notes**
- **Legend**
- **Revision block**
- **Drawing grid**

b) Given an engineering piping and instrument drawing, identify the symbols used for:

- **Types of valves**
- **Types of valve operators**
- **Types of eductors 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 on engineering P&IDs 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) Given a fluid power type drawing, determine the operation or resultant action of the stated component when hydraulic pressure is applied/removed.

These are performance-based competencies. The qualifying official will evaluate the completion of these competencies. Information related to engineering drawings is available in DOE-HDBK-1016-93, volumes 1 and 2.

1.27 Personnel shall demonstrate a working-level knowledge of electrical prints, diagrams and schematics.

a) Identify the symbols used on engineering electrical drawings.

b) Identify the symbols and/or codes used on engineering electrical drawings to depict the relationship between components.

These are performance-based competencies. The qualifying official will evaluate the completion of these competencies. Information related to engineering drawings is available in DOE-HDBK-1016-93, volumes 1 and 2.

c) State the condition in which all electrical devices are shown, unless otherwise noted on the diagram or schematic.

For electrical schematics that detail individual relays and contacts, the components are always shown in the de-energized condition (also called the shelfstate).

d) Given a simple electrical schematic and initial conditions, identify the power sources and/or loads and their status.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

1.28 Personnel shall demonstrate a working level-knowledge of electronic/logic block diagrams, prints, and schematics.

a) Identify basic component symbols and explain their functions.

Some common electronic component symbols are shown in figures 14 and 15.

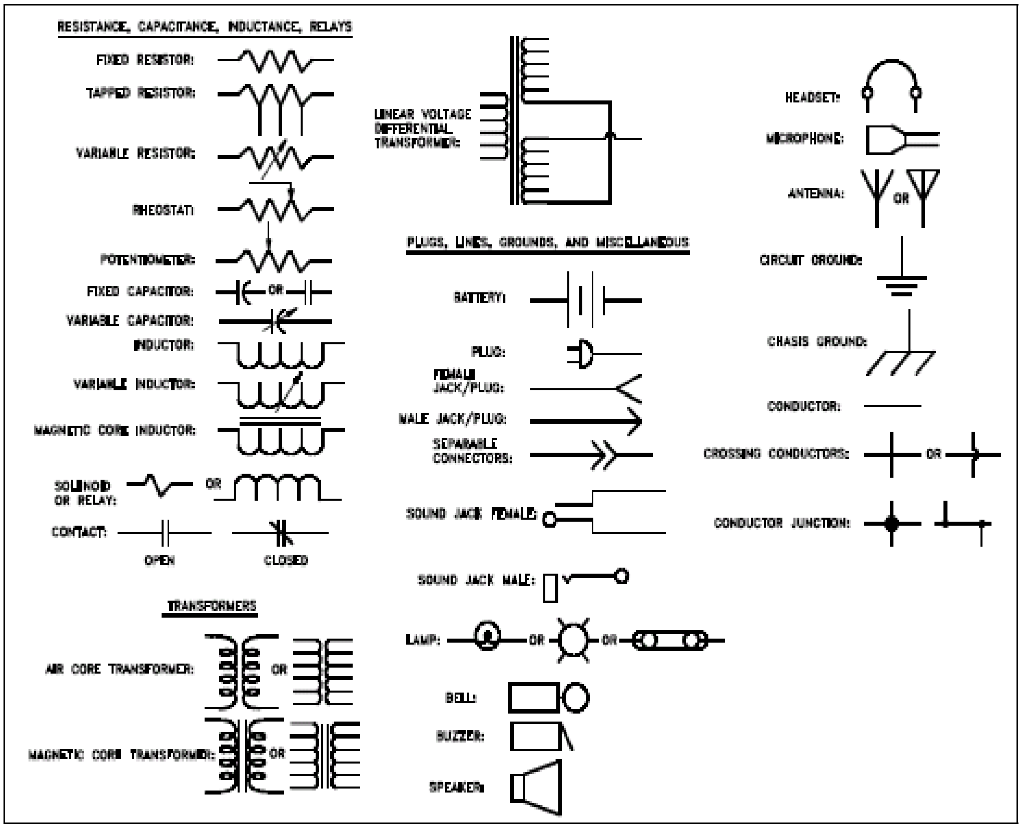


Figure 14. Electronic symbols

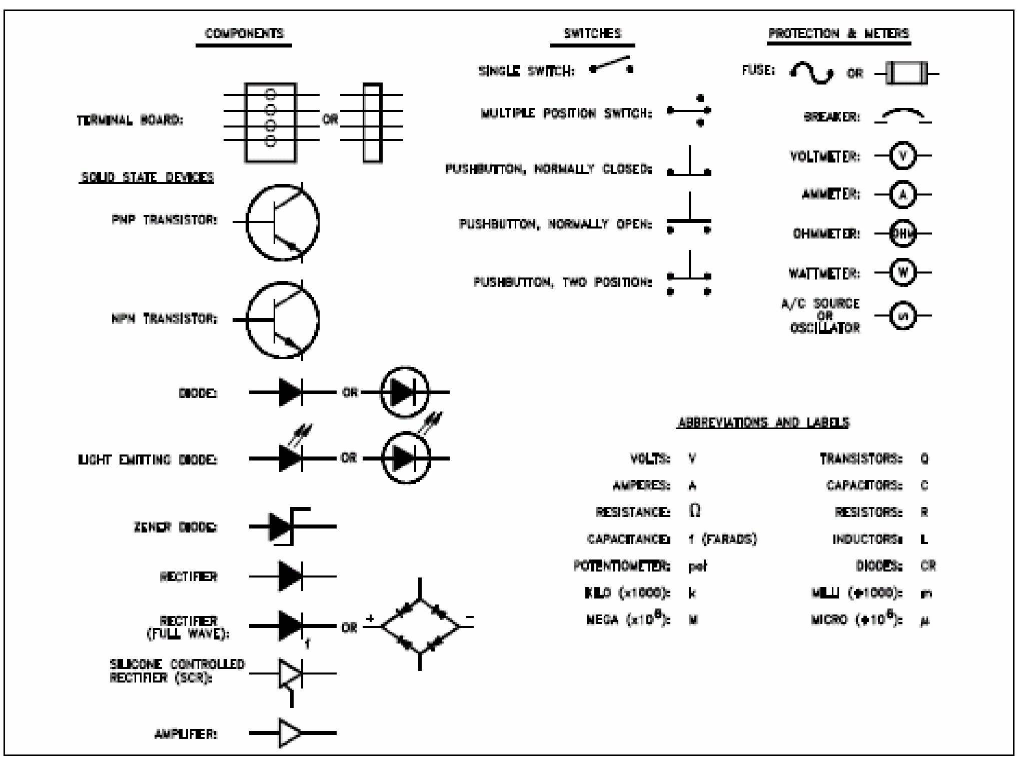


Figure 15. Electronic symbols (continued)

b) Identify the symbols used on logic diagrams to represent the components.

Figure 16 illustrates the symbols covering the three basic logic gates plus NAND and NOR gates. The IEEE/ANSI symbols are used most often; however, other symbol conventions are provided for information.

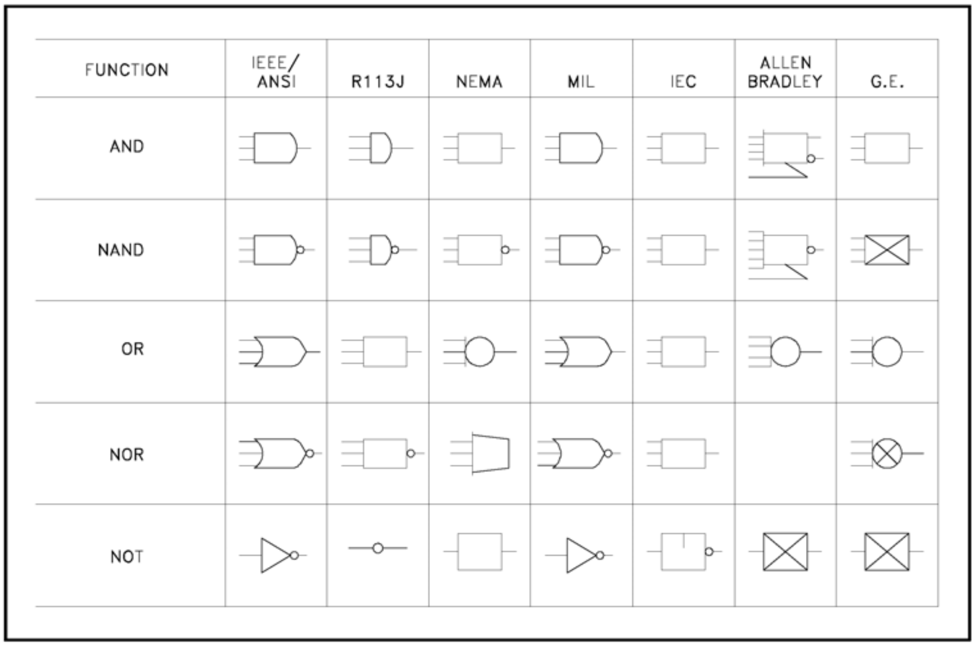


Figure 16. Basic logic symbols

In addition to the seven basic logic gates, there are several complex logic devices that may be encountered in the use of logic prints.

Memory Devices

In many circuits, a device that can remember the last command or the last position is required for a circuit to function. Like the AND and OR gates, memory devices have been designed to work with on/off signals. The two input signals to a memory device are called set and reset. Figure 17 shows the common symbols used for memory devices.

Flip-Flop

As the name implies, a flip-flop is a device in which as one or more of its inputs changes, the output changes. A flip-flop is a complex circuit constructed from OR and NOT gates, but is used so frequently in complex circuits that it has its own symbol. Figure 17 shows the common symbol used for a flip-flop. This device, although occasionally used on component and system type logic diagrams, is principally used in solid state logic diagrams (computers).

Binary Counter

Several types of binary counters exist, all of which are constructed of flip-flops. The purpose of a counter is to allow a computer to count higher than 1, which is the highest number a single flip-flop can represent. By ganging flip-flops, higher binary numbers can be constructed. Figure 17 illustrates a common symbol used for a binary counter.

Shift Register

A shift register is a storage device constructed of flip-flops that is used in computers to provide temporary storage of a binary word. Figure 17 shows the common symbol used for a shift register.

Half Adder

A half adder is a logic circuit that is used in computer circuits to allow the computer to carry numbers when it is performing mathematical operations (for example to perform the addition of 9 + 2, a single 10s unit must be carried from the ones column to the tens column). Figure 17 illustrates the symbol used for a half adder.

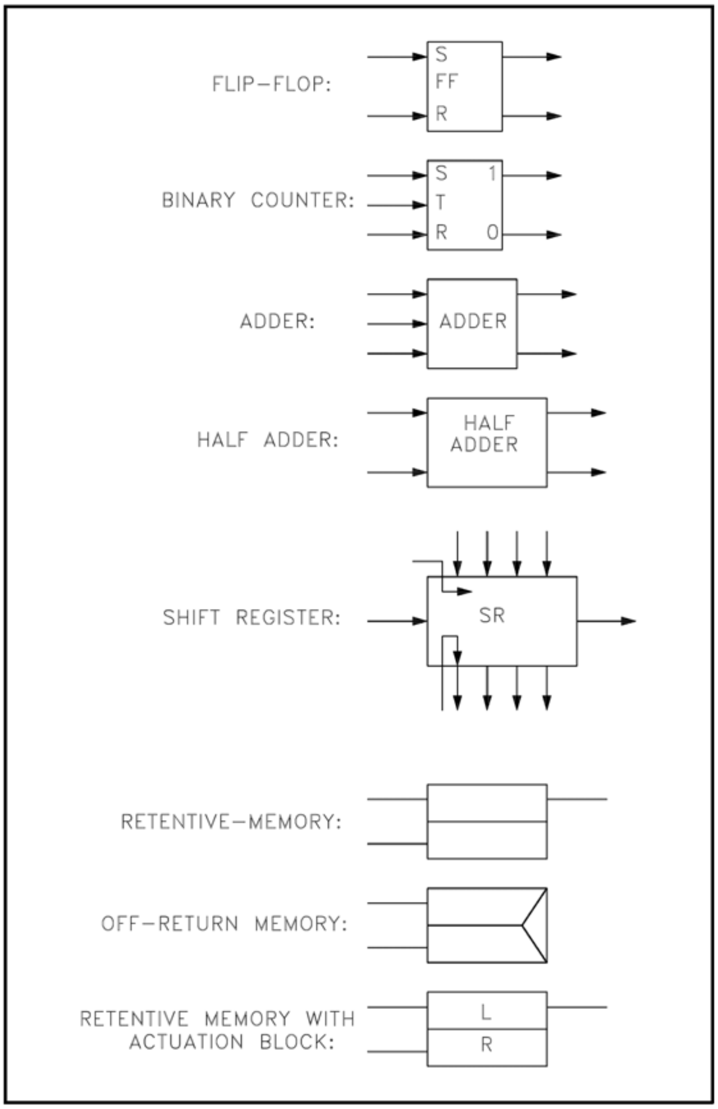


Figure 17. Symbols for complex logic devices

c) Explain the operation of the three types of time delay devices.

When logic diagrams are used to represent start/stop/operate circuits, the diagrams must also be able to symbolize the various timing devices found in the actual circuits. There are three major types of timers. They are (1) the type-one time delay device, (2) the type-two time delay device, and (3) the type-three time delay device.

Upon receipt of the input signal, the type-one time delay device delays the output (on) for the specified period of time, but the output will stop (off) as soon as the input signal is removed.

The type-two time delay device provides an output signal (on) immediately upon receipt of the input signal, but the output is maintained only for a specified period of time once the input signal (off) has been removed.

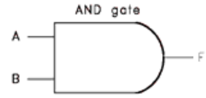
Upon receipt of an input signal, the type-three time delay devices provide an output signal for a specified period of time, regardless of the duration of the input.

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

There are three basic types of logic gates (see figure 18). They are AND, OR, and NOT gates. Each gate is a very simple device that only has two states, on and off. The states of a gate are also commonly referred to as high or low, 1 or 0, or true or false, where on = high = 1 = true, and off = low = 0 = false. The state of the gate, also referred to as its output, is determined by the status of the inputs to the gate, with each type of gate responding differently to the various possible combinations of inputs. Specifically, these combinations are as follows:

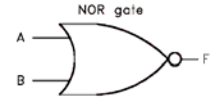
- The AND gate provides an output (on) when all its inputs are on. When any one of the inputs is off, the gate's output is off.
- The OR gate provides an output (on) when any one or more of its inputs is on. The gate is off only when all of its inputs are off.
- The NOT gate provides a reversal of the input. If the input is on, the output will be off. If the input is off, the output will be on. Because the NOT gate is frequently used in conjunction with AND and OR gates, special symbols have been developed to represent these combinations. The combination of an AND gate and a NOT gate is called a NAND gate. The combination of an OR gate with a NOT gate is called a NOR gate.
- The NAND gate is the opposite (NOT) of an AND gate's output. It provides an output (on) except when all the inputs are on.
- The NOR gate is the opposite (NOT) of an OR gate's output. It provides an output only when all inputs are off.
- EXCLUSIVE OR provides an output (on) when only one of the inputs is on. Any other combination results in no output (off).
- EXCLUSIVE NOR is the opposite (NOT) of an EXCLUSIVE OR gate's output. It provides an output only when all inputs are on or when all inputs are off.

AND gate



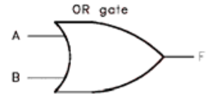
INPUT		OUTPUT
A	B	F
0	0	0
0	1	0
1	0	0
1	1	1

NOR gate



INPUT		OUTPUT
A	B	F
0	0	1
0	1	0
1	0	0
1	1	0

OR gate

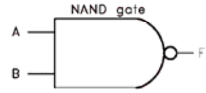


INPUT		OUTPUT
A	B	F
0	0	0
0	1	1
1	0	1
1	1	1

EXCLUSIVE OR

INPUT		OUTPUT
A	B	C
0	0	0
0	1	1
1	0	1
1	1	0

NAND gate

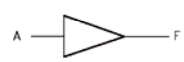


INPUT		OUTPUT
A	B	F
0	0	1
0	1	1
1	0	1
1	1	0

EXCLUSIVE NOR

INPUT		OUTPUT
A	B	C
0	0	1
0	1	0
1	0	0
1	1	1

NOT gate



INPUT	OUTPUT
A	F
0	1
1	0

Figure 18. Truth tables

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

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

1.29 Personnel shall demonstrate a working-level knowledge of engineering fabrication, construction, and architectural drawings.

a) Given one of each of the above drawings, read and interpret:

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

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

1.30 Personnel shall demonstrate familiarity-level knowledge of lasers in the area of safety.

a) Describe principle hazards associated with non-ionizing radiation.

Nonbeam Laser Hazards

Industrial hygiene. Potential hazards associated with compressed gases, cryogenic materials, toxic and carcinogenic materials, and noise should be considered. Adequate ventilation shall be installed to reduce noxious or potentially hazardous fumes and vapors, produced by laser welding, cutting and other target interactions, to levels below the appropriate threshold limit values, e.g., American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs) or Occupational Safety and Health Administration's (OSHA) permissible exposure limits (PELs).

Explosion hazards. High-pressure arc lamps and filament lamps or laser welding equipment shall be enclosed in housings that can withstand the maximum pressures resulting from lamp explosion or disintegration. The laser target and elements of the optical train, which may shatter during laser operation, shall also be enclosed.

Nonbeam optical radiation hazards. This relates to optical beam hazards other than laser beam hazards. Ultraviolet radiation emitted from laser discharge tubes, pumping lamps, and laser-welding plasmas shall be suitably shielded to reduce exposure to levels below the ANSI Z 136.1 (extended source), OSHA PELs, and/or ACGIH TLVs.

Collateral radiation. Radiation (other than laser radiation) associated with the operation of a laser or laser system (e.g., radio frequency [RF] energy associated with some plasma tubes, x-ray emission associated with the high-voltage power supplies used with excimer lasers) shall be maintained below the applicable protection guides. Lasers and laser systems that, by design, would be expected to generate appreciable levels of collateral radiation should be monitored.

Electrical hazards. The intended application of the laser equipment determines the method of electrical installation and connection to the power supply circuit (for example, conduit versus flexible cord).

Flammability of laser beam enclosures. Enclosure of Class IV laser beams and terminations of some focused Class IIIB lasers can result in potential fire hazards if the enclosure materials are exposed to irradiances exceeding 10 W/cm2. Plastic materials are not precluded as an enclosure material, but their use and potential for flammability and toxic fume release following direct exposure should be considered. Flame-resistant materials and commercially available products specifically designed for laser enclosures should also be considered.

Biological Effects of Laser Beams

Eye injury. Because of the high degree of beam collimation, a laser serves as an almost ideal point source of intense light. A laser beam of sufficient power can theoretically produce retinal intensities at magnitudes that are greater than conventional light sources, and even larger than those produced when directly viewing the sun. Permanent blindness can be the result.

Thermal injury. The most common cause of laser-induced tissue damage is thermal in nature, where the tissue proteins are denatured due to the temperature rise following absorption of laser energy.

The thermal damage process (burns) is generally associated with lasers operating at exposure times greater than 10 microseconds and in the wavelength region from the near ultraviolet to the far infrared. Tissue damage may also be caused by thermally induced acoustic waves following exposures to sub-microsecond laser exposures.

With regard to repetitively pulsed or scanning lasers, the major mechanism involved in laser-induced biological damage is a thermal process wherein the effects of the pulses are additive.

The principal thermal effects of laser exposure depend on the following factors:

- Absorption and scattering coefficients of the tissues at the laser wavelength
- Irradiance or radiant exposure of the laser beam
- Duration of the exposure and pulse repetition characteristics, where applicable
- Extent of the local vascular flow
- Size of the area irradiated

Other Hazards

Other damage mechanisms have also been demonstrated for other specific wavelength ranges and/or exposure times. For example, photochemical reactions are the principal cause of threshold level tissue damage following exposures to either actinic ultraviolet radiation for any exposure time or blue light visible radiation when exposures are greater than 10 seconds.

To the skin, UV-A can cause hyperpigmentation and erythema.

Exposure in the UV-B range is most injurious to skin. In addition to thermal injury caused by ultraviolet energy, there is the possibility of radiation carcinogenesis from UV-B either directly on DNA or from effects on potential carcinogenic intracellular viruses.

Exposure in the shorter UV-C and the longer UV-A ranges seems less harmful to human skin. The shorter wavelengths are absorbed in the outer dead layers of the epidermis, and the longer wavelengths have an initial pigment-darkening effect followed by erythema if there is exposure to excessive levels.

The hazards associated with skin exposure are of less importance than eye hazards; however, with the expanding use of higher-power laser systems, particularly ultraviolet lasers, the unprotected skin of personnel may be exposed to extremely hazardous levels of the beam power if used in an unenclosed system design.

Note: The primary purpose of an exiting laser beam (e.g., cutting or welding of hard materials) must not be forgotten! Some laser beams designed for material alteration may be effective some distance from their intended impact point.

b) Describe types and classifications of lasers (ANSI Z136.1-2000).

The laser medium can be a solid (state), gas, dye (in liquid), or semiconductor. The type of lasing material employed commonly designates lasers.

Laser Types

Solid state. Solid state lasers have lasing material distributed in a solid matrix, e.g., the ruby or neodymium-YAG (yttrium aluminum garnet) lasers.

Gas. Gas lasers (helium and helium-neon are the most common gas lasers) have a primary output of a visible red light. CO2 lasers emit energy in the far infrared and are used for cutting hard materials.

Excimer. Excimer lasers use reactive gases such as chlorine and fluorine mixed with inert gases such as argon, krypton, or xenon. When electrically stimulated, a pseudomolecule or dimer is produced and when lased, produces light in the ultraviolet range.

Dye. Dye lasers use complex organic dyes like rhodamine 6G in liquid solutions or suspensions as lasing media. They are tunable over a broad range of wavelengths.

Semiconductor. Semiconductor lasers, sometimes called diode lasers, are not solid-state lasers. These electronic devices are generally very small and use low power. They may be built into larger arrays, such as the writing source in some laser printers or compact disk players.

Laser Classifications

Lasers and laser systems are assigned one of four broad classes (I to IV) depending on the potential for causing biological damage.

Class I. Class I lasers cannot emit laser radiation at known hazard levels (typically continuous wave). Users of Class I laser products are generally exempt from radiation hazard controls during operation and maintenance (but not necessarily during service). Since lasers are not classified on beam access during service, most Class I industrial lasers will consist of a higher-class (high power) laser enclosed in a properly interlocked and labeled protective enclosure. In some cases, the enclosure may be a room (walk-in protective housing) that requires a means to prevent operation when operators are inside the room.

Class IA. Class IA is a special designation that is based upon a 1000-second exposure and applies only to lasers that are not intended for viewing such as a supermarket laser scanner. The emission from a Class IA laser is defined such that the emission does not exceed the Class I limit for emission duration of 1000 seconds.

Class II. Class II lasers are low-power visible lasers that emit above Class I levels but at a radiant power not above 1 mW. The concept is that the human aversion reaction to bright light will protect a person. Only limited controls are specified.

Class IIIA. Class IIIA lasers are intermediate power lasers and are only hazardous for intra-beam viewing. Some limited controls are usually recommended.

Class IIIB. Class IIIB lasers are moderate-power lasers. In general, Class IIIB lasers will not be a fire hazard nor are they generally capable of producing a hazardous diffuse reflection. Specific controls are recommended.

Class IV. Class IV lasers are high-power lasers that are hazardous to view under any condition (directly or diffusely scattered) and are a potential fire hazard and a skin hazard. Significant controls are required of Class IV laser facilities.

c) Describe engineering controls and use of personnel protective equipment for laser safety.

- **Laser Control Area**
- **Protective housing, barriers and curtains**
- **Beam attenuators and stops**
- **Interlocks**
- **Key control**
- **Eyewear**

Important in all controls is the distinction between the functions of operation, maintenance, and service. First, laser systems are classified on the basis of the level of the laser radiation accessible during operation. Maintenance is defined as those tasks specified in the user instructions for assuring the performance of the product, and may include items such as routine cleaning or replenishment of expendables. Service functions are usually performed with far less frequency than maintenance functions (e.g., replacing the laser resonator mirrors or repair of faulty components) and often require access to the laser beam by those performing the service functions. The safety procedures required for such beam access during service functions should be clearly delineated in the laser product's service manual.

Laser Control Area

When the entire beam path from a Class IIIB or Class IV laser is not sufficiently enclosed and/or baffled to ensure that radiation exposures will not exceed the maximum permissible exposure (MPE), a laser-controlled area is required. During periods of service, a controlled area may be established on a temporary basis. The controlled area will encompass the nominal hazard zone (NHZ).

Protective Housing, Barriers and Curtains

A laser shall have an enclosure around it that limits access to the laser beam or radiation at or below the applicable MPE level (the level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin). A protective housing is required for all classes of lasers except, of course, at the beam aperture. In some cases, the walls of a properly enclosed room can be considered as the protective housing for an open beam laser. The barrier will be described with a barrier threshold limit: the beam will penetrate the barrier only after some specified exposure time, typically 60 seconds.

Area control can be affected in some cases using special barriers specifically designed to withstand either direct or diffusely scattered beams. It is essential that the barrier also not support combustion or be itself consumed by flames during or following a laser exposure.

Beam Attenuators and Stops

Class IV lasers require a permanently attached beam stop or attenuator which can reduce the output emission to a level at or below the appropriate MPE level when the laser system is on standby. Such a beam stop or attenuator is also recommended for Class IIIA and Class IIIB lasers.

Interlocks

Interlocks, which cause beam termination or reduction of the beam to MPE levels, must be provided on all panels that are intended to be opened during operation and maintenance of all Class IIIA, Class IIIB, and Class IV lasers. The interlocks are typically electrically connected to a beam shutter. The removal or displacement of the panel closes the shutter and eliminates the possibility of hazardous exposures.

All Class IV lasers or laser systems must have a remote interlock connector to allow electrical connections to an emergency master disconnect (panic button) interlock or to room, door, or fixture interlocks. When open circuited, the interlock shall cause the accessible laser radiation to be maintained below the appropriate MPE level. The remote interlock connector is also recommended for Class IIIB lasers.

Key Control

All Class IV lasers and laser systems require a master switch control. The switch can be operated by a key or computer code. When disabled (key or code removed), the laser cannot be operated. Only authorized system operators are to be permitted access to the key or code. Inclusion of the master switch control on Class IIIB lasers and laser systems is also recommended but not required.

Eyewear

Eye-protection devices designed to protect against radiation from a specific laser system shall be used when engineering controls are inadequate to eliminate the possibility of potentially hazardous eye exposure (i.e., whenever levels of accessible emission exceed the appropriate MPE levels.) This generally applies only to Class IIIB and Class IV lasers. All laser eyewear shall be clearly labeled with the optical density value (a logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter) and wavelengths for which protection is afforded.

d) Discuss administrative controls and the role of the Laser Safety Officer.

- **Training**
- **Authorized personnel**
- **Operating and alignment procedures**
- **Laser Safety Officer**

Training

The Laser Safety Officer (LSO) should receive detailed training that includes laser fundamentals, laser biological effects, exposure limits, classifications, NHZ computations, control measures (including area controls, eye wear, barriers, etc.), and medical surveillance requirements.

Authorized Personnel

Only qualified and authorized personnel operate lasers. Training of the individuals in aspects of laser safety is required for Class IIIB and Class IV laser installations.

Operating and Alignment Procedures

Many laser eye accidents occur during alignment. The procedures require extreme caution. A written standard operating procedure is recommended for all recurring alignment tasks.

Laser Safety Officer

The LSO has the authority to monitor and enforce the control of laser hazards and to effect the knowledgeable evaluation and control of laser hazards. The LSO administers the overall laser safety program where the duties include, but are not limited to, items such as confirming the classification of lasers, doing the NHZ evaluation, assuring that the proper control measures are in place and approving substitute controls, approving standard operating procedures, recommending and/or approving eye wear and other protective equipment, specifying appropriate signs and labels, approving overall facility controls, providing the proper laser safety training as needed, conducting medical surveillance, and designating the laser and incidental personnel categories.

In many industrial situations, LSO functions will be a part-time activity, depending on the number of lasers and the amount of general laser activity. The individual in the LSO role is often in the corporate industrial hygiene department or may be a laser engineer with safety responsibility. Some corporations implement an internal laser policy and establish safety practices based upon the ANSI Z 136.1 standard as well as their own corporate safety requirements.

e) Describe requirements of laser warning signs, labels, and postings.

Class IIIA, Class IIIB, and Class IV lasers require the ANSI DANGER sign format: a white background and a red laser symbol with black outlining and black lettering. Note that under ANSI Z 136.1 criteria, area posting is required only for Class IIIB and Class IV lasers.

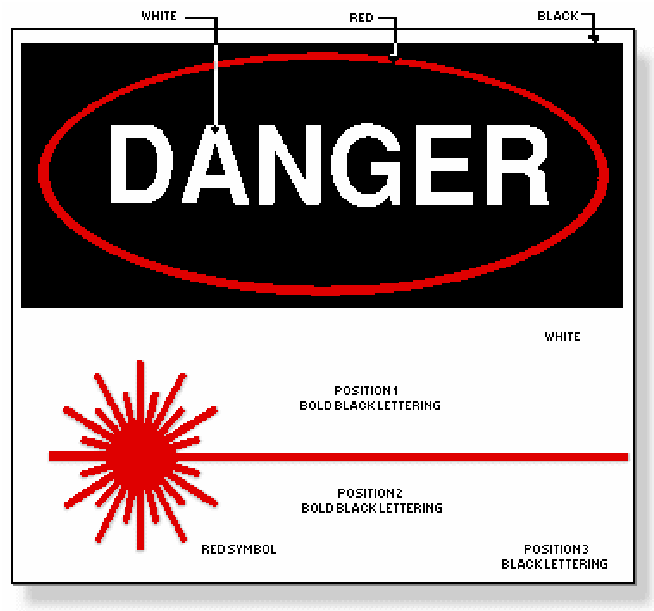


Figure 19. ANSI danger sign

In Class II or Class IIIA areas (if area warning is deemed unnecessary by the LSO), all signs (and labels) associated with these lasers (when beam irradiance for Class IIIA does not exceed 2.5 mW/cm2) use the ANSI CAUTION format: a yellow background with a black symbol and black lettering.

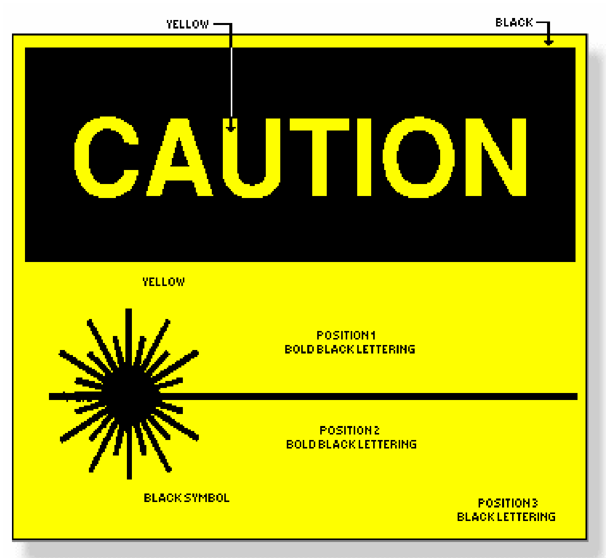


Figure 20. ANSI caution sign

During times of service and other times when a temporary laser-controlled area is established, an ANSI NOTICE sign format is required: a white background and a red laser symbol with a blue field and black lettering. This sign is posted only during the period of time that service is in progress.

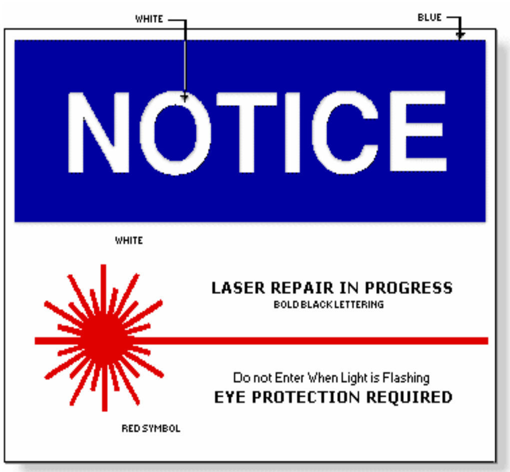


Figure 21. ANSI notice sign

2.1 A facility representative shall demonstrate a working-level knowledge of the purpose, scope, and application of applicable federal regulations to include:

- **10 CFR 820, Procedural Rules for DOE Nuclear Activities**
- **10 CFR 830, Nuclear Safety Management**
- **10 CFR 835, Occupational Radiation Protection**
- **29 CFR 1910.120, Occupational Safety and Health Standards, Hazardous Waste Operations and Emergency Response**

a) Discuss the purpose, scope, and application of the listed federal regulations. Include in this discussion the key terms, essential elements, and personnel responsibilities and authorities.

10 CFR 820, Procedural Rules for DOE Nuclear Activities

Purpose. The DOE has adopted procedural rules in 10 CFR 820 to provide for the enforcement of violations of DOE nuclear safety requirements for which civil and criminal penalties can be imposed under the Price-Anderson Amendments Act (PAAA) of 1988. Appended to the rule is a general statement of enforcement policy (Enforcement Policy). The Enforcement Policy sets forth the general framework through which DOE would seek to enforce compliance with DOE's nuclear safety rules, regulations, and Orders by a DOE contractor, subcontractor, or a supplier.

Refer to 10 CFR 820 for information related to key terms, essential elements, and personnel responsibilities and authorities, at http://www.access.gpo.gov/nara/cfr/waisidx_06/10cfr820_06.html.

10 CFR 830, Nuclear Safety Management

Purpose. Title 10 CFR 830 governs the conduct of DOE contractors, DOE personnel, and other persons conducting activities, including providing items and services that affect, or may affect, the safety of DOE nuclear facilities.

Refer to 10 CFR 830 for information related to key terms, essential elements, and personnel responsibilities and authorities, at http://www.access.gpo.gov/nara/cfr/waisidx_06/10cfr830_06.html.

10 CFR 835, Occupational Radiation Protection

Purpose. The rules in 10 CFR 835 establish radiation protection standards, limits, and program requirements for protecting individuals from ionizing radiation resulting from the conduct of DOE activities.

Refer to 10 CFR 835 for information related to key terms, essential elements, and personnel responsibilities and authorities, at http://www.access.gpo.gov/nara/cfr/waisidx_06/10cfr835_06.html.

29 CFR 1910.120, Occupational Safety and Health Standards, Hazardous Waste Operations and Emergency Response

This section covers the following operations, unless the employer can demonstrate that the operation does not involve employee exposure or the reasonable possibility for employee exposure to safety or health hazards:

- Clean-up operations required by a governmental body, whether federal, state, local, or other involving hazardous substances that are conducted at uncontrolled hazardous waste sites, including, but not limited to, the Environmental Protection Agency's (EPA's) National Priority Site List (NPL), state priority site lists, sites recommended for the EPA NPL, and initial investigations of government-identified sites that are conducted before the presence or absence of hazardous substances has been ascertained
- Corrective actions involving clean-up operations at sites covered by the Resource Conservation and Recovery Act of 1976 (RCRA) as amended (42 U.S.C. 6901 et seq.)
- Voluntary clean-up operations at sites recognized by federal, state, local, or other governmental bodies as uncontrolled hazardous waste sites
- Operations involving hazardous wastes that are conducted at treatment, storage, and disposal (TSD) facilities regulated by 40 CFR parts 264 and 265 pursuant to RCRA, or by agencies under agreement with U.S.E.P.A. to implement RCRA regulations
- Emergency response operations for releases of, or substantial threats of releases of, hazardous substances without regard to the location of the hazard

Refer to 29 CFR 1910.120 for information related to key terms, essential elements, and personnel responsibilities and authorities, at http://www.access.gpo.gov/nara/cfr/waisidx_05/29cfr1910_05.html.

b) Discuss what constitutes acceptable contractor work performance in categories as defined by the above Rules.

In complying with the above rules, contractors must ensure that any work done is consistent with any other safety, design, or other analysis or requirements applicable to the affected facility. In particular, work must be performed in accordance with the integrated safety management (ISM) requirements of 48 CFR 970.5223-1, Integration of Environment, Safety, and Health into Work Planning and Execution, and the quality assurance requirements of either Subpart A of 10 CFR 830, Nuclear Safety Management, or DOE O 414.1C, Quality Assurance, dated 6-17-05 or successor document, as applicable. All new construction, at a minimum, must comply with national consensus industry standards and the model building codes applicable for the state or region, supplemented in a graded manner with additional safety requirements for the associated hazards in the facility that are not addressed by the codes.

c) Describe the methods by which Rule noncompliance is determined and communicated to contractor and DOE management.

When an employee files a complaint with the Department of Labor (DOL), and the DOL collects information relating to allegations of DOE contractor retaliation against a contractor employee for actions taken concerning nuclear safety, the Director may use this information as a basis for initiating enforcement action by issuing a preliminary notice of violation (10 CFR 820.24). DOE may consider information collected in the DOL proceedings to determine whether the retaliation may be related to a contractor employee's action concerning a DOE nuclear activity.

The Director may also use DOL information to support the determination that a contractor has violated or is continuing to violate the nuclear safety requirements against contractor retaliation and to issue civil penalties or other appropriate remedy in a final notice of violation (10 CFR 820.25).

The Director will have discretion to give appropriate weight to information collected in DOL and Office of Hearings and Appeals (OHA) investigations and proceedings. In deciding whether additional investigation or information is needed, the Director will consider the extent to which the facts in the proceedings have been adjudicated as well as any information presented by the contractor. In general, the Director may initiate an enforcement action without additional investigation or information.

Normally, the Director will await the completion of a proceeding before the Office of Hearings and Appeals or a proceeding at DOL before deciding whether to take any action, including an investigation under 10 CFR 820 with respect to alleged retaliation. A proceeding would be considered completed when there is either a final decision or a settlement of the retaliation complaint, or no additional administrative action is available.

DOE encourages its contractors to cooperate in resolving whistleblower complaints raised by contractor employees in a prompt and equitable manner. Accordingly, in deciding whether to initiate an enforcement action, the Director will take into account the extent to which a contractor cooperated in a proceeding, and, in particular, whether the contractor resolved the matter promptly without the need for an adjudication hearing.

In considering whether to initiate an enforcement action and, if so, what remedy is appropriate, the Director will also consider the egregiousness of the particular case, including the level of management involved in the alleged retaliation and the specificity of the acts of retaliation.

In egregious cases, the Director has the discretion to proceed with an enforcement action, including an investigation with respect to alleged retaliation irrespective of the completion status of the proceeding. Egregious cases would include: (1) cases involving credible allegations for willful or intentional violations of DOE rules, regulations, Orders, or federal statutes which, if proven, would warrant criminal referrals to the U.S. Department of Justice for prosecutorial review; and (2) cases where an alleged retaliation suggests widespread, high-level managerial involvement and raises significant public health and safety concerns.

When the Director undertakes an investigation of an allegation of DOE contractor retaliation against an employee under 10 CFR 820, the Director will apprise persons interviewed and interested parties that the investigative activity is being taken pursuant to the nuclear safety procedures of 10 CFR 820 and not pursuant to the procedures of 10 CFR 708.

At any time, the Director may begin an investigation of a noncompliance of the substantive nuclear safety rules based on the underlying nuclear safety concerns raised by the employee regardless of the status of completion of any related whistleblower retaliation proceedings. The nuclear safety rules include: 10 CFR 830, 10 CFR 835, and 10 CFR 820.11.

2.2 A facility representative shall demonstrate a working-level knowledge of the purpose, scope, and application of applicable DOE Orders to include:

- **O 151.1B, Comprehensive Emergency Management System**
- **O 231.1A, Environment, Safety and Health Reporting**
- **O 232.1A, Occurrence Reporting and Processing of Operations Information**
- **O 414.1C, Quality Assurance**
- **O 420.1B, Facility Safety**
- **O 420.2B, Safety of Accelerator Facilities**
- **O 425.1C, Start-Up and Restart of Nuclear Facilities**
- **O 430.1B, Real Property Asset Management**
- **O 433.1, Maintenance Management Program for DOE Nuclear Facilities**
- **O 435.1, Radioactive Waste Management**
- **O 440.1A, Worker Protection Management for DOE Federal and Contractor Employees**
- **O 451.1B, National Environmental Policy Act Compliance Program**
- **O 460.1B, Packaging and Transportation Safety**
- **O 5480.4, Environmental Protection, Safety, and Health Protection Standards**
- **O 5480.19, Conduct of Operations Requirements for DOE Facilities**
- **O 5480.20A, Personnel Selection, Qualification, and Training, Requirements for DOE Nuclear Facilities**

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

The purpose, scope, and objectives for the listed DOE Orders are described below. Key terms, essential elements, and personnel responsibilities and authorities are available on the DOE Directives website, http://www.directives.doe.gov/.

O 151.1C, Comprehensive Emergency Management (supersedes O 151.1A)
The purpose, scope, and objectives of this Order are

- to establish policy and to assign and describe roles and responsibilities for the DOE emergency management system. The emergency management system provides the framework for development, coordination, control, and direction of all emergency planning, preparedness, readiness assurance, response, and recovery actions. The emergency management system applies to DOE and to the National Nuclear Security Administration (NNSA).

- to establish requirements for comprehensive planning, preparedness, response, and recovery activities of emergency management programs or for organizations requiring DOE/NNSA assistance.
- to describe an approach to effectively integrate planning, preparedness, response, and recovery activities for a comprehensive, all-emergency management concept.
- to integrate public information and emergency planning to provide accurate, candid, and timely information to site workers and the public during all emergencies.
- to promote more efficient use of resources through greater flexibility (i.e., the graded approach) in addressing emergency management needs consistent with the changing missions of the Department and its facilities.
- to ensure that the DOE emergency management system is ready to respond promptly, efficiently, and effectively to any emergency involving DOE/NNSA facilities, activities, or operations, or requiring DOE/NNSA assistance.
- to integrate applicable policies and requirements, including those promulgated by other federal agencies (e.g., stockpiling stable iodine for possible distribution as a radiological protective prophylaxis), and interagency emergency plans into the Department's emergency management system.
- to eliminate duplication of emergency management efforts within the Department.

O 231.1A, Environment, Safety and Health Reporting (supersedes O 231.1 and O 232.1A)
The objectives of this Order are to ensure timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues as required by law or regulations or as needed to ensure that the DOE/NNSA are kept fully informed on a timely basis about events that could adversely affect the health and safety of the public or the workers, the environment, the intended purpose of DOE facilities, or the credibility of the Department.

O 414.1C, Quality Assurance (supersedes O 414.1A)
The objectives of this Order are

- to ensure that DOE/NNSA products and services meet or exceed customers' expectations.
- to achieve quality assurance (QA) for all work based on the principles
  - that quality is assured and maintained through a single, integrated, effective QA program (i.e., management system);
  - that management support for planning, organization, resources, direction, and control is essential to QA;
  - that performance and quality improvement require thorough, rigorous assessment and corrective action;
  - that workers are responsible for achieving and maintaining quality;
  - that environmental, safety, and health risks and impacts associated with work processes can be minimized while maximizing reliability and performance of work products.
- to establish quality process requirements to be implemented under a QA program (QAP) for the control of suspect/counterfeit items (S/CIs), safety issue corrective actions, and safety software.

O 420.1B, Facility Safety (supersedes O 420.1)

The objectives of this Order are

- to establish facility and programmatic safety requirements for DOE/NNSA for
  - nuclear and explosives safety design criteria
  - fire protection
  - criticality safety
  - natural phenomena hazards (NPH) mitigation
  - the System Engineer Program

O 420.2B, Safety of Accelerator Facilities (supersedes O 420.2A)

The objective of this Order is to establish accelerator-specific safety requirements which, when supplemented by other applicable safety and health requirements, will serve to prevent injuries and illnesses associated with DOE/NNSA accelerator operations.

O 425.1B, Start-Up and Restart of Nuclear Facilities (supersedes O 425.1A)

The objective of this Order is to establish the requirements for DOE/NNSA for startup of new nuclear facilities and for the restart of existing nuclear facilities that have been shut down. Nuclear facilities are activities or operations that involve radioactive and/or fissionable materials in such form or quantity that a nuclear hazard potentially exists to the employees or the general public. The requirements specify a readiness review process that must, in all cases, demonstrate that it is safe to start (or restart) the applicable facility. The facility must be started (or restarted) only after documented independent reviews of readiness have been conducted and the approvals specified in this Order have been received. The readiness reviews are not intended to be tools of line management to achieve readiness. Rather, the readiness reviews provide an independent confirmation of readiness to start or restart operations.

O 430.1B, Real Property Asset Management (supersedes O 430.1A)

The objective of this Order is to establish a corporate, holistic, and performance-based approach to real property life-cycle asset management that links real property asset planning, programming, budgeting, and evaluation to program mission projections and performance outcomes. To accomplish the objective, this Order identifies requirements and establishes reporting mechanisms and responsibilities for real property asset management. This Order implements DOE P 580.1, Management Policy for Planning, Programming, Budgeting, Operation, Maintenance, and Disposal of Real Property, dated 05-20-02.

O 433.1, Maintenance Management Program for DOE Nuclear Facilities

The objective of this Order is to define the program for the management of cost-effective maintenance of DOE nuclear facilities. Guidance for compliance with this Order is contained in DOE G 433.1-1, Nuclear Facility Maintenance Management Program Guide for use with DOE O 433.1, which references federal regulations, DOE directives, and industry best practices using a graded approach to clarify requirements and guidance for maintaining DOE-owned Government property.

O 435.1, Radioactive Waste Management

The objective of this Order is to ensure that all DOE radioactive waste is managed in a manner that is protective of worker and public health and safety and the environment.

O 440.1A, Worker Protection Management for DOE Federal and Contractor Employees

The objective of this Order is to establish the framework for an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE federal and contractor workers with a safe and healthful workplace.

O 451.1B, National Environmental Policy Act Compliance Program

The purpose of this Order is to establish DOE internal requirements and responsibilities for implementing the National Environmental Policy Act of 1969 (NEPA), the Council on Environmental Quality Regulations Implementing the Procedural Provisions of NEPA (40 CFR Parts 1500-1508), and the DOE NEPA Implementing Procedures (10 CFR Part 1021). The goal of establishing the requirements and responsibilities is to ensure efficient and effective implementation of DOE's NEPA responsibilities through teamwork. A key responsibility for all participants is to control the cost and time spent on the NEPA process while maintaining its quality.

O 460.1B, Packaging and Transportation Safety (supersedes O 460.1A)

The objective of this Order is to establish safety requirements for the proper packaging and transportation of DOE/NNSA offsite shipments and onsite transfers of hazardous materials and for modal transport. (Offsite is any area within or outside a DOE site to which the public has free and uncontrolled access; onsite is any area within the boundaries of a DOE site or facility to which access is controlled.)

O 5480.4, Environmental Protection, Safety, and Health Protection Standards

The purpose of this Order is to specify and provide requirements for the application of the mandatory environmental protection, safety, and health (ES&H) standards applicable to all DOE and DOE contractor operations; to provide a listing of reference ES&H standards; and to identify the sources of the mandatory and reference ES&H standards. The provisions of this Order apply to all departmental elements and contractors performing work for the Department as provided by law and/or contract and as implemented by the appropriate contracting officer.

O 5480.19, Conduct of Operations Requirements for DOE Facilities

The purpose of this Order is to provide requirements and guidelines for departmental elements, including the NNSA, to use in developing directives, plans, and/or procedures relating to the conduct of operations at DOE facilities. The implementation of these requirements and guidelines should result in improved quality and uniformity of operations.

O 5480.20A, Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities

The purpose of this Order is to establish selection, qualification, and training requirements for management and operating (M&O) contractor personnel involved in the operation, maintenance, and technical support of DOE/NNSA category A and B reactors and non-reactor nuclear facilities.

b) Discuss what constitutes acceptable contractor work performance in categories as defined by the listed Orders.

The general requirements for each of the listed Orders are described below. Additional requirements are available in each of the Orders on the DOE Directives Web page, at http://www.directives.doe.gov/.

O 151.1C, Comprehensive Emergency Management System

Contractors must develop and implement a comprehensive emergency management system designed to

- minimize the consequences of all emergencies involving or affecting Departmental facilities and activities (including transportation operations/activities);
- protect the health and safety of all workers and the public from hazards associated with DOE/NNSA operations and those associated with decontamination, decommissioning, and environmental restoration;
- prevent damage to the environment;
- promote effective and efficient integration of all applicable policies, recommendations, and requirements, including federal interagency emergency plans.

O 414.1C, Quality Assurance

Regardless of the performer of the work, the contractor is responsible for complying with the requirements of the contractor requirements document (CRD). The contractor is responsible for flowing down the requirements of this CRD to subcontractors at any tier to the extent necessary to ensure the contractor's compliance with the requirements and the safe performance of work. When the contractor conducts activities or provides items or services that affect or may affect the safety of DOE/NNSA nuclear facilities, the contractor must conduct work in accordance with the quality assurance (QA) requirements of 10 CFR 830. The CRD includes a requirement to integrate multiple QA program (QAP) drivers imposed by QA regulations, the Nuclear Regulatory Commission, and other Federal agencies. The CRD includes activity-specific requirements for work that also may need to comply with QA regulations. This integration requirement supplements but does not supersede or alter compliance with QA regulations. Where a work activity, process, or item is specifically identified as within the scope of a QA regulation (e.g., 10 CFR 830 or 10 CFR 63), that regulation prevails. In the event of a conflict between the CRD and any QA regulation, the regulation prevails.

O420.1B, Facility Safety

Contractors must ensure that any work done is consistent with any other safety, design, or other analysis or requirements applicable to the affected facility. In particular, work must be performed in accordance with the integrated safety management requirements of 48 CFR 970.5223-1, Integration of Environment, Safety, and Health into Work Planning and Execution, and the quality assurance requirements of either Subpart A of 10 CFR 830, Nuclear Safety Management, or DOE O 414.1C, Quality Assurance, dated 6-17-05, or successor document, as applicable. All new construction, at a minimum, must comply with national consensus industry standards and the model building codes applicable for the state or region, supplemented in a graded manner with additional safety requirements for the associated hazards in the facility that are not addressed by the codes.

DOE O 420.2B, Safety of Accelerator Facilities

The following items are required of the contractor organization:

- A safety assessment document (SAD). An SAD must
  - o identify hazards and associated onsite and offsite impacts to workers, the public, and the environment from the facility for both normal operations and credible accidents;
  - o contain sufficient descriptive information and analytical results pertaining to specific hazards and risks identified during the safety analysis process to provide an understanding of risks presented by the proposed operations;
  - o provide appropriate documentation and detailed descriptions of engineered controls (e.g., interlocks and physical barriers) and administrative measures (e.g., training) taken to eliminate, control, or mitigate hazards from operation;
  - o include or reference a description of facility function, location, and management organization in addition to details of major facility components and their operation;
  - o be prepared as a single document addressing the hazards of the entire accelerator facility or as separate SADs prepared for discrete modules of the facility such as injectors, targets, experiments, experimental halls, or other types of modules;
  - o be maintained current and consistent with the administrative control measures and physical configuration of the facility and major safety equipment.
- An accelerator safety envelope (ASE). A documented ASE must define the physical and administrative bounding conditions for safe operations based on the safety analysis documented in the SAD. Any activity violating the ASE must be terminated immediately, and the activity must not recommence before DOE/NNSA has been notified.
- Unreviewed safety issues. Activities that involve unreviewed safety issues must not be performed if significant safety consequences could result from either an accident or a malfunction of equipment that is important to safety and for which a safety analysis has not been performed. Activities involving identified unreviewed safety issues must not commence before DOE/NNSA has provided written approval.
- Accelerator readiness reviews (ARRs). ARRs must be performed before approval for commissioning and routine operation and as directed by the DOE cognizant Secretarial Officer/NNSA Deputy Administrator or a DOE/NNSA field manager.
- Training and qualification. Requirements must be established for each individual at an accelerator facility whose activities could affect safety and health conditions or whose safety and health could be affected by facility activities. Training and qualification must be documented and kept current. Only appropriately trained and qualified personnel, or trainees under the direct supervision of trained and qualified personnel, are permitted to perform tasks that may affect safety and health. All personnel assigned to or using the accelerator facility (including emergency response personnel) must be trained in the safety and health practices and emergency plans consistent with their involvement and the hazards present.
- Written procedures. Written procedures and instructions for conducting activities safely must be maintained; must be clear, current, and consistent with management systems and the configuration of the facility and equipment; and must be approved by a facility contractor's senior line manager who is actively involved in the day-to-day operation of the facility. Procedures must include descriptions of the tasks to be performed; appropriate safety and health precautions and controls; and requirements

for initial conditions to be verified, operating conditions to be maintained, and data to be recorded, as applicable. At a minimum, the contractor must prepare procedures for

- operation startup
- normal operation
- emergency conditions
- conduct of maintenance
- approval and conduct of experiments
- review and approval of facility modifications
- management of safety-related changes
- control of facility access

- An internal safety review system. An internal safety review system must be established and maintained to periodically assess and document the condition of the facility, equipment, and engineered safety systems. Appropriateness and implementation of procedures, administrative controls, and personnel training and qualifications must be periodically reviewed and documented by the internal safety review system.
- A shielding policy. The contractor must approve and implement a written statement of the shielding policy for ionizing and non-ionizing radiation.

O 425.1C, Startup and Restart of Nuclear Facilities

Contractor management must determine if operational readiness reviews are required for startup or restart of nuclear facilities. Contractors must conduct an operational readiness review when any of the following conditions occur:

- Initial startup of a new hazard category 1, 2, or 3 nuclear facility
- Restart after a DOE management official directs the unplanned shutdown of a nuclear facility for safety or other appropriate reasons
- Restart after an extended shutdown for hazard categories 1 and 2 nuclear facilities (Extended shutdown for a hazard category 1 nuclear facility is 6 months. Extended shutdown for a hazard category 2 nuclear facility is 12 months.)
- Restart of hazard categories 1 and 2 nuclear facilities after substantial process, system, or facility modifications (The restart authority must determine if the modifications are substantial based on the impact of the changes on the safety basis and the extent and complexity of changes; this would not necessarily be determined by the unreviewed safety question process.)
- Restart after a nuclear facility shutdown because of operations outside the safety basis
- When deemed appropriate by DOE management officials, including restarts of hazard category 3 nuclear facilities

O 430.1B, Real Property Asset Management

The contractor provides services to DOE related to real property asset planning, real estate, maintenance, disposition and long-term stewardship, and value engineering to balance acquisition, sustainment, recapitalization, and disposal to ensure that real property assets are available, used, and in a suitable condition to accomplish DOE's missions.

O 433.1, Maintenance Management Program for DOE Nuclear Facilities

The general contractor requirements for this Order are as follows:

- Develop and submit for DOE approval a maintenance implementation plan (MIP).

- Establish metrics to measure the performance of the maintenance program and incorporate appropriate voluntary consensus standards.
- Confirm that the nuclear facility maintenance management program established under DOE 4330.4B remains effective until it is updated to meet the requirements of DOE O 433.1.
- Review and update the MIP every two years and submit any changes to DOE for approval.

O 435.1, Radioactive Waste Management

In the performance of this contract, the contractor is required to

- systematically plan, document, execute, and evaluate the management of DOE radioactive waste, and assist the government in planning, executing and evaluating the management of DOE radioactive waste in accordance with the requirements of DOE O 435.1, Radioactive Waste Management.
- assist the government in managing DOE radioactive waste so as to
  - protect the public from exposure to radiation from radioactive materials;
  - protect the environment;
  - protect workers, including following requirements for radiation protection.
- assist DOE in meeting its obligations and responsibilities under Executive Order 12856, Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements, and Executive Order 13101*,* Greening the Government through Waste Prevention, Recycling, and Federal Acquisition, and The Pollution Prevention Act of 1990.
- comply with the requirements in DOE M 435.1-1, Radioactive Waste Management Manual, unless such activities are specifically exempted by DOE O 435.1, section 3.d.
- incorporate these requirements into the contracts of all sub-contractors which are involved in the management of DOE radioactive waste.

O440.1A, Worker Protection Management for DOE Federal and Contractor Employees

The general requirements for this Order are as follows:

- Implement a written worker protection program that provides a place of employment free from recognized hazards that are causing or are likely to cause death or serious physical harm to employees, and integrates all requirements contained in the contractor requirements document and other related site-specific worker protection activities.
- Establish written policy, goals, and objectives for the worker protection program.
- Use qualified worker protection staff to direct and manage the worker protection program.
- Assign worker protection responsibilities, evaluate personnel performance, and hold personnel accountable for worker protection performance.
- Encourage employee involvement in the development of program goals, objectives, and performance measures and in the identification and control of hazards in the workplace.
- Provide workers the right, without reprisal, to
  - accompany DOE worker protection personnel during workplace inspections;
  - participate in activities provided for herein on official time;
  - express concerns related to worker protection;

  - decline to perform an assigned task because of a reasonable belief that, under the circumstances, the task poses an imminent risk of death or serious bodily harm to that individual, coupled with a reasonable belief that there is insufficient time to seek effective redress through the normal hazard reporting and abatement procedures established in accordance with the requirements in the Order;
  - have access to DOE worker protection publications, DOE-prescribed standards, and the organization's own worker protection standards or procedures applicable to the workplace;
  - observe monitoring or measuring of hazardous agents and have access to the results of exposure monitoring;
  - be notified when monitoring results indicate they were overexposed to hazardous materials;
  - receive results of inspections and accident investigations upon request.
- Implement procedures to allow workers, through their supervisors, to stop work when they discover employee exposures to imminent danger conditions or other serious hazards. The procedure shall ensure that any stop work authority is exercised in a justifiable and responsible manner.
- Inform workers of their rights and responsibilities by appropriate means, including posting the appropriate DOE worker protection poster in the workplace where it is accessible to all workers.
- Identify existing and potential workplace hazards and evaluate the risk of associated worker injury or illness.
- Analyze or review
  - designs for new facilities, and modifications to existing facilities and equipment;
  - operations and procedures;
  - equipment, product, and service needs.
- Assess worker exposure to chemical, physical, biological, or ergonomic hazards through appropriate workplace monitoring (including personal, area, wipe, and bulk sampling), biological monitoring, and observation. Monitoring results shall be recorded. Documentation shall describe the tasks and locations where monitoring occurred, identify workers monitored or represented by the monitoring, and identify the sampling methods and durations, the control measures in place during monitoring (including the use of personal protective equipment), and any other factors that may have affected sampling results.
- Evaluate workplaces and activities (accomplished routinely by workers, supervisors, and managers and periodically by qualified worker protection professionals).
- Report and investigate accidents, injuries, and illnesses, and analyze related data for trends and lessons learned.
- Implement a hazard prevention/abatement process to ensure that all identified hazards are managed through final abatement or control.
- Provide workers, supervisors, managers, visitors, and worker protection professionals with worker protection training.
- Comply with the following worker protection requirements:
  - 29 CFR 1910, Occupational Safety and Health Standards
  - 29 CFR 1915, Shipyard Employment
  - 29 CFR 1917, Marine Terminals
  - 29 CFR 1918, Safety and Health Regulations for Longshoring

- 29 CFR 1926, Safety and Health Regulations for Construction
    - 29 CFR 1928, Occupational Safety and Health Standards for Agriculture
    - American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (When ACGIH TLVs are lower than OSHA PELs: When ACGIH TLVs are used as exposure limits, DOE operations shall nonetheless comply with the other provisions of any applicable OSHA-expanded health standard. The TLVs for exposures to laser emissions in the ACGIH Indices are excluded from this requirement.)
    - ANSI Z136.1, Safe Use of Lasers
    - ANSI Z88.2, Practices for Respiratory Protection
    - ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes
    - National Fire Protection Association (NFPA) 70, National Electrical Code
    - NFPA 70E, Electrical Safety Requirements for Employee Workplaces
- Ensure that subcontractors performing work on DOE-owned or DOE-leased facilities comply with the CRD and the contractor's own site worker protection standards (where applicable).

Additional requirements for specific functional areas (addressed in paragraphs 14-22 of the Worker Protection Management for DOE Contractor Employees section in the Order) apply only if the contract is involved in these activities.

O 460.1B. Packaging and Transportation Safety

Offsite shipment of hazardous materials on vehicles operated by contractors that are not otherwise subject to U.S. Department of Transportation (DOT) jurisdiction shall follow the hazardous materials regulations of DOT and the applicable tribal, state, and local regulations not otherwise preempted by DOT.

Each contractor subject to the hazardous materials regulations (49 CFR 171-180) with a non-compliant package or shipment shall apply for a DOT exemption through the Field Element to the Office of Environmental Management or the NNSA for processing to DOT. Applications shall follow the directions in 49 CFR 107.105. Each contractor, who is not subject to DOT jurisdiction but who must comply with the 49 CFR requirements specified in the CRD, must prepare the package or shipment in accordance with a valid DOE exemption.

For specific radioactive material packagings, follow the regulations listed in the CRD.

Each contractor who participates in the design, fabrication, procurement, use, or maintenance of hazardous materials packaging, shall have an approved quality assurance program that, for type B and fissile radioactive materials packagings, satisfies the applicable requirements of 10 CFR 71, subpart H.

Each contractor who uses a type B, fissile, or plutonium packaging shall implement operating controls and procedures that satisfy the requirements of 10 CFR 71, subpart G.

Each contractor may follow international packaging and transportation regulations for domestic segments of transportation by air, vessel, rail, or highway of shipments in international traffic as authorized by the DOT regulations, as appropriate. In all instances, adherence to 49 CFR 171.11 is required for use of the International Civil Aviation Organization's Technical Instructions, and 49 CFR 171.12(b) for use of the International Maritime Dangerous Goods Code.

Each contractor shall comply with 49 CFR 171-180 for onsite hazardous materials transfers, or comply with an approved site- or facility-specific transportation safety document that describes the methodology and compliance process to meet equivalent safety for any deviation from 40 CFR 171-180. For multiple-tenant sites, safety documents for several contractor organizations may be combined into a single document. Approval shall be by the cognizant operations office or field office/field manager for field operations, NNSA. Approved transportation safety documents shall be in effect no later than 1 year from the incorporation of the CRD into the contractor's contract.

Each contractor shall implement and/or expand lessons learned programs to include sharing transportation and packaging safety successes and problems throughout the site and with other DOE contractors. This information will be provided to the responsible head of operations office or field office/site office manager, NNSA.

Each contractor who offers for transportation, or transports or transfers hazardous materials, substances, and wastes, shall develop and implement a training program and procedures for the safe packaging, transfer, and transportation of hazardous materials; assure that all personnel who support and/or perform packaging, transfer, and transportation operations are appropriately trained and qualified; and maintain auditable training records in accordance with site record retention requirements.

O 5480.19, Conduct of Operations Requirements for DOE Facilities

Each field element and contractor shall use this Order and attachment 1 in the review and development of existing and proposed directives, plans, or procedures relating to the conduct of operations at DOE facilities.

A graded approach shall be used in the application of the guidelines provided in attachment I to ensure that the depth of detail required and the magnitude of resources expended for operations are commensurate with each facility's programmatic importance and potential environmental, safety, and/or health impact.

Conformance with the requirements of this Order shall be documented. However, it is not necessary to develop a separate manual or plan. At a minimum, a document (e.g., a matrix) shall be prepared in coordination with the head of the field element and the cognizant program Secretarial Officer(s) that indicates whether a specific guideline applies to a facility, and where and how each of the guidelines (attachment 1) of this Order are applied within the field element's and contractor's existing policies and procedures, and that identifies any deviations or exemptions from the guidelines.

O 5480.20a, Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities

Contractors awarded DOE procurement M&O contracts for operable DOE nuclear facilities shall do the following:

- Implement the requirements of DOE Order 5480.20A as they apply to the facility and the position.
- Prepare and submit a training implementation matrix to the site office manager/field manager for NNSA Operations for review and approval.
- Prepare and submit procedures which establish the requirements for granting exceptions to specific training or qualification requirements for an individual to the site office manager/field manager for NNSA Operations for review and approval.
- Provide written requests for certification extensions to the site office manager for approval.
- Prepare and submit an assessment of the need for a simulator to the site office manager/field manager for NNSA Operations for review and approval (category A test and research reactors only).
- Perform periodic systematic evaluations of training and qualification programs.

c) Describe the methods by which Order noncompliance is determined and communicated to contractor and DOE management.

The methods by which Order noncompliance is determined and communicated to contractor and DOE management vary from site to site. The local qualifying official will evaluate the completion of this competency.

2.3 A facility representative shall demonstrate a working-level knowledge of the purpose, scope, and application of applicable DOE Guides to include:

- **G 421.1-2, Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Non-Nuclear Facilities**
- **G 423.1-1, Implementation Guide for Use in Developing Technical Safety Requirements**
- **G 424.1-1, Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements**
- **G 450.4-1B, Volumes 1 and 2, Integrated Safety Management System Guide**

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

G 421.1-2, Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Non-Nuclear Facilities
Note: The guide number and title do not match. DOE G 421.1-2, Implementation Guide for Use in Developing Documented Safety Analyses to Meet Subpart B of 10 CFR 830, will be used. G 420.1-2, Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Non-Nuclear Facilities does not fit the competency category.

DOE G 421.1-2 elaborates on the documented safety analysis (DSA) development process and the safe harbor provisions of the appendix to 10 CFR 830, subpart B. The information contained in this guide is intended for use by all Department elements, including the NNSA, and all contractors for a DOE-owned or DOE-leased hazard category 1, 2, or 3 nuclear facility or nuclear operation. This guide does not apply to (a) DOE nuclear activities that are regulated through a license by the Nuclear Regulatory Commission (NRC) or a state under an agreement with the NRC, including activities certified by the NRC under section 1701 of the

Atomic Energy Act (Act); (b) activities conducted under the authority of the Director, Naval Nuclear Propulsion, pursuant to Executive Order 12344, as set forth in Public Law 106–65; (c) transportation activities which are regulated by the DOT; (d) activities conducted under the Nuclear Waste Policy Act of 1982, as amended, and any facility identified under section 202(5) of the Energy Reorganization Act of 1974, as amended; and (e) activities related to the launch approval and actual launch of nuclear energy systems into space.

Accelerators and their operations are excluded from the safety basis requirements of the rule because their activities normally do not use, store, or form radioactive materials. However, target areas associated with the accelerators and areas associated with the radioactive materials produced by the accelerators are not considered to be part of the accelerator, and continue to be subject to the provisions of 10 CFR 830 to the extent that they use, store, or form radioactive materials. Thus, target areas that contain or form radioactive inventories within the DOE-STD-1027 limits are subject to 10 CFR 830. This guide does not prescribe the format for a DSA.

G 423.1-1, Implementation Guide for Use in Developing Technical Safety Requirements

The TSR rule requires contractors to prepare and submit TSRs for DOE approval. This guide provides guidance in identifying important safety parameters and developing the content for the TSRs that are required by 10 CFR 830.205.

This guide provides elaboration for the content of TSRs. In providing this guidance, it is recognized that the diversity of DOE facilities may necessitate varying degrees of emphasis to be placed on some of the TSR sections, but the following guidance is intended to be generally applicable. This implementation guide provides two different formats that are effective in highlighting the important features of TSRs.

The information contained in this guide is intended for use by all Department elements, including the NNSA, and all contractors for DOE-owned or DOE-leased hazard category 1, 2, or 3 nuclear facilities or nuclear operations. This guide does not apply to (a) activities that are regulated through a license by the NRC or a state under an agreement with the NRC, including activities certified by the NRC under section 1701 of the Atomic Energy Act (Act); (b) activities conducted under the authority of the Director, Naval Nuclear Propulsion, pursuant to Executive Order 12344, as set forth in Public Law 106–65; (c) transportation activities that are regulated by DOT; (d) activities conducted under the Nuclear Waste Policy Act of 1982, as amended, and any facility identified under section 202(5) of the Energy Reorganization Act of 1974, as amended; and (e) activities related to the launch approval and actual launch of nuclear energy systems into space.

G 424.1-1, Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements

This guide provides information to assist in the implementation and interpretation of 10 CFR 830.203, Unreviewed Safety Question Process, of the Nuclear Safety Management Rules for applicable nuclear facilities owned or operated by DOE/NNSA. Section 830.203, Unreviewed Safety Question Process, allows contractors to make physical and procedural changes and to conduct tests and experiments without prior DOE approval if the proposed change can be accommodated within the existing safety basis. The contractor must carefully evaluate any proposed change to ensure that it will not explicitly or implicitly affect the safety basis of the facility. The unreviewed safety question (USQ) process is primarily applicable to the documented safety analysis (DSA). Although the rule references only the DSA, the DSA must include conditions of approval in safety evaluation reports and facility-specific commitments made in compliance with DOE rules, Orders, or Policies. Because application of the USQ process depends on facility-specific information, results of a USQ determination in one facility generally cannot be extrapolated to other facilities. DOE approval of the procedure to implement the USQ process is required by 10 CFR 830.203.

Section 830.203 is expected to be implemented using contractor procedures that ensure that proposed changes to physical characteristics or operating procedures are adequately evaluated relative to the approved safety basis, and that those proposed changes determined to involve USQs are brought to the attention of DOE for review and approval before changes are made. A proposed change or test involves a USQ if

- the probability or consequences of an accident or malfunction of equipment important to safety could be increased
- the possibility of a different type of accident than previously evaluated in the DSA could be introduced
- margins of safety could be reduced

For the purposes of this guide, equipment important to safety should be understood to include any equipment whose function can affect safety either directly or indirectly. This includes safety class and safety significant structures, systems, and components (SSCs) and other systems that perform an important defense-in-depth function; equipment relied on for safe shutdown; and in some cases, process equipment. These considerations apply to both workers and the public. In the case of workers, these considerations apply to all workers, those in immediate proximity to the hazard as well as collocated workers. In addition to proposed changes, 10 CFR 830.203(g) of the USQ rule requires notification of DOE and USQ determinations when a potential inadequacy in the safety analysis is identified. In this case, situations of concern are those wherein it is found that the current safety analysis may not be bounding or the current safety basis may be otherwise inadequate. This could be because of an error in the current safety analysis or because the facility configuration is not what was analyzed.

The existence of a USQ does not mean that the facility or operation is unsafe. The purpose of the USQ process is to alert DOE of events, conditions, or actions that affect the DOE-approved safety basis of the facility or operation and ensure appropriate DOE line management action. If a change is proposed or a condition is discovered that could increase the risk of operating a facility beyond that established in the current safety basis, DOE line management, including, where applicable, the NNSA, must review and determine the acceptability of that risk through the process of approving a revised safety basis that would be developed and submitted by the contractor.

Section 830.203 applies to all category 1, 2 and 3 nuclear facilities. All changes to a nuclear facility, whether temporary or permanent, require application of the USQ process unless a decision to request DOE approval already has been made. Some changes may be such that they can be screened out from a detailed USQ determination.

The applicability of section 830.203 is broad. Non-safety-related systems are not excluded by the scope of section 830.203 if they could affect the proper operation of equipment important to safety that is relied on in the safety basis. For example, losses of certain non-safety-related systems may represent critical operational occurrences identified as initiators in the accident analysis. Therefore, changes to non-safety-related systems must be evaluated and may be determined to involve a USQ.

Physical interactions may also fall under the purview of section 830.203. For example, the installation of a non-seismically supported piece of equipment above a seismically qualified component designed to perform a safety function explicitly or implicitly assumed in the existing safety analyses may constitute a USQ and must be evaluated.

G 450.4-1B, Volumes 1 and 2, Integrated Safety Management System Guide
Attachments 1 through 5 to volume 1 contain the relevant safety management system (SMS) sections of the Department of Energy Acquisition Regulation (DEAR).

Volume 1 of this Guide addresses the following topics:
- Introduction
- Chapter I, SMS Integration and Products
- Chapter II, ISMS Core Functions and Principles
- Chapter III, ISMS Development, Implementation, Review, and Approval
- Chapter IV, Maintaining (Through an ISMS Configuration Control Process) an Approved ISMS and Reporting ISMS Status to DOE on an Annual Basis

Volume 2 of the Guide includes the following appendices:
- Appendix A: Glossary
- Appendix B: Resources for Complying with the SMS Policies, the FRAM, and the DEAR
- Appendix C: Superseded
- Appendix D: Discussion of Safety Management Assessment
- Appendix E: ISMS Evaluation Guidance
- Appendix F: Examples of Topics Addressed in ISMS Description Documents
- Appendix G: Feedback and Improvement Mechanisms

This guide has two purposes. One purpose is to assist DOE contractors in developing, describing, and implementing an Integrated Safety Management System (ISMS) in compliance with DOE P 450.4, Safety Management System Policy (the SMS Policy); DOE P 411.1, Safety Management Functions, Responsibilities, and Authorities (FRAM), January 28, 1997; and the following DEAR provisions:
- 48 CFR 970.5223-1, which requires integration of environment, safety, and health into work planning and execution
- 48 CFR 970.5204-2, which deals with laws, regulations, and DOE directives
- 48 CFR 970.1100-1, which requires performance-based contracting

A second purpose of this guide is to assist DOE line managers and contracting officers (COs) who

- provide ISMS guidance and requirements;
- review and approve ISMS products;
- verify implementation of the ISMS, and perform various integrating activities (e.g., planning, budgeting, review, approval, and oversight) that complement or are required for the ISMS.

DOE responsibilities for these activities are described in the three ISMS-related DEAR clauses listed, in DOE M 411.1-1B, Manual of Safety Management Functions, Responsibilities, and Authorities (the FRAM), and in the lower-tier functions, responsibilities, and authorities (FRA) documents.

This guide does not override, alter, or minimize the requirements of the SMS policies, the DEAR, the FRAM, or other DOE regulations and requirements. It is not a prescriptive document, but instead offers flexible guidance that complies with the requirements of the Policies, the law, and the FRAM. Other practices that meet the intent of this guide and comply with the requirements may be used.

This guide applies to the activities required of DOE/NNSA line managers and contracting officials (referred to as contracting officers, heads of contracting authorities, or field element managers) in fulfilling their responsibilities, as specified in the ISMS policies, the DEAR, and the FRAM. This guide also applies to the activities required of DOE contractors in fulfilling their responsibilities, as specified in the policies and in the DEAR. The DEAR describes ISMS responsibilities for DOE and contractors, while the FRAM (the Headquarters Level 1 FRAM and the lower-tier directives known as “FRAs”) describes responsibilities and authorities for DOE only.

2.4 A facility representative shall demonstrate a working-level knowledge of the purpose, scope, and application of applicable DOE Standards to include:

- **DOE-STD-1063-2000, Facility Representatives**
- **DOE-STD-1073-93, Guide for Operational Configuration Management Program**
- **DOE-STD-1104-96, Review and Approval of Nonreactor Nuclear Facility Safety Analysis Reports**
- **DOE-STD-3009-94, Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports**

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

The purpose and scope for each of the listed standards is described below. Additional information is available in each of the standards on the DOE Directives Web page, at http://www.directives.doe.gov/.

DOE-STD-1063-2000, Facility Representatives

This standard defines the duties, responsibilities, and qualifications for DOE facility representatives based on facility hazard classification; risks to workers, the public, and the environment; and the operational activity level. This standard provides the guidance necessary to ensure that DOE's hazardous nuclear and non-nuclear facilities have sufficient staffing of technically qualified facility representatives to provide day-to-day oversight of contractor operations.

The purpose of this standard is to help ensure that DOE facility representatives are selected based on consistently high standards and from the best qualified candidates available, that they receive the training required for them to function effectively, and that their expected duties, responsibilities, and authorities are well understood and accurately documented. To this end, this guidance provides the following practical information:

- The duties, responsibilities, and authorities expected of a facility representative and other personnel relative to the facility representative program
- An approach for use in determining the required facility coverage
- The training and qualifications expected of a facility representative
- Elements necessary for successful facility representative programs at DOE field offices

DOE-STD-1073-2003, Guide for Operational Configuration Management Program (supersedes DOE-STD-1073-93)

The purpose of this standard is to define the objectives of a configuration management process for DOE nuclear facilities (including activities and operations), and to provide detailed examples and supplementary guidance on methods of achieving those objectives.

The detailed examples and methodologies in this standard are provided to aid those developing their configuration management processes; however, they are provided for guidance only and may not be appropriate for application to all DOE nuclear activities. The individuals defining the configuration management process for a particular nuclear activity will need to apply judgment to determine if the examples and methods presented in this standard are appropriate for the activity.

Nevertheless, the basic objectives and general principles of configuration management are the same for all activities. The objectives of configuration management are to:
(1) establish consistency among design requirements, physical configuration, and documentation (including analysis, drawings, and procedures) for the activity, and
(2) maintain this consistency throughout the life of the facility or activity, particularly as changes are being made.

DOE-STD-1104-96, Review and Approval of Nonreactor Nuclear Facility Safety Analysis Reports

The body of this standard focuses on management of the review and approval process, provides guidelines for establishing the basis of approval, and recommends a format and content for safety evaluation reports (SERs). Specific review guidelines that are technical in nature are more appropriately addressed individually by subject matter and require more detailed guidance and discussion. Therefore, the body provides general guidelines as opposed to a comprehensive list of technical safety criteria (e.g., standardized review plan [SRP]).

This standard is applicable to government-owned, government-operated (GOGO) facilities in which DOE performs the function of the facility contractor.

DOE-STD-3009-94 Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports

This standard was revised in March 2006 and is now titled Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Documented Safety Analyses (DSA).

This standard describes a DSA preparation method that is acceptable to the DOE as delineated for those specific facilities listed in table 2 of appendix A, General Statement of Safety Basis Policy, to subpart B, Safety Basis Requirements, of 10 CFR 830. It was developed to assist hazard category 2 and 3 facilities in preparing safety analysis reports (SARs) that will satisfy the requirements of 10 CFR 830. Hazard category 1 facilities are typically expected to be category A reactors for which extensive precedents for SARs already exist.

Guidance provided by this standard is generally applicable to any facility required to document its safety basis in accordance with 10 CFR 830. For new facilities in which conceptual design or construction activities are in progress (i.e., Preliminary Documented Safety Analyses [PDSAs]), elements of this guidance may be more appropriately handled as an integral part of the overall design requirements process (e.g., preliminary design to design criteria). The methodology provided by this standard focuses more on characterizing facility safety (i.e., back-end approach) with or without well-documented information than on the determination of facility design (i.e., front-end approach).

Accordingly, contractors for facilities that are documenting conceptual designs for PDSAs should apply the process and format of this standard to the extent it is judged to be of benefit.

Beyond conceptual design and construction, the methodology in this standard is applicable to the spectrum of missions expected to occur over the lifetime of a facility. As the phases of facility life change, suitable methodology is provided for use in updating an existing DSA and in developing a new DSA if the new mission is no longer adequately encompassed by the existing DSA. This integration of the DSA with changes in facility mission and associated updates should be controlled as part of an overall safety management plan.

b) Discuss the process described in DOE-STD-1063-2000, Facility Representatives, by which DOE line management determines an appropriate level of coverage by a facility representative. Include in this discussion, factors that may be considered to adjust the established level of coverage.

Note: DOE-STD-1063-2000 as been superseded by DOE-STD-1063-2006. The following information is from the current standard.

Field element managers shall evaluate each hazardous facility to determine an appropriate level of facility representative coverage. Appendix C, Process to Determine Facility Representative Staffing, provides a detailed process to determine appropriate facility coverage and assignment, and is the expected methodology to be used. The field element manager, or designee, should prepare staffing plans to document these assignments and supporting rationale.

Field element managers shall assign one or more full-time facility representatives to each hazard category 1 facility, unless the field element manager and cognizant Secretarial Officer agree that less coverage is necessary. For nuclear hazard category 2 or 3 facilities, radiological facilities, and hazardous non-nuclear facilities, field element managers may assign a facility representative to two or more facilities. In unusual situations, when it is impractical to assign a sufficient number of facilities to occupy a person full-time, the field element manager may assign the duties of a facility representative to be performed part-time as a collateral function.

It is important that a facility representative's primary duty of providing DOE an on-site presence not be diminished. Field element managers should make assignments so that facility representatives spend a significant portion of their time in their assigned facility(ies). It is preferable that facility representative offices be located within the facility of primary responsibility. Field element managers should make assignments so that administrative work does not prevent facility representatives from performing their primary function of monitoring the performance of the facility and its operations.

To the degree that facility representatives are advanced or otherwise lost from the program, field element managers should take necessary steps to ensure departing facility representatives are replaced in a timely manner. The goal of the field element manager should be to recruit and hire technically capable personnel to fill facility representative vacancies in an expeditious manner. Recognizing the lengthy average time for a new facility representative candidate to achieve full qualifications (i.e., approximately 18 months), field element managers should strive to recruit experienced candidates from technically rigorous programs, both from within DOE and from external sources, to minimize time in qualification. Such potential sources include DOE safety system oversight personnel, DOE subject matter expert personnel, and personnel from directly related fields such as naval nuclear power, commercial nuclear power, radioactive waste management, nuclear weapons, nuclear research, industrial safety, chemical safety, or accelerator facility programs.

As part of the overall staffing strategy, field element managers should also consider making use of existing DOE and NNSA technical intern programs to provide a source of prospective facility representative candidates, especially for sites that have experienced historically high attrition rates.

Field element managers should review staffing plans and assignments of facility representatives at least annually to ensure that coverage assignments and responsibilities are appropriate to the hazards and level of activity involved.

Field element managers may also establish provisions for changing coverage. For example, as the degree of hazard, complexity, or other governing factors is reduced, the field element managers may increase the number of processes, facilities, buildings or areas covered by a single facility representative. Field element managers may use special coverage assignments for a facility that operates only intermittently. Also, field element managers should consider periodically rotating facility representatives to different facilities to maintain objective oversight, to broaden each facility representative's experience base, and to provide flexibility for backup coverage during periods when facility representatives are absent.

Field element managers should make facility representative assignments to optimize effective interaction with the facility operating organization line management responsible for ensuring safe and efficient performance at the facility. For example, field element managers may make assignments based on facility and/or operating organization subdivisions. If the contractor has established a building or facility manager concept, the field element manager may assign facility representatives on a similar basis.

c) Using the guidance in DOE-STD-1073-93, Guide for Operational Configuration Management Program, discuss the System Engineer concept as it applies to Facility Representative oversight of safety systems. Specifically address the areas of configuration management, assessment of system status and performance, and the technical support for operation and maintenance activities.

Where there is a cognizant system engineer (CSE) for a system, the CSE should be involved in the configuration management process for that system. DOE O 420.1A, Facility Safety, requires contractors to designate a CSE for each system for DOE Category 1, 2, or 3 nuclear facilities. The qualifications for the CSE must be consistent with those defined in DOE O 420.1A. In addition, as stated in DOE O 433.1, Maintenance Management Program for DOE Nuclear Facilities, the CSE has the lead responsibility for the configuration management of design.

The CSE must be knowledgeable of the system and the related safety basis. The CSE must also retain a working knowledge of the facility's operation and the existing condition of the system. Consequently, the CSE is also responsible for overseeing the configuration of the assigned system to ensure that it continues to be able to perform its expected functions. The CSE should

- be knowledgeable of the system safety functions, requirements, and performance criteria and their bases;
- understand how the system SSCs are designed and how they function to meet the requirements and performance criteria;
- understand system operation;
- be knowledgeable of the testing and maintenance necessary to ensure the system continues to be able to perform its safety functions;
- be responsible for ensuring that documents related to the system are complete, accurate, and up-to-date, including SDDs, technical drawings, diagrams, and procedures for surveillance, testing, and maintenance; be appropriately involved in the design, review, and approval of changes affecting/impacting system design, operation, and maintenance.

Because the CSEs are expected to have a thorough understanding of system design expectations, operating requirements, and current configuration, the CSEs should have a major role in identifying the CM SSCs. CSEs should also participate in the identification of the design requirements for their system and the SSCs within the system. Finally, each CSE should participate in the configuration management review of any changes that are made to the system for which the CSE has cognizance responsibility. A change to a component also may impact system performance. Consequently, a CSE should be engaged in the review process. A change to a component or system may impact nearby or interconnected components or systems. This potential should be assessed in the review. The CSEs for nearby or interfacing systems should be consulted as appropriate.

The CSE concept has been used in the commercial nuclear industry to provide a technical focal point for each system. The CSE develops resident technical expertise and facility knowledge, centralizes resolution of SSC performance problems for more timely and effective response, and interfaces between the facility operations and maintenance organizations and the design engineering organization.

The CSE concept benefits configuration management as well as many other facility activities including facility status and troubleshooting, operations support, coordination of testing and other system-related activities, and communication among departments.

The duties, responsibilities, and interfaces of each CSE need to be clearly defined, documented, communicated to, and understood by supporting facility organizations. To facilitate the change control process, each CSE should perform the following functions:

- Monitor and track the status of the assigned system, especially during changes (e.g., physical changes in progress and temporary physical changes).
- Conduct and/or observe equipment performance monitoring, evaluating the results of performance monitoring and surveillance, trending important data, and initiating corrective actions.
- Review and approve post-modification, post-maintenance, surveillance, and special test procedures and test results.
- Provide assistance to operations and maintenance, as needed.
- Identify any situation where the design engineering organization should be consulted for advice or services.

Contractors should include the design engineers, as well as CSEs, in the periodic review of operating and maintenance procedures to alert maintenance and other organizations to any design changes in the affected systems.

3.1 A facility representative shall demonstrate a working-level knowledge of the Department of Energy/facility contract provisions necessary to provide oversight of the operating contractor operations.

a) Describe the facility representative’s role in contractor oversight.

The purpose of the DOE Facility Representative Program is to ensure that competent DOE personnel are assigned to oversee the day-to-day contractor operations at DOE’s most hazardous facilities. Oversight performed by facility representatives provides DOE line managers with accurate objective information on the effectiveness of contractor work performance and practices, including implementation of the integrated safety management system.

For each major facility or group of lesser facilities, a facility representative is an individual assigned responsibility by the field element manager (or designee) for monitoring the safety performance of the facility and its operations. This individual is the primary point of contact with the contractor for operational and safety oversight, and is responsible to the facility's DOE line manager.

DOE facility representatives perform oversight of their assigned facilities to ensure that
- the contractor is operating facilities safely and efficiently (i.e., within the boundaries of those controls invoked in the facility authorization basis);
- the contractor's management system is effectively controlling conduct of operations and implementing integrated safety management objective, principles, and functions;
- DOE line/program managers are cognizant of the operational performance of facility contractors;
- effective lines of communication between DOE and its operating contractors are maintained during periods of normal operation, and following reportable events, in accordance with DOE Orders and requirements.

The facility representative is assigned to monitor the performance of facility operations and management. The facility representative is a direct safety oversight extension of DOE line management to each respective facility.

b) Compare and contrast the following:
- **Department of Energy's expectations of the operating contractor**
- **Operating contractor's expectations of the Department of Energy**

The facility representative should observe, evaluate, and report on the effectiveness of the operating contractor in multiple areas important to safe, efficient, and productive operation, such as operational performance, quality assurance, management controls, emergency response readiness activities, and assurance of worker health and safety. Additionally, the facility representative should evaluate the overall effectiveness of the operating contractor in implementing corrective actions to deficiencies identified by facility reviews, including corrective actions which stem from identifying, reporting, and tracking nuclear safety noncompliance under the Price-Anderson Amendments Act of 1988. The frequent presence of a facility representative in the facility is intended and expected to improve communications between DOE and the operating contractor. This improved communications is intended and expected to lead to a better understanding of DOE expectations by the contractor, and aid in the implementation of enhancements to facility work practices and operating conditions.

The field element manager should clearly define the relationship between the facility representative and the facility operating contractor, and ensure that these expectations are understood by both parties. Field element managers should document responsibilities and expectations in the contract between DOE and the facility operating contractor. Facility representatives occupy a unique position in the transmission of information between DOE and its contractors. Facility representatives should be able to communicate effectively with all levels of the contractor organization. They should be familiar with the contractor chain of command for facility operations. The facility representative should always strive to work constructively and effectively with contractor personnel to meet the shared goals of productive and safe facility operations, in accordance with relevant DOE and contractual expectations.

Facility representatives should represent DOE to the contractor and ensure the contractor carries out DOE operational safety policies in a manner consistent with DOE Program Office and field element expectations, relevant contract requirements, and the contractor's Integrated Safety Management (ISM) System description. In defining the relationship between a facility representative and contractor, the following points are emphasized:

- The facility representative functions as a part of DOE line management, and therefore should exercise authority consistent with specific program and management guidance established by the field element.
- The contractor is responsible for the safety and efficient operation of the facility. The contractor is accountable to DOE to perform its operations in a manner that ensures the safety and health of personnel and protection of the environment. No facility representative activity or inactivity can diminish the contractor's responsibility.
- The facility representative is responsible for determining that the contractor is operating the facility in a safe manner, consistent with the established safety expectations and requirements. Facility representatives fulfill this responsibility by assessing the contractor's performance and discussing identified deficiencies and corrective action with contractor management.
- Although the facility representative identifies deficiencies, the ultimate responsibility for identifying and correcting deficiencies rests with the operating contractor. Field element managers should ensure that the contractor does not rely solely on the facility representative to identify or correct deficiencies.
- Minor events or problems are frequently clues that indicate more general problems in the contractor's organization, management, personnel abilities, or practices. Therefore, attention to detail in the identification and correction of minor problems can result in significant improvements in the contractor's performance. When corrective actions are called for, DOE line/program managers should initiate formal action with the operating contractor. Additionally, the facility representative should also provide input to formal mechanisms such as confirmation of actions or orders, if necessary.
- The facility representative shall adhere to certain rules of conduct, or protocol, while performing assigned duties, including the facility's approved conduct of operations procedures. The field element manager should establish a formal protocol for facility representatives.

c) Identify the key elements and features of an effective DOE and operating contractor relationship.

Facility Representative Program assessment criteria include the following objective evaluation:

- Do facility representatives actually have unencumbered access and "Stop Work" authority at their assigned facilities? Has this been communicated formally to the contractor?
- Has "Stop Work" authority been exercised? Was it appropriate? Was it effective? Were there occasions when it was appropriate for facility representatives to exercise "Stop Work" authority, but they did not do so?
- What is the effectiveness of the facility representatives as verified by observing selected qualified personnel who are monitoring training, operations, or maintenance evolutions?
- Are reviews of occurrence reports accomplished in a timely manner while ensuring that the root cause has been determined and effective action proposed?
- Do facility representatives accomplish facility assessments, surveillances, and audits as scheduled, and are the findings meaningful and consistent with facility performance? Do assessments limit the amount of time the facility representative can spend on day-to-day facility oversight?
- How effective is the process for correcting deficiencies when comparing reported dates against the completed action dates? Have all completed actions actually been performed?
- How are tracking, follow-up, and closure of facility representative findings performed? Is there follow-up on issues informally identified by the facility representative?
- How effective is the documentation of facility representative activities (e.g., reports, log keeping)?
- How are facility representative findings reported (formally and informally) to the contractor? Are the reports provided to the contractor consistent with the information recorded by the facility representative? How clear is the process of reporting findings to the contractor?
- Does the facility representative have access to all levels of facility management? How often does the facility representative discuss facility operations issues with the facility manager?
- Do the facility representatives regularly interface with facility operations personnel?
- Are facility representative to contractor interactions formal or informal; collegial or confrontational; helpful or adversarial? Are these interactions effective or harmful to operational safety?
- Does a process exist for ensuring the continued objectivity of facility representatives assigned to a given facility?

d) Describe the facility representative's responsibility associated with contractor compliance under the Price-Anderson Amendments Act.

For all contractors, subcontractors, and suppliers thereto, DOE has the authority to issue notices of violation when non-compliances with nuclear safety requirements are identified. In addition, for cases involving for-profit contractors, DOE has the authority to issue fines for violations of nuclear safety rules for up to $110,000 per day per occurrence. Civil penalties are not applicable to individual employees or to contractors specifically exempted by section 234A(d) of the Atomic Energy Act of 1954 (as amended).

Non-compliances may also be identified during the course of external audits, assessments, surveillances, inspections, or visits conducted by DOE Headquarters (HQ) oversight, field, or site personnel, Defense Nuclear Facility Safety Board representatives, or employees of state governments or federal government entities such as EPA or OSHA. A deficient condition identified to the contractor by these individuals should be evaluated for nuclear safety requirement noncompliance. If a contractor has an effective self-audit/surveillance program, there should be a minimal number of non-compliances identified through this mechanism.

Although non-compliances so identified may be candidates for enforcement action because they were not identified by the contractor, DOE may refrain from such action or from issuing a civil penalty if the contractor requested assistance from DOE or another government agency in resolving problems, and the noncompliance was discovered by DOE or the outside agency while giving assistance. These non-compliances, once identified to facility management, should be evaluated for safety significance and reporting.

Another means of noncompliance identification is the review process associated with the observation of an undesirable event or discovery of degraded equipment. These may be events to be considered for reporting to the Occurrence Reporting and Processing System (ORPS). Of prime importance are the underlying noncompliance conditions that led or contributed to the incident. It is the set of non-compliances that should be considered for reporting to the Noncompliance Tracking System (NTS), depending on whether the set meets reporting thresholds.

e) Describe the role of the facility representative with respect to the contractor performance evaluation process.

Facility representatives perform oversight of their assigned facilities to ensure that DOE line/program managers are cognizant of the operational performance of contractors. Facility representatives assess the contractor's performance and discuss identified deficiencies and corrective action with contractor management.

f) Review and discuss the most recently completed contractor award fee or similar performance evaluation documentation (as applicable).

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

3.2 A facility representative shall demonstrate a working-level knowledge of the DOE/facility authorization agreement process necessary to provide oversight of the operating contractor operations.

a) Identify the purpose and key elements of an effective DOE and operating contractor facility authorization agreement.

Authorization agreements are documented agreements between DOE and the contractor for high-hazard facilities (categories 1 and 2), incorporating the results of DOE's review of the contractor's proposed authorization basis for a defined scope of work. The authorization agreement contains key terms and conditions under which the contractor is authorized to perform the work. Any changes to these terms and conditions would require DOE approval. The need for an authorization agreement will depend on the organization and adequacy of the existing, contractually binding documentation containing key terms and conditions. For example, at sites or facilities that have Standards/Requirements Identification Documents (S/RIDs) in place, it would be undesirable to duplicate the S/RID commitments in an authorization agreement. If an authorization agreement were required, it could simply reference the S/RIDs. The Department and the contractor should ensure that the ISMS includes procedural mechanisms that trigger a review to determine the necessity of having, revising, or eliminating an authorization agreement.

The authorization agreement may serve a number of purposes, such as

- incorporating the results of DOE's review of the contractor's proposed authorization basis for a defined scope of work;
- defining key terms and conditions (controls and commitments) under which the contractor is authorized to perform work (these key terms and conditions must be clearly identified in the agreement and any changes to these key terms and conditions would require DOE approval);
- delineating the key references DOE will approve versus that information that will simply be reviewed for information;
- consolidating the basis for a DOE determination to authorize operations by combining key DOE and contractor authorization basis and assessment documentation into one document;
- minimizing the amount of correspondence required between the contractor and the Department when agreements for routine tasks and activities, which require approval at certain unique facilities, can be approved.

Authorization agreements have also proved beneficial to DOE and contractors for facilities being affected by significant changes in mission, those requiring significant upgrade for their authorization bases, and those undergoing decontamination and decommissioning.

b) Describe the facility representative's responsibility associated with contractor compliance.

Facility representatives perform oversight of their assigned facilities to ensure that the contractor is operating facilities within the boundaries of those controls invoked in the facility authorization basis.

4.1 A facility representative shall demonstrate a working-level knowledge of problem analysis principles and techniques necessary to identify problems, determine potential causes of the problems, and identify corrective action(s).

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 Analysis**

Root Cause Analysis

Root cause analysis includes the following basic steps:

- Identify the problem. Actuation of a protective system constitutes the occurrence but is not the real problem; the unwanted, unplanned condition or action that resulted in actuation is the problem to be solved. For example, dust in the air actuates a false fire alarm. In this case, the occurrence is the actuation of an engineered safety feature. The smoke detector and alarm functioned as intended; the problem to be solved is the dust in the air, not the false fire alarm. Another example is when an operator follows a defective procedure and causes an occurrence. The real problem is the defective procedure; the operator has not committed an error. However, if the operator had been correctly trained to perform the task and, therefore, could reasonably have been expected to detect the defect in the procedure, then a personnel problem may also exist.
- Determine the significance of the problem. Were the consequences severe? Could they be next time? How likely is recurrence? Is the occurrence symptomatic of poor attitude, a safety-culture problem, or other widespread program deficiency? Base the level of effort of subsequent steps of your assessment upon the estimation of the level of significance.
- Identify the causes immediately preceding and surrounding the problem. Then identify the reasons why the causes in the preceding identification step existed, working your way back to the root cause (the fundamental reason that, if corrected, will prevent recurrence of this and similar occurrences throughout the facility and other facilities under your control). This root cause is the stopping point in the assessment of causal factors. It is the place where, with appropriate corrective action, the problem will be eliminated and will not recur.

Causal Factor Analysis

Causal factor analysis is used for multi-faceted problems or long, complex causal factor chains. Cause and effects diagrams describe the time sequence of a series of tasks and/or actions and the surrounding conditions leading to an event. The event line is a time sequence of actions or happenings, while the conditions are anything that shapes the outcome, and ranges from physical conditions (such as an open valve or noise) to attitude or safety culture. The events and conditions as given on a chart describe a causal factor chain.

Change Analysis

Change analysis looks at a problem by analyzing the deviation between what is expected and what actually happened. The evaluator essentially asks what differences occurred to make the outcome of this task or activity different from all the other times this task or activity was successfully completed. This technique consists of asking the questions: What? When? Where? Who? How?

Answering these questions should provide direction toward answering the root-cause determination question: Why? Primary and secondary questions included within each category will provide the prompting necessary to thoroughly answer the overall question. Some of the questions will not be applicable to any given condition. Some amount of redundancy exists in the questions to ensure that all items are addressed. Several key elements to be addressed include the following:

- Consider the event containing the undesirable consequences.

- Consider a comparable activity that did not have the undesirable consequences.
- Compare the condition containing the undesirable consequences with the reference activity.
- Set down all known differences, whether they appear to be relevant or not.
- Analyze the differences for their effects in producing the undesirable consequences. This must be done with careful attention to detail, ensuring that obscure and indirect relationships are identified (e.g., a change in color or finish may change the heat transfer parameters and consequently affect system temperature).
- Integrate information into the investigative process relevant to the causes of, or the contributors to, the undesirable consequences.

Change analysis is a good technique to use whenever the causes of the condition are obscure, you do not know where to start, or you suspect a change may have contributed to the condition. Not recognizing the compounding of change (e.g., a change made five years previously combined with a change made recently) is a potential shortcoming of change analysis. Not recognizing the introduction of gradual change as compared with immediate change also is possible. This technique may be adequate to determine the root cause of a relatively simple condition. In general, though, it is not thorough enough to determine all the causes of more complex conditions.

Barrier Analysis

There are many things that should be addressed during the performance of a barrier analysis. The following questions are designed to aid in determining what barrier failed, thus resulting in the occurrence:

- What barriers existed between the second, third, etc., condition/situation and the second, third, etc., problem?
- If there were barriers, did they perform their functions? How?
- Did the presence of any barriers mitigate or increase the occurrence severity? Why?
- Were any barriers not functioning as designed? Why?
- Was the barrier design adequate? How?
- Were there any barriers in the condition/situation source(s)? Did they fail? Why?
- Were there any barriers on the affected component(s)? Did they fail? Why?
- Were the barriers adequately maintained?
- Were the barriers inspected prior to expected use?
- Were any unwanted energies present? Why?
- Is the affected system/component designed to withstand the condition/situation without the barriers? How?
- What design changes could have prevented the unwanted flow of energy? Why?
- What operating changes could have prevented the unwanted flow of energy? Why?
- What maintenance changes could have prevented the unwanted flow of energy? Why?
- Could the unwanted energy have been deflected or evaded? How?
- What other controls are the barriers subject to? How?
- Was this event foreseen by the designers, operators, maintainers, anyone?
- Is it possible to have foreseen the occurrence? How?
- Is it practical to have taken further steps to have reduced the risk of the occurrence?
- Can this reasoning be extended to other similar systems/components?

- Were adequate human factors considered in the design of the equipment?
- What additional human factors could be added? Should be added?
- Is the system/component user friendly?
- Is the system/component adequately labeled for ease of operation?
- Is there sufficient technical information for operating the component properly? How do you know?
- Is there sufficient technical information for maintaining the component properly? How do you know?
- Did the environment mitigate or increase the severity of the occurrence? How?
- What changes were made to the system/component immediately after the occurrence?
- What changes are planned to be made? What changes might be made?
- Have these changes been properly and adequately analyzed for effect?
- What related changes to operations and maintenance have to be made now?
- Are expected changes cost effective? Why? How do you know?
- What would you have done differently to have prevented the occurrence, disregarding all economic considerations (as regards operation, maintenance, and design)?
- What would you have done differently to have prevented the occurrence, considering all economic concerns (as regards operation, maintenance, and design)?

Barrier analysis is a systematic process that can be used to identify physical, administrative, and procedural barriers or controls that should have prevented the occurrence. This technique should be used to determine why these barriers or controls failed and what is needed to prevent recurrence.

Management Oversight Risk Tree (MORT) Analysis
MORT analysis is used to prevent oversight of the identification of causal factors. It lists, on the left side of the tree, specific factors relating to the occurrence, and on the right side of the tree, the management deficiencies that permit specific factors to exist. The management factors all support each of the specific barrier/control factors. Included is a set of questions to be asked for each of the factors on the tree. As such, it is useful in preventing oversight and ensuring that all potential causal factors are considered. It is especially useful when there is a shortage of experts to ask the right questions. However, because each of the management factors may apply to the specific barrier/control factors, the direct linkage or relationship is not shown but is left up to the analyst. For this reason, events and causal factor analysis and MORT should be used together for serious occurrences: one to show the relationship, the other to prevent oversight.

b) Describe and explain the application of the following root cause analysis processes in the performance of occurrence investigations:
- **Events and Causal Factors Charting**
- **Root Cause Coding**
- **Recommendation Generation**
- **Corrective Action development**
- **Corrective Action verification**

Events and Casual Factors Charting
An events and casual factors chart is a cause and effects diagram that describes the time sequence of a series of tasks and/or actions and the surrounding conditions leading to an

event. The event line is a time sequence of actions or happenings while the conditions are anything that shapes the outcome and ranges from physical conditions (such as an open valve or noise) to attitude or safety culture. The events and conditions as given on the chart describe a causal factor chain. The direct, root, and contributing cause relationships in the causal factor chain may be shown in flowcharts.

Root Cause Coding

Root cause coding is used to assign codes to the root causes of an event. Codes are assigned based on categories. Three major categories of root causes are

- technical (equipment, software, forms)
- organizational (policies, procedures, and protocols)
- human (knowledge-based, rule-based, and skill based)

This is an application that is used in most types of software for root cause analysis.

Recommendation Generation

Recommendation generation is the process of developing recommendations for correcting cause as identified in root cause investigation. As issues arise in the root-cause analysis, potential recommendations for correcting the root cause may be identified.

Corrective Action Development

Root cause analysis enables the improvement of reliability and safety by selecting and implementing effective corrective actions. To begin, identify the corrective action for each cause. Then apply the following criteria to the corrective actions to ensure they are viable. If the corrective actions are not viable, re-evaluate the solutions.

- Will the corrective action prevent recurrence?
- Is the corrective action feasible?
- Does the corrective action allow meeting the primary objectives or mission?
- Does the corrective action introduce new risks? Are the assumed risks clearly stated? (The safety of other systems must not be degraded by the proposed corrective action.)
- Were the immediate actions that were taken appropriate and effective?

A systems approach, such as Kepner-Tregoe, should be used in determining appropriate corrective actions. It should consider not only the impact they will have on preventing recurrence, but also the possibility that the corrective actions may actually degrade some other aspect of nuclear safety. Also, the impact the corrective actions will have on other facilities and their operations should be considered. The proposed corrective actions must be compatible with facility commitments and other obligations. In addition, those affected by or responsible for any part of the corrective actions, including management, should be involved in the process. Proposed corrective actions should be reviewed to ensure the above criteria have been met, and should be prioritized based on importance, scheduled (a change in priority or schedule should be approved by management), entered into a commitment tracking system, and implemented in a timely manner. A complete corrective action program should be based not only on specific causes of occurrences, but also on items such as lessons learned from other facilities, appraisals, and employee suggestions.

A successful corrective action program requires management that is involved at the appropriate level and is willing to take responsibility and allocate adequate resources for corrective actions. Additional specific questions and considerations in developing and implementing corrective actions include the following:

- Do the corrective actions address all the causes?
- Will the corrective actions cause detrimental effects?
- What are the consequences of implementing the corrective actions?
- What are the consequences of not implementing the corrective actions?
- What is the cost of implementing the corrective actions (capital costs, operations, and maintenance costs)?
- Will training be required as part of the implementation?
- In what time frame can the corrective actions reasonably be implemented?
- What resources are required for successful development of the corrective actions?
- What resources are required for successful implementation and continued effectiveness of the corrective actions?
- What impact will the development and implementation of the corrective actions have on other work groups?
- Is the implementation of the corrective actions measurable? (For example, "Revise step 6.2 of the procedure to reflect the correct equipment location," is measurable; "Ensure the actions of procedure step 6.2 are performed correctly in the future," is not measurable.)

Corrective Action Verification

Follow-up includes determining if corrective actions have been effective in resolving problems. First, the corrective actions should be tracked to ensure that they have been properly implemented and are functioning as intended. Second, a periodic structured review of the corrective action tracking system, normal process and change control system, and occurrence tracking system should be conducted to ensure that past corrective actions have been effectively handled. The recurrence of the same or similar events must be identified and analyzed. If an occurrence recurs, the original occurrence should be re-evaluated to determine why corrective actions were not effective. Also, the new occurrence should be investigated using change analysis. The process change control system should be evaluated to determine what improvements are needed to keep up with changing conditions. Early indications of deteriorating conditions can be obtained from tracking and trend analyses of occurrence information. In addition, the ORPS database should be reviewed to identify good practices and lessons learned from other facilities. Prompt corrective actions should be taken to reverse deteriorating conditions or to apply lessons learned.

c) Describe the following types of investigations and discuss an example of the application of each:

- **Type A**
- **Type B**

DOE O 225.1 provides an accident investigation categorization algorithm as attachment 2. This algorithm provides the criteria for categorizing an accident investigation as either a type A or a type B investigation. A table representation of the algorithm breaks the criteria into four different categories of effects: human, environmental, property, and other.

Type A Investigation	Type B Investigation
Human Effects	
Any fatal, or likely to be fatal, injury or chemical or biological exposure to an employee or a member of the public	Any one or series of injuries, chemical exposures, or biological exposures that results in hospitalization of one or more employees or members of the public for more than five continuous days
Any one accident that requires the hospitalization for treatment of three or more individuals	Any one or series of injuries, chemical exposures, or biological exposures that results in permanent partial disability of one or more employees or members of the public
Any one accident that has a high probability of resulting in the permanent total disability due to injuries, chemical exposures, or biological exposures of DOE, contractor, or subcontractor employees or members of the public	Any one accident or series of accidents within a one-year time period resulting in five or more lost-workday cases, or any series of similar or related accidents involving five or more persons, one or more of which is a lost-workday case
A single radiation exposure to an individual resulting in a. a total effective dose equivalent >25 rem b. a dose equivalent to the lens of the eye >75 rem c. a shallow dose equivalent to an extremity of skin >250 rem d. the sum of the deep dose equivalent for external exposure and the committed dose equivalent to any organ or tissue other than the lens of the eye >250 rem e. a dose equivalent to the embryo or fetus of a declared pregnant worker >2.5 rem	A single radiation exposure to an individual resulting in a. a total effective dose equivalent >10 but <25 rem b. a dose equivalent to the lens of the eye >30 but <75 rem c. a shallow dose equivalent to an extremity of skin >100 but <250 rem d. the sum of the deep dose equivalent for external exposure and the committed dose equivalent to any organ or tissue other than the lens of the eye >00 rem but <250 rem e. a dose equivalent to the embryo or fetus of a declared pregnant worker >1.0 but <2.5 rem
Environmental Effects	
Release of a hazardous substance, material, waste, or radionuclide from a DOE facility (onsite or offsite) in an amount greater than five times the reportable quantities specified in 40 CFR 302 that results in serious environmental damage	Release of a hazardous substance, material, waste, or radionuclide from a DOE facility (onsite or offsite) in an amount greater than or equal to two times but less than five times the reportable quantities specified in 40 CFR 302 that results in serious environmental damage

Type A Investigation	Type B Investigation
Property Effects	
Estimated loss of, or damage to, DOE or other property, including aircraft damage, greater than or equal to $2.5 million or requiring estimated costs greater than or equal to $2.5 million for cleaning, decontaminating, renovating, replacing, or rehabilitating structures, equipment, or property	Estimated loss of, or damage to, DOE or other property, greater than or equal to $1 million but less than $2.5 million, including aircraft damage, and costs of cleaning, decontaminating, renovating, replacing, or rehabilitating structures, equipment, or property
Any apparent loss, explosion, or theft involving radioactive or hazardous material under the control of DOE, contractors or subcontractors in such quantities and under such circumstances as to constitute a hazard to human health and safety or private property	The operation of a nuclear facility beyond its authorized limits
Any unplanned nuclear criticality	
Other Effects	
Any accident or series of accidents for which a Type A investigation is deemed appropriate by the Secretary or the Assistant Secretary of Environment, Safety, and Health	Any accident or series of accidents for which a Type B investigation is deemed appropriate by the Secretary or the Assistant Secretary of Environment, Safety, and Health; the associate deputy secretary for field management; the cognizant Secretarial Officer; or the head of the field element (This includes departmental crosscutting issues and issues warranting the attention of local news or interest groups.)

d) Explain the necessity for and differences between the immediate, short-term, and long term actions taken as the result of a problem identification or occurrence.

Immediate actions are usually those required to fix or mediate the problem and prevent re-occurrence. The time frame for completion of short-term and long-term corrective actions depends on many factors, including priority (urgency), available budget and personnel, and technology.

e) Explain and apply problem analysis techniques to the identification of potential problems and/or the prevention of problems. Include in your explanation, data gathering techniques and the use of trending/history.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

f) Observe a contractor problem analysis and critique their results.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

4.2 A facility representative shall demonstrate a working-knowledge of assessment techniques such as the planning and use of observations, interviews, and document reviews to assess facility performance, report results of assessments, and follow up on actions taken as the result of assessments.

a) Describe the facility representative's role with respect to performance of oversight of Government-Owned Contractor Operated facilities.

Facility representatives are assigned to oversee the day-to-day contractor operations at hazardous facilities. Oversight performed by facility representatives provides DOE/NNSA line managers with accurate, objective information on the effectiveness of contractor work performance and practices, including implementation of the ISM system. The information that they provide can be used proactively to ensure that work is completed in a safe and environmentally responsible manner.

Facility representatives are the eyes and ears of line management within the facilities. Well-managed and well-trained facility representatives are an important line management tool for ensuring safe operations.

Facility representatives, on a day-to-day basis, are primarily concerned with formality of operations, authorization basis controls, and occurrence reporting. These functions are part of an ISM system that incorporates safety into management and work practices at all levels, addressing all types of work and all types of hazards to ensure safety for the workers, the public, and the environment. The applicable ISM core functions are the implementation of hazards controls, performance of work within controls, and feedback and continuous improvement.

NNSA facility representatives perform oversight of their assigned facilities to ensure that

- contractors operate facilities safely and efficiently (i.e., within the boundaries of those controls invoked in the facility authorization basis);
- contractor management systems effectively control conduct of operations and implement ISM objectives, principles, and functions;
- DOE/NNSA line/program managers are cognizant of the operational performance of facility contractors;
- effective lines of communication between DOE/NNSA and its operating contractors are maintained during periods of normal operation and following reportable events, in accordance with DOE/NNSA Orders and requirements.

Facility representatives ensure that the conduct of operations at facilities is managed so that

- operations at DOE facilities are conducted in a manner that ensures an acceptable level of safety;
- operators at facilities have procedures in place to control the conduct of their operations;

- line organizations review existing and planned programs important to safe and reliable facility operations;
- line organizations assess the effectiveness of corporate directives, plans, or procedures at facilities under their cognizance.

b) Describe the assessment requirements and limitations associated with the facility representative's interface with contractor employees.

Facility representatives perform assessments per the annual line oversight plan that uses a tailored approach to ensure that a broad-based and systematic review of all aspects of facility operations is conducted over an established period of time. Facility assessments are not intended to conflict with or duplicate other assessment efforts, nor are they intended to unduly restrict the facility representative's day-to-day oversight of assigned facilities. In addition, facility representatives perform field observations to allow for the early identification of specific and systemic issues, and serve as input for determining if an assessment is needed. Areas of emphasis include conduct of operations, weapons and explosives operations, and surveillance and maintenance activities. Reports are used to document facility representative activities and are an essential communications tool for presenting issues to senior management. Additionally, these reports allow for trending individual findings and for identifying issues that cross facility or divisional boundaries.

Facility representatives require a special relationship with the contractor's staff that recognizes that, although facility representatives have oversight responsibility for DOE/NNSA, their contribution is expected to be positive and constructive. It is important that facility representatives neither put the contractor's interests above those of DOE/NNSA nor limit themselves to being inspectors for DOE/NNSA.

The contractor is responsible for the safe and efficient operation of the facility. The contractor is accountable to DOE/NNSA for performing its operations in a manner that ensures the safety and health of personnel and the protection of the environment. No facility representative activity or inactivity can diminish the contractor's responsibility. Although the facility representative may identify deficiencies, the ultimate responsibility for identifying and correcting deficiencies rests with the operating contractor.

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

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

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

Investigation
It is important to begin an investigation as soon as an assessment is called for to ensure that data is not lost. The information that should be collected consists of conditions before, during, and after operation of the facility; personnel involvement; environmental factors; and other information having relevance to the operation of the facility.

Fact Finding

Once all the data has been collected, the data should be verified to ensure accuracy. The investigation may be enhanced if some physical evidence is retained. Establishing a quarantine area, or the tagging and segregation of pieces and material, should be performed for failed equipment or components. The basic need is to determine the direct, contributing, and root causes so that effective corrective actions can be taken that will prevent recurrence. Some areas to be considered when determining what information is needed include the following:

- Activities related to the operations of the facility
- Initial or recurring problems
- Hardware (equipment) or software (programmatic-type issues) associated with the facility
- Recent administrative program or equipment changes
- Physical environment or circumstances

Some methods of gathering information include conducting interviews and collecting statements. Interviews must be factual. Preparing questions before the interview is essential to ensure that all necessary information is obtained. Interviews should be conducted, preferably in person, with those people who are most familiar with the system. Individual statements could be obtained if time or the number of personnel involved makes interviewing impractical. Interviews can be documented using any format desired by the interviewer. Consider conducting a walk-through of the system or facility as part of the interview if time permits.

Reporting

Review of reports and documents helps develop the foundation for identifying weaknesses and areas that are of concern to an auditor.

Review relevant documents or portions of documents as necessary, and reference their use in support of facility operation. Record appropriate dates and times associated with the occurrence on the documents reviewed. Examples of documents include the following:

- Operating logs
- Correspondence
- Inspection/surveillance records
- Maintenance records
- Meeting minutes
- Computer process data
- Procedures and instructions
- Vendor manuals
- Drawings and specifications
- Functional retest specifications and results
- Equipment history records
- Design basis information
- Safety analysis report (SAR)/technical specifications
- Related quality control (QC) evaluation reports
- Operational safety requirements

- Safety performance measurement system/occurrence reporting and processing system (SPMS/ORPS) reports
- Radiological surveys
- Trend charts and graphs
- Facility parameter readings
- Sample analyses and results (e.g., chemistry, radiological, and air)
- Work orders

e) Describe the contents of an assessment report.

The assessment report provides documentation necessary to support findings and concerns identified by the assessor(s). The report should clearly state the status of reviewed areas and act as the reference for future discussions regarding corrective action plans.

Each assessment report will be unique, depending on the scope and results of the assessment. A typical assessment report includes the following sections:
- Cover page
- Summary
- Background
- Description of assessment
- Results and recommendations
- Conclusion

f) Explain the essential elements and processes associated with the following assessment activities including:
- **Exit Interviews**
- **Closure Process**
- **Tracking to Closure**
- **Follow-up**
- **Corrective Action Implementation**

Exit Interviews
Assessments can gain value from an exit interview. This interview is used primarily to present the assessment summary and provide the assessed organization an opportunity to verify the factual accuracy of assessment results. To facilitate this, assessors should be prepared to provide detailed supporting information for those results (ideally, a draft assessment report should be available at this time). This interview also offers an opportunity for the assessed organization to present its management position and any plans for addressing the results. Reasonable time should be allowed to discuss any concerns, but this interview should not be used to argue the assessment agenda or methodology.

Closure Process
Contractors send a letter to the directives management group (DMG) requesting closure and stating that the corrective actions in the implementation plan have been completed. Any ongoing activities specified in the letter must be noted. The DMG coordinates approval of the closure with the appropriate division of primary interest and the contracting officer’s representative.

Management responsible for the activities assessed is also responsible for the development of effective corrective action of the problem areas or deficiencies discovered during the assessment. At a minimum, the corrective action should address the following:

- Measures to correct each deficiency
- Identification of all root causes for significant deficiencies
- Determination of the existence of similar deficiencies
- Corrective actions to preclude recurrence of like or similar deficiencies
- Assignment of corrective action responsibility
- Completion dates for each corrective action

For independent assessments, the assessment team leader should review the proposed corrective action for concurrence. This will help ensure that the planned actions will be effective in resolving the problem areas and deficiencies reported by the assessment team.

Tracking to Closure

Tracking to closure allows the organization and DOE to track progress made on addressing implementation of assessment findings. This can be done by checklist method or by reviewing the organization's response to findings. This is done to ensure that corrective action is taken in a timely manner.

Follow-Up

After a reasonable period of time has elapsed, follow-up activities should be performed to verify the effectiveness of the corrective actions and how they were implemented. The verification should, at a minimum, sample the corrective actions to determine whether the problem/issue to be addressed has been resolved. The organization's reporting systems (e.g., noncompliance tracking system, occurrence reporting and processing system, external oversight reports and regulatory violations, performance indicators) should be reviewed for evidence of the problem (or a similar problem) recurring. The same techniques used to conduct assessments may be used for verifying corrective actions; however, there are several common ways to verify the implementation of corrective actions, including the following:

- Reassessment of the deficient areas
- Review of new or revised quality-affecting documents such as manuals, procedures, and training records
- Verification during the next scheduled assessment
- Verification by conducting a surveillance covering the areas of concern

Corrective Action Implementation

Contractors will receive approval from DOE for implementing a corrective action plan. Each individual facility and process will differ regarding requirements for receiving approval of its implementation plan.

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

Disputes over the assessment findings, the corrective action plan, or its implementation (such as timeliness or adequacy) must be resolved at the lowest possible organizational level. The organization that disagrees with the disposition of a given issue may elevate the dispute for timely resolution. The organization that disagrees with the disposition of a given issue must elevate the dispute in a step-wise manner through the management hierarchy. The dispute must be raised via a deliberate and timely dispute resolution process that provides each party with equal opportunity for input and a subsequent opportunity to appeal decisions up to the Secretary of Energy, if necessary.

h) Participate in formal meetings between DOE management and senior contractor management to discuss results of Facility Representative assessments.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

4.3 A facility representative shall demonstrate a working-level knowledge of the DOE emergency management system and response practices.

a) Describe the key elements of emergency preparedness, including planning, operations, principles, and methods.

Emergency planning must include identification of hazards and threats, hazard mitigation, development and preparation of emergency plans and procedures, and identification of personnel and resources needed for an effective response.

Emergency preparedness must include acquisition and maintenance of resources, training, drills, and exercises.

Emergency response must include the application of resources to mitigate consequences to workers, the public, the environment, national security, and the initiation of recovery from an emergency.

Recovery must include planning for, and actions taken following, termination of the emergency to return the facility/operations to normal.

Readiness assurance must include assessments and documentation to ensure that stated emergency capabilities are sufficient to implement emergency plans.

b) Explain the facility representative’s role and responsibilities associated with emergency management and response to unplanned events.

Facility representatives will periodically evaluate emergency response readiness activities.

c) Explain the difference between the occurrence reporting and processing system notification requirements and emergency management systems event classification and notification requirements.

Operational Emergencies (OEs) (defined in DOE O 151.1C, Comprehensive Emergency Management System) are the most serious occurrences and require an increased alert status for onsite personnel and, in specified cases, for offsite authorities. The prompt notification requirements, definitions, criteria, and classifications of OEs and appropriate responses are provided in DOE O 151.1C.

An OE is categorized according to the following types:
- Health and safety OE
- Environmental OE
- Security and safeguards OE
- Offsite DOE transportation OE
- Hazardous materials OE

If the emergency is a hazardous materials OE, it is then classified according to the following options:
- Alert
- Site area emergency
- General emergency

An event must be categorized as an OE as promptly as possible, but no later than 15 minutes after event recognition/identification/discovery.

For OEs, initial emergency notifications must be made to workers, emergency response personnel, and organizations, including DOE/NNSA elements and other local, state, tribal, and federal organizations. The manager/administrator of each DOE/NNSA or contractor-operated site/facility must notify
- state and local officials and the Cognizant Field Element Emergency Operation Center and Headquarters Operations Center within 15 minutes, and all other organizations within 30 minutes of the declaration of an alert, site area emergency, or general emergency;
- the Cognizant Field Element Emergency Operation Center and Headquarters Operations Center within 30 minutes of the declaration of an operational emergency not requiring classification;
- local, state, and tribal organizations within 30 minutes, or as established in mutual agreements for declaration of an operational emergency not requiring classification.

The facility manager must categorize all occurrences, except OEs, within 2 hours of discovery by the cognizant facility staff. The significance categories listed below are for those occurrences of interest for complex-wide occurrence reporting:
- Significance Category 1 occurrences are not OEs, and have a significant impact on safe facility operations, worker or public safety and health, regulatory compliance, or public/business interests. These require a prompt notification to the facility representative and to the DOE HQ Operations Center (OC).
- Significance Category R occurrences are those identified as recurring, as determined from the periodic performance analysis of occurrences across a site.
- Significance Category 2 occurrences are not OEs, and have a moderate impact on safe facility operations, worker or public safety and health, regulatory compliance, or public/business interests. These require a prompt notification to the facility representative and, if directed by the facility representative, to the DOE HQ OC.

- Significance Category 3 occurrences are not OEs, and have a minor impact on safe facility operations, worker or public safety and health, regulatory compliance, or public/business interests. These require a prompt notification to the facility representative.
- Significance Category 4 occurrences are not OEs, and have some impact on safe facility operations, worker or public safety and health, and public/business interests.

4.4 A facility representative shall demonstrate a working-level knowledge of applicable DOE Orders sufficient to conduct independent assessment of contractor and/or federal employee work activities.

a) Conduct a minimum of three assessments of contractor or federal employee (as appropriate) work performance related to the following DOE Orders:

- **DOE O 430.1B, Real Property Asset Management (for non-nuclear facilities)**
- **DOE O 5480.19, Conduct of Operations Requirements for DOE Facilities**
- **DOE O 5480.20A, Personnel Selection, Qualification, and Training, Requirements for DOE Nuclear Facilities**
- **DOE O 425.1C, Start-Up and Restart of Nuclear Facilities**
- **DOE O 433.1, Maintenance Management Program for DOE Nuclear Facilities**

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

4.5 A facility representative shall demonstrate a working-level knowledge of conduct of maintenance principles and DOE requirements to ensure maintenance is performed in a safe and efficient manner.

a) Explain the DOE's role in the oversight of contractor maintenance operations.

DOE is responsible for ensuring that a cost-effective and efficient maintenance program is developed and implemented for all DOE nuclear facilities consistent with DOE's mission, safety and health, reliability, quality, and environmental protection objectives. DOE will use operational awareness reviews for evaluation of maintenance program performance and effectiveness.

b) Describe work activity observation skills.

Any field observation process consists of four phases:

- Preparation. Preparation for observing an operation can involve any or all of the following: obtaining and reviewing the procedures that the operations will be using; reviewing records (training records and previous reports); developing a list of questions and key points to be checked; and ensuring that you, as the observer, are aware of the worker's requirements. Preparation is important but not mandatory. Some of the significant issues that have been discovered were not the result of a planned field observation.

- Observation. While observing an operation in progress, ask questions so as not to interfere with the operators, minimize your obtrusiveness by trying to blend into the background and become unnoticed, and, if available, follow along in the procedures that the operators are using. If you see things that do not make sense, or that seem wrong based on your knowledge or experience, address your questions or concerns to the operators.
- Follow-up. A good way to start the follow-up is to prepare a draft report. This will help you identify the questions that still remain unanswered. Keep asking "why" until you have a reasonable understanding of the cause of the problem (i.e., "pull the string"). When reading the draft report, ask yourself "so what?" to determine the significance, whether there really is a problem, what the point is that you are trying to make clear and understandable/defensible, whether or not you need more information, etc.
- Write-up. The report should be written so that senior management can read the report and understand the facts, understand why what you observed is a problem, what the cause(s) is, if known, and the significance of the issues.

NOTE: Keep the following in mind when documenting observations:

- Be specific and factual.
- Be objective (you cannot define the solution before the problem is defined).
- Have your report reviewed by peers.
- Include two or more examples where possible.
- Limit report distribution to only necessary recipients.
- Avoid acronyms.
- Do not procrastinate. Write the report in a timely manner.
- Include strengths when a practice is truly noteworthy.
- Do not disregard problems because other DOE/NNSA individuals are responsible for their resolution.
- Turnover issues to SMEs when possible. However, do not overlook the fact that SME ineffectiveness may be part of the problem.
- Follow-up on the issues. Have they been fixed? If not, why not?

Other good observation techniques and practices are addressed below.

Observe workers in real situations. Some portion of the observation should be performed on the back shift to assure consistent operating contractor performance.

When conducting observations, it is essential that the evaluation be done based on consistent, valid requirements (these may include best business practices and the like), and not to some expectation of the observer's that is not a requirement.

If a deficiency is found, allow the contractor personnel to identify and correct the deficiency on their own. If contractor personnel do not recognize the deficiency, the observer should point out the deficiency and allow the contractor personnel to "do the right thing." If the personnel on the scene do not take appropriate action, bring the problem to the attention of their immediate supervisor and the appropriate manager (e.g., facility representative, facility or building manager, or production supervisor).

Observe the attentiveness of the operators in carrying out their assigned duties and whether the area is free of distractions.

Verify operators are adhering to approved and current procedures for any on-going activity. Procedure adequacy and usability should also be evaluated. Verify the status of selected indications and ensure the operators understand the reasons alarms or annunciations are activated.

Review logbooks, operating orders, and work permits to obtain information concerning operating trends and activities and to note any out-of-service safety system. Visually inspect tags on the panels to determine their age, whether they are consistent with the lockout/tagout log, and how they impact the operators. Apparent anomalies may require follow-up to ensure adequate safety practices are followed and that appropriate corrective actions are completed.

Be alert for alterations or modifications to safety or safety-related equipment.

The operating contractor's programs and culture should be evaluated to ensure that it exhibits and promotes, at a minimum

- clear assignment of responsibility and authority (ownership)
- personal accountability in all aspects of operation
- a sound technical basis for operation
- a conservative, formal approach to operations
- compliance with procedures
- effective and timely communications
- attention to detail
- properly trained and qualified personnel
- strong teamwork
- openness in recognizing and communicating problems
- responsiveness in solving problems
- a questioning attitude among personnel and management
- management involvement in day-to-day operations and performance

c) Explain the application of DOE O 433.1, Maintenance Management Program for DOE Nuclear Facilities and DOE Order 430.1B, Real Property Asset Management (for non-nuclear facilities).

A work-control program based on the requirements of DOE O 433.1 should be integrated with the planning system. The implementation of this program should ensure that the maintenance activities in nuclear facilities are conducted in a manner that preserves and restores the availability and operability of the SSCs important to safe and reliable facility operation. The work-control program should include a work order system, job planning and estimating, time standards, a priority system, procedures and documentation, scheduling, post-maintenance testing, backlog work management, equipment repair history and vendor information, training and qualifications, an ISMS, lockouts/tagouts, work performance standards, human factors, and engineering.

DOE O 430.1B requires that real property assets be maintained in a manner that promotes operational safety, worker health, environmental protection and compliance, property preservation, and cost-effectiveness, while meeting the program missions. This requires a balanced approach that not only sustains the assets, but also provides for their re-capitalization.

Sustainment consists of maintenance and repair activities necessary to keep the inventory of facilities in good working order, and includes regularly scheduled maintenance and anticipated major repairs or replacement of components that occur periodically over the expected service life of the facilities. Lack of sufficient levels of sustainment can result in a reduction in service life.

Each site must have a maintenance program to maintain each real property asset (including plant, property, and equipment) in a condition suitable for its intended use. Preventive, predictive, and corrective maintenance will be used to ensure real property asset availability for planned use and/or proper disposition.

d) Define each of the following maintenance related terms and explain their relationship to each other:

- **Corrective**
- **Preventive**
- **Periodic**
- **Planned**
- **Reliability centered**

Corrective
Corrective maintenance refers to changes made to a system to repair flaws in its design, coding, or implementation.

Preventive
Preventive maintenance is maintenance performed according to a fixed schedule involving the routine repair and replacement of machine parts and components.

Periodic
Preventive, predictive, or seasonal maintenance activities performed on a routine basis (typically based on operating hours or calendar time) that may include any combination of external inspections, alignments or calibrations, internal inspections, overhauls, and SSC replacements.

Planned
Planned maintenance is any maintenance activity for which a pre-determined job procedure has been documented, and for which all labor, materials, tools, and equipment required to carry out the task have been estimated and their availability assured before commencement of the task.

Reliability Centered
Reliability centered maintenance is the practice of maintaining equipment on the basis of the logical application of reliability data and expert knowledge of the equipment, i.e., a systems approach. Normal preventive maintenance (PM) is performed on the basis of time, i.e., maintenance operations are performed on a schedule to prevent poor performance or failure.

e) Explain the purpose and content of a master equipment list.

A master equipment list (MEL) is a detailed list of equipment, components, and structures included in a maintenance program.

f) Observe a contractor preventive maintenance activity and describe the preventive maintenance factors to be considered as the activity is planned.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

g) Observe Post-Maintenance Testing and discuss the activity including several examples of maintenance activities to which Post-Maintenance Testing would be applied.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

h) Describe the procedure development, verification, and validation process.

The basic steps in the procedure development, verification, and validation process are as follows:

- Select the appropriate format and steps.
- If a procedure is being revised, evaluate the change request (including supporting actions).
- Create a draft for review and evaluation.
- Route the draft for review and evaluation.
- Resolve comments and changes.
- Incorporate comments and changes.
- Prepare for final approval or validation of the procedure.
- Approve or validate the procedure.
- Incorporate comments.
- Obtain an additional review, if needed.
- Determine implementing requirements.
- Determine training requirements.
- Complete USQ and hazards control evaluation reviews.
- Publish the document.

i) Explain the purpose of maintaining good facility condition and housekeeping.

Maintaining good facility condition and housekeeping helps prevent fires or minimizes losses if a fire does occur. In addition, it helps worker morale and shows pride in the workplace (conversely, poor facility condition and/or housekeeping is indicative of low morale and poor work practices).

Some elements of an effective housekeeping program are

- using, storing, and disposing of combustible materials, supplies, and wastes;
- using, storing, and disposing of hazardous materials;

- using, storing, and disposing of Resource Conservation and Recovery Act (RCRA) regulated wastes;
- maintaining combustible loading as low as reasonably achievable or to the least amount needed to conduct daily operations;
- using Underwriter's Laboratories (UL) listed or Factory Mutual (FM) approved metal waste containers with self-closing lids or containers designed to be the self-extinguishing type in operating areas;
- using waste containers with an open top and constructed of noncombustible material in offices and restrooms, provided they are seven gallons or smaller in size;
- emptying trash carts in dumpsters before the carts overflow;
- involving line management and facility occupants in maintaining plant cleanliness;
- inspecting work areas to detect and correct housekeeping problems;
- keeping fire doors, exits, and exit access clear and unobstructed;
- properly storing cleaning materials, chemicals, and equipment;
- maintaining clear areas around fire hydrants, post indicator valves, and fire department sprinkler connections;
- maintaining clear areas around electrical distribution equipment;
- assuring electrical equipment is in good working condition;
- assuring that motors and equipment are free of excess lubricant and dust, and that extension cords are not abraded or worn;
- enforcing the smoking policy and the use of designated, approved smoking areas;
- initiating corrective actions when an unsatisfactory condition is observed;
- requesting assistance from fire protection program personnel when developing and establishing procedures, cleanliness standards, and code interpretation;
- maintaining cleanliness in facilities and personal areas.

j) Conduct a facility observation walk through and identify deficiencies often found with respect to material, housekeeping, industrial safety, and radiological areas.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

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

The objectives of configuration management are (1) to establish consistency among design requirements, physical configuration, and documentation (including analysis, drawings, and procedures) for the activity, and (2) to maintain this consistency throughout the life of the facility or activity, particularly as changes are being made.

The key configuration management elements are

- design requirements
- work control
- change control
- document control
- assessments

To ensure that work is appropriately evaluated and coordinated before it is performed, contractors must incorporate a work control process into their procedures. Work control is an administrative process by which work activities are identified, initiated, planned, scheduled, coordinated, performed, approved, validated and reviewed for adequacy and completeness, and documented. Work control processes should ensure that when work activities are performed, consistency is maintained among the documents, the procedures, and the physical configuration of the nuclear facility.

The objective of a maintenance history program is to document SSC maintenance and performance data as a basis for improving facility reliability. This history should assist in ensuring that root causes of failures are determined and corrected and that the information gained is used in future work planning. This may be accomplished by a thorough review and analysis of maintenance performed, diagnostic monitoring data, and industry experience reports.

An effective maintenance history program should contain the following elements:

- A maintenance history file
- Component identification/description
- A maintenance record
- Diagnostic monitoring data
- Vendor correspondence
- Provisions for engineering review and analysis

l) Explain the intent of a maintenance problem analysis program and discuss a maintenance problem where this program has been recently employed.

Systematic analysis should be used to determine and correct root causes of unplanned occurrences related to maintenance. Maintenance history that has been collected and trended to reduce recurring or persistent equipment failures should be reviewed by the analysis program. Incident reports, post-trip reviews, and other similar operating experience review documents and methods supplement the maintenance history program and provide data, including human error data, which should be reviewed by the analysis program.

The intent of an analysis program is to reduce recurring maintenance problems by identifying and resolving their root causes.

m) Explain facility management's role in facility maintenance.

Management should ensure that plant configuration, including the manner in which the facility is maintained, conforms to the established design basis requirements. Many routine activities, if carried out improperly, can have an adverse impact on facility configuration and cause eventual equipment damage or increase the probability or consequences of a significant event. Effective control of facility configuration requires rigorous attention to detail as well as the understanding and commitment of every member of the maintenance organization to observe and report/record material condition and status.

The maintenance policy regarding the control of plant configuration should be clearly defined and communicated to all levels of the organization. The policy should address the scope of configuration management controls, the responsibilities of the maintenance organization, and the principal interfaces between the facility and maintenance organization that directly control material condition assessments and facility design basis requirements. In addition, the policy should identify each maintenance line manager's responsibility for implementing the necessary controls to ensure effective implementation of the configuration management policy.

n) Describe the principles of instrument calibration to ensure safe and efficient operation.

A comprehensive Measuring and Test Equipment (M&TE) program should include the following elements:
- Unique identification numbers on all M&TE that accurately identify the specific devices and provide traceability
- A current MEL identifying all M&TE
- Calibration standards that are traceable to a national standard or are themselves recognized as standards
- Procedures for calibrating M&TE to help control the performance of calibration and to provide repeatable calibrations and acceptance criteria
- Establishment of a calibration frequency that helps maintain M&TE accuracy and availability
- Provision for checking the function of M&TE, when applicable
- Provision of facilities to control storage, issue, and calibration of M&TE
- Segregation and marking of M&TE devices with suspected or actual deficiencies to prohibit their use
- Clear marking to indicate limitations of M&TE devices that are not fully calibrated or usable
- Records for accountability and traceability of use
- A recall system developed for recalibrations
- A maintenance policy that minimizes contamination of M&TE
- Timely evaluations of M&TE devices found to be out of calibration or defective to determine the validity of all measurements and/or calibrations for which they were used
- Trending of M&TE reliability problems to determine if any corrective actions are needed
- Periodic reviews to determine whether the control of M&TE is effective

o) Conduct an assessment of maintenance activities.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

4.6 A facility representative shall demonstrate a working-level knowledge of the occurrence reporting and processing system necessary to ensure that occurrences are properly reported and processed in accordance with DOE O 232.1A, Occurrence Reporting and Processing of Operations Information.

Note: DOE O232.1A has been superseded by DOE M 231.1-2, Occurrence Reporting and Processing of Operations Information. The following information is from the current manual.

a) Define the term reportable occurrence, and using an actual facility-specific occurrence report, discuss the factors contributing to the occurrence.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

b) Describe the intent and contents of DOE O 232.1A requirements for Notification Reports including the following:

- **Reporting philosophy**
- **Identification**
- **Categorization**
- **Notification process**
- **Reporting requirements**
- **Analysis**
- **Root cause determination**
- **Generic implications**
- **Corrective action implementation**
- **Tracking**
- **Closeout**

Reporting Philosophy

To implement the occurrence categorization, notification, reporting, and processing system, the key responsible personnel must be identified and procedures must be developed, approved, and implemented to ensure that all of the occurrence reporting requirements, as delineated in DOE M 231.1-2, are met. The facility manager must be available at all times to carry out the responsibilities for the categorization, notification, and reporting requirements. Facility operators are required to ensure that occurrences resulting from activities performed by subcontractors in support of facility operation are reported in accordance with the provisions of this manual.

For reportable occurrences, facility personnel are required to categorize the occurrences, notify DOE as required, and prepare and submit occurrence reports.

The documentation and distribution requirements will be satisfied by use of a centralized unclassified DOE operational database, the computerized Occurrence Reporting and Processing System (ORPS). However, under no circumstances will occurrence reports containing classified information or Unclassified Controlled Nuclear Information (UCNI) be entered into the ORPS database.

Occurrences involving foreign personnel, governments, organizations, entities, or influence must be reported by the facility manager to the Office of Counterintelligence or the Office of Defense Nuclear Counterintelligence, as appropriate. Such reporting is not intended to interfere with or delay any actions directed toward protection of personnel or property.

Identification

Occurrences may be identified by direct observation of equipment or process malfunctions, log or record reviews, operator recognition of their own or others' errors, or other means.

Operations personnel must take appropriate, immediate action to stabilize and/or place the facility/operation in a safe condition and ensure that any potential environmental effects are stabilized and workers are treated for injuries sustained. Also, actions should be taken to preserve conditions for continued investigation; however, these actions are not to interfere with establishing a safe condition.

The facility staff and operators must, upon identification of an abnormal or suspected abnormal event or condition, promptly notify the appropriate line management and the facility manager of the event status and record and/or archive all pertinent information, including details concerning the discovery of the occurrence and actions taken to stabilize or place the facility/operation in a safe condition.

Categorization

The facility manager must categorize all occurrences, except operational emergencies, within two hours of discovery by the cognizant facility staff following the site/facility-specific procedures developed in accordance with DOE M 231.1-2. The significance categories, as outlined in the occurrence reporting model, are for those occurrences of interest for complex-wide occurrence reporting, and are described very generally below.

Operational emergencies (OEs). OEs are defined in DOE O 151.1C, Comprehensive Emergency Management System. OE occurrences are the most serious occurrences, and require an increased alert status for onsite personnel and, in specified cases, for offsite authorities. The prompt notification requirements, definitions, criteria, and classifications of OEs and appropriate responses are provided in DOE O 151.1C. Written occurrence reports must be completed in accordance with DOE M 231.1-2.

Significance category 1. Occurrences in this category are those that are not OEs and that have a significant impact on safe facility operations, worker or public safety and health, regulatory compliance, or public/business interests.

Significance category R. Occurrences in this category are those identified as recurring, as determined from the periodic performance analysis of occurrences across a site.

Significance category 2. Occurrences in this category are those that are not OEs and that have a moderate impact on safe facility operations, worker or public safety and health, regulatory compliance, or public/business interests.

Significance category 3. Occurrences in this category are those that are not OEs and that have a minor impact on safe facility operations, worker or public safety and health, regulatory compliance, or public/business interests.

Significance category 4. Occurrences in this category are those that are not OEs and that have some impact on safe facility operations, worker or public safety and health, or public/business interests.

If the consequences are not fully determined or the event exceeds the threshold of more than one criterion, then the event must be categorized at the higher criteria level being considered. The occurrence criterion must be continuously reevaluated and changed, as needed, when new information becomes available.

Notification Process

For OEs, the requirements for the prompt and follow-up notifications to DOE, including NNSA and other agencies, and the appropriate emergency responses to be taken, are provided in DOE O 151.1C, Comprehensive Emergency Management System. The specific procedures on how these events are categorized and how and when DOE is notified are included in the site/facility-specific emergency response plans or procedures. If an event has been declared an OE, the facility manager will be responsible for the written notification report and for the completion of all other occurrence reporting requirements, as described below.

Prompt notification requirements for significance category 1, 2, 3, and 4 reportable occurrences are addressed below.

The facility manager must notify the DOE facility representative (in a manner determined locally) and the DOE HQ OC, as required, of the following reportable occurrences as soon as practical (i.e., promptly), but no later than two hours after categorization:

- All significance category 1 occurrences require a prompt notification to the facility representative and DOE HQ OC.
- All significance category 2 occurrences require a prompt notification to the facility representative and, if directed by the facility representative, to the DOE HQ OC.
- All significance category 3 occurrences require a prompt notification to the facility representative.
- Additionally, specific significance category 2, 3, and 4 occurrences (identified as requiring prompt notification with an asterisk in the reporting criteria listed in section 6 of the manual) require prompt notification to the facility representative and DOE HQ OC.

The DOE HQ OC will relay notifications to the appropriate HQ-level program manager and make any further notifications, as required.

The facility manager may use the local field/site emergency operations center to expedite establishing the communication link required and to record and archive conversations. The prompt notification process is as follows:

- The facility manager must e-mail the prompt notification of the reportable occurrence to the DOE HQ OC, and follow up with a phone call to the DOE HQ OC to ensure receipt of the e-mail.
- The prompt notification must clearly state/select the significance category (1, R, 2, 3, or 4) and identify the specific reporting criteria associated with the occurrence.
- Prompt notification to the DOE HQ OC must include information on the following items:
  - Occurrence significance category
  - Location and description of the event
  - Date and time of discovery
  - Damage and casualties
  - Impact of the event on other activities and operations
  - Protective actions taken or recommended
  - Weather conditions at the scene
  - Level of media interest at the scene/facility/site
  - Other notifications made
- All information should be clear and succinct. Avoid jargon. Uncommon or site/facility-specific abbreviations and acronyms should be fully described.
- The facility manager must follow the appropriate security procedures if the notification to DOE may contain classified or sensitive information.
- If the occurrence is recategorized, then the occurrence must be reconsidered for prompt notification. If appropriate, the facility manager must notify the facility representative and the DOE HQ OC as soon as practical, but within the prompt notification time requirements of the new significance category for the recategorized occurrence, and provide the occurrence report number. The DOE HQ OC will make any required internal DOE HQ notifications.
- Follow-up notifications must be made to DOE for any further degradation in the level of safety or impact on the environment, health, or operations of the facility or other worsening conditions subsequent to the previous notification. If a degradation results in upgrading the event to an operational emergency, the DOE HQ OC must be notified in accordance with DOE O 151.1C, Comprehensive Emergency Management System.

Reporting Requirements

In preparing the notification report, and subsequently the final report, the following writing instructions must be followed:

- The report should enable the general reader to understand the basic "what, who, when, where, and how" of the event, the safety issues involved, and the actions taken.
- The subject/title and the first paragraph of the occurrence description should relay the essential nature of the event (i.e., a summary of the occurrence in newspaper style).
- All information should be clear and succinct. Avoid redundant and unnecessary text and lengthy log book accounts, unless a discussion of the event in chronological order is considered essential to understanding the event.
- Complex and more significant occurrences should warrant a greater level of detail. Significance category 4 occurrences would likely need only a short paragraph under occurrence description. However, all reports should present enough information so that the general reader understands why the event needs to be reported and what the effect is.

- Avoid jargon and uncommon or site/facility-specific abbreviations and acronyms. If used, acronyms should be initially spelled out.
- Unless necessary to record and explain the event (e.g., suspect/counterfeit items or material), use general descriptions of equipment, procedures, etc., rather than presenting lengthy detailed titles and the numbers and letters assigned to those items.
- Quantify the level of contamination, dose, release, and damage (e.g., estimate the acres of wild land burned) when possible, instead of merely stating a reportable limit was exceeded.
- Use active rather than passive voice whenever possible. For example, write, "the electrician severed the conduit" rather than "the conduit was severed."
- When appropriate for clarification, photos, sketches, and drawings must be maintained with the occurrence report record. In addition, sites are encouraged but not required to make photos, sketches, and drawings available via a Web page, with the Web page address included as a hyperlink in the ORPS report.

Analysis
The facility manager should use the graded approach described in the occurrence reporting model when determining the level of effort required for the investigation into the causes of the occurrence. The graded approach is based on the significance, severity, or risk associated with the event or condition.

For operational emergencies, in general, the investigation, problem analysis, and corrective action process should parallel the process for significance category 1 occurrences. However, the facility manager should consider a graded approach when determining the level of effort for the investigation into the cause of the operational emergency. The graded approach is based on whether the operational emergency was directly caused by DOE operations or resulted from non-DOE operations or natural phenomena. For example, investigations of an operational emergency involving the release of hazardous materials might require an accident investigation or the assembly of a team of investigators and subject matter experts. Investigation of an operational emergency resulting from a DOE facility being required to implement protective actions because a non-DOE activity offsite released hazardous materials, or investigation of an operational emergency resulting from an earthquake, may not require root cause determination because the initiating event was clearly beyond DOE's control.

Root Cause Determination
All causes must be identified as required in the occurrence reporting model and included in the occurrence report. The cause codes to be used for reporting are provided in the causal analysis tree. Guidance on selecting the appropriate cause code is provided in DOE G 231.1-2, Occurrence Reporting Causal Analysis Guide. The cause description field should include a brief discussion to clearly link the event to the cause code(s).

For those occurrences that require a formal root cause analysis, any of the site-approved root cause analysis methodologies are permitted. The methodology used must be included in the cause description field of the occurrence report.

In addition to determining the causes of the occurrence, any weaknesses in the facility's implementation of the ISM program must be identified and entered in the ISM field, as discussed in DOE G 231.1-1, Occurrence Reporting and Performance Analysis Guide.

Generic Implications
Generic (or programmatic) implications are identified and elevated to the proper level for appropriate action. Generic implications should be reviewed (and shared) to ensure that actions are taken to minimize or prevent recurrence, and may be used to improve operations.

Facility representatives are responsible for reviewing and assessing reportable occurrence information from facilities under their cognizance to determine the acceptability of the facility manager's evaluation of generic implications, and to ensure that facility personnel involved in these operations perform the related functions. Facility representatives are responsible for ensuring that occurrences that may have generic or programmatic implications are elevated to the site manager for appropriate action.

Corrective Action Implementation
The facility manager is responsible for corrective action implementation and closeout.

Facility representatives are responsible for reviewing and assessing reportable occurrence information from facilities under their cognizance to determine the acceptability of corrective action implementation and closeout, and to ensure that facility personnel involved in these operations perform the related functions.

Tracking
The facility manager must track all corrective actions to closure, including independent verification or sampling at the facility level, and must also evaluate the effectiveness of the corrective actions to prevent recurrence (if applicable); he or she may use the ORPS database to track the status of final report corrective actions. Site/contractor corrective action programs must include management of significance category 4 occurrences, whose corrective actions are not managed through ORPS.

Closeout
The facility manager is responsible for corrective action implementation and closeout.

Facility representatives are responsible for reviewing and assessing reportable occurrence information from facilities under their cognizance to determine the acceptability of the closeout, and to ensure that facility personnel involved in these operations perform the related functions.

c) Explain the facility representative and operating contractor's responsibilities for occurrence reporting, including a discussion of the following:

- **Notification report**
- **Final report**
- **Closing out and verifying occurrence reports**
- **Processing occurrence reports which cross lines of facility representative responsibility**
- **Contractor occurrence reporting procedures**

Notification Report
The report should enable the general reader to understand the basic "what, who, when, where, and how" of the event, the safety issues involved, and the actions taken. It should relay the essential nature of the event (i.e., a summary of the occurrence in newspaper style). Complex and more significant occurrences should warrant a greater level of detail (e.g., significance category 4 occurrences would likely need only a short paragraph under occurrence description); however, all reports should present enough information so that the general reader understands why the event needs to be reported and what the effect is.

Final Report
The final report must be prepared by the facility manager and submitted as soon as practical, but within 45 calendar days after initial categorization of the occurrence. The final report must document the following:

- The significance, nature, and extent of the event or condition
- Causes of the event or condition (including the root cause, as required)
- Immediate actions taken and the corrective action(s) to be taken
- Lessons learned

If the facility representative or program manager does not approve the final report, the facility representative or program manager who is rejecting the report must provide the reason for disapproval in the comment section of the report at the time the action is taken. The revised final report must be resubmitted within 21 calendar days of the disapproval. If it cannot be re-submitted within this time, an update report must be submitted within the 21 calendar days explaining the delay and providing an estimated date for re-submittal of the final report. This information must be reported in the "evaluation" block of the occurrence report.

Closing Out and Verifying Occurrence Reports
For operational emergencies and significance category 1, R, and 2 final reports, the facility representative must review, approve, and add any comments, as necessary, within 14 calendar days after receipt of the report. For operational emergencies and significance category 1 final reports, after the facility representative has approved the occurrence report, the program manager must review, approve, and add any comments to the final report within 14 calendar days. If the ORPS database is being used, the facility representative's and program manager's comments should be provided through ORPS. Facility representative and program manager comments are not required for their approval of the report.

Processing Occurrence Reports Which Cross Lines of Facility Representative Responsibility
When occurrence reports cross lines of facility representative responsibility, one facility representative will be assigned responsibility for the report. That facility representative will consult with any other interested facility representative, but will retain ultimate responsibility for the occurrence.

Contractor Occurrence Reporting Procedures
For reportable occurrences, contractors must categorize the occurrences, notify DOE as required, and prepare and submit occurrence reports. At sites with more than one facility

management contractor, contractors may make arrangements for one of the contractors to prepare and submit reports for the entire site; however, each contractor is responsible for ensuring that occurrence reports are submitted for activities within its scope of work.

d) Given an actual occurrence report, determine the adequacy of the review process used, that causes were appropriately defined, that corrective actions addressed causes, that the lessons learned were communicated, that planned corrective actions were appropriate, and verify that corrective actions have been completed.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

e) Explain the facility representative's responsibilities associated with DOE O 442.1A, Department of Energy Employee Concerns Program with respect to the identification, reporting, reviewing, and documentation of employee concerns.

Facility representatives, like all DOE/NNSA employees, are responsible for the prompt identification of employee concerns regarding DOE facilities or operations in a manner that provides the highest degree of safe operations.

The Order requires that DOE employees, including NNSA and DOE contractor employees (i.e., any person working for a DOE contractor or subcontractor on a DOE project), be informed of the employee concerns program (ECP) process. Facility representatives should encourage employees to first seek resolution of problems with first-line supervisors or through existing complaint or dispute resolution systems, but should also ensure that employees know that they have the right to report concerns through the DOE ECP. Facility representatives should look out for management's intolerance for reprisals against or intimidation of employees who have reported concerns. Independent assessments must be planned and conducted to measure item and service quality, to measure the adequacy of work performance, and to promote improvement. The group performing independent assessments must have sufficient authority and freedom from the line to carry out its responsibilities. Persons conducting independent assessments must be technically qualified and knowledgeable in the areas assessed.

f) Discuss the process for, and importance of, applying lessons learned from occurrence reports to facility operations.

One of the major purposes of ORPS is to provide feedback of safety and operational information identified in the Occurrence Reports to other DOE facilities. Identifying and sharing with others lessons learned and generic or programmatic implications from occurrences, and taking actions to minimize or prevent recurrence are of great importance. Lessons learned must be identified in the final report and applied and validated before closure of the OR.

The contractor must collect and disseminate to their personnel information from occurrences related to their facilities and similar DOE facilities. This information includes both lessons learned and good practices. Additionally, the contractor should use this information for trending and analysis, and for early identification and correction of deteriorating conditions.

4.7 A facility representative shall demonstrate a working-level knowledge of the Department's philosophy and approach to implementing integrated safety management.

a) Explain the basis upon which the safety management functions could differ from facility to facility.

The mission varies from facility to facility: manufacturing to assembly, design to test, and so on. Each facility performs a different type of work. The safety management functions should be designed to accommodate the needs of the specific facility. The core functions of the ISM address this design. The scope of work performed in the facility is defined. The hazards associated with performing that work is then analyzed. Controls are then developed to reduce the potential for injury due to exposure to those hazards. Finally, work instructions are developed to ensure that work is performed within the controls established for that facility.

b) Discuss the underlying safety management issues affecting the design, construction, operation, and maintenance of the Department's facilities, activities, and assets.

Safety mechanisms define how the core functions are performed. The mechanisms may vary from facility to facility and from activity to activity, based on the hazards and the work being performed, and may include the following:

- Departmental expectations expressed through directives (policy, rules, Orders, notices, standards, and guidance) and contract clauses
- Directives on identifying and analyzing hazards and performing safety analyses
- Directives that establish processes to be used in setting safety standards
- Contractor policies, procedures, and documents established to implement safety management and fulfill commitments made to the Department

c) Describe the Departmental capabilities/resources that could be utilized to solve short-term technical safety issues.

Resources that can be used to solve short-term technical safety issues include the following:

- Local site office and contractor subject matter experts
- NNSA Service Center subject matter experts
- NNSA HQ subject matter experts
- National Laboratories subject matter experts (particularly Tri Labs)

4.8 A facility representative shall demonstrate a working-level knowledge of the Department's philosophy and approach to implementing quality assurance programs.

a) Identify the purpose and key elements of quality assurance programs.

The purpose of quality assurance (QA) programs is to ensure that the quality of DOE/NNSA products and services meet or exceed customers' expectations.

QA for all work is based on the following principles:

- Quality is assured and maintained through a single, integrated, effective Quality Assurance Program (i.e., management system).
- Management support for planning, organization, resources, direction, and control is essential to QA.
- Performance and quality improvement require thorough, rigorous assessment and corrective action.
- Workers are responsible for achieving and maintaining quality.
- Environmental, safety, and health risks and impacts associated with work processes can be minimized, while maximizing reliability and performance of work products.

DOE endorses the use of a single, integrated Quality Assurance Program (QAP) to satisfy the requirements for the regulated work, quality assurance drivers (e.g., 10 CFR 830 and DOE O 414.1C), any additional quality requirements imposed by DOE elements, and the requirements of this Order. Quality process requirements are implemented under a QAP for the control of suspect/counterfeit items (S/CI) and safety issue corrective actions. The quality management system is intended to support the Department's Integrated Safety Management System (ISMS).

b) Describe performance measures for measuring the effectiveness of quality assurance programs.

Quality assurance programs can be measured using the following criteria.
Criterion 1, Program. Organizations must

- establish an organizational structure, functional responsibilities, levels of authority, and interfaces for those managing, performing, and assessing work;
- establish management processes, including planning, scheduling, and providing resources for work.

Criterion 2, Personnel Training and Qualification. Organizations must

- train and qualify personnel to be capable of performing assigned work;
- provide continuing training to personnel to maintain job proficiency.

Criterion 3, Quality Improvement. Organizations must

- establish and implement processes to detect and prevent quality problems;
- identify, control, and correct items, services, and processes that do not meet established requirements;
- identify the causes of problems, and include prevention of recurrence as a part of corrective action planning;

- review item characteristics, process implementation, and other quality-related information to identify items, services, and processes needing improvement.

Criterion 4, Records and Documents. Organizations must
- prepare, review, approve, issue, use, and revise documents to prescribe processes, specify requirements, or establish design;
- specify, prepare, review, approve, and maintain records.

Criterion 5, Work Processes. Organizations must
- perform work consistent with technical standards, administrative controls, and hazard controls adopted to meet regulatory or contract requirements, using approved instructions, procedures, etc.;
- identify and control items to ensure their proper use;
- maintain items to prevent their damage, loss, or deterioration;
- calibrate and maintain equipment used for process monitoring or data collection.

Criterion 6, Design. Organizations must
- design items and processes using sound engineering/scientific principles and appropriate standards;
- incorporate applicable requirements and design bases in design work and design changes;
- identify and control design interfaces;
- verify/validate the adequacy of design products using individuals or groups other than those who performed the work;
- verify/validate work before approval and implementation of the design.

Criterion 7, Procurement. Organizations must
- procure items and services that meet established requirements and perform as specified;
- evaluate and select prospective suppliers on the basis of specified criteria;
- establish and implement processes to ensure that approved suppliers continue to provide acceptable items and services.

Criterion 8, Inspection and Acceptance Testing. Organizations must
- inspect and test specified items, services, and processes using established acceptance and performance criteria;
- calibrate and maintain equipment used for inspections and tests.

Criterion 9, Management Assessment. Organizations must
- ensure that managers assess their management processes and identify and correct problems that hinder the organization in achieving its objectives.

Criterion 10, Independent Assessment. Organizations must
- plan and conduct independent assessments to measure item and service quality and the adequacy of work performance, and to promote improvement;
- establish sufficient authority and freedom from line management for independent assessment teams;
- ensure that persons conducting independent assessments are technically qualified and knowledgeable in the areas to be assessed.

c) Contrast quality assurance and quality control.

QA aims to assure that quality is built into work; QC aims to confirm that quality was built into work. QA has auditors; QC has inspectors. QA auditors evaluate implementation and effectiveness of processes used to complete work; QC inspectors evaluate completed work for conformance to specifications and drawings.

d) Explain the factors applicable to and methods of implementing the graded approach to quality.

The graded approach must be used to evaluate hazards or risks and to determine the appropriate controls to address those hazards or risks. This process is accomplished by ensuring the level of analyses, documentation, and actions used to comply with requirements are commensurate with the following:

- Relative importance to safety, safeguards, and security
- Magnitude of any hazard involved
- Life-cycle stage of a facility or item
- Programmatic mission of a facility
- Particular characteristics of a facility or item
- Relative importance of radiological and non-radiological hazards
- Any other relevant factors

The first step in the grading process is to identify the consequences and probability of a failure. The second step is to identify the specific requirements to be applied. The third step is to determine the depth, extent, and degree of rigor necessary to comply with the requirements. The final step is to communicate and implement the requirements using documented procedures and controls.

e) Explain the intent of 10 CFR 830, Subpart A and DOE O 414.1C.

Independent assessments must be planned and conducted to measure item and service quality, to measure the adequacy of work performance, and to promote improvement. The group performing independent assessments must have sufficient authority and freedom from the line to carry out its responsibilities. Persons conducting independent assessments must be technically qualified and knowledgeable in the areas assessed.

f) Compare the scope and exclusions of 10 CFR 830, Subpart A, DOE O 414.1C, RW/333P, and other quality assurance program documents.

Title 10 CFR 830, subpart A, establishes quality assurance requirements for contractors conducting activities, including providing items or services that affect, or that may affect, nuclear safety of DOE/NNSA nuclear facilities.

DOE O 414.1C ensures that DOE/NNSA products and services meet or exceed customers' expectations. Its contractor requirements are found in attachment 2, CRD. In the event of a conflict between the CRD and any QA regulation, the regulation prevails. When the contractor conducts activities or provides items or services that affect, or that may affect, the safety of DOE/NNSA nuclear facilities, it must conduct work in accordance with the QA requirements of 10 CFR 830, subpart A.

RW/333P provides quality assurance requirements for the radioactive waste management programs.

g) Describe methods for assessing the implementation of quality assurance program elements.

The implementation of QAP elements is evaluated through independent assessments of contractor organizations to determine adequacy and effectiveness.

h) Explain facility management's and the individual's role in Quality Assurance.

Management retains the primary responsibility and accountability for the scope and implementation of the quality management system. However, every individual in the organization is responsible for achieving quality in his or her activities.

4.9 A facility representative shall demonstrate a working-level knowledge in the area of industrial safety programs.

a) Identify the purpose and key elements of industrial safety programs.

The Occupational Safety and Health Act of 1970 created the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA). OSHA is in the U.S. Department of Labor, and is responsible for developing and enforcing workplace safety and health regulations. NIOSH is in the U.S. Department of Health and Human Services, and is an agency established to help assure safe and healthful working conditions for working men and women by providing research, information, education, and training in the field of occupational safety and health. NIOSH and OSHA often work together toward the common goal of protecting worker safety and health.

The Federal Employee Occupational Safety and Health (FEOSH) program is described in DOE O 440.1A.

Key elements of the program are listed below:

- Implement a written worker protection program.
- Assign worker protection responsibilities, evaluate personnel performance, and hold personnel accountable for worker protection performance.
- Encourage the involvement of employees in the development of program goals, objectives, and performance measures, and in the identification and control of hazards in the workplace.
- Provide workers, without reprisal, the rights to: accompany DOE worker protection personnel during workplace inspections; participate in activities provided for in this Order on official time; express concerns related to worker protection; decline to perform an assigned task because of a reasonable belief that, under the circumstances, the task poses an imminent risk of death or serious bodily harm to that individual, coupled with a reasonable belief that there is insufficient time to seek effective redress through the normal hazard reporting and abatement procedures established in accordance with DOE Orders; have access to DOE worker protection publications,

DOE-prescribed standards, and the organization's own worker protection standards or procedures applicable to the workplace; observe monitoring or measuring of hazardous agents and have access to the results of exposure monitoring; be notified when monitoring results indicate they were overexposed to hazardous materials; and receive results of inspections and accident investigations upon request.

- Implement procedures to allow workers to stop work when they discover serious hazards. The procedures shall ensure that any stop work authority is exercised in a justifiable and responsible manner.
- Inform workers of their rights and responsibilities by appropriate means, including posting the appropriate DOE worker protection poster in the workplace where it is accessible to all workers.
- Identify existing and potential workplace hazards and evaluate the risk of associated worker injury or illness.
- Implement suspect/counterfeit item (S/CI) controls.
- Implement a hazard prevention/abatement process to ensure that all identified hazards are managed through final abatement or control.
- Provide workers, supervisors, managers, visitors, and worker protection professionals with worker protection training.

b) Describe performance measures for measuring the effectiveness of industrial safety programs.

Performance indicators such as lost work time, accident reports, accident severity, and personnel injury are statistics that are tracked and monitored to review the overall effectiveness of a program and to help improve the program.

c) Explain facility management's and the individual's role in industrial safety.

Facility management's roles are to furnish employees a place of employment that is free from recognized hazards that cause or are likely to cause death or serious physical harm, and to comply with the occupational safety and health standards applicable to their agency and with all rules, regulations, and orders issued by the head of the agency with respect to the agency occupational safety and health program.

The individual's roles in industrial safety are to

- comply with the standards, rules, regulations, and orders issued by his/her agency;
- use safety equipment, personal protective equipment, and other devices and procedures provided or directed by the agency and necessary for the individual's protection;
- have the right to report unsafe and unhealthful working conditions to appropriate officials;
- receive authorized official time to participate in the activities provided for in the agency's occupational safety and health program.

d) Describe the basic requirements for the following elements of the Industrial Safety programs:

- **Hearing protection**
- **Eye protection**
- **Fall Protection (including scaffolding)**

- **Machine guarding**
- **Lockout/tagout**
- **Confined Spaces**
- **Non-radiological respirator protection**
- **Hoisting and rigging**

Hearing Protection
The basic requirements for hearing protection are to remove hazardous noise from the workplace whenever possible, and to use hearing protection in those situations where dangerous noise exposures have not yet been controlled or eliminated.

Eye Protection
Engineering controls should be used to reduce eye injuries and to protect against ocular infection. Personal protective eyewear, such as goggles, face shields, safety glasses, or full-face respirators must also be used when an eye hazard exists. The eye protection chosen for specific work situations depends upon the nature and extent of the hazard, the circumstances of exposure, other protective equipment used, and personal vision needs.

Fall Protection
An unprotected side or edge that is six feet or more above a lower level should provide protection from falling by the use of a guardrail system, a safety net system, or a personal fall arrest system.

Examples of requirements related to scaffolds include the following. Additional requirements are available in 29 CFR 1926.451.

Each scaffold and scaffold component shall be capable of supporting, without failure, its own weight and at least 4 times the maximum intended load applied or transmitted to it.

Direct connections to roofs and floors, and counterweights used to balance adjustable suspension scaffolds, shall be capable of resisting at least 4 times the tipping moment imposed by the scaffold operating at the rated load of the hoist, or 1.5 (minimum) times the tipping moment imposed by the scaffold operating at the stall load of the hoist, whichever is greater.

Each suspension rope, including connecting hardware, used on non-adjustable suspension scaffolds shall be capable of supporting, without failure, at least 6 times the maximum intended load applied or transmitted to that rope.

Each suspension rope, including connecting hardware, used on adjustable suspension scaffolds shall be capable of supporting, without failure, at least 6 times the maximum intended load applied or transmitted to that rope with the scaffold operating at either the rated load of the hoist, or 2 (minimum) times the stall load of the hoist, whichever is greater.

The stall load of any scaffold hoist shall not exceed 3 times its rated load.

Scaffolds shall be designed by a qualified person and shall be constructed and loaded in accordance with that design.

Machine Guarding
Any machine part, function, or process that may cause injury must be safeguarded. When the operation of a machine or accidental contact with it could injure the operator or others in the vicinity, the hazards must be controlled or eliminated.

Lockout/Tagout
Locks and/or tags are used when servicing machines or equipment where the unexpected energization or startup of the machines or equipment or the release of stored energy could cause injury to employees. Title 29 CFR 1910.147 establishes minimum performance requirements for the control of such hazardous energy.

Employers are required to establish a program and utilize procedures for affixing appropriate lockout devices or tagout devices to energy isolating devices, and to otherwise disable machines or equipment to prevent unexpected energization, start up, or release of stored energy in order to prevent injury to employees.

Confined Spaces
A confined space is a space that: (1) is large enough and so configured that an employee can bodily enter and perform assigned work; (2) has limited or restricted means for entry or exit (e.g., tanks, vessels, silos, storage bins, hoppers, vaults, and pits); and (3) is not designed for continuous employee occupancy.

If the employer decides that its employees will enter confined spaces, the employer shall develop and implement a written permit space program that complies with 29 CFR 1910.146. The written program shall be available for inspection by employees and their authorized representatives.

Non-Radiological Respirator Protection
Respirators protect the user in two basic ways. The first way respirators protect the user is by removing contaminants from the air; respirators of this type include particulate respirators, which filter out airborne particles, and gas masks, which filter out chemicals and gases. The second way respirators protect the user is by supplying clean air from another source; respirators that fall into this category include airline respirators, which use compressed air from a remote source, and self-contained breathing apparatus (SCBA), which include their own air supply.

Respirators should only be used as a "last line of defense" when engineering control systems are not feasible. Engineering control systems, such as for providing adequate ventilation or scrubbing of contaminants, should be used to negate the need for respirators.

Hoisting and Rigging
Hoisting equipment is commercially manufactured lifting equipment designed to lift and position a load of known weight to a location at some known elevation and horizontal distance from the equipment's center of rotation. Hoisting equipment includes, but is not limited to, cranes, derricks, tower cranes, barge-mounted derricks or cranes, gin poles, and gantry hoist systems. Rigging usually refers to slings used (in conjunction with other material handling equipment) for the movement of material by hoisting. Types of slings

are those made from alloy steel chain, wire rope, metal mesh, natural or synthetic fiber rope (conventional three strand construction), and synthetic web (nylon, polyester, and polypropylene).

Title 29 CFR 1926.753 establishes minimum performance requirements for the control of hoisting and rigging.

4.10 A facility representative shall demonstrate a working-level knowledge of the safety authorization basis, including the documented safety analysis, technical safety requirements, and safety evaluation reports.

a) Explain DOE's role in the oversight of the safety authorization basis.

In the oversight of the safety authorization basis, DOE must

- determine if the contractor methodology used to prepare the DSA is appropriate;
- review and approve the nuclear safety design criteria to be used in preparing the Preliminary DSA (PDSA);
- review and approve the PDSA for any new facilities or for major modifications to hazard category 1, 2, or 3 facilities;
- determine if the contractor may perform limited procurement and construction activities without approval of the PDSA for a new (or for major modifications to an existing) hazard category 1, 2, or 3 facility;
- issue a SER for any new (or major modification to an existing) hazard category 1, 2, or 3 facility before operations or modification can begin;
- review and approve the contractor TSR(s) and any changes to the TSR(s);
- review the safety basis for an existing hazard category 1, 2, or 3 facility and issue a SER;
- review and approve the contractor's USQ procedure (initial approval of existing facilities was done on April 10, 2001) and any revisions thereafter;
- review and approve (or take other action, as appropriate) USQs submitted by the contractor, including those for facility changes and discovery conditions.

Operation outside of the approved safety basis could: (1) reduce the margin of safety for a facility, (2) remove a barrier assumed to be in place that mitigates a release or accident, and (3) place the operation or facility in an unsafe or unanalyzed condition. Operation outside of the safety basis places the facility outside of the risk envelope that DOE has accepted for that facility, and it may carry legal and financial penalties under the PAAA.

The key ways to keep operations within the safety basis are as follows:

- Keep the systems, equipment, and components as they are described in the safety basis documents.
- Operate within the constraints of the limits, procedures, tests, and experiments described in the safety basis documents.
- Implement a change control process that determines if a proposed change, test, experiment, or discovery has an effect (explicitly or implicitly) on the safety basis.

b) Explain the application of 10 CFR 830 subpart B and associated implementation guides and standards.

The safety basis requirements of 10 CFR 830 require the contractor responsible for an NNSA nuclear facility to analyze the facility, the work to be performed, and the associated hazards, and to identify the conditions, safe boundaries, and hazard controls necessary to protect workers, the public, and the environment from adverse consequences. These analyses and hazard controls constitute the safety basis upon which the contractor and NNSA rely to conclude that the facility can be operated safely. Performing work consistent with the safety basis provides reasonable assurance of adequate protection of workers, the public, and the environment.

DOE G 421.1-2, Implementation Guide for Use in Developing Documented Safety Analyses to Meet Subpart B of 10 CFR 830, describes suggested non-mandatory approaches for meeting requirements in 10 CFR 830 related to developing a DSA. The contractor responsible for DOE non-reactor nuclear facilities may prepare its DSA by using the method in DOE-STD-3009-94, Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports.

The contractor responsible for a hazard category 1, 2, or 3 NNSA nuclear facility must establish and maintain the safety basis for the facility. In establishing the safety basis for a hazard category 1, 2, or 3 NNSA nuclear facility, the contractor responsible for the facility must categorize the facility in a manner consistent with DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports.

The contractor responsible for a DOE nuclear explosive facility may prepare its DSA by developing a SAR according to STD-3009 and a hazards analysis report according to DOE-STD-3016-99, Hazards Analysis Reports for Nuclear Explosive Operations.

DOE G 423.1-1, Implementation Guide for Use in Developing Technical Safety Requirements, is used to develop TSRs. TSRs define the performance requirements of safety SSCs and identify the safety management programs that ensure safety. TSRs are aimed at confirming the ability of the SSCs and personnel to perform their intended safety functions under normal, abnormal, and accident conditions. These requirements are identified through hazard analyses of the activities and through identification of the potential sources of safety issues.

DOE G 424.1-1, Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements provides guidance on the USQ process. The USQ process allows contractors to make physical and procedural changes and to conduct tests and experiments without prior NNSA approval if the proposed change can be accommodated within the existing safety basis. The contractor must evaluate any proposed change to ensure that it will not affect the safety basis of the facility. Title 10 CFR 830.203, Unreviewed Safety Question Process, requires NNSA approval of the procedure to implement the USQ process.

DOE-STD-1104-96, Review and Approval of Nuclear Facility Safety Basis Documents (DSAs and TSRs), is used to standardize the process of reviewing and approving DSAs and TSRs. Certain benefits are gained by standardizing fundamental elements of the review and approval process. To that end, this standard establishes NNSA guidelines for the review and approval of these documents, including preparation of SERs for nuclear facilities.

c) Define each of the safety authorization basis related terms and explain their relationship to each other:

- **Documented Safety Analysis (DSA)**
- **Technical Safety Requirements (TSR): This should include Safety Limit, Limiting Safety System Setting, Limiting Condition for Operation, and Administrative Control**
- **Unreviewed Safety Question (USQ) process**
- **Safety Evaluation Report (SER)**
- **Safety System, Structure, or Component (safety SSC)**
- **Defense in depth**

Documented Safety Analysis (DSA)
A DSA reviews the extent to which a nuclear facility can be operated with respect to workers, the public, and the environment, including a description of the conditions, safe boundaries, and hazard controls that provide the basis for ensuring safety.

Technical Safety Requirements (TSRs)
TSRs are comprised of the limits, controls, and related actions that establish the specific parameters and requisite actions for the safe operation of a nuclear facility.

Safety Limit (SL)
SLs are limits on process variables associated with those passive physical barriers that are necessary for the intended facility function and that are required to guard against the uncontrolled release of hazardous materials.

Limiting Safety System Setting (LSSS)
LSSSs are the settings on process variables associated with safety systems that control the facility function and will prevent exceeding the associated safety limits.

Limiting Condition for Operation (LCO)
LCOs are the limits that represent the lowest functional capability or performance level of one or more safety-related items required for the safe operation of a facility.

Administrative Control (AC)
ACs are the provisions relating to organization and management, procedures, record keeping, assessment, and reporting necessary to ensure the safe operation of a facility.

Unreviewed Safety Question (USQ) Process
The USQ rule has a primary role in preserving the DOE safety basis for each nuclear facility. The concept of the USQ allows contractors to make physical and procedural changes and to conduct tests and experiments without prior DOE approval, as long as

these changes do not affect the safety basis of the facility. If the changes do affect the safety basis, DOE must approve the USQ.

Safety Evaluation Report (SER)
The purpose of the SER is to allow DOE to review the safety basis developed by the contractor and to approve operation of the facility to the standards set in the DSA and TSRs.

Safety System, Structure, or Component (SSC)
An SSC is designated as safety class if its failure could adversely affect the environment or the safety and health of the public as identified by the safety analysis. An SSC that is not designated as safety class, but which has a preventive or mitigative function that is a major contributor to defense in depth (i.e., prevention of uncontrolled material releases) and/or worker safety as determined from hazard analysis, is considered safety significant. As a general rule of thumb, safety-significant SSC designations based on worker safety are limited to SSCs whose failure is estimated to result in an acute worker fatality or serious injuries to workers.

Defense in Depth
Defense in depth classification consists of two components: (1) equipment and administrative features that provide preventive or mitigative functions so that multiple features are relied on for prevention or mitigation to a degree proportional to the hazard potential; and (2) integrated safety management programs that control and discipline operations.

d) Describe how safety authorization basis requirements are implemented in a facility.

The safety basis of the facility is implemented in operations through the TSR, and any proposed change to the facility or its operations (as described in the DSA) goes through the USQ process.

e) Describe configuration control and its relationship to the safety authorization basis.

The basic objectives and general principles of configuration control (management) are the same for all activities: establish consistency among design requirements, physical configuration, and documentation (including analysis, drawings, and procedures) for the activity, and maintain this consistency throughout the life of the facility or activity, particularly as changes are being made.

One overall commitment made in a DSA is that the contractor will not change the facility configuration underlying the documented safety basis without implementing and completing the USQ process. A configuration management process ensures the integrity of the nuclear facility safety SSCs (using a graded approach).

f) Observe a contractor TSR surveillance activity and describe the factors to be considered as the activity is planned and performed.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

g) Conduct a facility walk through and identify all facility safety SSCs as well as defense in depth SSCs or SSCs considered important to safety.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

4.11 A facility representative shall demonstrate a working-level knowledge of the training and qualification requirements for facility operations personnel.

a) Describe the five elements of a systematic approach to training described in DOE O 5480.20A.

A vital component in ensuring a well-trained and qualified work force is the implementation of a systematic approach to training. The five basic elements of a systematic approach to training are addressed below.

Analysis. Performing needs analysis, job analysis, and/or task analysis identifies training requirements. Analyses form the basis for determining training needs, developing and maintaining valid task lists, and selecting tasks for which training will be required.

Design. Design phase activities include writing terminal objectives, selecting appropriate training settings, and developing training/evaluation standards (TES) for each task selected for training. It is during the development of the TES that the bulk of the tasks are further analyzed, the enabling objectives are written, and decisions are made regarding how training will be conducted and evaluated.

Development. Development phase activities include writing qualification cards and standards, and associated training materials such as checklists and guides. Qualification standards are documents that contain the knowledge and skill requirements necessary for the successful completion of a training program. They should include program-specific evaluation standards to be used during performance testing and provide explicit guidance to the instructor and to the trainee to aid in the preparation for, and the consistent administration of, performance tests. Additional activities include the selection and training of instructors. The specifications generated in the design phase are used to develop a program and all required training materials. Care should be taken to keep materials simple and usable.

Implementation. Implementation phase activities include implementing the program's administrative guidance, conducting evaluations, and maintaining training records.

Evaluation. Evaluation activities include assessing the knowledge and skills of trainees entering a training program to determine if they meet the entry-level requirements for that specific program. When trainees enter a training program, they need to learn how the program operates and what will be expected of them. They should be provided with a checklist, a qualification standard, and other supporting self-study materials. Key factors in successful instruction and performance testing (implementation) include the following:

- Learning objectives should be clearly understood by the instructor and the trainee.
- Standards for successful completion of the training should be clearly understood by both the instructor and the trainee.
- Instructors should have the knowledge and the ability to instruct and evaluate the trainee in accordance with the learning objectives and performance tests.
- Training and the performance tests should be documented to meet training record requirements and to provide feedback to the training program.

b) Discuss the relationship between training, risk, and safe facility operations.

A graded approach is used to establish the systematic approach to training for operations personnel, maintenance personnel, technicians, and the technical staff. For example, the methods used to develop training programs and materials for personnel at category 3 (low) hazard nuclear facilities do not need to be as detailed or formally developed and implemented as some of the training programs and materials for the category 1 and 2 (higher-hazard) nuclear facilities because the nuclear safety-related risk to the work force, the environment, and the public is significantly lower.

c) Discuss key elements of an effective on-the-job training program as described in DOE-HDBK-1206-98, Guide to Good Practices for On-the-Job Training.

Analysis. See element “b” of this competency.

Design. On-the-job training (OJT) may be conducted using general instructions and task-specific evaluation materials for low-hazard potential facilities or tasks. Instructors and training material designers/developers should design each evaluation standard so that different OJT instructors will administer the test consistently. The test should require actual task performance if possible. The DOE Guide to Good Practices for Design, Development, and Implementation of Examinations contains detailed guidance for developing performance tests. The methods of conducting OJT and the required level of accomplishing performance testing are determined during the TES development process, and the acceptable level of accomplishment (perform, simulate, observe, discuss) should be specified in each TES. Certain tasks should require that a trainee demonstrate achievement of the terminal objective through actual task performance.

Development. A qualification standard should be prepared consistent with the program’s OJT guides and evaluation standards. It should list the specific procedures and training resource materials required for each task (e.g., operating procedures, system descriptions, fundamentals text). This type of information may also be specified on the qualification card/checklist or in other training documents or procedures. The qualification standard may also include reading assignments, self-study requirements, study questions, problem analysis exercises, figures and diagrams, and amplifying information. Qualification standards should not include copies of facility procedures or training manuals/materials; they should instead reference these resources.

Performance-based training programs should require the use of OJT guides (or equivalents) to ensure consistent delivery of training. An OJT guide is a document that outlines instructor and trainee activities, learning objectives, training content, and the resources (equipment, material, etc.) necessary for the consistent conduct of training. The contents of an OJT guide for a specific task should be based on the training standard portion of the TES. An OJT guide should identify trainee prerequisites, learning activities, training equipment, and materials needed for training including specific guidance for their use. OJT guides also provide specific direction to the instructor for guiding the learning process.

OJT instructors should be technically competent. They should have the skills necessary to train and evaluate assigned trainees. Additional factors to be considered when selecting OJT instructors include recognition of responsibilities, professionalism, maturity, judgment, integrity, safety awareness, communication skills, personal standards of performance, and a commitment to quality.

Implementation. Instructors should use the Three Ts of effective training as they conduct OJT. The first T is tell them what you are going to tell them, the second is tell them, and the third is to tell them what you told them. Use of the three Ts helps to ensure effective on-the-job training.

The primary instructional method used in the on-the-job training setting is the demonstration-performance method. In this method, the instructor tells and shows the trainee how to perform the task. The instructor explains and demonstrates the particular task to the trainee, and then coaches while the trainee practices the task. This method is based on the principle that trainees learn best by doing. During the practice, the instructor points out errors and helps the trainee improve techniques or eliminate errors in performance. The trainee is allowed repeated practice to achieve the terminal objective. When the trainee has satisfied the objective, the instructor concludes the training and documents it on the trainee's OJT checklist.

The instructor should stress safety while establishing the ground rules regarding how he/she intends to conduct the training, and should explain under what circumstances the evolution will be interrupted (e.g., to demonstrate if needed) and under what circumstances the evolution will be stopped (e.g., if personnel or equipment safety concerns arise). The instructor should stress that facility procedures (e.g., administrative, operations, maintenance, lockout and tagout, and radiological procedures) must be adhered to at all times.

The instructor should closely supervise the trainee's initial practice to ensure safe and correct task performance.

Evaluation. In-training evaluations are necessary to provide data that will be used in the evaluation phase of the systematic approach to training (SAT) process. In-training evaluations usually consist of (1) the instructor's critique of the training, (2) the trainee's critique of the training, (3) trainee performance data (e.g., pre-tests, progress, and post-tests), and (4) the OJT program coordinator's evaluation of instructor and trainee performance.

A performance test (sometimes called a practical factor) is a hands-on demonstration by the trainee of the knowledge and skills required to perform a task. The instructor uses an evaluation standard from a TES (or equivalent) to determine if the trainee has the knowledge and skills to perform the task. A trainee's knowledge may be assessed prior to, during, or following task completion. It is suggested that safety-related questions be asked prior to task performance. A limited number of questions may be asked during the performance test if they will not distract the trainee from the task's performance, with the remaining questions asked following task completion.

d) Using guidelines provided in the applicable DOE Standard or Handbook as a reference, observe and evaluate a contractor training evolution (technical staff training, written or oral examination, on-shift training, etc.).

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

e) Using contractor training procedures, applicable Department of Energy Orders, and DOE-STD-1070-94, *Guidelines for Evaluation of Nuclear Facility Training Programs,* select three elements of the contractor training program and assess for compliance and adequacy.

This is a performance-based competency. The qualifying official will evaluate the completion of this competency.

4.12 A facility representative shall demonstrate a working-level knowledge of conduct of operations principles and DOE requirements to ensure facility operations are performed in a safe and efficient manner.

a) Explain DOE's role in the oversight and implementation of the contractor's conduct of operations program.

DOE's role is to provide requirements and guidelines for Departmental elements to use in developing directives, plans, and/or procedures relating to the conduct of operations at DOE facilities. The implementation of these requirements and guidelines should result in improved quality and uniformity of operations.

It is the policy of the Department that the conduct of operations at DOE facilities be managed with a consistent and auditable set of requirements, standards, and responsibilities consistent with the requirements of this Order:

- Operations at DOE facilities must be managed, organized, and conducted in a manner to assure an acceptable level of safety.
- Operators at facilities must have procedures in place to control the conduct of their operations.
- Line organizations must review existing and planned programs important to safe and reliable facility operations.
- Line organizations must assess the effectiveness of corporate directives, plans, or procedures at facilities under their cognizance.

b) Describe the facility representative's role relative to conduct of operations at DOE facilities as is provided in Conduct of Operations Requirements for DOE Facilities, DOE O 5480.19.

For each major facility or group of lesser facilities, the facility representative is an individual assigned responsibility by the Head of the Field Element (e.g., Site Manager) for monitoring the performance of the facility and its operations. The facility representative should be the primary point of contact with the contractor and is responsible to the appropriate DOE Program Office and field elements for implementing the requirements of this Order.

c) Explain how the graded approach is used in the application of the guidelines provided in DOE O 5480.19, attachment I.

A graded approach shall be used in the application of the guidelines provided in attachment 1 to assure that the depth of detail required and the magnitude of resources expended for operations are commensurate with each facility's programmatic importance and potential environmental, safety, and/or health impact.

d) Describe contractor responsibilities associated with implementing the conduct of operations at DOE facilities.

Each DOE contractor shall use this Order and attachment 1 in the review and development of existing and proposed directives, plans, or procedures relating to the conduct of operations at DOE facilities.

e) Explain the key elements of conduct of operations associated with each chapter of DOE O 5480.19:

- **Chapter I, Operations Organization and Administration**
- **Chapter II, Shift Routines and Operating Practices**
- **Chapter III, Control Area Activities**
- **Chapter IV, Communications**
- **Chapter V, Control of On-Shift Training**
- **Chapter VI, Investigation of Abnormal Events**
- **Chapter VII, Notifications**
- **Chapter VIII, Control of Equipment and System Status**
- **Chapter IX, Lockouts and Tagouts**
- **Chapter X, Independent Verification**
- **Chapter XI, Logkeeping**
- **Chapter XII, Operations Turnover**
- **Chapter XIII, Operations Aspects of Facility Chemistry and Unique Processes**
- **Chapter XIV, Required Reading**
- **Chapter XV, Timely Orders to Operators**
- **Chapter XVI, Operations Procedures**
- **Chapter XVII, Operator Aid Postings**
- **Chapter XVIII, Equipment and Piping Labeling**

Note: Following are brief descriptions of the content of each of the eighteen chapters of attachment 1, DOE Order 5480.19. Additional information is available on the DOE Directives Web site at http://www.directives.doe.gov/.

Chapter I, Operations Organization and Administration
The organization and administration of operations should ensure that a high level of performance in DOE facility operations is achieved through effective implementation and control of operations activities. Operations activities should recognize that environment, safety, and productivity are compatible goals. DOE facility policies should describe the philosophy of standards of excellence under which the facility is operated and clear lines of responsibility for normal and emergency conditions are established. Effective implementation and control of operating activities are primarily achieved by establishing written standards in operations, periodically monitoring and assessing performance, and holding personnel accountable for their performance. This chapter discusses the policies, resources, monitoring, and accountability needed in operations.

Chapter II, Shift Routines and Operating Practices
Standards for the professional conduct of operations personnel should be established and followed so that operator performance meets the expectations of DOE and facility management. The guidelines of this chapter describe watchstanding practices that apply to all operating personnel. Additional guidelines are delineated in Chapter III, Control Area Activities. Chapter IV, Communications, describes some communication practices applicable to all operations personnel. This chapter describes some important aspects of routine shift activities and watchstanding practices.

Chapter III, Control Area Activities
Control area activities should be conducted in a manner that achieves safe and reliable facility operations. Other shift activities are discussed in Chapter II, Shift Routines and Operating Practices. This chapter addresses the important elements of control area activities that are necessary to support safe and efficient facility operation.

Chapter IV, Communications
Communications should be highly reliable in providing accurate transmission of information within the facility. This chapter describes the important aspects of a plant program for audible communications.

Chapter V, Control of On-Shift Training
Facility operation by personnel under instruction should be carefully supervised and controlled to avoid mistakes in operations by unqualified personnel and to use trainees' time effectively. On-shift training should be conducted so that the trainee satisfactorily completes all of the required training objectives and receives the maximum learning benefit from this experience. The guidelines of this chapter relate to control of training activities by operations personnel. Other aspects of training are covered by other DOE Orders.

Chapter VI, Investigation of Abnormal Events
A program for the investigation of abnormal events should ensure that facility events are thoroughly investigated to assess the impact of the event, to determine the root cause of

the event, to ascertain whether the event is reportable to DOE in accordance with DOE M 231.1-2, Occurrence Reporting and Processing of Operations Information, and to identify corrective actions to prevent recurrence of the event. The program should include the investigation of "near miss" situations, thus reducing the probability of a similar situation recurring as an actual facility event. Abnormal events are not unique to the operating organization. Therefore, the guidelines of this chapter may have applicability in other areas besides operations. Required notifications associated with abnormal events are addressed in chapter VII and in DOE M 231.1-2. This chapter covers important aspects of the abnormal event investigation program.

Chapter VII, Notifications
Timely notification of appropriate DOE personnel and other agencies, when required, should be employed to ensure that the facility is responsive to public health and safety concerns. This chapter provides guidelines to ensure uniformity, efficiency, and thoroughness of these notifications to support fulfillment of DOE requirements that are consistent with DOE M 231.1-2.

Chapter VIII, Control of Equipment and System Status
Good operating discipline should ensure that facility configuration is maintained in accordance with design requirements and that the operating shift knows the status of equipment and systems. Specific applications of equipment control are addressed in Chapter IX, Lockout/Tagout; Chapter X, Independent Verification; Chapter XI, Logkeeping; and Chapter XII, Operations Turnover. This chapter provides an overall perspective on control of equipment and system status.

Chapter IX, Lockouts and Tagouts
The purpose of this chapter is to provide a method for equipment status control through component tagging or locking, which should protect personnel from injury, protect equipment from damage, maintain operability of plant systems, and maintain the integrity of the physical boundaries of plant systems. If there is a potential for equipment damage or injury during equipment operation, servicing, maintenance, or modification activities due to inadvertent activation of equipment, a facility lockout/tagout program should be established and used. The lockout/tagout program should provide for independent verification of the removal from service and the restoration to service of safety-related and other facility equipment. This chapter describes the important elements of a lockout/tagout program and is intended to meet the requirements of 29 CFR 1910.

Chapter X, Independent Verification
An independent verification program should provide a high degree of reliability in ensuring the correct facility operation and the correct position of components such as valves, switches, and circuit breakers. This chapter describes the important aspects of an independent verification program. Other equipment status control programs are addressed in Chapter VIII, Control of Equipment and System Status, and some applications of independent verification are addressed in Chapter IX, Lockouts and Tagouts. Additionally, appropriate investigations for component mispositioning events are discussed in Chapter VI, Investigation of Abnormal Events.

Chapter XI, Logkeeping
The operations records should contain a narrative log of the facility's status and of all events as required to provide an accurate history of facility operations. As used in this context, logs are defined as a narrative sequence of events or functions performed at a specific shift position, as opposed to the operator round sheets that are discussed in Chapter II, Shift Routines and Operating Practices. This chapter describes the features needed in the operation logs to ensure they are properly maintained.

Chapter XII, Operations Turnover
Operations shift turnovers should provide oncoming operators with an accurate picture of the overall facility status. This chapter complements the guidelines of Chapter II, Shift Routines and Operating Practices, and Chapter III, Control Area Activities, and describes the important aspects of a good shift turnover.

Chapter XIII, Operations Aspects of Facility Chemistry and Unique Processes
Operational monitoring of facility chemistry or unique recess data and parameters should ensure that parameters are properly maintained. Maintenance of proper processes will promote maximum component life. Monitoring will identify problems such as air in leakage, failed fuel, or resin depletion before components or safety are adversely affected. A close coordination between the operations and chemistry or process departments is necessary for this to be effective. This chapter describes the important aspects of operations involvement in chemistry and unique processes.

Chapter XIV, Required Reading
Proper use of a required reading file by operations personnel should ensure that appropriate individuals are made aware of important information that is related to job assignments. This chapter describes an effective required-reading program.

Chapter XV, Timely Orders to Operators
A means for operations management to communicate short-term information and administrative instructions to operations personnel should exist. Other means of disseminating guidance to operators are addressed in Chapter XVI, Operations Procedures, and Chapter XVII, Operator Aid Postings. This chapter describes the key features of an effective operator orders program.

Chapter XVI, Operations Procedures
Operations procedures are written to provide specific direction for operating systems and equipment during normal and postulated abnormal and emergency conditions.

Operations procedures should provide appropriate direction to ensure that the facility is operated within its design bases and should be effectively used to support safe operation of the facility. Other methods of disseminating operational information are addressed in Chapter XV, Timely Orders to Operators, and Chapter XVII, Operator Aid Postings. This chapter describes the important aspects of operations procedure development and use.

Chapter XVII, Operator Aid Postings
Facility operator aids (information posted for personnel use) should provide information useful to operators in performing their duties. An operator aid program should be established to ensure that operator aids are current, correct, and useful. This chapter describes the important aspects of an operator aid program.

Chapter XVIII, Equipment and Piping Labeling
A well-established and maintained equipment labeling program should help ensure that facility personnel are able to positively identify equipment they operate. In addition, equipment labeling is required by OSHA regulations. This chapter describes the important aspects of a labeling program.

f) Explain the relationship between the guidelines provided in DOE O 5480.19, Attachment I, Chapters I through XVIII, and the DOE Technical Standards associated with each Chapter:

- **Chapter I — DOE-STD-1032-92, Guide to Good Practices for Operations Organization and Administration**
- **Chapter II — DOE-STD-1041-93, Guide to Good Practices for Shift Routines and Operating Practices**
- **Chapter III — DOE-STD-1042-93, Guide to Good Practices for Control Area Activities**
- **Chapter IV — DOE-STD-1031-93, Guide to Good Practices for Communications**
- **Chapter V — DOE-STD-1040-93, Guide to Good Practices for Control of On-Shift Training**
- **Chapter VI — DOE-STD-1045-93, Guide to Good Practices for Notifications and Investigation of Abnormal Events**
- **Chapter VII — DOE-STD-1045-93, Guide to Good Practices for Notifications and Investigation of Abnormal Events**
- **Chapter VIII — DOE-STD-1039-93, Guide to Good Practices for Control of Equipment and System Status**
- **Chapter IX — DOE-STD-1030-96, Guide to Good Practices for Lockouts and Tagouts**
- **Chapter X — DOE-STD-1036-93, Guide to Good Practices for Independent Verification**
- **Chapter XI — DOE-STD-1035-93, Guide to Good Practices for Logkeeping**
- **Chapter XII — DOE-STD-1038-93, Guide to Good Practices for Operations Turnover**
- **Chapter XIII — DOE-STD-1037-93, Guide to Good Practices for Operations Aspects of Facility Chemistry and Unique Processes**
- **Chapter XIV — DOE-STD-1033-92, Guide to Good Practices for Operations and Administration Updates Through Required Reading**
  Chapter XV — DOE-STD-1034-93, Guide to Good Practices for Timely Orders to Operators
- **Chapter XVI — DOE-STD-1029-92, Writer's Guide for Technical Procedures**
- **Chapter XVII — DOE-STD-1043-93, Guide to Good Practices for Operator Aid Postings**
- **Chapter XVIII — DOE-STD-1044-93, Guide to Good Practices for Equipment and Piping Labeling**

Chapter I — DOE-STD-1032-92, Guide to Good Practices for Operations Organization and Administration

Operational excellence is the main goal of DOE and DOE facilities; protecting the environment and improving safety and productivity complement this goal. A facility's organization must be properly directed to ensure that all three elements are effectively addressed. Establishing policies and setting goals to achieve a safe, environmentally conscious, and efficient operating facility are essential to focus this direction. These policies and goals are an effective method of communicating direction to all personnel.

The organization and administration of facility operations should clearly define the process for providing and supporting safe, reliable, and efficient conduct of all facility activities. Emphasis must be placed on teamwork to ensure this occurs. A clear understanding by personnel of their authorities, responsibilities, accountabilities, and interfaces is essential to proper functioning of the organizational team. The organizational structure must be clearly defined, and the administrative controls implementing the structure must be formally documented to achieve this understanding.

Management must emphasize performance standards and individual accountability in adhering to policies and accomplishing goals. When personnel are aware of the performance standards required to meet the goals, they will be more inclined to acknowledge their accountability. In addition, personnel must be allowed the opportunity to supply input to the policies, goals, and standards so that they have a sense of ownership of the facility. Given this opportunity, personnel will more willingly support standards and accept accountability.

Personnel must have the resources needed to perform their jobs. Restricting or delaying resources will only hinder operational effectiveness and may result in adverse consequences. Because personnel are one of the resources required to operate a facility, a plan to retain sufficient personnel to safely and efficiently operate the facility must be developed.

To ensure that resources are being properly used and operating activities are directed towards goals, management must monitor operations. Monitoring facility operating performance is the best way to measure the facility's effectiveness in accomplishing goals. Monitoring activities such as audits, reviews, tours, and self-assessments are part of the checks and balances needed in an effective operating program to ensure that management obtains a clear picture of facility operations. Touring also allows management to interface with facility personnel and reinforce policies and goals. Audits, reviews, investigations, and self-assessments supply information for facility performance reports. These reports provide evidence of the operating performance of the facility. Facility performance reports enable tracking and trending of performance indicators and can be used to adjust goals. When operating problems or undesirable performance trends are noted during monitoring, corrective actions must be developed and implemented to redirect performance. Follow-up monitoring activities allow management to verify the effectiveness of the corrective actions.

To effectively monitor operations and manage resources, managers must be trained. A management development program will enhance the skills and knowledge of upcoming managers and supervisors. This is especially true of first-line supervisors because they usually have no previous management experience, but must possess the proper attributes to handle their responsibilities.

Management must strive to develop and maintain a proper safety attitude in all facility personnel. A comprehensive safety program must include planning for safety. If safety planning accompanies work planning, safety issues will be confronted before actual work is started. Planning will minimize work holdups and operating schedule delays that result from correcting safety issues. Personnel must also be trained in safe operating practices and the need to identify potential personnel hazards at their work stations. Management's monitoring of performance, stressing safety, and planning for safety, will reinforce this attitude.

Chapter II — DOE-STD-1041-93, Guide to Good Practices for Shift Routines and Operating Practices

This guide addresses the professional conduct and good work station practices that result in appropriate attention to facility conditions. It discusses the authority to operate equipment and the status control that is essential to controlling and coordinating facility activities. Emphasis is also placed on effective equipment monitoring and data recording, including notifying supervisors promptly of unusual or unexpected situations. This notification process ensures proper attention is given to changing and off-normal conditions. Industrial safety practices, including radiological and hazardous material protection, are also addressed.

Industrial, military, and commercial utility operating experience has shown that professional conduct and sound operating practices result in a safer, more efficiently run facility. Two key principles to professional conduct and sound operating practices are formality and ownership. Formality is performing all duties according to approved practices and procedures. It ensures a more alert work force and business-like atmosphere. Ownership is an attitude whereby individuals accept total responsibility for maintaining their assigned work station in the best possible operating condition.

The responsibility for safely operating a DOE facility rests with the on-shift personnel. Safe operation is accomplished through adherence to procedures, technical safety requirements (formerly technical specifications or operational safety requirements), and sound operating practices. The authority and responsibility for facility operations should be vested in the cognizant supervisor or manager and be transferred only through formal turnover to a qualified relief.

Establishing clear lines of authority and responsibility for controlling facility operations, including equipment and systems, will enhance facility operations. The authority for operating certain equipment and systems may be given to specific work stations; however the supervisor maintaining ultimate responsibility for the equipment must be notified prior to changes in status. During emergencies, operators should be authorized to take the necessary actions to place the facility in a safe operating or shutdown condition. In this case, the change in status would be reported to the supervisor after the fact.

During special tests, evolutions, or abnormal conditions, personnel should be aware that the responsibility and authority to decide corresponding operating conditions, system alignments, or equipment manipulations rests fully with the on-duty supervisor. This supervisor should not permit any individual to bypass or overrule his/her operational judgment without bringing the matter to the attention of a higher operational authority.

An effective equipment and area monitoring program will help ensure that abnormal conditions and adverse trends are detected in a timely manner. The program should address the equipment and areas to be monitored and the monitoring frequency. This monitoring or inspecting can be accomplished through operator inspection tours (inspection tours). A list of areas and associated equipment under an operator's control should be used to assist personnel in performing inspection tours.

Round inspection sheets (round sheets) can also be used to record equipment parameters during inspection tours. Recording these parameters will assist personnel in detecting trends and serve as a historical record of facility operations. Trending is necessary to detect abnormal conditions or adverse trends so appropriate action can be taken before equipment malfunction occurs. Establishing procedures which specify when to take readings, how to record readings, how to identify out-of-specification readings, how to make corrections on the round sheets, and what actions to take for out-of-specification readings will improve the accuracy, completeness, and neatness of round sheets.

Procedures should also specify a program for developing and maintaining round inspection sheets. Training on these procedures will ensure the proper round sheet information is communicated to all affected personnel.

Sound operating practices also include a strong emphasis on personnel safety practices required to perform a job. Following personnel safety practices should keep personnel alert to detect, prevent, and mitigate all possible hazards. The correct safety practices should be demonstrated to personnel during their initial training and during refresher training (e.g., on a yearly basis), and reinforced continuously, by all personnel, while on the job. Safe work station practices also include maintaining exposure to personnel hazards (e.g., radiation, toxic materials) as low as reasonably achievable (ALARA).

Additional operating practices information for control areas are delineated in DOE Order 5480.19, Chapter III, Control Area Activities.

Chapter III — DOE-STD-1042-93, Guide to Good Practices for Control Area Activities
The control area of a DOE facility is the focal point of safe and efficient facility operations. It is a central operating base and coordination point for important facility activities. A control area may range in size from a desk or computer terminal to a room of instrumentation and control panels. Whatever the size, a professional atmosphere must be maintained so activities performed in the control area remain focused on the operation of the facility. A properly organized and structured control area should enhance safe and efficient operations.

Large facilities may have a central control area for coordinating overall facility operations, and several other areas designated as control areas for specific portions of the facility. Similarly, small facilities may have only one designated area that controls operations. The guidance provided in this document can be used to enhance facility operations in either situation.

DOE Order 5480.19, Chapter III, Control Area Activities, deals only with situational elements specific to the control area. The information contained in this guide should be used in addition to the information contained in DOE Order 5480.19, Chapter II, Shift Routines and Operating Practices, to ensure that shift routines for control areas are properly addressed.

Control of access is the key to limiting the number of personnel in the control area. By limiting the number of personnel in the control area, the associated noise, confusion, and possible distractions will be minimized. Access must be controlled to maintain a formal, disciplined atmosphere that promotes teamwork and professionalism.

Professional, businesslike behavior by personnel will enhance the quality of control area activities. Although this behavior is the focus in each chapter of the guidelines to DOE Order 5480.19, nowhere is there a greater need for this type of behavior than in the control area. Whether it is in communications, logkeeping, turnover, or any of the other chapters, these professional practices embody high standards of technical and ethical performance and help build a foundation for safe and reliable facility operation. Professional behavior during normal operations carries over to handling off-normal and emergency situations safely and efficiently. Maintaining a clean, quiet, neat and orderly environment enhances control area professionalism. Also, this type of environment makes it easier to operate, and makes a positive statement about the personnel working there.

Monitoring the instrumentation and control panels in the control area provides personnel with current facility operating information and a means of detecting abnormal conditions before they become problem situations. Although some of the parameters displayed in the control area may also be displayed locally, the control area provides a central area for displaying and monitoring these parameters.

Besides providing an area for consolidating remote indications, the control area may have controls for operating facility equipment. These controls could be used to operate remote equipment in areas with high personnel hazards (e.g., radiation areas, toxic environments) or emergency equipment. In either case, unauthorized operation of controls may hinder facility operation, stop facility operation, or create an adverse environmental, safety, or health situation. These situations can be avoided by identifying who has the authority and responsibility to operate control area equipment.

Monitoring and operating the instrumentation and control panels are the primary responsibilities of control area personnel. When ancillary responsibilities are assigned, they compete with the primary responsibilities for the time and attention of control area personnel. Overburdening control area personnel with ancillary responsibilities will distract them from properly monitoring facility parameters. A structured program for assigning ancillary duties will prevent this situation.

Chapter IV — DOE-STD-1031-93, Guide to Good Practices for Communications
All of us depend on verbal communication for the exchange of information or instructions. Depending on the job, an individual may be responsible for transmitting or receiving information in the form of operating instructions, feedback on the results of operations, reports of operational data, or emergency warnings and instructions. Whether communicated face-to-face or through electronic communication, this information has to be transmitted and received, accurate and complete, and most importantly, understood.

Communication problems have caused many adverse situations in DOE facilities. Inadequate communication can be identified as a causal or contributing factor in human performance-related events. Principal areas in which poor communications can cause problems include shift turnover, pre-job briefings, and during job performance. Facilities can reduce the contribution to adverse situations by ensuring that verbal communications are conducted in a formal and disciplined manner and that communication systems are properly used. Formality in communication is especially important when personnel safety is involved or complex evolutions are performed.

Just as there are different messages to be communicated, there are different methods of audible communication (e.g., face-to-face, party-line, point-to-point, and public address announcements). Each method requires the use of specific techniques to effectively communicate the necessary information. This guide presents communication techniques that have proven to be successful in the commercial industry, in government, and in the military.

Chapter V — DOE-STD-1040-93, Guide to Good Practices for Control of On-Shift Training
On-shift training provides the mechanism for applying the knowledge and skills learned in the classroom, through self-study, and in the laboratory to operating the facility. On-shift training activities are required to provide the trainee with hands-on experience, because neither an outstanding classroom presentation of fundamentals and facility-specific knowledge, nor specific laboratory exercises, sufficiently prepares an operator to operate a facility safely and efficiently. Since on-shift training allows unqualified personnel the opportunity to operate the facility, controls must be implemented during the performance of on-shift training to ensure that the facility is operated safely and reliably. These controls should prevent accidental, inadvertent, or incorrect manipulation of components, equipment, or systems by trainees. On-shift instructors and trainees must understand the controls that regulate the performance of on-shift training.

On-shift training is commonly conducted using the instructional method of on-the-job training (OJT). This form of training has proven very effective in qualifying trainees. OJT addresses the steps necessary to successfully train an individual in the performance of a task, but does not specifically address the controls of the training process and their relationship to the operation of the facility. For information concerning the OJT process, refer to DOE-HDBK-1206-98, Guide to Good Practices for On-the-Job Training. Control of on-shift training addresses the formal, disciplined controls that are required in the operating environment to ensure that on-shift training is conducted safely and efficiently.

On-shift training includes activities that a trainee performs in the operating environment under supervision, as well as training activities that are performed in the operating environment as part of the operator continuing training program. The primary purpose of on-shift training is to allow personnel to acquire first-hand experience by performing or observing operations, special processes, tests, inspections, and other work activities.

In addition to the necessary administrative controls, qualified instructors are also important to the successful control of on-shift training. Competent instructors ensure quality and consistent training of potential operators without compromising the safety and reliability of facility operations. Trainees receive the best and most consistent training concurrent with meeting the production goals of the facility when the instructors are proficient in performing their assigned operational duties while conducting on-shift training. These instructors are best able to interrupt the training when a compromise to safety is becoming evident.

Chapters VI and VII — DOE-STD-1045-93, Guide to Good Practices for Notifications and Investigation of Abnormal Events
An effective notification program provides a positive means for the facility to respond to public health and safety concerns. DOE policy encourages a positive attitude toward reporting occurrences. Facilities should develop notification guidelines that are directed toward ensuring uniformity, efficiency, and thoroughness of notifications consistent with the requirements of DOE M 231.1-2, Occurrence Reporting and Processing of Operations Information.

The need for facility-specific notification guidelines is apparent if one considers the situation of a supervisor during, and immediately after, a serious operating event. The supervisor's first priority is to ensure safety. This may involve implementing emergency operating procedures, reassigning operating personnel, and/or personally supervising immediate actions. In the midst of this activity, the supervisor requires concise notification guidelines that clearly indicate the appropriate level of notification for the specific event, based on an evaluation of its potential to impact safety, health, the environment, or operations. The supervisor also needs to know the time available to make the notification within regulatory requirements, the individuals to be notified, and the method to be used to notify each.

Well-designed guidelines will ensure that notifications do not interfere with the immediate actions that are needed in response to abnormal conditions. They should also ensure that notifications are regarded as an integral part of the response, not an action to be considered after conditions have returned to normal.

A manager has overall responsibility for the event investigation process. However, the manager may delegate specific tasks in the investigation process to other personnel as appropriate.

Prompt investigation of abnormal events and conditions is important so facilities can assess the impact of each event or condition, determine the root cause, and identify corrective actions to prevent recurrence. Abnormal events and conditions include all occurrences requiring formal notification under DOE Manual 231.1-2. Additionally, investigation is appropriate for all events, conditions, near misses, or other indications of situations within or outside the operations organization that, if uncorrected, can impact safety or reliability. Acts of actual or suspected sabotage represent a special case for investigation.

The investigative process described in this guide is intended to assist the operating organization in evaluating and responding to operational abnormalities. These investigations are not intended to replace the formal type A or B investigations that are required for certain occurrences in accordance with DOE O 231.1A, Environmental, Safety, and Health Reporting, although both investigations have similar objectives. Consider again the situation of a supervisor immediately after a serious operating event. Even though immediate actions have been taken in accordance with appropriate procedures, the event may still impact personnel or facility safety. Therefore, it is important that the operations organization begin the investigative process as soon as possible.

To ensure consistency, facilities should provide written guidelines to address all aspects of the investigative process. Concise instructions will aid the supervisor in properly collecting and/or preserving physical evidence that may be needed in the investigation.

Standard forms, or an example format, will aid in documenting statements from the personnel present during the event. Checklists may be useful for ensuring that all appropriate operating records (e.g., recorder charts, round sheets, logs) are collected or copied for use in the investigation. Finally, clear instructions for conducting the investigation will make effective use of time and will aid personnel in evaluating the corrective actions taken and the results of those actions. This process will enable personnel to determine the current safety status of the facility and the capability for continued operation.

Chapter VIII — DOE-STD-1039-93, Guide to Good Practices for Control of Equipment and System Status

DOE facilities are required to establish administrative programs to control equipment and system status. A program for controlling equipment and system status, or status control, must be broad in scope. It should incorporate measures to ensure awareness by operating personnel concerning the physical configuration and operating status of equipment and systems. It should contain methods to maintain system operability in accordance with design requirements. DOE Order 5480.19 addresses several individual programs that comprise portions of the status control program, including Lockouts and Tagouts (chapter IX), Independent Verification (chapter X), Logkeeping (chapter XI), and Operations Turnover (chapter XII). These programs assist in establishing effective control of equipment and system status and are appropriately referenced within this guide.

Proper control of equipment and systems requires clear lines of responsibility and authority. The facility status control program should clearly designate the authority and responsibility for controlling status to ensure proper configuration. All personnel must understand the importance of keeping the operations supervisor and other designated operations personnel informed of activities that could affect the status or operability of equipment.

Effective control of equipment and system status also means coordinating operations and maintenance activities. Equipment deficiencies must be promptly identified for correction in the work control system. Locking and tagging should be performed by qualified operations personnel to ensure that all energy and hazardous material sources are properly isolated and required safety functions are not inadvertently disabled. The operations supervisor should sign the work control documents to authorize the start of all maintenance activities, including testing, calibration, and related activities. A process for post-maintenance testing should be in place to ensure that all operation of equipment is controlled by approved operating procedures and that appropriate maintenance and operations personnel are represented during the testing. The status or alignment of equipment should be verified as part of restoring the equipment to service following outages for maintenance or design modifications.

Special administrative controls are required whenever equipment must be operated with temporary modifications (e.g., jumpers, blocks, bypasses) in place. These controls should include methods for ensuring that operators are aware of the modified status of the equipment and its operating limitations. The controls should provide for appropriate safety and technical reviews, documentation, updating of procedures and drawings, and training.

The status control program requires specific methods for verifying and documenting the configuration of equipment and systems, changes in equipment status, and compliance with operational and safety limits. Status control documentation may include checklists, logs, status boards, or a combination of these. Requirements for status control documentation should be coordinated with other documentation requirements (e.g., logkeeping) to avoid unnecessary forms or duplication of information. This ensures that status information is updated as a regular part of the job, and not treated as an added administrative task. It also provides those personnel having operating responsibility with simple, direct access to current status information.

Chapter IX — DOE-STD-1030-96, Guide to Good Practices for Lockouts and Tagouts
A program for lockout and/or tagout (lockout/tagout) is of primary importance for ensuring worker safety in DOE facilities. The overall program for safety at DOE facilities is described in guidelines published by the DOE Office of Environment, Safety, and Health. Lockout/tagout is an essential part of this overall safety program.

A lockout/tagout program is designed to identify sources of energy and hazardous materials that could adversely affect maintenance activities, isolate all such sources from the work area, and ensure that the isolation remains effective until the work is completed. Lockout/tagout should be applied whenever workers are performing maintenance on facility equipment or systems where there is any possibility of injury or damage as a result of release of energy or hazardous materials.

If a facility's lockout/tagout program is to be effective, it must be understood by all affected personnel, it must be applied uniformly in every job, and it must be respected by every worker and supervisor. The requirements for lockout/tagout in U.S. industry are identified in OSHA regulations.

The lockout/tagout procedures in many DOE facilities, like the procedures used in electric utility power plants, must apply to situations requiring special control measures. In these facilities, measures to protect the individual worker must be integrated with the operation of larger safety systems designed to protect the public, the environment, and the facility. The procedures used in these facilities address protecting personnel from injuries resulting from unexpected operation or energizing of equipment. They also address preventing the unexpected or inadvertent loss of essential safety systems and operating facility systems.

Operation of equipment in these facilities is usually performed by an operations organization. Qualifications for operations personnel are distinct from the qualifications of maintenance or other service personnel. The specialized knowledge operators must possess regarding system functions and interactions mandates that only qualified operators may manipulate facility controls for any purpose, including lockout/tagout.

Within this guide to good practices, two methods of lockout/tagout implementation are discussed. For facilities or situations where the application of lockout/tagout is limited and has no effect on the overall facility safety or environmental systems, the method is called an individual-controlled lockout/tagout. For facilities where the application of a lockout/tagout is far-reaching and may alter an integrated process, the method is called centrally controlled lockout/tagout. For example, centralized operations control (similar to electric utilities) or situations requiring integration of lockout/tagout with other functions would use a centrally controlled lockout/tagout. This guide identifies many lockout/tagout practices that apply to both methods. It also identifies many additional or alternative practices that apply to only one method. DOE facilities may have operating characteristics addressed by either method. As part of the implementation of a lockout/tagout program, each facility must determine which guidelines are most applicable to the facility's own function and organization. The goal of the lockout/tagout program is the same for all DOE facilities: the control of potentially hazardous energy sources and hazardous materials to ensure safety.

Chapter X — DOE-STD-1036-93, Guide to Good Practices for Independent Verification
Independent verification compensates for the human element in facility operation. It recognizes that any operator, no matter how proficient, can make a mistake. However, the chance that two operators will independently make the same mistake is unlikely. Therefore, independent verification provides an extra measure of safety and reliability to facility operations. Industry experience shows that verifying, or double-checking, important operating parameters and component alignments reduces the occurrence of unintended operational events (shutdowns, environmental violations, etc.).

Independent verification is an activity designed to enhance the reliability of facility operations and safety functions, and to aid in the control of equipment and system status. Its intent is similar to the quality assurance and engineering checks that are performed during design and installation of facility systems. However, independent verification is an ongoing process performed by operations personnel during operations. Independent verification activities are built on the two concepts portrayed through their name: verification and independence.

Verification is the act of checking that an operation, the status of equipment, a calculation, or the position of a component conforms to established criteria. Verification only checks for conformance with the criteria; it does not alter the status of equipment or the position of components. The criteria used for verification are normally contained in operating procedures or alignment checklists. All persons performing verification must receive specific training and qualification on the systems they will verify, and on techniques for verifying component position or status.

Independence means that the person performing the verification will not be influenced by observation of, or involvement in, the activity that establishes the component position or status. For most operating activities, independence can best be achieved by separating the operation and the verification by time and distance. For example, if a verifier watches an operator read from a procedure, check the component label, operate the component, and then mark the item off in the procedure, it would be natural for the verifier to assume that the operation was performed correctly. However, the operator could have misread the procedure, misread the label, incorrectly identified the equipment, or performed the wrong operation. If the verifier is not present during the operation (separated by distance) and performs the verification at a later time, then the verification will not be affected by the operator's actions. If the verifier walks through the procedure, personally checking the label information and verifying the position of the components, any mistake made by the operator is likely to be detected.

For some operating activities, separating the operation and the verification by time and distance may not be possible. For example, verifying the position of a throttle valve or other control may require observation of the positioning activity. Verification for the installation or removal of jumpers may require checking the intended action before it is performed, because incorrect performance could cause a shutdown of critical equipment or actuation of a safety system. For these types of operating activities, the operator and verifier should independently identify the component and then concur on the action to be performed. The verifier should observe that the operation is performed correctly. This method is termed concurrent dual verification.

Independent verification will be most effective if it is incorporated into existing operating activities. Each facility's operating guidelines should identify the specific systems, structures, and components that require independent verification. Within those systems, structures, and components, the guidelines should identify the occasions when independent verification should be performed. Facility procedures should provide instructions for the independent verification techniques appropriate to specific systems and components. These instructions are necessary to ensure that verification is performed consistently and that verification activities do not change the component status or upset the process. Independent verification requirements should be addressed in pre-job briefings to identify the personnel involved and to clarify the methods that will be used. Facility training programs should include subjects related to independent verification, such as development of a questioning attitude, self-checking techniques, and methods to avoid undue influences while acting as the performer or verifier.

Separate from the requirement for independent verification of specific operations activities, the concepts of independent verification can be applied to other functions or activities that can affect operations. For example, independent appraisals of operating procedures and training should be performed to verify that environmental, safety, and health considerations have been addressed in accordance with operational requirements. Personnel should apply the principles of independent verification to all operating systems in their work areas, not just those having safety functions. System parameters should be checked against each other and against expectations. When problems are identified, individuals should notify supervisors and initiate corrective action in accordance with applicable procedures. This process helps ensure that problems are identified early and corrected before they cause larger problems.

Chapter XI — DOE-STD-1035-93, Guide to Good Practices for Logkeeping
This guide has been prepared to aid facilities and individuals in maintaining logs, both as working documents used in the daily conduct of facility operations and as permanent legal records.

The guidelines of DOE Order 5480.19 identify logs as part of the overall program for controlling equipment and system status. Logs have many characteristics in common with round sheets in that both provide information concerning the condition and status of equipment, and both are treated as legal records. Round sheets normally record only data collected from instruments. Logs are used to record an understandable account of the changes in the status of equipment, information obtained from sources in addition to instruments, and explanations for unusual data readings. This information makes logs a valuable tool in reconstructing events. If an unusual event occurs, its precursors and its progress can often be traced by analyzing logs, round sheets, and other records.

Logs provide a method for transferring information from one person or shift to another, and are an important part of the operations turnover described in DOE Order 5480.19, chapter XII. The transfer of information through logs enables current personnel to benefit from the experiences of previous operators of the equipment. The record of problems and attempted solutions may be reviewed whenever a new or similar problem occurs. The lessons learned can save time and effort in the search for solutions to current problems, and can help personnel avoid situations that caused problems in the past. The information contained in logs is also often used by engineers to track the performance of components or processes by training personnel to provide examples for instruction, and by others requiring specific information concerning operations.

Logkeeping enhances the formality that must be a part of good operating practices, and encourages individual accountability for operating decisions and actions. Logkeeping may also reduce paperwork by providing a single location and format for documenting operating activities.

DOE Order 5480.19 recommends logs for all key shift or process operator positions. Since logs are regarded as legal documents, they should meet high standards for accuracy and consistency. Facility guidelines should specify the positions required to maintain logs, the type of information to be recorded, and the requirements for format, timeliness, and legibility. Facility guidelines should also provide instructions for correcting errors in logs, periodic review of logs, and disposition of completed logs.

Chapter XII — DOE-STD-1038-93, Guide to Good Practices for Operations Turnover
An operations shift turnover (turnover) is the process of transferring duties and responsibilities of facility job positions between personnel. Thorough turnovers are crucial to the safety of DOE facility operation. Turnover activities ensure that on-coming personnel have an accurate picture of current facility status, and provide a review of past and scheduled operations. The information obtained by on-coming personnel during turnovers promotes safe, efficient, and continuous operation. To ensure the most efficient and productive transfer of facility information, the turnover should be strictly focused on the work station status and operation.

The turnover process should be conducted in a formal, businesslike manner because it prepares on-coming personnel to operate the facility. Consistent with facility policy, on-coming personnel are responsible for arriving at the facility in a condition ready to work (i.e., physically and mentally fit to assume the duties of the job).

A turnover checklist enhances the turnover process by serving as a guide for the on-coming person. Used properly, the checklist will take the on-coming person through the turnover process step-by-step. The turnover process will thus become a standard routine, thereby minimizing the possibility of missing important information during the turnover.

Documents specified by management should be reviewed by on-coming personnel before accepting their assigned responsibility. Reviewing these documents will augment the information obtained during the remainder of the turnover. The review will refresh and supplement the on-coming person's knowledge of past operations, as well as present and scheduled operational commitments. It can also provide information about work station status. This is especially important when a person has been absent for several days.

A pre-shift walkdown allows the on-coming person to inspect the work station before accepting responsibility. It provides the on-coming person an opportunity to check the status of the area and associated equipment. The walkdown is most beneficial when the off-going person accompanies the on-coming person. This enables the on-coming person to ask questions regarding work station status and also obtain immediate feedback.

A discussion of all information concerning the work station must be accomplished, and the oncoming and off-going personnel must be confident that an appropriate information exchange has taken place prior to transferring responsibility. If properly focused, this discussion is the most effective method of communicating work station information to the on-coming person. After the discussion, a formal transfer of the duties and responsibilities of the work station should conclude the turnover. This will officially end the duties and responsibilities of the off-going person and start those of the on-coming person.

Personnel briefings reinforce information communicated during the turnover. During the briefing, the appropriate supervisor has the chance to provide personnel with a picture of overall facility operations, both current and planned, including support group activities. A briefing of all personnel is the best way to quickly disseminate information important to everyone and to address questions personnel have concerning the facility.

In addition to turnovers to persons working a rotating schedule, turnovers to a staffed/unstaffed condition (e.g., office, laboratory, and research personnel) should also be considered. These single-shift positions should be considered because illness, vacation, or other instances may require that a work station be filled by an alternate person. The alternate must have sufficient knowledge of work station status to maintain operational continuity during the other person's absence. In this case, the transfer of information may only require written communication, but should still be communicated.

The information contained in this document complements the guidelines of Shift Routines and Operating Practices, chapter II, Control Area Activities, chapter III, and Logkeeping, chapter XI, of DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities.

Chapter XIII — DOE-STD-1037-93, Guide to Good Practices for Operations Aspects of Facility Chemistry and Unique Processes

A unique process is a separate process that is not directly controlled by operations personnel, but can affect, or be affected by, an operator's activities. It could be directly related to the safety or reliability of the facility, compliance with environmental and health requirements, fulfillment of the facility mission, or unrelated to any of these. A unique process may be the result of a specialized procedure (e.g., testing or research) and performed only once, or it may be an established routine. The operations aspects of unique processes can be described as the effects unique processes or activities may have on interrelated systems, and the actions that must be taken to avoid an adverse impact on operations.

Interactions between operations and unique processes can affect the safety and reliability of DOE facilities. In some cases, interactions with unique processes are anticipated in procedures and other operating documents. However, in many cases, an otherwise appropriate and permissible response to parameters in one system can produce an adverse effect in another system. To correctly interpret indications in a system, and to determine the best response, the operator must have an integrated knowledge of unique process interactions within the facility.

Effective operation also requires communication of relevant information between operators and process support personnel. In some cases, the operator must communicate intended actions to the process support personnel to prevent problems in the unique process. In other cases, the unique process is capable of affecting operations, therefore requiring two-way communication between process support personnel and operators. The following examples illustrate some of the effects of unique process interactions.

- A facility operates a chilled water system to support a variety of domestic and research needs. The system contains multiple chiller units which can be operated in combination to accommodate cooling loads. When personnel in a research project started several large pieces of equipment, the added cooling load caused the chilled water temperature to exceed the normal operating range before another chiller unit could be placed on line. This example illustrates how a unique process can affect an operator's activities. The research was a unique process to the chilled water system operator. Although the operator did not require detailed knowledge of the research, integrated knowledge of the system interactions was needed. Effective communication with the research project personnel would have enabled the operator to anticipate the load increase and ensure that sufficient reserve cooling capacity was on line.

- A periodic chemistry sample from a fluid system is used to evaluate the condition of the system components and determine their fitness for continued operation. Just before the sample was taken, the system operator started a pump that had been in a standby status. The change in flow characteristics caused contamination to be picked up in the sample. The indicated level of contamination normally signals equipment damage, which requires resampling the system and possible shutdown of equipment. This example illustrates how a unique process can be affected by an operator's activity. To the operator, chemistry sampling is a unique process, even though it is routinely performed. To prevent adverse effects on the sample, the operator requires an integrated knowledge of the process interactions, i.e., how the sampling is affected by pump startup, and needs to inform chemistry support personnel of operating activities that can adversely affect sampling. This would permit coordination of operations and chemistry activities, and would have avoided the need for resampling.
- Technicians working with radioactive materials needed to move the materials through an operational area of the facility. Following their procedures, they took all appropriate precautions to prevent the spread of contamination or personnel exposure during the movement; however, they failed to coordinate their movement with the operations supervisor. The materials set off an operational radiation alarm, causing the operations organization to respond as if an emergency had occurred. The movement of radioactive material may have had nothing to do with the facility operation or mission. However, the movement was capable of affecting operations and was not under the control of operations personnel; therefore, it constituted a unique process. If the process support personnel (technicians) had coordinated their activities with the operations supervisor, the operations personnel would have prepared for the alarm and avoided the emergency response.

Note that in each of these events, the persons involved were properly trained and qualified to perform their own job responsibilities. What they lacked was knowledge of the effects their activities would have on other processes. An integrated knowledge of the interfacing unique processes, and effective communication based on that knowledge, could have prevented each problem. Integrated knowledge may include the following elements:

- The fundamentals of the applicable physical sciences (i.e., chemistry, electricity, physics, thermodynamics, etc.) involved in interfacing unique processes
- The purpose and fundamentals of system design for interfacing unique processes
- The normal and anticipated abnormal operating characteristics of interfacing unique processes

Facilities should ensure that personnel at all levels have sufficient knowledge of interfacing or unique processes to ensure safety and efficiency in the working environment. Training, job experience, and direct communication with process support personnel are all methods to provide this integrated knowledge to operators. Facilities should encourage personnel to be technically inquisitive, to detect, understand, and anticipate problems while monitoring process parameters, and to communicate effectively with process support personnel so appropriate and timely corrective action can be initiated.

Chapter XIV — DOE-STD-1033-92, Guide to Good Practices for Operations and Administration Updates Through Required Reading

A properly administered program for updating personnel with operations and administration information through required reading is essential to the safety of personnel, equipment, and the environment. Required reading provides a method for employees to be made aware of information related to their job assignments. It includes information such as lessons learned from industry operating experience, facility equipment and system changes, procedure changes, company policies, and human resource information. A required reading program can also supplement employee training by providing information that is not routinely included in a formal training program, or information that may be trained on at a later date. The decision on how the required reading program will be used in conjunction with the facility training program must be carefully considered for each reading assignment. The system used to enact the required reading program provides tracking of the information supplied to employees and the completion status of the reading assignments. Personnel should be informed of the importance of questioning any information received through required reading when it is not understood.

Essential to an effective required reading program is the administrative procedure governing the program. This procedure provides the necessary guidance to the manager or supervisor responsible for administering this program. The information herein will assist in the development of such a program.

Chapter XV — DOE-STD-1034-93 Guide to Good Practices for Timely Orders to Operators

Management often finds it necessary to provide written guidance and direction to employees, such as outlining activities during periods of maintenance or providing notice of an immediate document review located in the required reading file. This guidance needs to be provided in a formal and timely manner. Operator orders are designed to provide a means for management to communicate guidance and short-term information to personnel. They may be used whenever it is necessary to disseminate information to personnel concerning special operations, administrative details, or environmental, safety, and health issues, but should never be used to replace or change facility procedures.

Establishing an administrative policy or procedure which specifically addresses the requirements for content, format, issuing, segregating, reviewing, and removal of timely orders will ensure the process is standardized throughout the facility. Such a policy should provide managers and supervisors an effective means to communicate appropriate guidance and information in a timely manner. Other means of routinely communicating guidance to employees are addressed in DOE Order 5480.19, Chapter XIV, Required Reading; Chapter XVI, Operations Procedures; and Chapter XVII, Operator Aid Postings.

Chapter XVI — DOE-STD-1029-92, Writer's Guide for Technical Procedures

A primary objective of operations conducted in a DOE complex is safety. Procedures are a critical element of maintaining a safety envelope to ensure safe facility operation. The DOE Writer's Guide for Technical Procedures addresses the content, format, and style of technical procedures that prescribe production, operation of equipment and facilities, and maintenance activities. The DOE Writer's Guide for Management Control Procedures and DOE Writer's Guide for Emergency and Alarm Response Procedures are being developed to assist writers in developing non-technical procedures.

DOE is providing this guide to assist writers across the DOE complex in producing accurate, complete, and usable procedures that promote safe and efficient operations that comply with DOE Orders, including DOE Order 5480.19, Conduct of Operations for DOE Facilities.

Successful procedures assist users by presenting actions clearly, concisely, and in the proper sequence. This guide provides a method for writers to ensure the following key questions are addressed and that procedures contribute to maintaining safe operations:
- What technical and administrative requirements are to be met?
- Who is the user and what is the user's level of experience and training?
- How does this document relate to other procedures for this equipment and facility?
- What materials, equipment, and facilities are to be used?
- What tasks are to be accomplished?
- Why, when, where, and how are the tasks to be accomplished?

Chapter XVII — DOE-STD-1043-93, Guide to Good Practices for Operator Aid Postings
Operator aid postings (operator aids) provide information for personnel to use during the performance of tasks. This information may be in the form of a system drawing, a copy of a procedure, an information tag or sheet, or a curve, chart, or graph. Posted copies of procedures or portions of procedures that are used as operator aids may be useful when the performance of a task makes it impractical to refer to a procedure in a manual (e.g., the task requires the use of both hands). Operator aids may help the operator identify problems that might be encountered during performance of a task, or they may present a simple diagram of equipment, systems, or areas (e.g., piping diagrams, electrical schematics). Other examples of operator aids include the following:
- A list of approved facility communication terms, abbreviations, and emergency numbers posted by communication equipment
- A graph of flow versus pump speed for a variable speed pump hanging beside the pump speed control switch
- A simple diagram of control knobs, valves, and switches for infrequently used equipment
- Specifications for a particular step in a task (for example, pH minimum and maximum values and elemental concentrations for disposing of fluids posted by the drain, which may be particularly useful since specifications for different fluids can be found in many different manuals)

Operator aids must reflect the most current information and they must not conflict with any procedures or requirements. Using operator aids containing outdated or incorrect information may cause harm to personnel or damage to the equipment, system, area, or facility. Also, if operator aids are developed for other than normal operations (e.g., for temporary systems, abnormal system configurations, or emergency situations), it is a good practice to clearly identify the circumstances under which they apply.

Developing useful operator aids may require intensive research and forethought. The information presented in the operator aid must be factual, and organized in a manner usable for all intended users. A thoroughly developed operator aid will ensure that the approver and reviewers better understand its need and usefulness. During the development process, reviews by applicable technical personnel may be helpful to ensure clarity.

An initial review and approval process verifies that the information contained in an operator aid is accurate and useful. This process officially authorizes its use. Periodic reviews will help ensure that the information is kept up-to-date and will verify the continued usefulness of the operator aid. It is important to remove obsolete, conflicting, or non-useful operator aids as quickly as possible to eliminate personnel confusion when performing tasks.

Documentation of operator aids is essential to their control. Maintaining a centrally located file of all operator aids will enhance the periodic review process. This file will help personnel quickly review and take action to correct, update, or remove obsolete operator aids as necessary. Listing reference documents used in the development process facilitates finding and updating operator aids when reference information changes.

Placing an operator aid in a conspicuous place that will allow the user to access controls or instrumentation is essential to posting. If the operator aid blocks instruments or controls, it will be more of a hindrance than a help. Affixing operator aids to the desired location using an attachment device suitable to the posting surface and the environment will ensure that the operator aid remains posted. An operator aid will be of little use if it comes loose and falls from its desired location.

The operator is one of the most important elements in ensuring the success of the operator aid program. Using only approved and current operator aids will help ensure the operator aid promotes safe and efficient operation. Operators must identify and report unapproved or incorrect operator aids at their work stations. This will ensure that the operator aids remain a useful tool in conducting business safely at their facility.

Chapter XVIII — DOE-STD-1044-93, Guide to Good Practices for Equipment and Piping Labeling

A well-established and maintained labeling program is essential for safe, reliable operation and maintenance of DOE facilities. During the period December 1990 through August 1992, DOE facilities reported more than 40 occurrences in which ineffective or incorrect labeling of equipment and piping contributed to errors in implementation of lockout/tagout, maintenance on the wrong equipment, inadvertent equipment startup, failure of designated safety or backup systems, or improper operation of facility equipment. The consequences, or potential consequences, of these occurrences include personnel injury, equipment damage, release of hazardous or toxic material, and loss of proper control of nuclear materials and processes.

An effective labeling program will clearly identify each component required in the operation of the facility, warn of specific hazards, and clearly identify emergency equipment. Effective labeling will enhance training effectiveness and help reduce operator and maintenance errors resulting from incorrect identification of facility equipment. Effective labeling will help reduce personnel exposure to radiation or hazardous materials by reducing the time spent identifying components. Piping labels that identify the contents, or at least the type of hazard represented by the contents, and the normal direction of flow will aid in preventing or mitigating leaks and spills. Labels on electrical equipment identifying the applicable feeder panel or breaker will aid in isolation for lockout/tagout, and will aid in quick and accurate response to equipment emergencies.

Labels should be designed to present information in a manner that will enhance operations and maintenance. The equipment names and number designations used on labels should be consistent with those used in procedures and drawings. Label size, placement, arrangement, fabrication materials, color coding, lettering size, and type style can all affect the usability of labels. The Electric Power Research Institute (EPRI) report, EPRI NP-6209, Effective Plant Labeling and Coding, contains research data and illustrations showing how to use labels effectively in control room and plant environments.

To remain effective, the labeling program must be an ongoing process. Maintenance activities involving removal or replacement of equipment may also result in loss or misplacement of component labels. Spills, passage of time, or other environmental factors may cause labels to become damaged or unreadable. Equipment modifications may result in new label requirements. Facility procedures should provide instructions for temporarily labeling components, and a central point of contact to ensure timely response to ongoing labeling requirements.

Acronyms

AC	(1) alternating current; (2) administrative control
ACGIH	American Conference of Government Industrial Hygienists
ALARA	as low as reasonably achievable
ARRs	accelerator readiness reviews
BCC	body centered cubic
BTU	British thermal unit
C	Celsius
CFC	Chlorofluorocarbon
COs	Contracting Officers
CRD	contractor requirements document
CSE	Cognizant System Engineer
DC	direct current
DEAR	Department of Energy Acquisition Regulation
DMG	Directives Management Group
DOE	Department of Energy
DOL	Department of Labor
DOP	Dioctylphthlate
DOT	Department of Transportation
DP	differential pressure
DSA	documented safety analysis
ECP	Employee Concerns Program
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ES&H	environment, safety and health
F	Fahrenheit
FCC	face centered cubic
FEOSH	Federal Employee Occupational Safety and Health
FM	Factory mutual
FR	Facility Representative
FRA	functions, responsibilities, and authorities
FRAM	safety management functions responsibilities and authorities
GOCO	Government owned, contractor operated
HCFC	hydrochlorofluorocarbon
HCP	hexagonal close package
HEPA	high efficiency particulate air
HFC	Hydrofluorocarbon
HP	high pressure
HQ	Headquarters
HVAC	heating, ventilation, and air conditioning
ISM	integrated safety management
ISMS	integrated safety management system
K	Kelvin
KE	kinetic energy
kW	Kilowatts

LCO	limiting conditions for operation
LP	low pressure
LSO	laser safety officer
LSSS	limiting safety system setting
LVDT	linear variable differential transformer
M&TE	measuring and test equipment
M&O	management and operating
MEK	methyl ethyl ketone
MEL	master equipment list
MIP	maintenance implementation plan
MORT	management oversight risk tree
MPE	maximum permissible exposure
NRC	Nuclear Regulatory Commission
NDT	nil-ductility transition
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NHZ	nominal hazard zone
NIOSH	National Institute for Occupational Safety and Health
NNSA	National Nuclear Security Administration
NPL	national priority site list
NPSH	net positive suction head
$NPSH_A$	net positive suction head available
$NPSH_R$	net positive suction head required
NTS	Noncompliance Tracking System
OC	Operations Center
OEs	operational emergencies
OHA	Office of Hearings and Appeals
OJT	on-the-job training
ORPS	Occurrence Reporting and Processing System
OSHA	Occupational Safety and Health Administration
PAAA	Price-Anderson Amendments Act
PCBs	polychlorinated biphenyls
PDSA	preliminary documented safety analysis
PE	potential energy
PELs	permissible exposure limits
PM	preventive maintenance
PPE	personal protective equipment
PPM	parts per million
PSIA	absolute pressure
PSIG	gauge pressure
QA	quality assurance
QAP	quality assurance program
QC	quality control
R	Rankine
RCRA	Resource Conservation and Recovery Act
RF	radio frequency

RTD	resistance temperature detector
S/CIs	suspect/counterfeit items
S/RIDs	standards/requirements identification documents
SAR	safety analysis report
SAT	systematic approach to training
SCBA	self-contained breathing apparatus
SCC	stress corrosion cracking
SDDs	system design descriptions
SER	safety evaluation report
SG	specific gravity
SL	safety limit
SME	subject matter expert
SMS	safety management system
SPMS	safety performance measurement system
SRP	standardized review plan
SSCs	systems, structures, or components
TC	thermocouple
TES	training/evaluation standards
TLVs	threshold limit values
TSD	treatment, storage, and disposal
TSRs	technical safety requirements
UCNI	unclassified controlled nuclear information
UL	Underwriters Laboratories
USQ	unreviewed safety question
Wt	weight

Selected Bibliography and Suggested Reading

10 CFR 63, “Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada.” January 1, 2006.

10 CFR 71, “Packaging and Transportation of Radioactive Material.” January 2006.

10 CFR 708, “DOE Contractor Employee Protection Program.” January 2006.

10 CFR 820, “Procedural Rules for DOE Nuclear Activities.” January 2006.

10 CFR 820.11, “Information Requirements.” January 2006.

10 CFR 820.24, “Preliminary Notice of Violation.” January 1, 2006.

10 CFR 820.25, “Final Notice of Violation.” January 1, 2006.

10 CFR 830, “Nuclear Safety Management.” January 2006.

10 CFR 830.203, “Unreviewed Safety Question Process.” January 2006.

10 CFR 835, “Occupational Radiation Protection.” January 2006.

10 CFR 1021, “National Environmental Policy Act Implementing Procedures.” January 1, 2006.

29 CFR 1910, “Occupational Safety and Health Standards.” January 2006.

29 CFR 1910.147, “The Control of Hazardous Energy (Lockout/Tagout).” January 2006.

29 CFR 1910.120, “Occupational Safety and Health Standards, Hazardous Waste Operations and Emergency Response.” January 2006.

29 CFR 1915, “Shipyard Employment.” January 2006.

29 CFR 1917, “Marine Terminals.” January 2006.

29 CFR 1918, “Safety and Health Regulations for Longshoring.” January 2006.

29 CFR 1926, “Safety and Health Regulations for Construction.” January 2006.

20 CFR 1926.753, “Hoisting and Rigging.” January 2006.

29 CFR 1928, “Occupational Safety and Health Standards for Agriculture.” January 2006.

40 CFR 264, “Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities.” July 2005.

40 CFR 265, “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities.” July 2005.

40 CFR 1500-1508, “Council on Environmental Quality.” July 1, 2005.

48 CFR 970.1100-1, “Performance-Based Contracting.” October 1, 2005.

48 CFR 970.5223-1, “Integration of Environment, Safety, and Health into Work Planning and Execution.” October 1, 2005.

48 CFR 970.5204-2, “Laws, Regulations, and DOE Directives.” October 1, 2005.

49 CFR 107.105, “Application for Exemption.” October 2005.

49 CFR 171.11, “Use of ICAO Technical Instructions.” October 2005.

49 CFR 171.12, “Import and Export Shipments.” October 2005.

49 CFR 171-180, “Pipeline and Hazardous Materials Safety Administration, Department of Transportation.” October 2005.

42 U.S.C. 6901, “The Resource Conservation and Recovery Act of 1976.” 1976.

American Conference of Governmental Industrial Hygienists. *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*. 2001.

ANSI Z49.1, *Safety in Welding, Cutting and Allied Processes.* American National Standards Institute, 1999.

ANSI Z88.2, *Practices for Respiratory Protection.* American National Standards Institute, 1980.

ANSI Z136.1-2000, *Laser Safety Standards.* American National Standards Institute, 1993.

Executive Order 12344. “Naval Nuclear Propulsion Program.” February 1, 1982.

Executive Order 12856. “Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements.” August 3, 1993.

Executive Order 13101. “Greening the Government through Waste Prevention, Recycling, and Federal Acquisition, and The Pollution Prevention Act of 1990.” September 14, 1998.

NFPA 70, *National Electrical Code*. National Fire Protection Association, 2005.

NFPA 70E, *Electrical Safety Requirements for Employee Workplaces*. National Fire Protection Association, 2004.

U.S. Department of Energy. DOE Guide 231.1-1, *Occurrence Reporting and Performance Analysis Guide.* August 20, 2003.

U.S. Department of Energy. DOE Guide 433.1-1, *Nuclear Facility Maintenance Management Program Guide for use with DOE O 433.1*. September 5, 2001.

U.S Department of Energy. DOE-HDBK-1012/1-92, *DOE Fundamentals Handbook, Thermodynamics, Heat Transfer, and Fluid Flow*, vol. 1. June 1992.

U.S Department of Energy. DOE-HDBK-1012/2-92, *DOE Fundamentals Handbook, Thermodynamics, Heat Transfer, and Fluid Flow*, vol. 2. June 1992.

U.S. Department of Energy. DOE-HDBK-1016-93, *Engineering Symbology, Prints, and Drawings*, vols. 1 and 2. January 1993.

U.S. Department of Energy. DOE-HDBK-1018/2-93, *Mechanical Science*, vol. 2. January 1993.

U.S. Department of Energy. DOE-HDBK-1206-98, *Guide to Good Practices for On-the-Job Training*. April 1998.

U.S. Department of Energy. DOE Manual 231.1-2, *Occurrence Reporting and Processing of Operations Information*. August 19, 2003.

U.S. Department of Energy. DOE Manual 411.1-1B, *Manual of Safety Management Functions, Responsibilities, and Authorities.* December 31, 2003.

U.S. Department of Energy. DOE Manual 435.1-1, *Radioactive Waste Management Manual*. June 19, 2001.

U.S. Department of Energy. DOE Order 151.1C, *Comprehensive Emergency Management System*. November 2, 2005.

U.S. Department of Energy. DOE Order 231.1A, *Environment, Safety and Health Reporting*. June 2004.

U.S. Department of Energy. DOE Order 414.1C, *Quality Assurance*. June 17, 2005.

U.S. Department of Energy. DOE Order 420.1B, *Facility Safety*. December 22, 2005.

U.S. Department of Energy. DOE Order 420.2B, *Safety of Accelerator Facilities*. July 23, 2004.

U.S. Department of Energy. DOE Order 425.1C, *Start-Up and Restart of Nuclear Facilities*. March 13, 2003.

U.S. Department of Energy. DOE Order 430.1B, *Real Property Asset Management*. September 24, 2003.

U.S. Department of Energy. DOE Order 433.1, *Maintenance Management Program for DOE Nuclear Facilities*. June 1, 2001.

U.S. Department of Energy. DOE Order 435.1, *Radioactive Waste Management*. August 28, 2001.

U.S. Department of Energy. DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*. March 27, 1998.

U.S. Department of Energy. DOE Order 442.1A, *Department of Energy Employee Concerns Program.* June 6, 2001.

U.S. Department of Energy. DOE Order 451.1B, *National Environmental Policy Act Compliance Program*. September 28, 2001.

U.S. Department of Energy. DOE Order 460.1B, *Packaging and Transportation Safety*. April 4, 2003.

U.S. Department of Energy. DOE Order 5480.4, *Environmental Protection, Safety, and Health Protection Standards*. January 7, 1993.

U.S. Department of Energy. DOE Order 5480.19, *Conduct of Operations Requirements for DOE Facilities*. October 23, 2001.

U.S. Department of Energy. DOE Order 5480.20A, *Personnel Selection, Qualification, and Training, Requirements for DOE Nuclear Facilities*. July 12, 2001.

U.S. Department of Energy. DOE Policy 411.1, *Safety Management Functions, Responsibilities, and Authorities (FRAM).* January 28, 1997.

U.S. Department of Energy. DOE Policy 450.4, *Safety Management System Policy*. October 15, 1996.

U.S. Department of Energy. DOE Policy 580.1, *Management Policy for Planning, Programming, Budgeting, Operation, Maintenance and Disposal of Real Property*. May 20, 2002.

U.S. Department of Energy. DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*. September 1997.

U.S. Department of Energy. DOE-STD-1029-92, *Writer's Guide for Technical Procedures*. December 1998.

U.S. Department of Energy. DOE-STD-1030-96*, Guide to Good Practices for Lockouts and Tagouts.* May 1996.

U.S. Department of Energy. DOE-STD-1031-93, *Guide to Good Practices for Communications*. December 1998.

U.S. Department of Energy. DOE-STD-1032-92, *Guide to Good Practices for Operations Organization and Administration*. December 1998.

U.S. Department of Energy. DOE-STD-1033-92, *Guide to Good Practices for Operations and Administration Updates Through Required Reading*. December 1998.

U.S. Department of Energy. DOE-STD-1034-93, *Guide to Good Practices for Timely Orders to Operators*. December 1998.

U.S. Department of Energy. DOE-STD-1035-93, *Guide to Good Practices for Logkeeping.* December 1998.

U.S. Department of Energy. DOE-STD-1036-93, *Guide to Good Practices for Independent Verification*. December 1998.

U.S. Department of Energy. DOE-STD-1037-93, *Guide to Good Practices for Operations Aspects of Facility Chemistry and Unique Processes*. December 1998.

U.S. Department of Energy. DOE-STD-1038-93, *Guide to Good Practices for Operations Turnover*. December 1998.

U.S. Department of Energy. DOE-STD-1039-93, *Guide to Good Practices for Control of Equipment and System Status.* December 1998.

U.S. Department of Energy. DOE-STD-1041-93, *Guide to Good Practices for Shift Routines and Operating Practices*. December 1998.

U.S. Department of Energy. DOE-STD-1042-93, *Guide to Good Practices for Control Area Activities.* December 1998.

U.S. Department of Energy. DOE-STD-1043-93, *Guide to Good Practices for Operator Aid Posting.* December 1998.

U.S. Department of Energy. DOE-STD-1044-93*, Guide to Good Practices for Equipment and Piping Labeling*. December 1998.

U.S. Department of Energy. DOE-STD-1045-93, *Guide to Good Practices for Notifications and Investigation of Abnormal Events*. December 1998.

U.S. Department of Energy. DOE-STD-1063-2006, *Facility Representatives.* April 2006.

U.S. Department of Energy. DOE-STD-1073-93, *Guide for Operational Configuration Management Program*. October 2003.

U.S. Department of Energy. DOE-STD-1104-96, *Review and Approval of Nonreactor Nuclear Facility Safety Analysis Reports*. December 2005.

U.S. Department of Energy. DOE-STD-3009-94, *Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports*. March 2006.

Facility Representative
Qualification Standard
Reference Guide
JUNE 2006