United States Department of Energy

Technical Qualification Program

Nuclear
(non-weapons)
Self Study Guide

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Preface

Scope and Background

The scope of this study guide encompasses those competencies identified in the Department of Energy (DOE) Nuclear (non-weapons) Topical Area. The guide seeks to address the skills and knowledge which have been identified in the DOE *General Technical Base Qualification Standard* and other Department-Wide Functional Area Qualification Standards as identified in the training to competency matrix and the Nuclear (non weapons) study guide Cross-Competency Listing.

The acquisition of these competencies can be demonstrated by three methods: competency equivalency documented by previous training, education, and experience; competency evaluation of knowledge and skills using examinations and performance evaluations; and competency exemption, which is a written release from the requirement to meet a specific competency. Some general examples of these methods include documentation of equivalent training or education, a test-out (or challenge test), a requirement waiver, completion of applicable course work, and other learning activities (such as this study guide).

Intent

The intent of this study guide is:

- To provide subject matter content in a suitable self-study medium that supports the acquisition of familiar and/or working level skills and knowledge as required by the nuclear (non-weapon)Technical Qualification Program competencies. The scope and content of this study guide, is not meant to support an “expert level” knowledge for the included material.

- To be used as a review for those individuals who have been previously exposed to the material.

How to Use This Study Guide

- The following cross-competency listing shows the link between each section of this study guide and the relevant competencies of DOE Qualification Standards. Also, at the beginning of each section is a detailed matrix relevant to the competencies covered in that section.

- For those sections that have a quiz or exercise, use them to gage the level of review needed. Then focus on those sections of the guide for which a review is required.

- Follow the sections in sequence for an overall review of the subject matter.

- For assistance or additional information, don't hesitate to contact your supervisor or subject matter experts at your facility or site, or refer to identified resources as necessary.

- When you have completed the study guide, contact your organizational training administrator for a copy of the exam. The exam is a proctored, closed book exam and the allotted time is one hour. Once you have completed with the exam, present it to the proctor, who will then have the exam evaluated. Results shall be forwarded to you, your supervisor, and your training file.

- Your supervisor (or delegated qualifying official) shall determine whether you have satisfactorily completed the competencies.

- Your Technical Qualification Record will be updated to document the completed competencies.

DISCLAIMER
This guide was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, or any of their contractors, subcontractors, or their employees, makes any warrantee, expressed or implied, or assumes any legal liabilities or responsibility for the accuracy, completeness, or usefulness of information, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency, contractor, or subcontractor thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency, contractor or subcontractor thereof.

Nuclear (non weapons) Study Guide
Cross-Competency Listing

The following matrix shows where the Nuclear (non weapons) Study Guide addresses particular qualification standard competencies.

DOE Qualification Standard(s)															Study Guide
General Technical Base	Environment Safety and Health Resident	Radiation Protection	Nuclear Safety Systems	Chemical Processing	Instrum-entation and Control	Project Management	Electrical Systems	Facility Mainten-ance	Construction Management	Mechanical Systems	Nuclear Explosives Safety	Civil / Structural Engineering	Technical Manager	Waste Management	
GTB 1.1															Section 1-1
GTB 1.2															Section 1-2
GTB 1.3			NS 1.1												Section 1-3
			NS 1.5												Section 1-4
			NS 1.3												Section 2-1
			NS 2.5	*CP 2.12*							NES 2.10				Section 2-2
			NS 2.9												Section 2-3
			NS 1.4												Section 2-4
											NES 1.3				Section 2-5
GTB 7.1			NS 1.6												Section 3-1
GTB 7.1			NS 2.4 NS 2.12	CP 2.6	IC 2.13	PM 2.6	ES 2.8	FM 2.9	CM 2.8	MS 2.6	NES 2.9	*CSE 2.7*			Section 3-2
GTB 7.1			NS 1.7												Section 3-3
		RP 2.4													Section 3-4
		RP 2.11	NS 2.3	CP 2.5	IC 2.12	PM 2.5	ES 2.7	FM 2.8	CM 2.7	MS 2.5	NES 2.8	*CSE 2.7*			Section 4-1
GTB 7.1			NS 2.2	CP 2.4	IC 2.11	PM 2.4	ES 2.6	FM 2.7	CM 2.6	MS 2.4	NES 2.7	*CSE 2.7*			Section 5-1
GTB 7.1													TM 1.6	WM 1.7	Section 5-2
	EH 2.4		NS 2.7	*CP 2.12*											Section 6-1
			NS 2.6												Section 7-1
								FM 1.22							Section 7-2
	EH 2.21														Section 8-1
			NS 3.3												Section 9-1
			NS 2.11												Section 9-2
			NS 3.2											WM 2.10	Section 9-3

Note: Shaded competencies in italics require review of the multiple study guide sections indicated.

Nuclear Fundamentals
Cross Competency Listing

The following matrix shows where the Nuclear Fundamentals portion of the Study Guide addresses particular qualification standard competencies.

DOE Qualification Standard(s)		Study Guide
General Technical Base	Nuclear Safety Systems	
GTB 1.1		**Section 1-1**
GTB 1.1.a		Parts 1.A
GTB 1.1.b		1.B
GTB 1.1.c		1.C
GTB 1.1.d		1.D
GTB 1.2		**Section 1-2**
GTB 1.2.a		Parts 2.A
GTB 1.2.b		2.B
GTB 1.2.c		2.C
GTB 1.2.d		2.D
GTB 1.2.e		2.E
GTB 1.2.f		2.F
GTB 1.3	**NS 1.1**	**Section 1-3**
GTB 1.3.a	NS 1.1.a(.1-.2)	Parts 3.A
GTB 1.3.b	NS 1.1.a(.3-.5)	3.B
GTB 1.3.c		3.C
	NS 1.1.b	3.D
	NS 1.1.c	3.E
	NS 1.1.d	3.F
	NS 1.1.e	3.G
GTB 1.3.d		3.H
GTB 1.3.e		3.I
GTB 1.3.f		3.J
GTB 1.3.g		3.K
	NS 1.5	**Section 1-4**
	NS 1.5.a	Parts 4.A
	NS 1.5.b	4.B
	NS 1.5.c	4.C
	NS 1.5.d	4.D

Nuclear Fundamentals

Section 1

OBJECTIVES

1. Demonstrate knowledge of basic atomic structure.
2. Demonstrate knowledge of basic nuclear theory and principles.
3. Demonstrate knowledge of the fission process.
4. Demonstrate knowledge of neutron poisons

Introduction

Knowledge of nuclear fundamentals and an understanding of the terms used in the nuclear field, is essential for every Department of Energy's technical personnel supporting the operations, maintenance, and oversight of nuclear facilities.

1. Demonstrate knowledge of basic atomic structure. **1-1**

A. Identify the basic particles that compose the atom and describe their relationship, associated mass, and charge.

An atom is composed of three basic particles: (Research has revealed that these particles are composed of sub-particles)

- Protons
- Neutrons
- Electrons

Refer to the chart below: for relationship, charge and mass.

Figure 1-1

Particle	Location	Charge	Rest Mass
Proton	Nucleus	+1 ecu*	1.0073 amu‡ (1.6725×10^{-27} kg)
Neutron	Nucleus	None	1.0087 amu‡ (1.6748×10^{-27} kg)
Electron	Orbital Shell	-1 ecu*	0.0005 amu‡ (9.1091×10^{-31} kg)

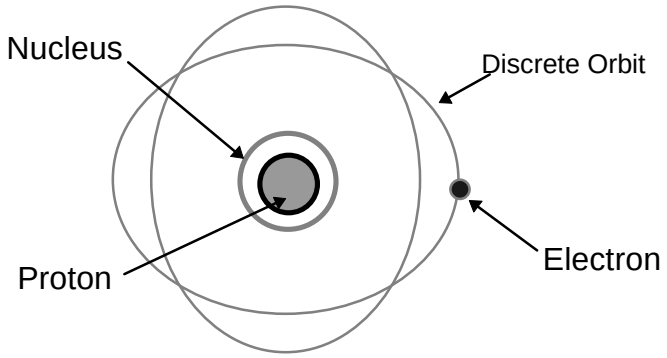
ecu* electron charge unit
amu‡ atomic mass unit

B. Describe the Bohr Model of the atom.

- Bohr's postulate for the Hydrogen Atom Model included:
  - Dense nucleus containing a proton,
  - Single electron traveling around nucleus in a discrete orbit,
  - All electron orbits are discrete,
  - Electrons could not remain in-between discrete allowable orbits, and
  - The delta in energy, exhibited by the change in an electron's orbit, would be fixed or quantized.

Figure 1-2

Bohr Model of The Atom



- Bohr Model can be used to understand atomic structure, with these exceptions:
  - Nucleus contains both protons and neutrons.
  - Electrons do not orbit the nucleus, but do occupy specific regions with defined shapes and sizes around the nucleus. (orbitals)

C. Define the following terms:

Atomic Number - The number of protons in the nucleus of an atom. The symbol for atomic number is Z. The number of protons and the corresponding equal number of electrons in the atom's orbital shells determines the chemical nature of the element. Thus a specific atomic number corresponds to the atom's chemical element symbol. For example: atomic number Z = 6 is C which is the chemical element symbol for carbon.

Mass Number - The number of protons and neutrons in the nucleus of an atom. The symbol for mass number is A**.** The particles in the nucleus of an atom (i.e. protons & neutrons) may also be referred to as nucleons.

Nuclide - Each type of atomic nucleus that contains a unique combination of protons and neutrons is called a nuclide. Not all combinations of numbers of protons and neutrons are possible, however approximately 2500 specific nuclides with unique combinations of neutrons and protons have been identified.

Isotope - Atoms or nuclides with the same atomic number (protons) but a different number of neutrons are isotopes of the same element. Isotopes of an element have the same chemical properties but different nuclear properties and mass numbers. Most elements have a few stable isotopes and several unstable radioactive isotopes.

D. Referring to the $^{A}_{Z}X$ notation for a specific nuclide, determine the number of protons, neutrons and electrons.

- A represents the mass number (protons + neutrons)
- Z represents the atomic number(protons)
- X represents the chemical symbol for the element
- In electrically neutral atoms the number of electrons is equal to the number of protons, therefore the number of electrons is normally equal to Z.
- If an atom has a different number of electrons than protons, then it has an electrical charge which is normally indicated by a superscript after the X, such as Cl^{-1} or He^{+2}

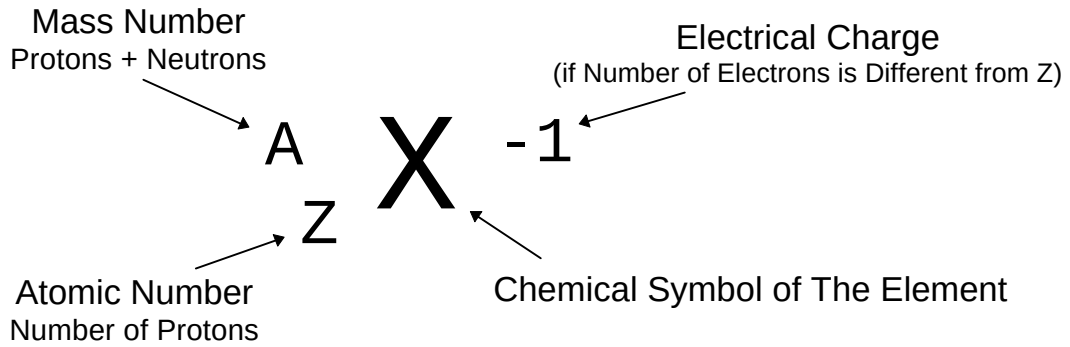


Figure 1-3

1-2

2. Demonstrate knowledge of basic nuclear theory and principles.

A. Describe the three forces that are found within a nucleus.

1) **Gravitational forces -** Gravitational forces exist between all bodies with mass. Gravitational forces tend to attract all nucleons toward each other within a nucleus, however the magnitude of this attractive force is extremely small compared to the electrostatic and nuclear forces within the nucleus.

2) **Electrostatic forces -** Electrostatic forces, as described by Coulomb's Law, exist between charged particles (protons +1) within a nucleus. Protons develop a strong repulsive force between other protons in the same nucleus due to their like charge. If only the electrostatic (repulsive) and the gravitational (attractive) forces within a nucleus are considered, the protons in a nucleus should repel one another and cause the nucleus to disintegrate.

3) **Nuclear forces -** A strong attractive Nuclear force exists between all nucleons regardless of charge. The strong nuclear force has a very short range and acts over distances approximately equal to the diameter of a nucleus (10^{-13} cm), is non-central (i.e.: does not follow the inverse square law) and exhibits saturation (i.e.: once a stable structure is achieved, additional nucleons are not strongly held).

B. Define mass defect and binding energy and discuss their relationship.

- **Binding Energy (BE)**

  The energy required to break up a nucleus into its component protons and neutrons.

- **Mass Defect (Δm)**

  The sum of the mass of the nucleons and electrons of an atom is greater than the actual mass of the atom, which is due to the conversion of mass into binding energy when the nucleus is formed.

- **Binding Energy and Mass Defect Relationship**

  This relationship is the result of the loss of energy in the formation of the atom, and the accompanying loss of mass(Δm). This is explained using Einstein's mass-energy equivalence relationship.

$$E = mc^2$$

where c is the speed of light **(2.998×10^8 m/sec)**

The energy equivalent of 1 amu can be determined by inserting this quantity of mass into Einstein's equations and apply conversion factors .

$$E = 1\ \text{amu}\left[\frac{1.6606 \times 10^{-27}\ \text{kg}}{1\ \text{amu}}\right]\left[2.998 \times 10^{8}\ \text{m/sec}\right]^2\left[\frac{1\ \text{N}}{1\ \frac{1\text{kg - m}}{\text{sec}^2}}\right]\left[\frac{1\ \text{J}}{1\ \text{N-m}}\right]$$

$$= 1.4924 \times 10^{-10}\ \text{J}\left[\frac{1\ \text{MeV}}{1.6022 \times 10^{-13}\ \text{J}}\right]$$

The conversion factor derived from the equation above is: 1 amu = 931.5 MeV. Thus:

$$BE = \Delta m(931.5\text{MeV/amu})$$

Where: Δm is in amu

C. Describe the following processes, and trace the decay chain for a specified nuclide on the chart of the nuclides.

Alpha Decay

- An alpha particle ($^{4}_{2}\alpha^{+2}$) has the same structure as a Helium nucleus and may also be indicated by the symbol $^{4}_{2}He^{+2}$.
- Alpha decay occurs when the ejection of an alpha particle (from the nucleus) causes the mass number (A) to decrease by 4 and the atomic number (Z) to decrease by 2. On a chart of the nuclides, an alpha decay is represented by a drop of two rows and a move to the left of two columns.
- Almost all naturally occurring alpha emitters are heavy elements with $Z \geq 83$.

Beta-Minus Decay

- A Beta-Minus decay is the emission of a Beta minus particle (β^-) or a negatively charged electron from the nucleus.
- When a β^- particle is emitted, a neutron within the nucleus is converted to a proton causing the atomic number to increase by one while the mass number remains constant. Thus on a chart of the nuclides a β^- decay is represented by an increase of one row and a move to the left of one column.

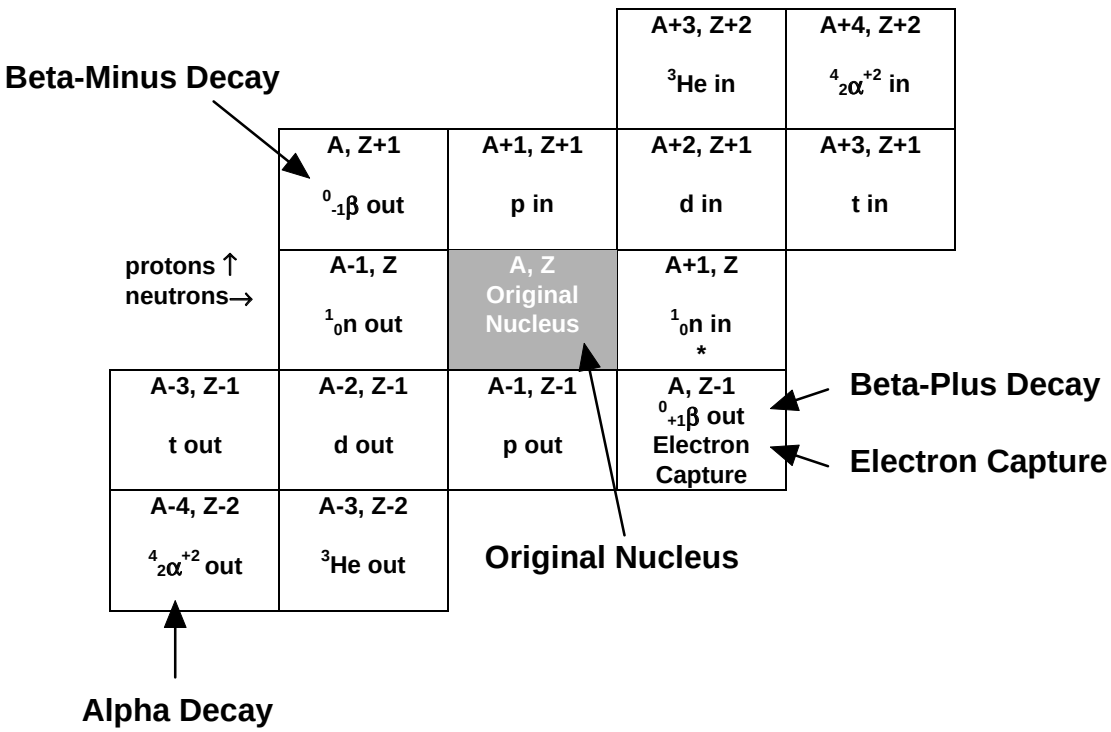
Beta-Plus Decay

- A Beta-Plus decay is the emission of a positively charged electron (also known as a positron emission) from the nucleus of an atom.
- When a Beta-Plus particle (β^+) is emitted, a proton within the nucleus is converted to a neutron causing the atomic number to decrease by one while the mass number remains constant. Thus on a chart of the nuclides a β^+ decay is represented by a decrease of one row and a move to the right of one column.

Electron Capture

- Electron Capture (ε) occurs when a nucleus absorbs or captures an electron from one of the inner orbits of the atom and the electron combines with a proton to form a neutron.
- This process occurs in nuclides with an excess number of protons. The electron captured is normally from the innermost orbit (the K shell), thus the process is sometimes called K-capture.
- Electron capture leaves an inner orbital shell vacant, and when electrons from outer shells (with higher energies) move to fill the vacancy in the lower energy shell, the excess energy is given off by the emission of a characteristic x-rays.
- Electron capture and Beta-Plus decay (positron emission) result in the production of the same daughter product and the same movement on a chart of the nuclides.

Figure 1-4



D. Define the following terms:

Radioactivity - a property of some nuclides characterized by the spontaneous emission of particles (Alpha, Beta or Neutron) and/or electromagnetic radiation (Gamma or X-rays). Radioactive nuclides decay in a random manner. However, the average behavior can be estimated for a specific nuclide if a statistically significant number of atoms of the nuclide are studied.

Radioactive Decay Constant (λ) - The radioactive decay constant (λ) is the probability that an atom of a specific radioactive isotope will decay per unit time. For a given number of atoms (N) of a radioactive isotope, the activity (A) is given by the expression:

$$A = \lambda N$$

The activity of a pure radionuclide is dependent upon the initial activity (A_0), radioactive decay constant, and decreasing exponentially as a function of time:

$$A(t) = A_0 e^{-\lambda t}$$

Curie (Ci) - A curie (Ci) is unit of measure used to describe the activity (A) of atoms in a specimen.

1 Ci = 3.7 x 10^{10} disintegrations per second

In SI units, activity is expressed in Becquerels (Bq)

1 Bq = 1 disintegration per second

Thus: **1 Ci = 3.7 x 10^{10} Bq**

Radioactive Half Life ($t_{1/2}$) - The radioactive half life of a specific nuclide is the amount of time required for half of the atoms of the nuclide to undergo radioactive decay. After half of the atoms have decayed the activity will also be half of the original activity. The Chart of the nuclides gives half life information for nuclide.

Solving $A(t) = A_0 e^{-\lambda t}$ for t yields $t = -(\ln A/A_0)/\lambda$.

If half of the nuclide is present at time $t_{1/2}$, then $A/A_0 = 1/2$ yielding

$$t_{1/2} = \ln 2 / \lambda$$

Radioactive Equilibrium - Radioactive equilibrium exists when a radioactive nuclide is decaying at the same rate at which it's being produced. Since the production rate and the decay rate are equal, the number of atoms remains constant over time.

E. Describe the following neutron/nucleus interactions:

A neutron scattering reaction occurs when a nucleus, after having been struck by a neutron, emits a single neutron. The two categories of scattering reactions, **elastic and inelastic scattering** are discussed below.

Elastic scattering - In an elastic scattering reaction between a neutron and a target nucleus, there is no energy transferred into nuclear excitation. Momentum and kinetic energy of the system are conserved.

Elastic Scattering

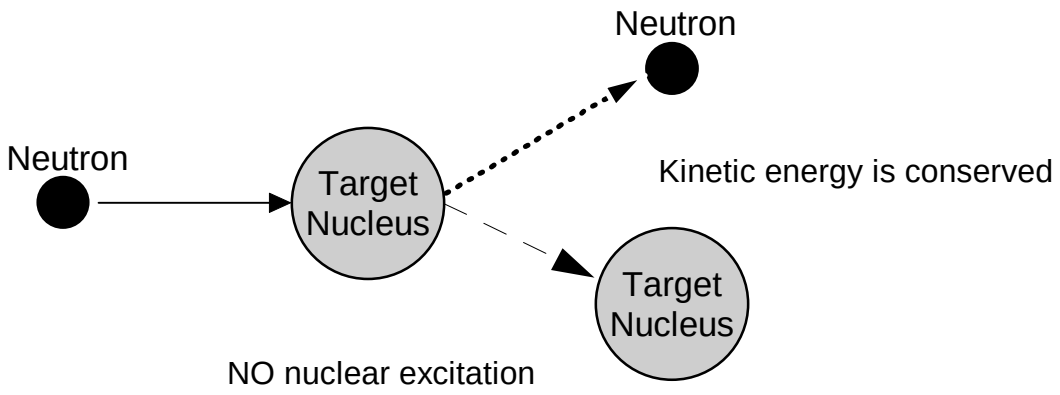


Figure 1-5

Inelastic scattering - In inelastic scattering, the incident neutron (and it's kinetic energy) is absorbed by the target nucleus, forming a compound nucleus. The compound nucleus then emits a neutron of lower kinetic energy than the incident neutron, leaving the nucleus in an excited state. The nucleus typically undergoes one or more gamma emissions to drop from its excited state to its ground state.

Inelastic Scattering

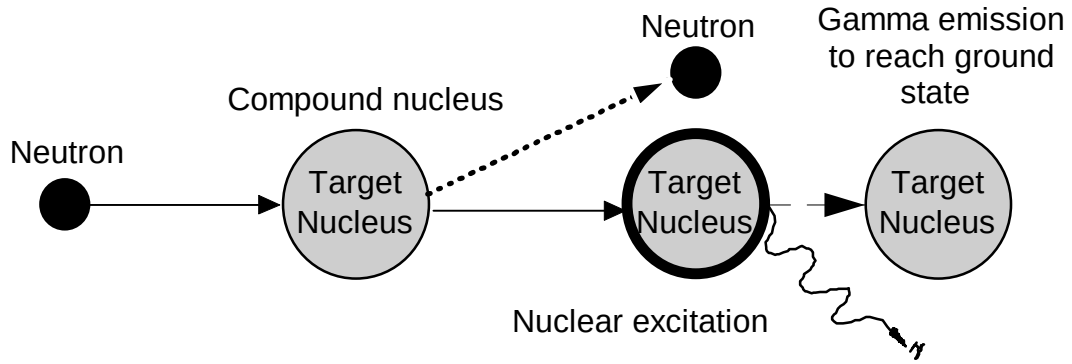


Figure 1-6

F. Compare and contrast capture (absorption), fission, and particle ejection nuclear reactions.

Absorption Reactions are neutron-nucleus reactions that result in the absorption of a neutron onto a nucleus coupled with the production of a charged particle or gamma ray. Capture, particle ejection, and fission are all categorized as absorption reactions. and are briefly described below.

- **Capture:** The incident neutron enters the target nucleus forming a compound nucleus. The compound nucleus then decays to its ground state by gamma emission, without ejecting another particle.

- **Particle Ejection**: The incident particle enters the target nucleus forming a compound nucleus. The newly formed compound nucleus has been excited to a high enough energy level to cause it to eject a new particle while the incident neutron remains in the nucleus. The remaining nucleus may or may not exist in an excited state depending upon the mass-energy balance of the reaction.

- **Fission**: The nucleus that absorbs the neutron actually splits into two similarly sized parts. Fission will be discussed in detail in the next section.

1-3

3. Demonstrate knowledge of the fission process.

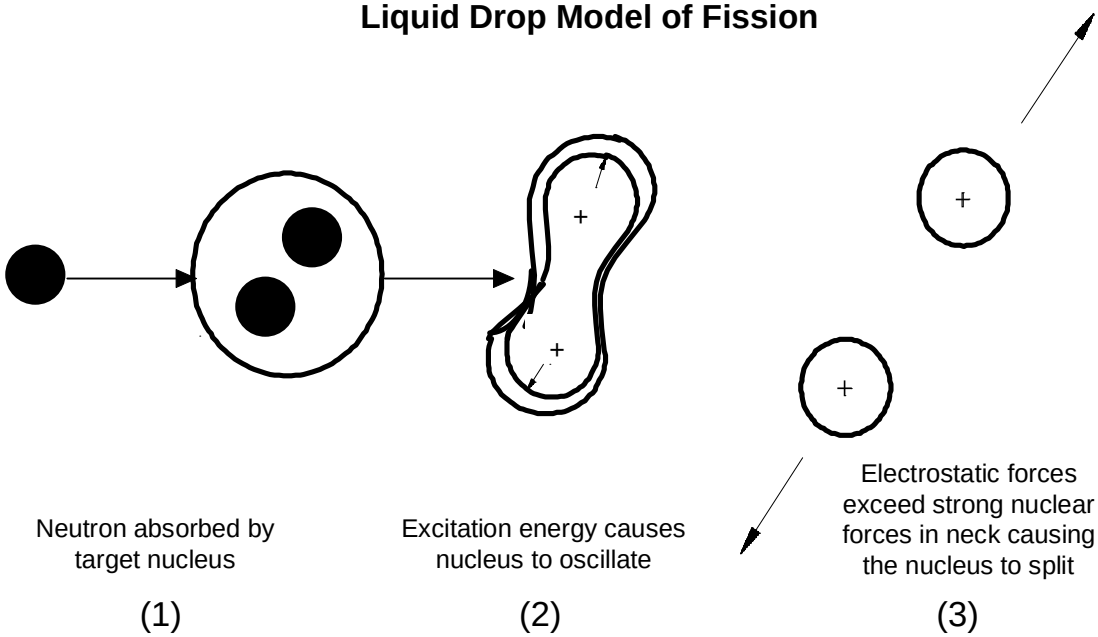
A. Explain the fission process using the liquid drop model.

- **Excitation Energy (E_{exc})** is the measure of how far the energy level of a nucleus is above its ground state.

- **Critical Energy for Fission(E_{crit})** is the minimum excitation energy required for fission to occur.

Figure 1-7

Liquid Drop Model of Fission



1. When an incident particle is absorbed by the target nucleus, a compound nucleus is formed. The compound nucleus temporarily contains all the charge and mass involved in the reaction and exists in an excited state.
2. The excitation energy imparted to the compound nucleus, may cause it to oscillate and become distorted. If the excitation energy is greater than a certain critical energy ($E_{exc} > E_{crit}$), the oscillations may cause the compound nucleus to become dumbbell-shaped.
3. If the oscillations continue, the repulsive electrostatic forces may exceed the attractive nuclear forces, causing the nucleus to fission.

B. Compare and contrast the characteristics of fissile material, fissionable material, and fertile material.

Fissile Material

- Composed of nuclides for which fission is possible with neutrons of any energy level, thus can be fissioned with <u>low kinetic energy neutrons</u> (thermal neutrons).
- Change in binding energy supplied by the neutron addition alone is high enough to exceed the critical energy.

- Examples of fissile nuclides are uranium-235, uranium-233, and plutonium-239.

Fissionable Material

- Material for which fission with neutrons is possible (including all fissile nuclides).
- Includes nuclides that can be fissioned only with high energy (fast) neutrons.
- The change in binding energy that occurs as the result of thermal neutron absorption results in a nuclear excitation energy level that is less than the required critical energy (E_{crit}).
- The additional excitation energy must be supplied by the kinetic energy of the incident neutron, hence the requirement for a fast neutron to fission.
- Differences in critical energy between Fissile and Fissionable (non-fissile) materials is due to the odd-even effect for nuclei (nuclei with even numbers of neutrons and/or protons are more stable than those with odd numbers).
- Examples of nuclides requiring high energy neutrons to cause fission are thorium-232, uranium-238, and plutonium-240.

Fertile Material

- Fertile materials are those materials that can undergo transmutation to become fissile.
- Transmutation begins when an isotope absorbs a neutron and a new isotope is created. Subsequent radioactive decays or additional transmutations can occur to change the nucleus into a fissile isotope.
- Fertile materials must be exposed to a neutron flux (i.e.: an operating nuclear reactor) in order to begin the conversion process.
- Fertile nuclides include thorium-232 and uranium-238, which transmutate into the fissile isotopes, uranium-233 and plutonium-239.

C. Discuss the various energy releases that result from the fission process.

- Most of the energy is released immediately (≈ 89%).
- Remainder is released over time as the fission products undergo radioactive decay.
- The immediate and delayed useful energy released by the fission of Uranium, Thorium or Plutonium is approximately the same and is about 200 MeV per fission.
- Majority of the energy released in a fission reaction is ultimately converted to heat energy and transferred to the material surrounding the fission site.

Figure 1-8

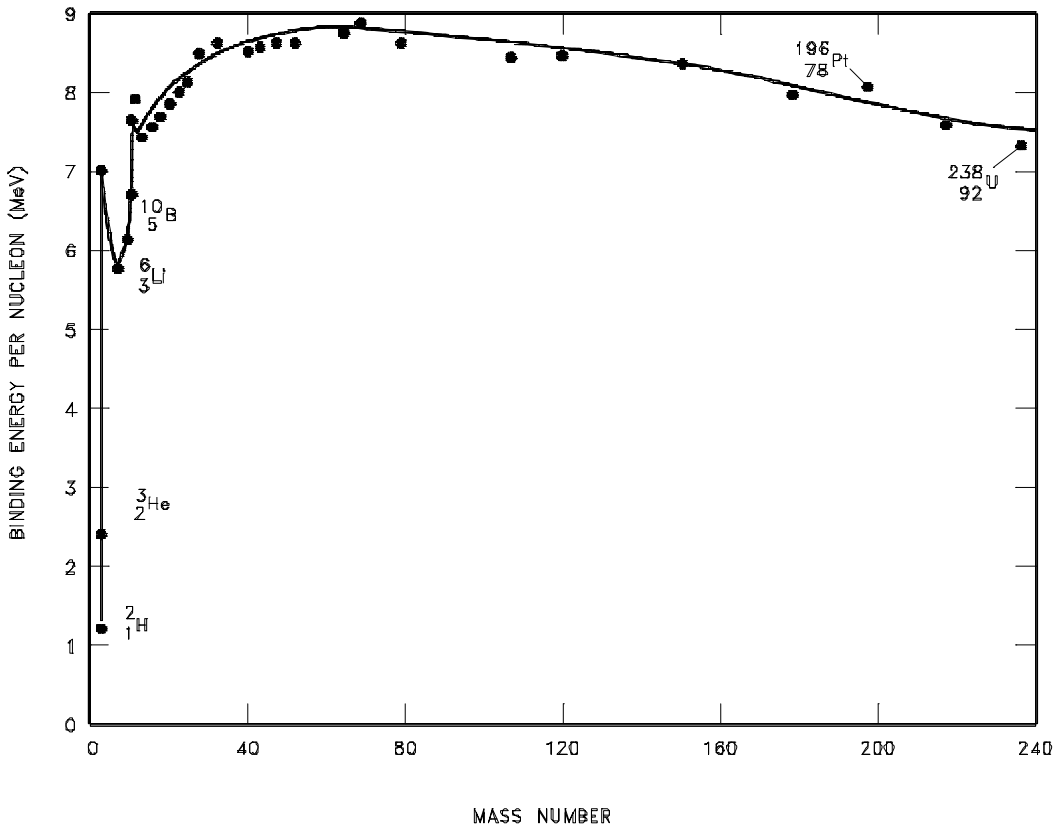
Energy Breakdown per Fission

Instantaneous Energy:	Kinetic Energy of fission products	167 MeV
	Energy of fission neutrons	5 MeV
	Instantaneous Gamma Photons	5 MeV
	Capture Gamma Photons	10 MeV
Total Instantaneous Energy		187 MeV
Delayed Energy:	Fission Product Beta Decay	7 MeV
	Fission Product Neutrinos (not useful)	10 MeV
	Fission Product Gamma	6 MeV
Total Delayed Energy		23 MeV
Total Energy per fission		210 MeV
Total Useful Energy per fission		**200 MeV**

D. Describe the curve of binding energy per nucleon vs. mass number and give a qualitative description of the reasons for its shape.

Figure 1-9

Binding Energy per Nucleon Curve



- For A $\geq$ 60; as the atomic mass number increases, the binding energy per nucleon decreases.
- As the atomic number and the atomic mass number increase, the repulsive electrostatic forces within the nucleus increase due to the greater number of protons in the heavy elements.
- The proportion of neutrons in the nucleus must increase to maintain stability.
- This increase in the neutron-to-proton ratio only partially compensates for the growing proton-proton repulsive force in the heavier, naturally occurring elements.
- Due to the increasing repulsive forces, less energy must be supplied, on the average, to remove a nucleon from the nucleus.

E. Explain why only the heaviest nuclei are easily fissioned.

(Refer to Figure 1-9 in going through the following bullets.)

- As the weight (A) increases BE/A decreases
- The heaviest nuclei require only a small distortion from a spherical shape (lower E_{crit}) which allows the large repulsive electrostatic (coulomb) forces to overcome the attractive nuclear forces holding the two halves together.
- The heaviest nuclei are easily fissionable compared to lighter nuclei.

F. Explain why uranium 235 fissions with thermal neutrons and uranium 238 fissions only with fast neutrons.

- Uranium 235 is a fissile material, uranium 238 is only a fissionable material.

Target Nucleus	Critical Energy E_{crit}	Binding Energy of Last Neutron BE_n	BE_n - E_{crit}
$_{92}^{238}U$	7.0 MeV	5.5 MeV	-1.5 MeV
$_{92}^{235}U$	6.5 MeV	6.8 MeV	+0.3 MeV

Figure 1-10

- Uranium 235 fissions with thermal neutrons because the binding energy released by the absorption of a neutron is greater than the critical energy for fission
- The binding energy released by uranium 238 absorbing a thermal neutron is less than the critical energy, so additional energy (kinetic) must be possessed by the neutron (fast) for fission to be possible.
-

G. Characterize the fission products in terms of mass groupings and radioactivity.

- The most common mass numbers of fission are grouped near 95 and 140.
- The fission products generally decay by β- emission.

H. Define criticality and explain how it is detected.

- Criticality can be defined as the state of a system of fissionable material where on average exactly one of the several neutrons emitted during a fission event causes another fission event to occur.
- The ratio of the number of neutrons in the next generation (N_{i+1}) to the number of neutrons in the current generation (N_i) is described by the terms critical, supercritical or subcritical.

$$k_{eff} = N_{i+1} / N_i$$

$k_{eff} = 1.0$ Critical
$k_{eff} > 1.0$ Supercritical
$k_{eff} < 1.0$ Subcritical

- Various monitors are used throughout the DOE to detect neutrons, gamma photons, or a combination of radiation emitted during a criticality incident.
- An example is a Lithium Fluoride (LiF) crystal and a diffused junction semiconductor detector system, which detects the charged particles created by the neutron reaction.

I. List the factors that affect criticality.

Seven interdependent factors may affect criticality of a system:

1. **Mass**: The potential for fission to occur increases as the mass and hence the number of fissionable target atoms increases.
2. **Density**: (Mass per unit volume) As more fissionable target atoms are packed into a smaller volume (increasing density), the probability of fission increases.
3. **Shape**: Surface area to volume ratio affects criticality. As the shape of a container is modified to reduce surface area per unit volume, the probability of neutrons escaping from the surface of the container is reduced. If the probability of escape is reduced then the probability of fission increases.
4. **Neutron Poisons:** Neutron Poisons are non-fissionable atoms that are effective at capturing or absorbing neutrons. Neutrons captured or absorbed by poisons are no longer available to cause fission. Please see Section 1-4 of this study guide for more information on neutron poisons.

5. **Moderation:** The probability of a neutron interacting with a fissionable atom increases greatly when the neutron has slowed to thermal velocities. When a neutron is slowed down or moderated, it will increase the probability of fission in a fissile material. However, once the neutron energy drops below a specific value for the isotope in question, the neutron will no longer be capable of causing fission.
6. **Reflection:** Reducing the amount of neutron leakage affects criticality. Neutrons that leak can be reflected back into a mass of fissionable target atoms by materials that do not absorb neutrons thereby increasing the probability of fission.
7. **Interaction:** Occurs when neutrons from one fissionable system can travel to and interact with another fissionable system.

J. Identify the hazards that result from an unwanted criticality.

A **Nuclear Criticality Accident** is an unintentional, uncontrolled nuclear fission chain reaction. Possible consequences of a criticality accident include:

- Radiation exposure and/or radioactive contamination
- Release of radioactive fission products
- Physical damage to the facility
- Fire

Health hazards to unshielded personnel may include:

- Death due to radiation exposure of physical damage depending on proximity to the excursion.
- Radiation Sickness
- Increased risk of cancer
- Increased risk of cataracts
- Sterility

Hazards are dependent on distance from accident and length of exposure.

K. Explain the double contingency principle as it relates to criticality control.

- Process designs must incorporate sufficient safety factors so that at least two unlikely, independent and concurrent changes in process conditions must occur before accidental nuclear criticality is possible.
- Thus, the failure or accident involving one process would not result in a criticality accident.

1-4

4. Demonstrate knowledge of neutron poisons.

A. Describe the use of neutron poisons.

Neutron poisons are used to control the criticality of a system. Neutron poisons are non-fissile neutron absorbers. Systems designed to operate at criticality for long periods of time must have excess fuel (above what is needed for criticality). The positive reactivity from excess fuel must be balanced with negative reactivity from neutron-absorbing materials to control the on-going fission process within a system.

B. Define the following terms:

Burnable Neutron Poison - a material that has a high neutron absorption cross section that is converted into a material of relatively low absorption cross section as the result of neutron absorption.

Non-Burnable Neutron Poison - a material that has relatively constant neutron absorption characteristics over core life. The absorption of a neutron by one isotope in the material produces another isotope that also has a high absorption cross section.

Chemical Shim - a soluble neutron poison that is circulated in the coolant during normal operation.

C. Explain the purpose and use of Raschig Rings as a neutron poison.

Borosilicate-glass Raschig Rings contain a form of Boron, a neutron poison. By placing several of the small glass rings (3 cm in height, 3 cm outside diameter and 0.5 cm thickness) in a container of soluble fissile material, the borosilicate glass absorbs neutrons, but most significantly, the surface area of the fissile solution increases, increasing the probability of neutron leakage into the ring and diminishing the likelihood of a criticality accident.

D . State an example of a material used as a fixed nonburnable neutron poison.

One example is **Hafnium**. The removal (by absorption of neutrons) of one isotope of hafnium leads to the production of another neutron absorber, and continues through a chain of five absorbers. This absorption chain results in a long-lived burnable poison which approximates non-burnable characteristics.

Section 1 References and Suggested Reading

References and Suggested Reading

Department of Energy, Fundamentals Handbook, Nuclear Physics and Reactor Theory, Module 1, Atomic and Nuclear Physics, (DOE-HDBK-1019 - 1-93), DOE, 1993

Department of Energy-Rocky Flats Field Office, General Technical Base Qualification Standard Study Guide, Revision 0, DOE, Golden CO., 1996

Thomas J. Connolly, Foundations of Nuclear Engineering, J Wiley & Sons, New York, 1978

S.K. Kim and E.N. Strait, Modern Physics for Scientists and Engineers, Macmillan, New York, 1978

Michael Chin, Chemistry, Random House, New York, 1987

SECTION 1 QUIZ

1. List the three basic particles that compose an atom, their relative location and charge (+,-)

Name: 1_____ 2_____ 3_____

Location: 1_____ 2_____ 3_____

Charge: 1_____ 2_____ 3_____

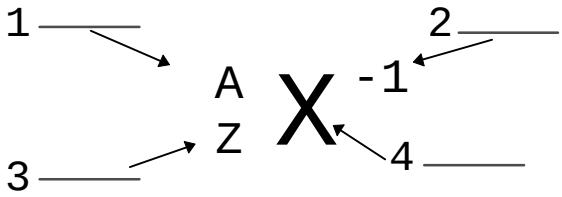
2. Match the terms on the left with their appropriate location on the right.

A. Number of Protons

B. Electrical Charge

C. Number of Protons and Neutrons

D. Chemical Symbol of Element



Of A through D on the left above which represents Atomic Number? _____

Of A through D on the left above which represents Mass Number? _____

3. Define the following terms:

Binding Energy:

Mass Defect:

How are Binding Energy and Mass Defect related?

4. Define the following terms:

Excitation Energy:

Critical Energy for Fission:

5. In reference to the Liquid Drop model of Fission:

Nuclear fission occurs when the attractive _____ forces in the neck of the oscillating compound nucleus are overcome by the repulsive _____ forces.

6. For the isotopes below, indicate which is likely a fissile isotope and which is likely a fissionable, non-fissile isotope.

Isotope	Critical Energy E_{crit}	Binding Energy of Last Neutron BE_n	BE_n - E_{crit}	Fissile or Fissionable
Isotope A	7.0 MeV	5.5 MeV	-1.5 MeV	
Isotope B	6.5 MeV	6.8 MeV	+0.3 MeV	

7. Define and give an example of a non-burnable neutron poison.

Section 1
Solutions

SECTION 1 QUIZ SOLUTIONS

1. List the three basic particles that compose an atom, their relative location and charge (+,-)

Name:	1 Proton	2 Neutron	3 Electron
Location:	1 Nucleus	2 Nucleus	3 Orbital Shell
Charge:	1 +1	2 None	3 -1

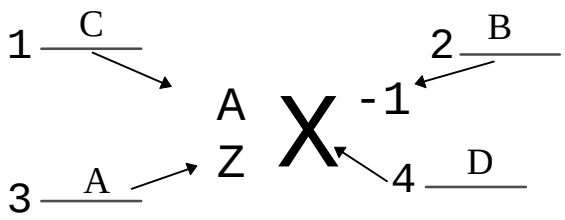
2. Match the terms on the left with their appropriate location on the right.

A. Number of Protons

B. Electrical Charge

C. Number of Protons and Neutrons

D. Chemical Symbol of Element



Of A through D on the right above which represents Atomic Number? A

Of A through D on the right above which represents Mass Number? C

3. Define the following terms:

Binding Energy:

The energy required to break up a nucleus into its component protons and neutrons.

Mass Defect:

The sum of the mass of the nucleons and electrons of an atom is greater than the actual mass of the atom, which is due to the conversion of mass into binding energy when the nucleus is formed.

How are Binding Energy and Mass Defect related?

The relationship between Binding Energy and Mass Defect is the result of the loss of energy in the formation of the atom, and the accompanying loss of mass(Δm).

4. Define the following terms:

Excitation Energy:

Excitation Energy is the measure of how far the energy level of a nucleus is above its ground state.

Critical Energy for Fission:

Critical Energy for Fission the minimum excitation energy required for fission to occur.

5. In reference to the Liquid Drop model of Fission:

Nuclear fission occurs when the attractive Nuclear forces in the neck of the oscillating compound nucleus are overcome by the repulsive Electrostatic or Coulomb forces.

6. For the isotopes below, indicate which is likely a fissile isotope and which is likely a fissionable, non-fissile isotope.

Isotope	Critical Energy E_{crit}	Binding Energy of Last Neutron BE_n	BE_n - E_{crit}	Fissile or Fissionable
Isotope A	7.0 MeV	5.5 MeV	-1.5 MeV	Fissionable
Isotope B	6.5 MeV	6.8 MeV	+0.3 MeV	Fissile

7. Define a non-burnable neutron poison.

A non-burnable neutron poison is a material that has relatively constant neutron absorption characteristics over core life. The absorption of a neutron by one isotope in the material produces another isotope that also has a high absorption cross section.

One example is Hafnium. The removal (by absorption of neutrons) of one isotope of hafnium leads to the production of another neutron absorber, and continues through a chain of five absorbers. This absorption chain results in a long-lived burnable poison which approximates non-burnable characteristics.

Nuclear Criticality Safety
Cross Competency Listing

The following matrix shows where the Nuclear Criticality Safety portion of the Study Guide addresses particular qualification standard competencies.

DOE Qualification Standard(s)			Study Guide
Nuclear Safety Systems	Chemical Processing	Nuclear Explosives Safety	
NS 1.3			**Section 2-1**
NS 1.3.a			Parts 1.A
NS 1.3.b			1.B
NS 1.3.c			1.C
NS 2.5		**NES 2.10**	**Section 2-2**
NS 2.5.a	CP 2.12.a	NES 2.10.a	Parts 2.A
NS 2.5.b		NES 2.10.b	2.B
NS 2.5.c	CP 2.12.b		2.C
NS 2.5.d	CP 2.12.d	NES 2.10.c	2.D
NS 2.9		**NES 2.9**	**Section 2-3**
NS 2.9.a		NES 2.9.a	Parts 3.A
NS 2.9.b		NES 2.9.b	3.B
NS 2.9.c		NES 2.9.c	3.C
NS 1.4			**Section 2-4**
NS 1.4.a			Parts 4.A
NS 1.4.b			4.B
NS 1.4.c			4.C
		NES 1.3	**Section 2-5**
		NES 1.3.a	Parts 5.A
		NES 1.3.b	5.B
		NES 1.3.c	5.C
		NES 1.3.d	5.D
		NES 1.3.e	5.E
		NES 1.3.f	5.F

Nuclear Criticality Safety

Section 2

OBJECTIVES

1. Demonstrate knowledge of criticality control and safety parameters.
2. Demonstrate knowledge of DOE Order 5480.24, Nuclear Criticality Safety, with respect to its impact on Department nuclear safety.
3. Demonstrate knowledge of criticality safety-related standards of the American National Standards Institute/American Nuclear Society (ANSI/ANS).
4. Demonstrate knowledge of alarm systems for criticality accidents.
5. Demonstrate knowledge of the criticality process and its application to nuclear explosive/weapon design and operations.

Introduction

Understanding nuclear criticality and means to contol it is essential to the safe handling of nuclear materials. Nuclear criticality safety programs have a long and distinguished history in the Department, and it is important to know how and why these programs are in place.

1. Demonstrate knowledge of criticality control and safety parameters. 2-1

A. Discuss the effects and applications of the following factors relevant to criticality safety of operations:

Mass: The potential for fission increases as the number of fissionable target atoms increases.

Geometry: Geometry normally refers to the defined geometric form of a vessel (in the case of liquids) or solid shape. Normal geometries used in criticality control processes consist of cylinders and slabs; spheres are not normally used since they represent the least leakage and therefore are the most favorable (minimum) with respect to critical mass. As with shape, the geometry of a vessel has an effect on neutron leakage. When a container cannot contain the minimum amount of fissionable material for criticality it is said to be geometrically favorable.

Shape: Surface area to volume ratio affects criticality. The shape of a container affects the ability of neutrons to escape from the container. As an example, a cylinder could be long and narrow or short and wide. The long and narrow shape would favor leakage while the short and wide would generally be less favorable.

Interaction: The potential for neutrons to leak from one unit of a system or process to another, thereby affecting criticality. Adequate spacing or neutrons absorbers will limit the effects of interaction.

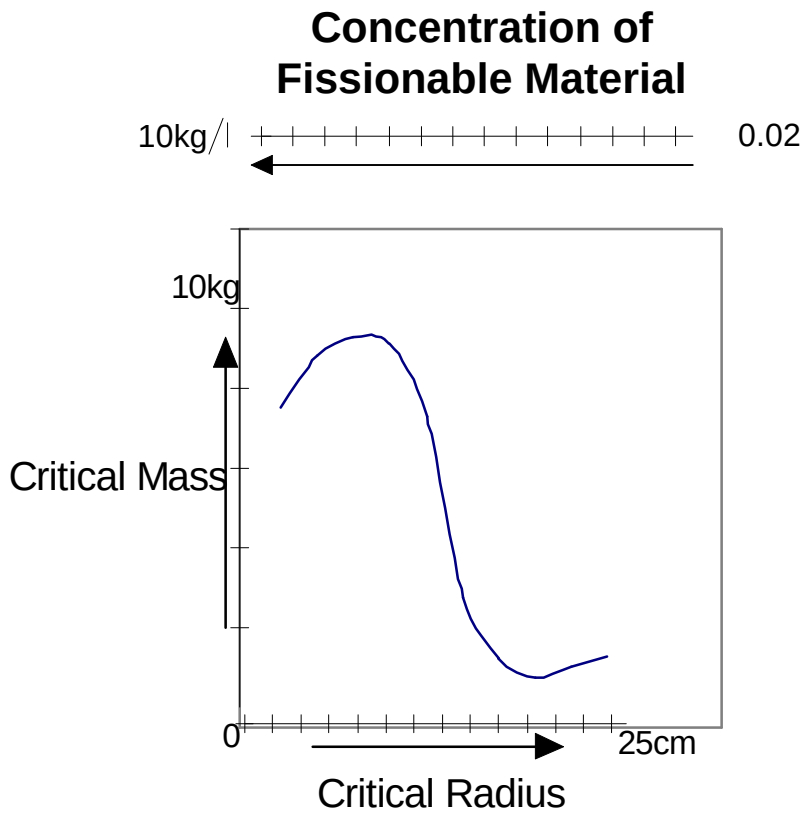
Separation: The physical distance, sometimes used in conjunction with shielding between systems or process to limit interaction. Separation essentially limits the effects of neutron leakage.

Moderation: The process of slowing down neutrons is commonly referred to as moderation. The probability of a neutron interacting with a fissile atom increases greatly when the neutron has slowed to thermal velocities. Thus when a neutron is “moderated” it will increase the probability of fission in a fissile material. However, for fissionable, non-fissile isotopes, once the neutron energy drops below a specific value for the isotope in question, the neutron will no longer be capable of causing fission.

Reflection: Reducing the amount of neutron leakage affects criticality. Neutrons that leak can be reflected back into a mass of fissionable target atoms by materials that do not absorb neutrons thereby increasing the probability of fission.

Concentration: Concentration of the fissionable material is very important to the criticality of a system. Note the following example:

Figure 2-1



- Dilution may move a system to or away from criticality depending on the initial concentration.
- Dilution increases effective moderation of neutrons when starting from an initial high concentration.
- As dilution increases, by adding more moderator, it causes the absorption process to dominate, leading to an increase in critical mass.

Density: (Mass per unit volume) As more fissionable target atoms are packed into a smaller volume (increasing density), the probability of fission increases. As density increases critical mass decreases.

Neutron absorbers: Neutron absorbers are non-fissionable atoms that are effective at capturing or absorbing neutrons. Neutrons captured or absorbed by poisons are no longer available to cause fission. Please see Section 1-4 of this study guide for more information on neutron poisons.

Heterogeneity: An alloy or solution containing different fissionable materials. Heterogeneous materials may have a higher critical mass than do homogenous materials.

Enrichment: The percentage of a fissile isotope contained in the nuclear material to be used as fuel or critical mass or being processed to create a fuel or critical mass.

B. Discuss the influence on nuclear criticality safety of the presence of non-fissionable materials mixed or in contact with fissionable material.

If the non-fissile material is a neutron absorber or neutron reflector, they would have an effect on the criticality as outlined previously. If the material altered the geometry, concentration, or moderation of the fissile material, this would also have an effect, as per the above descriptions of the factors that affect criticality.

C. Discuss the concept of contingencies for checking the validity of criticality safety limits.

In any operation, where there is interaction of humans in a process or procedure, there are likely to be errors. As a result and when processes have a potential criticality concern, ANS-8.1, “Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors,” delineates a requirement that two unlikely and independent, and concurrent changes in process conditions (contingencies) must occur for a criticality accident to result. This principle assures that no single mishap can lead to an inadvertent criticality and is normally referred to the “Double-Contingency” principle.

Where practical, the double-contingency principle should utilize engineering or design basis contingencies over administrative controls. As recommended by ANS-8.1, this results in the use of geometrically favorable vessels/shapes and sizes in conjunction with another factor such as limiting the mass or amount of a material allowed in a given area or the introduction of poisons in the form or borosilicate glass Raschig rings.

In shielded, remote operations facilities, single-contingency may be allowed. However, the presence of the shielding and administrative limits on facility access during operations effectively form the basis for the "second" contingency.

2. Demonstrate knowledge of DOE Order 5480.24, Nuclear Criticality Safety, with respect to its impact on Department nuclear safety. **2-2**

DOE Order 5480.24 was canceled in 9/95 and has been superseded by DOE O 420.1. Contractors must comply with the requirements of these Orders, as outlined in their contract.

A. Discuss the purpose and policy associated with DOE O 420.1, Nuclear Criticality Safety.

The purpose of DOE O 420.1 is to establish nuclear criticality safety program requirements ensuring that:

- Criticality safety is comprehensively addressed and receives an objective review with all identifiable risks reduced to acceptably low levels and management authorization of the operation is documented.
- The public, workers, government property and essential operations are protected from the effects of a criticality incident.

DOE policy expressed by 420.1, includes that fissionable materials shall be produced, processed, stored, transferred, disposed or handled in such a manner that probability of a criticality incident is acceptably low.

B. Define the following terms associated with nuclear criticality safety:

Criticality Incident - The release of energy as a result of accidentally producing a self sustaining or divergent nuclear fission chain reaction.

Double Contingency Principle - Process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible. In all cases, no single failure shall result in the potential for a criticality accident.

Geometry Control - The passive engineering control by which container equipment design limits fissionable material dimensions and the spacing between adjacent equipment. Reliance on geometry control shall be the first priority.

Nuclear Criticality Safety - The prevention or termination of inadvertent nuclear criticality and protection against injury or damage due to an accidental nuclear criticality. Generally, prevention is preferred.

Significant Quantity of Fissionable Material - The minimum mass of fissionable material for which control of at least one parameter is required to ensure subcriticality under all normal and credible abnormal conditions.

Temporary Exemption - A short term release from a criticality safety requirement.

C. Discuss the management and operating (M&O) contractor responsibilities for the following in relation to criticality safety activities:

Criticality Safety Evaluations - M&O contractors responsible for their nuclear facilities are required to perform and document detailed nuclear criticality safety analysis. The facility SAR shall contain a criticality safety section including the following:

- Detailed descriptions of all equipment and facilities in which a criticality hazard may exist;
- Descriptions of all the fissionable materials and process to be used including; maximum quantities, collection, handling, and transportation;
- Analysis of all criticality scenarios and their safety control parameters;
- Descriptions of all criticality alarm systems (CAS) and emergency procedures.

Monitoring and Surveillance - Responsible contractors shall establish monitoring and surveillance programs to prevent accumulation of fissionable materials in process and storage equipment, pipes and ventilation systems. Corrective measures shall be in place in order to avoid any possible criticality hazards.

Transportation and Storage: Requirements for transportation in 5480.24 shall be applicable when materials are transferred from one operation to another within a facility, and from one on-site location to another.

- Contractors must follow an approved on-site transportation safety manual.
- Requirements in DOE Order 5480.3 shall be complied with regarding off-site shipment of fissionable material.
- DOE Order 5610.1 shall apply for the safe transportation of weapon components and special assemblies shipped in national defense.

D. Discuss the role of Department nuclear safety personnel with respect to the implementation of the requirements of DOE Order 5480.24, Nuclear Criticality Safety.

DOE nuclear safety personnel shall ensure that contractors responsible for a DOE non-reactor nuclear facility shall establish a nuclear criticality safety program that:

1) Applies to fissionable materials (see section 4.3.3.a of DOE Order 420.1) that are produced, processed, stored, transferred, disposed, or otherwise handled, and that the probability of an accident resulting from these is acceptably low.
2) Comprehensively addresses criticality safety under both normal and abnormal conditions and documents the basis for such safety including documentation of acceptable levels of risk and management authorization of facility operations.
3) Demonstrates implementation of limits and controls identified by the criticality safety analyses.
4) Receives an objective, independent review.

5) Establishes reviews of operations to ensure that limits and controls are being followed and that process conditions have not been changed from those originally evaluated and approved.
6) Protects the public, workers, property (public and private), and the environment from the effects of a criticality accident.
7) Assesses the need for criticality accident detection devices and alarm systems, and installation where necessary.
8) Encompasses and addresses, as appropriate, the basic elements and control parameters of all ANSI/ANS nuclear criticality safety standards with specific exceptions as delineated under sections 4.3.3.d and e of DOE Order 420.1.

2-3

3. Demonstrate knowledge of the following criticality safety-related standards of the American National Standards Institute/American Nuclear Society (ANSI/ANS):

- ANSI/ANS-8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors
- ANS-8.3 (ANSI N-16.2), Criticality Accident Alarm System
- ANS-8.5 (ANSI N-16.4), Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material
- ANSI/ANS-8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials
- ANS-8.15, Nuclear Criticality Control of Special Actinide Elements
- ANS-8-19, Administrative Practices for Nuclear Criticality Safety

A. Describe the contents, requirements, and relationship among the above ANSI/ANS standards.

- Except for ANS-8.1 and 8.3, the student should refer to the individual standards for descriptions of the content of each standard. In general, content may be realized from the following titles and discussions. ANS-8.1 and 8.3 are general in nature and apply to all DOE nuclear facilities where a criticality hazard exists and are therefore outlined in more detail.

ANSI/ANS-8.1, Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors, is the general criticality safety standard, and presents generalized basic criteria and specified numerical limits for certain simple single fissile units.

Areas which are addressed by ANSI/ANS-8.1 are:

* Administrative Practices
* Double-Contingency Principle
* Geometry Control
* Control by Neutron Absorbers
* Subcritical Limits
* Safety Margins

- ANSI/ANS-8.3 1986, Criticality Accident Alarm System

  ANS-8.3 provides guidance on the need for alarms; alarm specifications including coverage, detection, alarm signal requirements, and dependability; criteria for system design, including reliability, vulnerability, seismic tolerance, failure warning, response time detection criteria, sensitivity and spacing; testing including initial tests, tests following repairs, radiation response tests, periodic tests, and test procedures, corrective actions, and records; and employee familiarization including instructions, training, and drills.

- ANSI/ANS-8.5 1986 Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material

  This standard provides specific guidance on the use of the Boron composite rings as neutron poison. The procedures and specifications for the rings are also included. Please see Section 1-5, (page 1-19) for more details on Borosilicate-Glass Raschig Rings.

- ANSI/ANS-8.7, Guide for Nuclear Criticality Safety in the Storage of Fissile Materials

  ANSI/ANS-8.7, details the procedures for storage of special materials. It refers to other standards that deal with criticality control and safety.

- ANS-8.15, Nuclear Criticality Control of Special Actinide Elements

  The standard covers the necessary special handling for specific Actinide elements.
- ANS-8-19, Administrative Practices for Nuclear Criticality Safety

  This standard provides guidelines for the development and implementation of management and technical policies and procedures relating to criticality safety.

B. Discuss the applicability of the above ANSI/ANS standards to the Department facilities and processes.

Unless otherwise stated, the basic elements and control parameters of programs for nuclear criticality safety shall satisfy the requirements of existing ANS criticality safety standards. Approved (with modifications as delineated within DOE Order 420.1) versions for use at DOE nuclear facilities include the following:

- ANSI/ANS-8.1-1983, R88, “Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors”;
- ANSI/ANS-8.3-1986, “Criticality Accident Alarm System”;
- ANSI/ANS-8.5-1986, “Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material”;
- ANSI/ANS-8.6-1982, R88, “Safety in Conducting Subcritical Neutron-Multiplication Measurements in Situ”;
- ANSI/ANS-8.7-1975, R87, “Guide for Nuclear Criticality Safety in the Storage of Fissile Materials”;
- ANSI/ANS-8.9-1987, “Nuclear Criticality Safety Criteria for Steel-Pipe Intersections Containing Aqueous Solutions of Fissile Materials”;

- ANSI/ANS-8.10-1983, R88, “Criteria for Nuclear Criticality Safety Controls in Operations with Shielding and Confinement”;
- ANSI/ANS 8.12-1987, R93, “Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors”;
- ANSI/ANS-8.15-1981, R87, “Nuclear Criticality Control of Special Actinide Elements”;
- ANSI/ANS-8.17-1984, R89, “Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors”;
- ANSI/ANS-8.19-1984, R89, “Administrative Practices for Nuclear Criticality Safety”;
- ANSI/ANS-8.21-1995, “Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors.”

C. Discuss the role of the Department nuclear safety personnel in implementing the requirements of these standards.

As stated previously, DOE nuclear safety personnel shall ensure that contractors responsible for a DOE non-reactor nuclear facility shall establish a nuclear criticality safety program that:

- Encompasses and addresses, as appropriate, the basic elements and control parameters of all ANSI/ANS nuclear criticality safety standards with specific exceptions as delineated under sections 4.3.3.d and e of DOE Order 420.1.

4. Demonstrate knowledge of alarm systems for criticality accidents. **2-4**

A. Define the following terms:

Criticality accident - the release of energy as a result of accidentally producing a self sustaining or divergent nuclear fission chain reaction; or, an inadvertent nuclear fission chain reaction in a non-reactor environment.

Minimum accident of concern - the smallest accident a criticality alarm system is required to detect; a criticality accident such as this would produce ~10^{15} fissions in its first minute and provide an absorbed dose in free air of 20 rad at 2 meters if no significant shielding were present.

Process area - any area involved in the chemical processing, mechanical processing, handling, or storage of fissionable materials.

B. Discuss the general principles associated with the use of criticality alarm systems including the following:

- **Installation** - where installed, an alarm system implies a nontrivial risk of a criticality accident and emergency plans following alarm actuation shall be maintained.
- **Coverage** - where inventory of fissionable materials in individual, unrelated areas exceed 700g of U-235, 520g of U-233, 450g of Pu-239, or 450g of any combination of these three isotopes, the need for a criticality alarm system shall be evaluated.
- **Detection** - where criticality alarm coverage is required, a means shall be provided to detect excessive amounts or intensities of radiation and to signal personnel evacuation.
- **Alarms** - when implemented criticality alarms shall be for immediate evacuation purposes only and of sufficient volume and coverage to be adequately heard in all areas that are to be evacuated. They shall be capable of automatic actuation and set high enough to minimize actuation by sources other than criticality, but low enough to detect the minimum accident of concern. Upon actuation, the signal shall be of the lock-in type and shall not reset even if the radiation levels fall below the alarm setpoint. A corresponding evacuation alarm shall be signaled immediately following detection of a criticality accident; in addition, it shall be capable of manual initiation.

- **Dependability** - consideration shall be given to the detection of false alarms. To achieve this, methods such as the use of concurrent response of two or more detectors or reliable single channel detectors shall be used. A means (that will not cause an evacuation) to test the response and performance of the alarm system shall be provided. Upon completion of testing the system shall be immediately returned to normal operating condition. Where operations continue in process areas during a loss of normal power, emergency power supplies shall be provided for alarm systems or they shall be monitored by portable alarms. Detectors shall not fail to actuate when subject to a radiation field of at least 10 rad/second.

C. Testing and inspection of a criticality detection alarm system shall include the following:

- **Initial Tests** - verify that the fabrication and installation were made in accordance with design plans and specifications.
- **Tests Following Repairs** - tests and checks shall be equivalent to initial installation tests
- **Response to Radiation** - radiation response checks shall be measured periodically to confirm continuing instrument performance
- **Periodic Tests** - the entire alarm system shall be checked periodically. Each audible signal generator shall be tested at least once every three months.

5. Demonstrate knowledge of the criticality process and its application to nuclear explosive/weapon design and operations.

2-5

A. Discuss the following processes and their applications in nuclear explosive/weapon design:

- **Nuclear Fission** - neutron induced splitting of fissionable isotopes to form nuclides with more binding energy per nucleon.
- **Nuclear Fusion** - the combining of two light nuclei to form nuclides with more binding energy per nucleon.

Nuclear weapon design is comprised of both nuclear and non-nuclear components including:

- **Non-Nuclear Components**
  - Radar Systems
  - Battery
  - Guidance and Navigation components
  - Arming and Firing
  - Gas Transfer System
  - Explosive Actuators
  - Parachutes

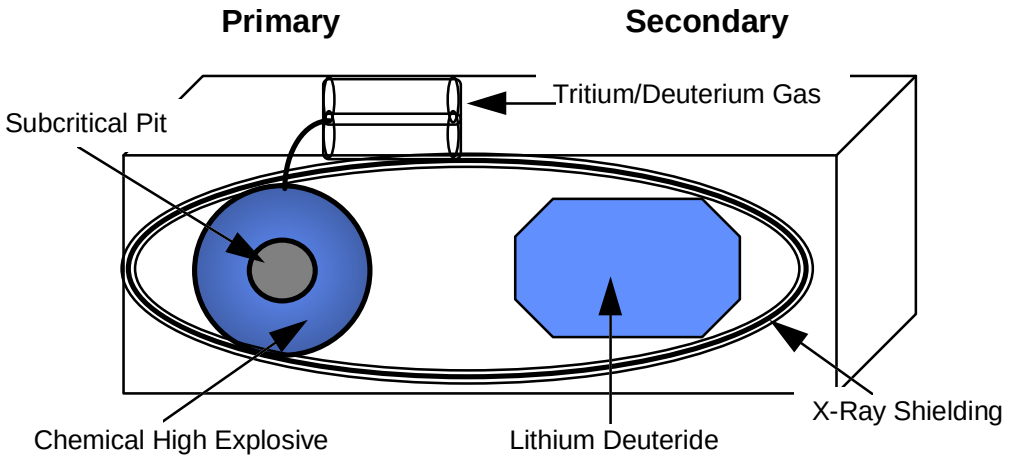
- **Nuclear Explosive Package**

  Nuclear explosions are produced by initiating and sustaining nuclear chain reactions in highly compressed material which can undergo both fission and fusion reaction. Modern designs use nuclear explosive packages with two assemblies:

  - **Primary:** This assembly is used as the initial source of energy and is predominately a fission reaction.
  - **Secondary:** A fusion reaction which provides additional yield via thermonuclear explosion.

  Prior to firing of the weapon the small pit, often composed of plutonium-239 is subcritical.

Figure 2-2



Primary Detonation: The primary nuclear explosion is initiated by detonating the layer of chemical high explosive that surrounds the pit. This drives the pit into a compressed mass, while simultaneously achieving supercritical.

Boosting: In order to achieve higher explosive yields for primaries a technique called boosting is used: Tritium (T) and Deuterium (D) are injected into the pit The fission process of the pit heats the D-T gas to the point that the mixture undergoes fusion. The fusion process produces large quantities of very high energy neutrons, thereby "boosting" the fission yield of the primary.

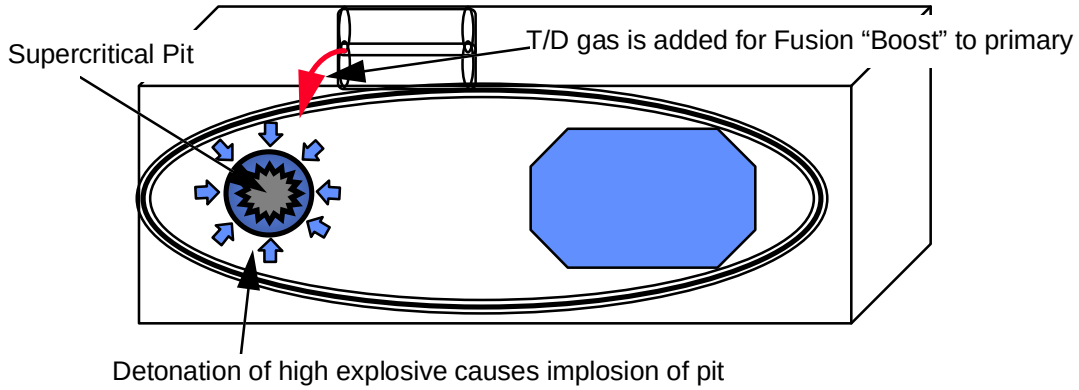


Figure 2-3

Secondary Detonation: The energy released by the primary boosted explosion activates the secondary assembly. The secondary is composed of lithium deuteride and other materials.

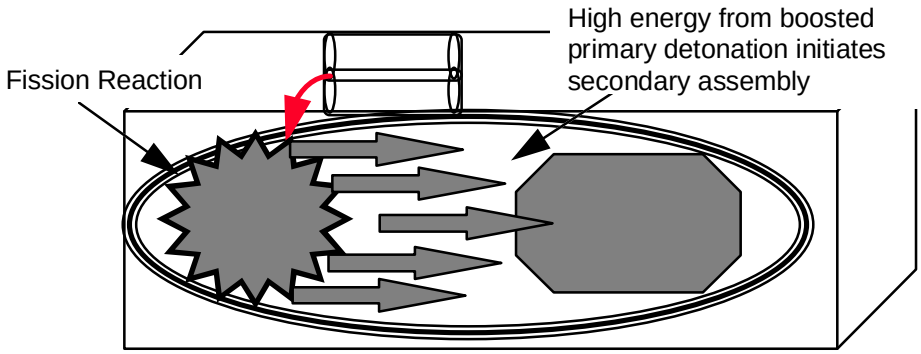
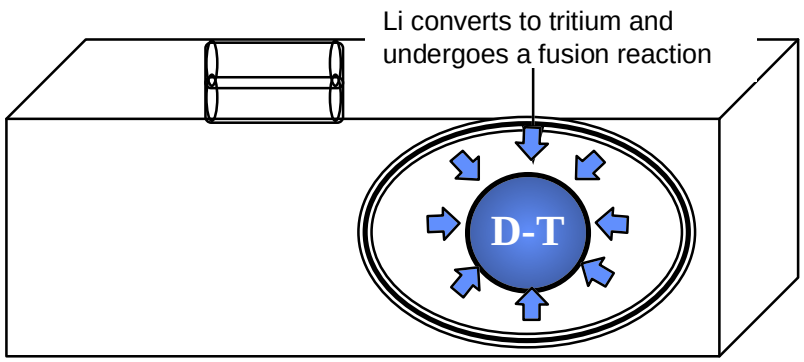


Figure 2-4

Due to the high focused primary energy, the Li is converted to tritium and helium, a subsequent fusion reaction takes place. The energy density of a fusion reaction is far greater than that of a fission reaction.

Figure 2-5



Functionally, the Lithium is used to create an abundant/ localized supply of tritium from the following key neutron capture reaction:

$$^{6}_{3}Li + ^{1}_{0}n \longrightarrow ^{3}_{1}H + ^{4}_{2}He$$

Using the tritium byproducts the elements to achieve the following fusion reaction are present:

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n + 17.59\ MeV$$

Other fusion reactions occur but the above reaction is the easiest to achieve with the highest energy output at the “lowest” required ignition temperature.

B. Define the term “fissile materials” and give examples applicable to nuclear explosive/weapon design.

Fissile materials - an isotope in which the fission reaction can be caused by low energy, thermal neutrons.

Nuclear weapon fissile material examples - U-235 and Pu-239

C. Describe the effects of each of the following on critical mass:

Reflectors - reduces the amount of fissionable material required for a critical mass by reflecting neutrons back into the critical assembly. These neutrons would normally be lost in an unreflected assembly through leakage.

Absorbers - act as a neutron sponge by absorbing neutrons that would otherwise be available for fission interaction. This has the effect of increasing the amount of fissionable material required for a critical mass by removing neutrons from the critical assembly.

Moderators - can reduce the critical mass of thermally fissionable material. Moderators slow fast neutrons to thermal energies which may be the favorable energy to initiate fission of a particular material. If the material is primarily fissionable by fast neutrons, moderation (slowing fast neutrons to thermal energies) will reduce the number of (fast) neutrons to cause fission thereby requiring a greater mass for criticality.

Stray neutrons - neutrons that originate from sources outside the critical assembly. Normally considered to be neutrons that "wander" into a critical assembly and that originate from other than deliberate neutron sources. Stray neutrons have the effect of reducing the amount of fissionable material required for a critical mass by providing a source of neutrons that can lead to fission interaction. They may also initiate pre-triggering of a critical assembly resulting in a yield less than the design yield.

Geometry - container (in the case of aqueous solutions) or solid geometric configurations that favor maximum surface per volume result in increased amounts of material required for critical mass. Conversely, geometries that favor minimum surface areas per volume result in decreased amounts of material that are required for a critical mass. Spheres are least favorable geometries (normally representing minimum critical masses) while slabs and long, thin cylinders or annular cylinders represent more favorable geometries.

Poisons - non-fissionable constituents either deliberately introduced or that are present by design to absorb neutrons. The effect of poisons is to increase the amount of fissionable material required for a critical mass by removing neutrons that could lead to fission.

Enrichment - the process of increasing percent of the U-235 (fissile) isotope as a percentage from that which occurs naturally (~0.7%). The effect of the enrichment process is to decrease the amount of fissionable material required for a critical mass by increasing the amount of fissile isotope available to participate in the fission process.

D. Describe the methods used during the assembly, disassembly, transportation, and storage of nuclear explosives/weapons to prevent criticality.

In general, prevention of criticality must be based on the control of neutron production, absorption, leakage, moderation and interaction. Typical implementation methods include but are not limited to:

Geometry control - specification of shape, dimensions, or volume.

Poisons - the use of neutron absorbing, non-fissionable constituents to remove neutrons and thereby reduce the likelihood for fission interaction.

Mass and volume limits - control of mass or volume limits through control of fissile material composition, enrichment, and physical form of the material.

Moderation and concentration control - exclusion or minimization of hydrogenous or other low Z moderating material from areas where dry fissile material is processed, transported, stored, or otherwise handled.

Storage and transport - specially designed structures that facilitate transport or handling of appropriate numbers of containers at desired spacing.

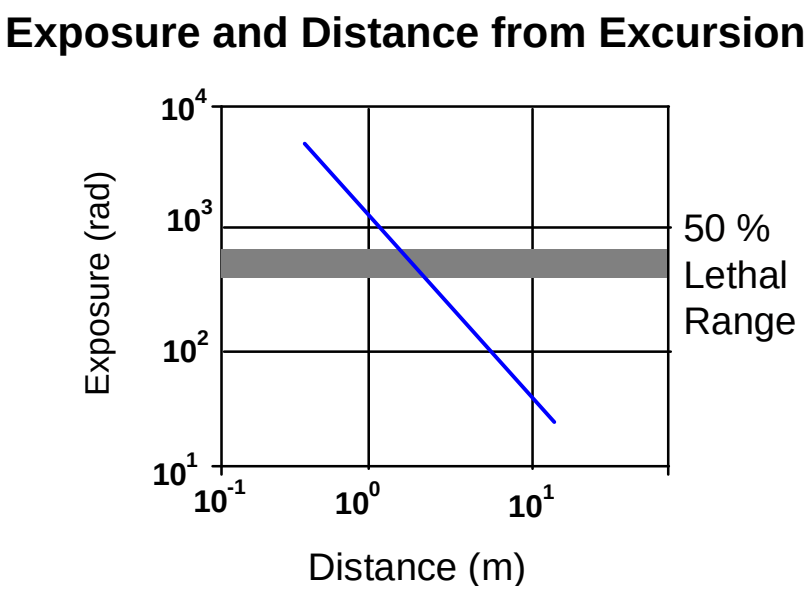
Control specifications - criticality control information postings, container identifications, floor markings, etc., that summarize operating limits.

E. Describe the criticality effects and criticality hazards associated with nuclear explosives/weapons in terms of personnel radiation exposure.

Typically, inadvertent criticality in weapons devices would result in acute, possibly lethal doses of gamma and neutron radiation to individuals immediately adjacent to or near such a criticality excursion. This probability is generally maintained at an acceptably low level through the use of design and administrative controls discussed previously.

Of two critical-measurement (weapons) related criticality accidents both of which occurred at Los Alamos Scientific Laboratory (LASL), each resulted in the death of the experimenter/handler. In the first incident, the fatality resulted from an estimated dose of 800 rads and occurred 28 days after exposure. In the second incident, the individual received a dose that proved to be lethal 9 days after exposure. In both cases, fatalities resulted from exposures inside of 1 meter from the source. Significant, non-lethal exposures were received by individuals out to 15 meters. Lethal doses from inadvertent criticality accidents of ~10^{17} fissions over 15 seconds are given in the following figure:

Figure 2-6



Note that this figure is a simplified log/log plot and it crudely shows that lethal doses are expected within ~3 meters of the fission source. These accidents demonstrate the need for remote handling, adequate shielding, and proper procedures and administrative controls in the handling of nuclear weapons.

F. Describe how each of the following categories of neutron interacting materials is used in, or may affect, the safe packaging, stacking, and storage of nuclear explosives/weapons. Give examples of materials and/or components within each category.

Reflectors - in general reflectors reduce the amount of material required for a critical mass. In nuclear weapons, reflectors are used to reflect neutrons back into the critical mass during the detonation of the warhead. This may be used to increase or otherwise control the weapon yield during detonation. Reflector types of materials for weapons typically include materials which have a high potential to scatter but not absorb neutrons. Material such as uranium 238, lead and iron are examples of reflectors that are effective in weapons.

Absorbers - around nuclear weapons, absorbers increase the amount of material required for a critical mass. Absorbers may be used in and around the packing, stacking, or storage containers for nuclear weapons for shielding and to reduce personnel exposures in and around weapons storage areas. Examples of absorbers are halfnium, cadmium, and boron. These absorbers are generally more effective at lower neutron energies, and therefore are normally used in conjunction with moderators.

Moderators - for nuclear weapons, moderators around stored, packaged, or stacked weapons are used in the packaging materials mentioned previously under reflectors. Since the neutron fluxes for some weapons tends to be fairly hard (high energy), moderators must be used in conjunction with absorbers to soften (lower neutron energies) the flux and achieve any desired shielding effects. Examples of moderators are rubber, plastics, water, and other hydrogenous packing materials.

Section 2 References and Suggested Reading

References and Suggested Reading

Department of Energy, Fundamentals Handbook, Nuclear Physics and Reactor Theory, Module 1, Atomic and Nuclear Physics, (DOE-HDBK-1019 - 1-93), DOE, 1993

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H.N. Jow, J.L. Sprung, J.A. Rollsitn, L.T. Ritchie, D.I. Chanin, U.S. Nuclear Regulatory Commission, MELCOR Accident Consequence Code System (MACCS), NRC, 1990

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Section 2 Quiz

SECTION 2 QUIZ

1. Identify 11 factors relevant to criticality safety.

2. The factor that addresses the potential for neutrons to leak from one unit or process into another unit or process is defined as what?

3. A material that absorbs neutrons but does not lead to fission is called what?

4. The process of slowing down neutrons to thermal velocities is defined as what?

5. As the concentration of a fissionable material in solution increases, the critical mass may decrease or increase. (T or F)

6. Does a thermal neutron always lead to fission when absorbed by a fissionable isotope?

7. Define the Double Contingency Principle.

8. Define a "Significant Quantity of Fissionable Material."

9. Define "Minimum Accident of Concern".

10. You are a line manager of a nuclear materials processing facility. The criticality safety engineer analyzes the process inventory and reports the following: "Our total inventory consists of 30 grams of Pu-236, 110 grams of Pu-239, 200 grams of U-233, and 150 grams of U-235. Since each of these is less than its respective limit, we do not need a criticality alarm system." Do you agree or disagree?

11. For the various factors given below, define the effect each has on a critical mass. For a positive effect (decrease in mass necessary for criticality) use a "+" and for a negative effect use a "-". If it may be both state "both." For the case of geometry assume a change from spherical to long cylindrical.

Reflectors -	Geometry -	Enrichment -
Absorbers -	Poisons -	Stray neutrons -
Moderators -		

Section 2
Solutions

SECTION 2 QUIZ SOLUTIONS

1. Identify 11 factors relevant to criticality safety.

Mass	Shape/Geometry	Interaction
Moderation	Reflection	Concentration
Volume	Density	Neutron absorbers
Heterogeneity	Enrichment	

2. The factor that addresses the potential for neutrons to leak from one unit or process into another unit or process is defined as what?

Interaction

3. A material that absorbs neutrons but does not lead to fission is called what?

Poison or a Neutron absorber

4. The process of slowing down neutrons to thermal velocities is defined as what?

Moderation

5. As the concentration of a fissionable material in solution increases, the critical mass may decrease or increase. (T or F)

True

6. Does a thermal neutron always lead to fission when absorbed by a fissionable isotope?

No, it may be captured or have inadequate energy to lead to fission.

7. Define the Double Contingency Principle.

Process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality event is possible.

8. Define a "Significant Quantity of Fissionable Material."

The minimum mass of fissionable material for which control of at least one parameter is required to ensure subcriticality under all normal and credible abnormal conditions.

9. Define "Minimum Accident of Concern".

The smallest accident a criticality alarm system is required to detect; a criticality accident such as would produce ~10^{15} fissions in its first minute and provide an absorbed dose in free air of 20 rad at 2 meters if no significant shielding were present.

10. You are a line manager of a nuclear materials processing facility. The criticality safety engineer analyzes the process inventory and reports the following: "Our total inventory consists of 30 grams of Pu-236, 110 grams of Pu-239, 200 grams of U-233, and 150 grams of U-235. Since each of these is less than its respective limit, we do not need a criticality alarm system." Do you agree or disagree?

Disagree, the combined inventory of Pu-239, U-233, and U-235 exceeds 450 grams. Therefore, an analysis/evaluation of the need for a criticality safety alarm must be performed.

11. For the various factors given below, define the effect each has on a critical mass. For a positive effect (decrease in mass necessary for criticality) use a "+" and for a negative effect use a "-". If it may be both state "both." For the case of geometry assume a change from spherical to long cylindrical.

Reflectors - (+)	Geometry - (+)	Enrichment - (+)
Absorbers - (-)	Poisons - (-)	Stray neutrons - (+)
Moderators - both		

Nuclear Safety Analysis
Cross-Competency Listing

The following matrix shows where the Nuclear Safety Analysis portion of the Study Guide addresses particular qualification standard competencies.

DOE Qualification Standard(s)												Study Guide
Instrumentation and Control	Project Management	Construction Management	Electrical Systems	Facilty Maintenance	Chemical Processing	Mechanical Systems	Nuclear Safety Systems	Technical Manager	Nuclear Explosives Safety	Civil / Structural Engineering	Radiation Protection	
							NS 1.6					**Section 3-1**
							NS 1.6.a	TM 1.5.c				Parts 1.A
							NS 1.6.b	TM 1.5.a				1.B
							NS 1.6.c	TM 1.5.a				1.C
							NS 1.6.d					1.D
							NS 1.6.e					1.E
							NS 1.6.f					1.F
							NS 1.6.g					1.G
							NS 1.6.h					1.H
IC 2.13	**PM 2.6**	**CM 2.8**	**ES 2.8**	**FM 2.9**	**CP 2.6**	**MS 2.6**	**NS 2.4, NS 2.12**		**NES 2.9**			**Section 3-2**
IC 2.13.a	PM 2.6.a	CM 2.8.a	ES 2.8.a	FM 2.9.a	CP 2.6.a	MS 2.6.a	NS 2.4.a		NES 2.9.a	CSE 2.7.a		Parts 2.A
IC 2.13.b	PM 2.6.b	CM 2.8.b	ES 2.8.b	FM 2.9.b	CP 2.6.b	MS 2.6.b	NS 2.4.b					2.B
IC 2.13.c	PM 2.6.c	CM 2.8.c	ES 2.8.c	FM 2.9.c	CP 2.6.c	MS 2.6.c	NS 2.4.c					Parts 3-1.A,.C
IC 2.13.d	PM 2.6.d	CM 2.8.d	ES 2.8.d	FM 2.9.d	CP 2.6.d	MS 2.6.d	NS 2.4.d	TM 1.5.g		CSE 2.7.b		2.C
IC 2.13.e	PM 2.6.e						NS 2.4.e		NES 2.9.c	CSE 2.7.c		2.D
IC 2.13.f	PM 2.6.f	CM 2.8.e	ES 2.8.e	FM 2.9.e	CP 2.6.e	MS 2.6.e						2.E
		CM 2.8.f										2.F
					CP 2.6.f		NS 2.4.f	TM 1.5.j				2.G
					CP 2.6.g		NS 2.4.g					2.H
					CP 2.6.h		NS 2.4.h					2.I
							NS 2.12.a					2.J
							NS 2.12.b		NES 2.9.d			2.K
							NS 2,12.c					2.L
							NS 2.12.d					2.M
									NES 2.9.b			2.N
							NS 1.7					**Section 3-3**
							NS 1.7.a					Parts 3.A
							NS 1.7.b					3.B
							NS 1.7.c					3.C
							NS 1.7.d					3.D
											RP 2.4	**Section 3-4**
											RP 2.4.a	Parts 4.A
											RP 2.4.b	4.B

Nuclear Safety Analysis

Section 3

OBJECTIVES

1. Demonstrate knowledge of terminology used in nuclear safety analysis.
2. Demonstrate knowledge of; Nuclear Safety Analysis Reports (DOE Order 5480.23), Safety Analysis and Review System (DOE Order 5481.1), and DOE Nonreactor Nuclear Facility Safety Analysis Reports (DOE-STD-3009-94), with respect to their impact on Department nuclear safety.
3. Demonstrate knowledge of nuclear accident analysis techniques.
4. Demonstrate knowledge of other DOE Orders related to safety analysis.

3-1

1. Demonstrate knowledge of terminology used in nuclear safety analysis.

A. Define the following accident related terms:

Accident: An unplanned event or sequence of events that result in undesirable consequences. An incident with specific safety impacts.

Authorization Basis: Those aspects of the facility design basis and operational requirements relied upon by DOE to authorize operation. The Authorization Basis is described in documents such as the facility SAR and other safety analysis documentation.

Design Basis: The set of requirements that bound the design of structures, systems and components within a facility. Areas included are; seismic qualifications, fire protection, and safe shutdown.

Design Basis Accidents (DBA): A postulated accident that establishes design and performance requirements for systems, structures, and components important to safety.

Beyond Design Basis Accident: An accident of the same type as a design basis accident, but defined by parameters that exceed in severity the parameters defined for the design basis accident. The same correlation applies to beyond derivative design basis accidents with regard to derivative design basis accidents.

Evaluation Guidelines: Hazardous material dose/exposure values that the safety analysis is evaluated against. Theoretically, individual doses/exposures exceeding the Evaluation Guideline should not occur at a given point inside the evaluation area. Offsite Evaluation Guidelines are established for the purpose of identifying and evaluating safety-class structures, systems, and components.

B. Define the following hazard related terms:

Hazard: A hazard is the existence of a source of danger which could cause illness, injury, or death to personnel, or, damage to a facility, or the environment.

Hazard Classification: DOE has established a process to classify facilities into hazard categories. DOE-STD-1027 contains the flow charts which, when followed, determine the hazard classification. This Standard also contains a table entitled "Thresholds for Radionuclides," which is used in determining the category.

Hazard Category 1: A hazard analysis shows the potential for significant offsite consequences. This classification is primarily reserved for reactors capable of operating at a steady state power level greater than 20 megawatts(Class A reactor). A facility may also be classified as Category 1 if the Program Secretarial Officer (PSO) deems it necessary. This designation would be due to the level of off-site emergency planning required to permit operation.

Hazard Category 2: A hazard analysis shows the potential for significant onsite consequences. The "Thresholds for Radionuclides" table provides threshold values for hazard category 2. A release of materials from a category 2 facility would result in exposures greater than that of 1 REM at 100 meters. Thus, emergency planning requirements are very important. The potential for a nuclear criticality accident at a facility will also earn it a category 2 classification.

Hazard Category 3: A hazard analysis shows the potential for only significant localized consequences. Minimum threshold values for a category 3 facility would result in less than a 10 REM exposure at 30 meters over a 24 hour period. The consequences of a localized release of materials would be in excess of State and Federal reporting requirements. The "Thresholds for Radionuclides" table is also used to arrive at these values.

Hazardous Materials:

C. Define the following safety limit related terms:

Limiting Conditions for Operations (LCO): 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.

Limiting Control Settings (LCS): The settings on process variables associated with safety systems that control the facility function and will prevent exceeding the associated safety limits.

Risk: The quantitative or qualitative expression of possible loss that considers both the probability that a hazardous event will cause harm and the consequences of that event.

Safety analysis: A Safety Analysis is a process to:

Systematically identify hazards of a DOE operation.

Analyze and evaluate potential accidents and their risks.

Describe and analyze the adequacy of hazard control measures.

Safety Basis: The information relating to the control of hazards at a nuclear facility upon which DOE depends for its conclusion that activities at the facility can be conducted safely.

Safety Limits(SL): A limit 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 material.

Engineered Safety Features: Systems, components, or structures that prevent and/or mitigate the consequences of all potential accidents including the bounding design basis accidents.

D. Differentiate between the following categories of individuals who may be affected by an accident at a Department nuclear facility:

Off-site individual: Any member of the public or any other individual who may not be normally assigned to or located within the subject site boundaries, and therefore would likely not be trained on site specific hazards. The offsite area consists of the area beyond the site boundaries.

On-site individual: Any member of the public or any other individual who may be normally or temporarily located within the subject site boundaries. This individual may not be trained on the presence of site specific hazards. The on-site area includes any area that has been established as a National Defense Area or National Security Area.

Public: The surrounding population of individuals not normally assigned to or having responsibilities in any way directly related to the construction, operation, maintenance, or administration of a site or any facilities within a site. This population is generally (but not always) located off-site (e.g. tours, roads, business, etc., may require the public to travel through or enter into a site.

Worker: That individual who by nature of employment has direct responsibilities related to the construction, operation, maintenance, or administration of any site or a facility within a site. This includes those workers who may not have direct responsibilities for a given site but may have responsibilities that result in being located within the site boundary. Consequently, workers in general are normally associated with being on-site, but may be either on-site or off-site.

E. Differentiate between the function of structures, systems, and components in the following classifications:

Safety-Class Structures Systems, and Components (SSCs): Systems, structures, or components whose failure could adversely affect the environment or safety and health of the public as identified by the safety analysis.

Safety-Significant Structures, Systems and Components (SSCs): SSCs that are not designated as safety-class, but whose preventive or mitigative function is a major contributor to defense in depth (i.e., prevention of uncontrolled material releases) and/or worker safety as determined from hazard analysis. 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. Considerations should be based on engineering judgment of possible effects and the potential added value of safety-significant SSC designation.

F. Differentiate between the function and contents of the following documents:

Safety Analysis Report (SAR)

Documents the results of the safety analysis and describes the facility or activity; its design features, construction standards, operational modes; and accident analysis.

Technical Safety Requirements (TSRs):

Defines the conditions, safe boundaries, and management or administrative controls necessary to ensure the safe operation of a nuclear facility.

Reduces potential risk to the public and the worker from uncontrolled releases of radioactive materials or from radiation exposure due to inadvertent criticality.

Consists of safety limits, operating limits, surveillance requirements, administrative controls, use and application instructions, and the basis thereof.

The TSRs commit the facility operators to maintaining the safety basis as it is defined in the SAR.

G. Differentiate between the plant/facility features which have the following designations:

- **Mitigating features:** Any structure, system, or component that serves to mitigate the consequences of a release of radioactive or other hazardous materials in an accident scenario.
- **Preventive features:** Any structure, system, or component that serves to prevent the release of radioactive or other hazardous material in an accident scenario.

H. Differentiate between the following types of facilities:

- **Nuclear Facility:** A facility that conducts activities or operations that involve radioactive and/or fissionable materials in such form and quantity that a nuclear hazard potentially exists to the employees or the general public. Included are reactors and accelerators.
- **Non-Reactor Nuclear Facility:** Nuclear facilities excluding reactors and accelerators.

3-2

2. Demonstrate knowledge of DOE Orders and Standards governing safety analysis report preparation and review with respect to its impact on Department nuclear safety.

A. Discuss the four basic purposes and the objectives of nuclear safety analysis reports.

1) To provide the bases for approval of new facilities and operations, major modifications thereto, and eventual decommissioning;
2) To define and control the safety bases and commitments;
3) To support DOE and contractor management safety oversight of facilities and operations; and,
4) To provide the analytical rationale for operations as delineated in TSRs.

B. Describe the responsibilities, regarding the development and maintenance of nuclear safety analysis reports, of contractors authorized to operate defense nuclear facilities.

- **Preparation and Submittal of SARs:** Contractors shall be required to prepare, and shall submit to DOE for its approval, SARs documenting safety analyses for each DOE nuclear facility under their cognizance using a graded approach.
- **Plan and Schedule for Safety Analysis Reports:** Each contractor responsible for submitting a SAR shall be required to submit, for review and approval, an overall plan and schedule for completing the SAR. This submittal shall describe the need for developing or upgrading the SAR as appropriate, and shall include a preliminary assessment of facility hazards, the basis for the content, schedule, and level of detail proposed, bases for interim operation or restrictions on interim operations, and administrative controls during the upgrade process.
- **Periodic Updates of Safety Analysis Reports:** Contractors shall be required to review and update SARs at least annually or more frequently as necessary. Revisions shall reflect all changes implemented up to 6 months prior to the filing of the updated SAR. The DOE approval of any Unreviewed Safety Question pursuant to DOE 5480.21, amendments to the TSRs, and the material submitted by the contractor in support of these approvals shall be considered an addendum to the SAR until the information is incorporated into the SAR as part of the next annual update.
- **Document Control:** Contractors must ensure all users of facility SARs produced under their cognizance have current editions.

C. Describe the requirements for the scope and content of a nuclear safety analysis report and discuss the general content of each of the required sections of a nuclear safety analysis report.

- SARs shall define the safety basis, document the logic of its derivation, demonstrate adherence to the safety basis, and justify its adequacy.

- Each SAR required shall include thorough documentation of the assumptions employed in the safety analysis.

- A SAR shall include the results of the safety analysis that identifies the dominant contributors to the risk of the facility so that these vulnerabilities can be better managed.

- **Topics to be addressed in the SAR:**

1) **Executive Summary:** Summarizes the results of safety analysis, safety assurance programs, identified vulnerabilities, compensatory measures and, in general, the rationale describing why the facility or activity is safe enough.

   Introduction: Describes the background for the facility/activity, including its location and relation to other site activities/facilities. Unique or special requirements are identified here. Some additional detail on subjects addressed in the executive summary.

2) **Applicable Statutes, Rules, Regulations and Orders:** Contains a summary of applicable local, state, federal, and departmental statutes, rules, regulations and orders.

3) **Site Characteristics:** Addresses those characteristics of the surrounding environment that influence the design, procedures, and safety of the operation.

4) **Facility Description and Operation:** Describes the facility/activities; designated mission; processes; and structures, systems, and components important to safety. Includes plans, provisions, and requirements for their operation, maintenance and surveillance.

5) **Hazard Analysis:** Identifies, assess, and describes hazards associated with the potential for releases of radioactive or other hazardous materials and energy sources. Determines facility or site hazard classification.

6) **Principal Health and Safety Criteria:** Describes facility specific health and safety criteria for safety significant SSCs and processes through references to OSHA, ANSI, IEEE, ASME, ANS, etc.

7) **Radioactive and Hazardous Material Waste Management Program:** Estimates the quantity and form of these materials generated at the facility. Identifies, equipment, provisions and plans for the management of such waste.

8) **Inadvertent Criticality Protection:** Addresses criticality safety issues according to the quantity of fissionable material to be processed at the facility/site. Demonstrates compliance with DOE 5480.24, 5480.3A, 5610.12, and 5700.6C.

9) **Radiation Protection Program:** Demonstrate compliance with DOE's radiation protection and instrumentation requirements given in DOE 4330.4A, 5400.5, 5480.11, 5480.19, 5484.1, 6430.1A, 5700.6C, 1324.2A, and DOE/EH-0256T.

10) **Hazardous Material Protection Program:** Lists all hazardous materials, including the physical and chemical form, amounts, and locations. Demonstrates compliance with applicable requirements for control of personnel exposures to hazardous materials.

11) **Analysis of Normal and Abnormal Operations and Accidents:** Analyses of normal, abnormal, and accident condition risk to the public, on-site, and offsite, including design and beyond design basis accidents. Analyses include consideration of both internal and external events.

12) **Management, Organization, and Institutional Safety Provisions:**
Describes the responsibilities, organizational structure, responsibilities interfaces, and controls necessary to provide adequate mechanisms for safe operation. Also addresses facility staffing and occurrence reporting requirements.

13) **Procedures and Training Program:** Addresses facility training and qualification programs demonstrating compliance with DOE 5680.20A and 5480.18. Describes development, verification, and validation of procedures and personnel training processes.

14) **Human Factors Engineering Program:** Describes how human factors are incorporated into control systems, procedure development, training development, performance assessment, communications, and ergonomics.

15) **Initial Testing, In-service Surveillance, and Maintenance:** Addresses the contractors proposed programs and technical bases for these areas. Demonstrates compliance with the requirements of DOE 4330.4A.

16) **Derivation of Technical Safety Requirements:** Discusses the safety envelope and the derivation of technical safety requirements including restrictions on operations, and administrative controls. Among the administrative controls should be identification of programs to control non-accident hazards to workers.

17) **Conduct of Operations:** Description of communications, review and audit of operations, investigation of abnormal events, security, and records and reporting processes and procedures. Describes the safe storage and criticality safety criteria for any SNM within the facility. Demonstrate compliance with DOE 5480.19 and 5480.7A.

18) **Quality Assurance Program:** Summary of facility quality assurance program as it applies to safety SSCs. Demonstrates compliance with 5700.6C.

19) **Emergency Preparedness Program:** Describe facility/site emergency response capabilities as they relate to accidents identified under chapter 11. Demonstrate compliance with DOE 5500.1A, 5500.2A, 5500.3, and 5500.3A.

20) **Provisions for Decontamination and Decommissioning:** Provides conceptual plans for the decontamination and decommissioning, as well as plans to minimize contamination during facility/site life.

21) **Facility Design Codes and Standards:** Discussion of overall safety objectives and general design criteria used in facility design and construction. Lists codes and standards employed in facility design of SSCs.

D. Discuss the required approvals for the nuclear safety analysis report for new facilities and, subsequent changes to the nuclear safety analysis report.

- A Program Secretarial Officer (PSO) is responsible for final approval of all SARs. The PSO is often the Assistant Secretary for the office with responsibility of the specific facility for which the SAR is submitted (i.e. DP, NE, ER etc.). The PSO's responsibilities include:
  - Review and approval of SARs and SAR revisions.
  - Issue a Safety Evaluation Report, (SER) which documents the DOE evaluation of the SAR to show an adequate level of safety, and the basis for granting approval of the SAR.
  - Exemptions require approval according to hazard category (1, 2, or 3) and type (temporary or permanent). See section 8 for more detail.
- The DOE Field Office or Program Manager responsible for the facility have the following duties with regard to the SAR approval:
  - Oversee the contractors' preparation and review of the safety analysis, hazard classification, and safety evaluation.
  - Review and make recommendations to the PSO regarding the adequacy of the SAR and any revisions.

E. Discuss the ways that contractor management makes use of nuclear safety analysis reports.

Among the uses that contractor management makes of SARs are the following:

- For new nuclear facilities, SARs will be the authoritative documentary record of safety commitments for project management, engineering, design, procurement and construction, and operation of the facility. It should also document the historical development and use of safety evaluation models employed in design and engineering.

- SARs should be used by the contractor to support models and evaluations outlined in the SAR for the following:
  - Project management;
  - Resolution of non-conformances, operational safety and health issues; and,
  - Evaluation of proposed changes and new information on the safety of the facility.
- FSARs (Final SARs) are the documented rationale used to develop the bases for the TSRs, along with commitments to engineering codes and standards.
- SARs need to be a practical basis for: program management, budgeting and planning, safety oversight, inspection, enforcement, and safety standards development.
- SARs must be practical references for the use of operations management in their day-to-day operations. They must be a living document conveying the contractors' commitments to safe operations throughout facility life consisting of initial design and construction through decontamination and decommissioning.

F. Discuss the relationship between the construction schedule and the development or modification of the facility nuclear safety analysis report.

- Contractors shall be required to obtain PSO approval of Preliminary Safety Analysis Reports (PSARs) prior to undertaking procurement of materials and components, construction, and preoperational testing of DOE nuclear facilities.
- PSARs shall document the adequacy of the safety basis for a new nuclear facility and provide assurance that the facility can be constructed, operated, maintained, and shut down safely and in compliance with applicable laws and regulations.

- A PSAR must contain:
  - The preliminary design;
  - Research or other data necessary to finalize the design, and document the preliminary approaches to startup and operations management;
  - Final commitments by the contractor to the management and oversight of the construction project;
  - Safety-related construction project commitments and goals will become the basis for DOE safety performance evaluation and compliance assessment during the construction phase of the project; and,
  - Identification and documentation of the laws and regulations that apply to the safety design or operation of the facility.
- Some changes to the PSAR may be expected to occur as design, procurement, and construction problems are faced.
- DOE may chose to authorize limited design, procurement, construction, and preoperational testing of facilities without approval of a PSAR.

G. Define who approves facility operations prior to achieving safety analysis report upgrade approval.

Continued facility operation is approved by the PSO by using the current PSAR or pre-existing authorization (safety) basis.

H. Discuss the provisions for temporary and permanent exemptions from the requirements of Safety Analysis Reports.

- The Secretary may grant permanent exemptions to the requirements of DOE Order 5480.23 for hazard Category 1 and hazard Category 2 facilities under his/her cognizance, with a formal request form the appropriate PSO, and the concurrence of the Office of Environment, Safety and Health and the Office of Nuclear Energy.

- The PSO may issue permanent exemptions to the requirements of DOE Order 5480.23 for nonreactor nuclear facilities under his/her cognizance where hazards are of a low magnitude (i.e., hazard Category 3 facilities).

  - Exemptions must be formally issued and must include an adequate basis justifying the action to ensure, that with proper controls, worker and public health and safety are not affected by the consequences of any postulated Design Basis Accidents (DBAs).
  - Exemptions may be granted only after obtaining the concurrence of the Office of Environment, Safety and Health and the Office of Nuclear Energy.

- The PSO may grant temporary exemptions to the requirements for any activity under his/her cognizance, for a duration not to exceed one year. NS-1 and EH-1 shall be notified of any temporary exemptions in a timely manner, in order to discharge their assigned responsibilities.

I. Discuss the requirements for the contractor to maintain the safety analysis report current.

- Contractors shall be required to review and update as necessary, SARs annually, to ensure that the information in each SAR is current and remains applicable.
- Revisions shall be submitted to the PSO at least annually and shall reflect all changes implemented up to 6 months prior to the filing of the updated SAR.
- DOE approval of any Unreviewed Safety Question pursuant to DOE 5480.21, amendments to the TSRs, and the material submitted by the contractor to the PSO in support of these approvals shall be considered an addendum to the SAR until the information is incorporated into the SAR as part of the next annual update.

  Contractors must ensure all users of facility SARs produced under their cognizance have current editions.

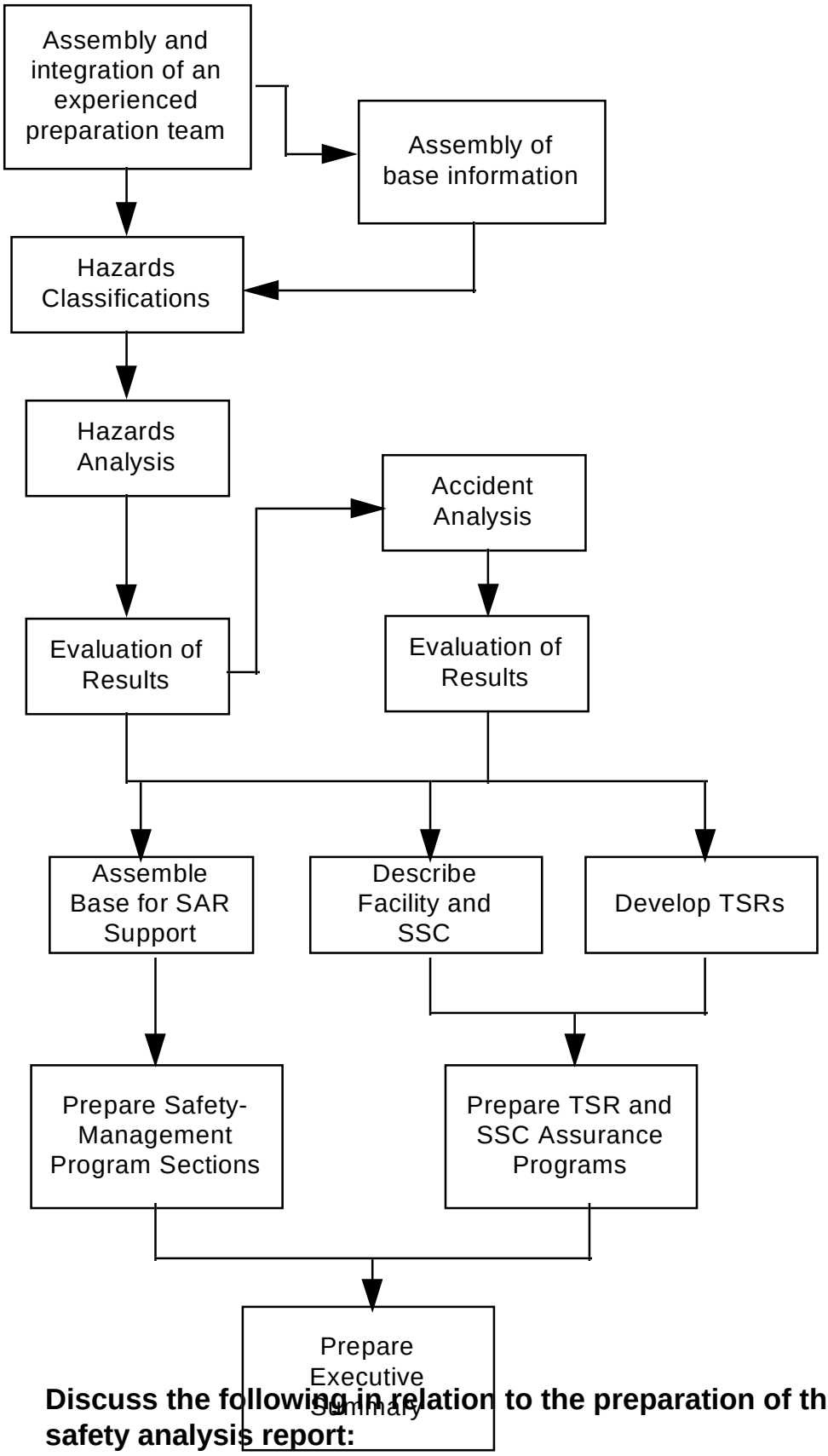
J. Discuss the conceptual basis and process for preparation of a facility/process safety analysis report (SAR).

- DOE 5480.23 forms the boundaries within which the safety analysis is performed and represent the means of assuring safe operation of DOE nuclear facilities.
- Hazard analysis and accident analysis are performed to identify specific controls and improvements that feed back into overall safety management.
- The result is documentation of analysis adequacy and development of the safety basis that emphasizes the controls needed to maintain safe operation of a facility.

Please refer to Figure 3-1 for an illustration of the SAR Process.

Figure 3-1

SAR Preparation Process Summary



K. Discuss the following in relation to the preparation of the safety analysis report:

Worker Safety

Many of the topics requiring coverage in OSHA Regulation 10 CFR 1910.119, “Process Safety Management of Highly Hazardous Chemicals (PSM)”, are design codes and standards, process hazard analysis, human factors, training, etc., and are directly parallel to the topics addressed by DOE 5480.23.

- DOE 5480.23 effectively merges PSM principles with traditional nuclear SAR precepts.

Defense-In-Depth

- Defense-in-depth as an approach to facility safety has extensive precedent in nuclear safety philosophy. It builds in layers of defense against release of hazardous materials so that no one layer by itself is completely relied upon.
- Defining defense-in-depth as it exists at a given facility is crucial for determining a safety basis.
- Items identified in the safety and hazard analysis are examined against TSR criteria to identify a subset of the most significant controls that prevent uncontrolled release of hazardous materials and nuclear criticality. These TSR controls include operational limits and administrative controls, including those on safety management programs. This collection of TSRs formally acknowledges features that are of major significance to defense in depth.

Programmatic Commitments

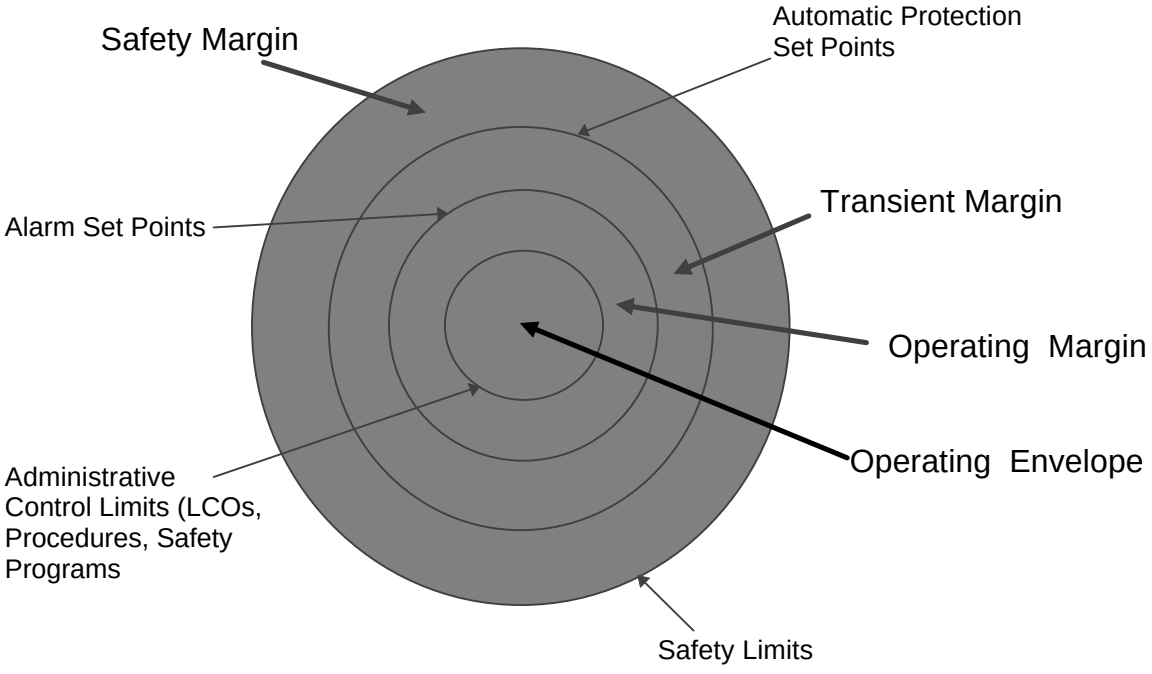
- Programmatic commitments (e.g., radiation protection, maintenance, quality assurance) encompass a large number of details that are more appropriately covered in specific program documents (e.g., plans and procedures) external to the SAR.
- The SAR safety basis includes only the top level summary of program elements, not the details of the program or its governing documents.
- Programmatic commitments, may be incorporated in TSRs as administrative controls.

Technical Safety Requirements

- TSRs comprise:
  - Safety Limits (SLs);
  - Operational Limits consisting of LCSs, LCOs and associated surveillance requirements; and,
  - Administrative Controls.
- TSRs are designated for:
  - Defense-in-Depth, in accordance with the screening criteria of DOE 5480.22;
  - Safety management programs for defense-in-depth or worker safety;
  - Safety-Class SSCs and controls needed to meet evaluation guidelines; and,
  - Safety-Significant SSCs.

Figure 3-2 visually depicts the TSR process as it relates to facility operational safety.

Figure 3-2



Structures, Systems, and Components (SSCs)

- Safety-class SSCs:
  - The safety-class designation has been traditionally reserved for SSCs needed for public protection.
  - Safety-class SSCs are those SSCs that accident analysis indicates are needed to prevent accident consequences from exceeding off-site evaluation guidelines.
  - Safety-class SSCs generally will not be associated with Hazard Category 2 and 3 facilities due to their limited potential for offsite impact.
- Safety-significant SSCs:
  - Safety-significant SSCs are those of particular importance to defense-in-depth or worker safety as determined in the hazard analysis.
  - Control of such SSCs does not require meeting the level of stringency associated with safety-class SSCs.
  - This category of SSCs is provided to ensure that important SSCs will be given adequate attention in the SAR and facility operations programs.

Nuclear Explosive Safety Rules (NESRs)

- Safety limits, operating limits, surveillance requirements, safety boundaries, and management and administrative controls that significantly contribute to minimizing the possibility of nuclear detonation, or high explosive detonation or deflagration, in nuclear explosive operations and associated activities are identified as specific NESRs. NESRs and their bases are described in the (Nuclear Explosive Operation) Hazard Analysis Report (HAR). NESRs are approved in conjunction with the Nuclear Explosive Safety (NES) Study Report.

Operational Safety Controls (OSCs)

- Requirements to protect workers, the public, and the environment from other hazards not described by NESRs are identified as Operational Safety Controls (OSCs). Like NESRs, OSCs and their bases are described in the HAR. OSCs are approved in conjunction with the HAR.

Hazard Analysis

- The initial analytical effort for all facilities is a hazard analysis that systematically identifies facility hazards and accident potentials through hazard identification and hazard evaluation.
- This largely qualitative effort forms the basis for the entire safety analysis effort, including specifically addressing defense in depth and protection of workers and the environment.
- The focus of the hazard analysis is on thoroughness and requires evaluation of the complete spectrum of hazards and accidents.

Figure 3-3 (page 21) gives a visual summary of the hazard analysis process.

Accident Analysis

- The complete spectrum of accidents are examined in hazard analysis where safety-significant SSCs are designated.
- A limited subset of accidents, (i.e., DBAs and derivative DBAs) are carried forward to accident analysis where safety-class SSCs are designated by comparison of accident consequences to Evaluation Guidelines.

Accident analysis need only document the basis used in hazard analysis for assigning accident likelihood to two-orders-of-magnitude bins. The quantified consequences are compared to numerical Evaluation Guidelines for the purpose of identifying safety-class SSCs and any accident specific assumptions requiring coverage by TSRs.

Please see Figure 3-4, page 22.

Figure 3-3

Hazard Analysis

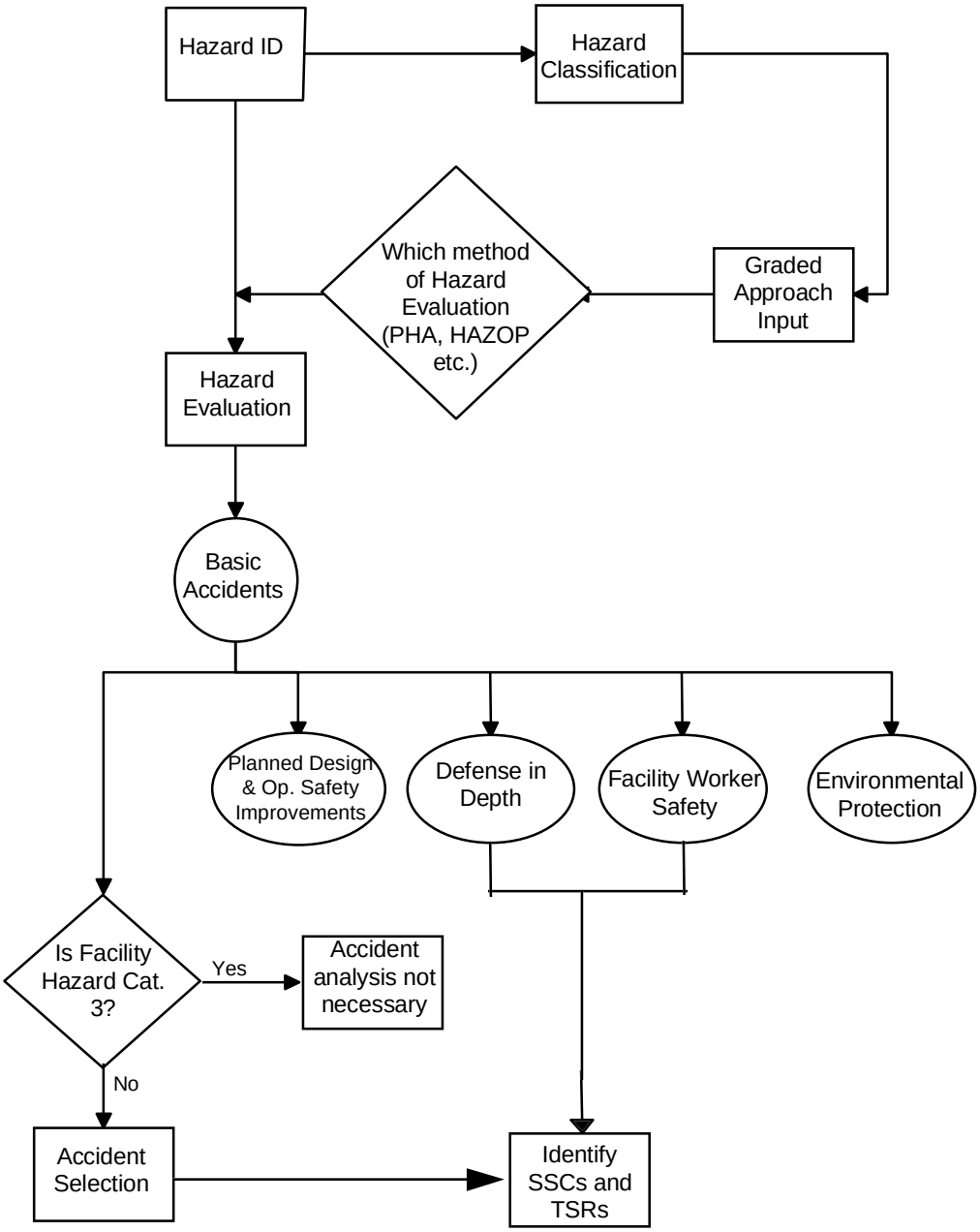
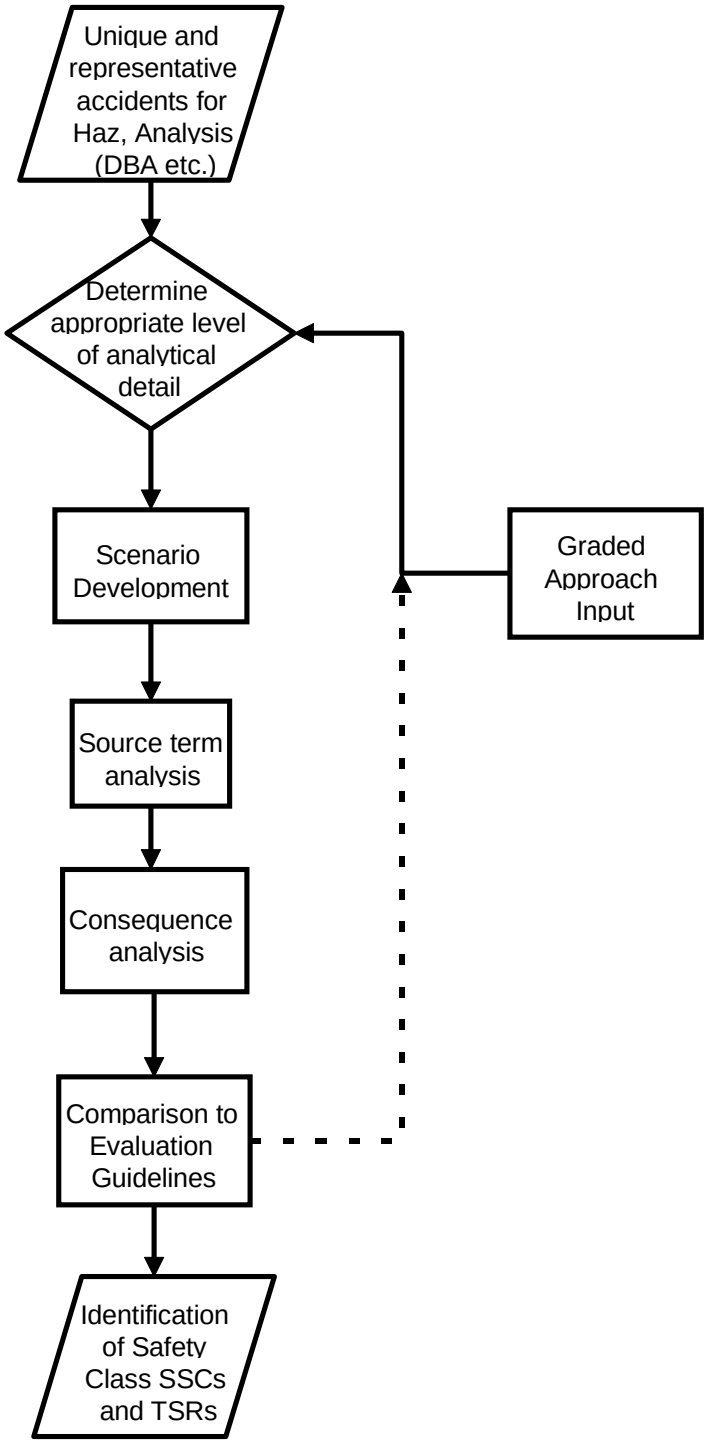


Figure 3-4

Accident Analysis



Application of the Graded Approach

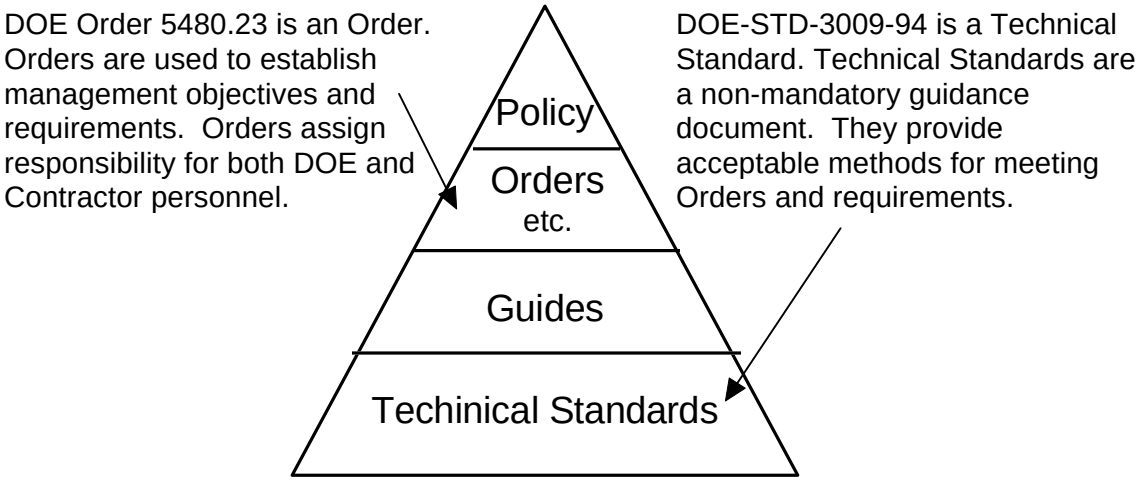
- The graded approach applied to SAR preparations and updates is intended to produce cost efficient safety analysis and SAR content that provide adequate assurance to the DOE that a facility has acceptable safety provisions without providing unnecessary information.
- The graded approach adjusts the magnitude of the preparation effort into the characteristics of the subject facility based on three attributes:
  - Facility hazard magnitude or severity;
  - Facility and systems' complexity including considerations for acceptable levels of risk; and
  - Facility life cycle stage.
- For facilities with few hazards resulting in a designation as a hazard Category 3, and for which only a modest reduction of risk is required, the SAR may be simple and short. In such cases all of the topics for the SAR will not be necessary, and with proper technical bases some topics may be omitted or reduced in the detail that would otherwise be required of Hazard Category 1 or 2 facilities.

L. Discuss the relationship between DOE-STD-3009-94, Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports, and DOE Order 5480.23, Nuclear Safety Analysis Reports.

Figure 3-5 graphically depicts the above relationships.

Figure 3-5

Relationship of Orders and Techinical Standards



M. Compare the requirements for the safety analysis report chapter structure and content as specified in each of the following:

- DOE-STD-3009-94, Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports; and
- DOE Order 5480.23, Nuclear Safety Analysis Reports.

The following table correlates the SAR preparation guide chapters with the 21 topical titles identified in and required to be addressed by DOE 5480.23. Topics b, f, and u are incorporated throughout the various chapters of DOE-STD 3009-94.

SAR Relationship to DOE-STD-3009-94 and DOE Order 5480.23

Figure 3-6

Topic (SAR Chapter)	DOE-STD-3009-94 Chapter	DOE 5480.23 Topic 8.b.(3)
Executive Summary	unnumbered	(a)
Site Characteristics	1	(c)
Facility Description	2	(d)
Hazard and Accident Analysis	3	(e), (k)
Safety Structures, Systems, and Components	4	(d)
Derivation of Technical Safety Requirements	5	(p)
Prevention of Inadvertent Criticality	6	(h)
Radiation Protection	7	(i), (k
Hazardous Material Protection	8	(j), (k)
Radioactive and Hazardous Waste	9	(g), (k)
Initial Testing, In-Service Surveillance, and Maintenance	10	(o)
Operational Safety	11	(q)
Procedures and Training	12	(m)
Human Factors	13	(n)
Quality Assurance	14	(r)
Emergency Preparedness Program	15	(s)
Provisions for Decontamination and Decommissioning	16	(t)
Management, Organization, and Institutional Safety Provisions	17	(l)

N. Describe the relationship between the SAR, Hazard Analysis Report (HAR) and Nuclear Explosive Hazard Assessment (NEHA).

Nuclear explosive operations are conducted on specific weapons in specific facilities. The facility SAR describes hazard analysis particular to the facility. The hazard analysis of each nuclear explosive operation (or group of related nuclear explosive operations) and associated activities are documented in a HAR. A subset of the HAR necessary to support Nuclear Explosive Safety (NES) studies is the NEHA. Requirements for the HAR, including the NEHA, are specified in DOE-STD-XXXX-95.

The facility SAR and the nuclear explosive operation HAR together constitute the safety analysis for the operation. The HAR identifies credible accident sequences and consequences, which must be compared to the facility SAR with sufficient detail to confirm they are bounded. The USQD process is used to for this comparison. If an accident sequence is identified that is not bounded by the SAR, be it a new accident type or an analyzed accident of greater consequence, then the SAR must be revised.

3-3

3. Demonstrate knowledge of nuclear accident analysis techniques.

A. Identify and discuss essential elements of deterministic and probabilistic risk assessment techniques.

- **Probabilistic Risk Assessment (PRA):** The use of probabilistic based accident and systems modeling techniques to quantitatively analyze, study, and define and prioritize credible accident scenarios. The process is normally broken into three levels:

  Level I - Estimation of accident frequencies;

  Level II - Transport of radionuclides into the environment; and,

  Level III - Estimation of effects of radionuclides in the environment on the surrounding population.

The Level II and III processes are further discussed below. In general the Level I process consists of the following elements:

1) Accident Identification and screening to identify credible accidents and eliminate incredible accidents. Credible events are normally associated with “initiators,” or events which could lead to onset of an accident. Therefore, one of the products of this effort would be identification of a set of “initiators”.
2) Development of accident progression event tree “top events” where success or failure of defense-in-depth SSCs or barriers, operator actions crucial to SSC or barrier integrity, and phenomenological events are modeled to define accident “end states.” Trees must be developed for each initiator of for groups of similar initiators identified above.
3) Quantification of event tree “top events.” This process often involves the development of detailed fault trees to determine top event failure probability. Fault trees generally reduce SSC success criteria to combinations of individual sub-component failures through the use of Boolean algebra.
4) Quantification of initiating events where the frequency of occurrence is determined for each initiator event of interest.
5) Accident sequence event quantification is the process of determining the sum total failure frequency for all credible accident sequences by combining the initiator frequency with subsequent failures of defense-in-depth SSCs, barriers, operator actions or phenomenological events as defined in the accident progression event tree.
6) Analysis and documentation of results.

- **Deterministic Risk Assessment:** The use of computer based integrated modeling numerical methods for simultaneous solution of multiple equations to study accident progression and related response phenomenon. This process is often used to quantify complex phenomenological events such as transport of radionuclides upon release.

B. Identify and discuss the methods used to determine and analyze failure modes.

Root Cause Analysis: The process of identifying and analyzing that cause that, if corrected, would prevent recurrence of this and similar occurrences. It is the most fundamental aspect of the cause that can be fundamentally be identified and corrected. The process consists of:

1) Data collection where information consisting of conditions before, during, and after an occurrence; personnel involvement (including actions taken); environmental factors; and other information having relevance to the occurrence should be collected.

2) Assessment, where the data gathered above are analyzed to:
   - Identify the problem;
   - Determine the significance of the problem;
   - Identify the causes (conditions or actions) immediately preceding and surrounding the problem; and,
   - Identify the reasons why the causes identified in the previous step existed, working back to the root cause.

3) Corrective actions consists of implementing actions for each root cause identified previously to reduce the probability that a problem will recur.

4) Inform and document by entering the report into the Occurrence Reporting and Processing System (ORPS). This process discusses and explains the results of the analysis, including corrective actions, with management and other affected/involved personnel as well as sharing the information with other facilities and sites.

5) Follow-up to determine if the corrective actions taken have been effective in correcting the problem.

C. Discuss the methods used in the calculation of criticality safety, source term, environmental transport, and dose assessment activities including commonly used computer models.

- **Criticality Safety Methods:** For most processes where the interaction of multiple criticality factors are studied to prevent inadvertent criticality, a computer based numerical methods analysis is performed to study the integrated effects. For most complex geometry processes, the most widely used computer based criticality safety codes used are KENO and MONK. These codes use a Monte Carlo, statistical neutron tracking method to study the various criticality factors simultaneously and thereby predict the neutron multiplication factor (K_{eff}) so as to give a best estimate of criticality.
- **Source Term Methods:** Source term estimation is the process of determining the amount and the types of radioactive isotopes released during a nuclear accident. This is generally part of the front end work performed in support of a Level II PRA, where to estimate a source term, the environmental conditions surrounding and evolving during an accident are studied using computer codes and laboratory experiments. Using this information, estimation of release fractions of nuclides (isotopes) are made based upon the estimated or known source isotopic content. Some of the factors that influence isotope release include:
    - temperature;
    - presence of a fire;
    - thermal-hydraulics;
    - explosions; and
    - breach of mechanical barriers to release such as cladding, sealed containers, etc.
- **Environmental Transport Methods:** This process estimates the methods by which those release fractions determined previously are transported from the source to the environment and is typical of a Level III analysis. Of specific interest are the multiple paths that releases may take into the environment, namely, airborne, surface waterborne, and subterranean hydrology. For most radiological accidents, the airborne path is the most significant and is therefore the basis for the majority of transport studies/models.

The main factors significantly affecting transport include:

a) Chemical state of the radionuclide (solid, liquid, or gas);
b) Release path (airborne or waterborne);
c) Initial energy of release (explosive, fire, steam effects);
d) Manmade barriers/mitigative measures (confinements, buildings, filters, spray removal systems, etc.);
e) Dispersion or plume effects; and,
f) Weather effects including prevailing winds, rain, snow, inversions, etc.

Examples of codes that assess transport effects are shown in figure 3-7:

Figure 3-7

Software	Description
CONTAIN	Analysis of nuclear containment/confinement phenomena including prediction of physical and radiological conditions inside containment/confinement.
MELCOR	Models severe accident progression in LWRs including thermal-hydraulic response of the RCS, reactor cavity, containment, and concrete buildings. It also predicts core heat-up, degradation, relocation, core-concrete interaction, H2 production, transport and combustion, fission product release and transport, and the impact of engineered safety features on thermal-hydraulic and radionuclide behavior.
RELAP5 - Reactor Excursion and Leak Analysis Program	Used in the analysis of transients and small and large break loss-of-coolant accidents in LWRs.
SAPHIRE - Systems Analysis Programs for Hands-on-Integrated Reliability Evaluations	A micro-computer based software system to perform complete Level I/II PRAs.
MAACS - MELCOR Accident Consequence Code System	Simulates the impact of severe accidents at nuclear power plants on the surrounding environment.
TRAC-P - Transient Reactor Analysis Code	A three-dimensional thermal hydraulic analysis code for PWRs. Used in analysis of transients and large break loss-of-coolant accidents.

- **Dose Assessment Methods:** This process estimates the dose to the on-site worker or individual and to the public as a result of a radiological accident where a release of radioactivity could occur. From historic studies of radiation ingestion, absorption, inhalation, and exposures, as well as from studies and knowledge on how specific radionuclides interact with the various organs of the body, the effects of exposure to the various radionuclides may be estimated. The result is the determination of dose zones or regions where it may be statistically estimated that a person located within a given region would receive (on average) the calculated dose associated with a specific release.

D. Discuss the methods used to identify and categorize the hazards associated with Department nuclear systems.

DOE Standard 1027-92 outlines the process and thresholds of radionuclides that help determine the hazard category of each facility. The process includes preliminary hazard identification, and then a determination on the type and amount of the hazard as outlined in the chart of Thresholds of Radionuclides.

4. Demonstrate knowledge of the following DOE Orders related to safety analysis*:*

3-4

A. Describe the relevant requirements, purpose, interrelationships and importance of the listed Orders.

- DOE Order 5480.24, Nuclear Criticality Safety
  1) Requires documenting the basis for criticality safety in SAR.
  2) Requires LCOs for criticality safety in TSR.
  3) Requires criticality alarm systems.
  4) Requires monitoring and surveillance programs.
  5) Mandates compliance with ANS standards.

- DOE Order 5480.29, Employee Concerns Management System

  Requires departmental elements and contractors to establish and follow a process for the acceptance and disposition of employee concerns relating to ES&H.

  Outlines the methods of categorization of the concerns and the administrative controls relating to the submission of concerns.

- Mandates the utilization of a 24 hour hot-line to accept concerns.DOE Order 5480.30, Nuclear Reactor Safety Design Criteria

  Outlines safety requirements for nuclear reactor design, including:

  - ◊ Defense in Depth;
  - ◊ Design basis for natural phenomena; and
  - ◊ Fire safety.

- DOE Order 5481.1B, Safety Analysis and Review System

  Canceled for nuclear facilities by DOE Order 5480.23.

  Outlines general and basic requirements for safety analysis, hazard classification, and approval.

  Scope and depth are an order of magnitude less than DOE Order 5480.23.

- DOE Order 6430.1A, General Design Criteria includes:

  - ∗ General design criteria for all DOE facilities;
  - ∗ Requires safety analysis;
  - ∗ Guidance on limiting exposure of public; and
  - ∗ Outlines general requirements for SSCs.

B. Discuss the role of radiation protection personnel with respect to these Orders.

Each DOE facility is required to establish a radiological protection program that complies with the tenets of the DOE Radiological Control Manual. The DOE Radiological Control Manual captures the philosophy and guidelines of the Orders as they relate to the role of radiation protection personnel.

For example, there are various facilities throughout DOE that have Continuous Air Monitors (CAMs) as an Operational Safety Requirement/Technical Safety Requirement (OSR/TSR). CAMs are one of the air monitoring systems mentioned in the Radiological Control Manual that alerts the workers of the presence of radioactive airborne particulate, which could lead to an internal exposure to the workers. The radiation protection personnel are responsible for ensuring that CAMs are functioning properly to support operations.

It is the role of the radiation protection personnel to assist workers throughout the DOE sites to minimize radiation exposure and prevent spread of contamination.

In support of this objective, radiation protection personnel need to understand the radiological hazards, safety limits, and administrative controls associated with the facility which they are supporting.

Section 3 References and Suggested Reading

References and Suggested Reading

Department of Energy, DOE Order 5480.23 Nuclear Safety Analysis Reports, DOE, 1992

Department of Energy, DOE Order 5481.1 Safety Analysis and Review Systems, DOE, 1986

Department of Energy, DOE Standard 3009-94 Non-Reactor Nuclear Facility Safety Analysis Reports, DOE, 1994

Department of Energy, DOE Standard 1027-92 Hazard Categorization and Accident Analysis Techniques, DOE, 1992

Department of Energy-Albuquerque Operations Office, Safety Documentation; Authorization Basis for Facility Representatives, Course workbook, DOE, 1996

Department of Energy-Systems Analysis and Standards (EH-64), Safety Analysis Report Preparation, Course instructor guide, DOE, 1993

Department of Energy-Environmental Management (EM-4), Authorization Basis, Course workbook, DOE, 1993

Department of Energy, DOE Order 420.1, DOE, 1995

Department of Energy, DOE Order 5610.11 Safety of Nuclear Explosive Operations, DOE, 1995

Department of Energy, DOE Standard XXXX-95 Prepartion Guide for the US Department of Energy Hazard Analysis Reports for Nuclear Explosive Operations, DOE, 1995

Technical Safety Requirements
Cross-Competency Listing

The following matrix shows where the Technical Safety Requirements portion of the Study Guide addresses particular qualification standard competencies.

DOE Qualification Standard(s)											Study Guide
Nuclear Safety Systems	Chemical Processing	Nuclear Explosives Safety	Project Manage-ment	Instrum-entation and Control	Construction Management	Electrical Systems	Mechanical Systems	Facility Mainten-ance	Civil / Structural Engineering	Radiation Protection	
NS 2.3	**CP 2.5**	**NES 2.8**	**PM 2.5**	**IC 2.12**	**CM 2.7**	**ES 2.7**	**MS 2.5**	**FM 2.8**		**RP 2.11**	**Section 4-1**
NS 2.3.a	CP 2.5.a	NES 2.8.a	PM 2.5.a	IC 2.12.a	CM 2.7.a	ES 2.7.a	MS 2.5.a	FM 2.8.a	CSE 2.7.d		Parts 1.A
NS 2.3.b	CP 2.5.b		PM 2.5.b	IC 2.12.b	CM 2.7.b	ES 2.7.b	MS 2.5.b	FM 2.8.b			1.B
NS 2.3.c	CP 2.5.c	NES 2.8.b	PM 2.5.c	IC 2.12.c	CM 2.7.c	ES 2.7.c	MS 2.5.c	FM 2.8.c			1.C
NS 2.3.d	CP 2.5.d		PM 2.5.d	IC 2.12.d	CM 2.7.d	ES 2.7.d	MS 2.5.d	FM 2.8.d			1.D
			PM 2.5.e	IC 2.12.e							1.E
NS 2.3.e	CP 2.5.e										1.F
NS 2.3.f	CP 2.5.f	NES 2.8.c	PM 2.5.g	IC 2.12.g					CSE 2.7.e		1.G
NS 2.3.g	CP 2.5.g	NES 2.8.d									1.H
NS 2.3.h	CP 2.5.h	NES 2.8.e	PM 2.5.f	IC 2.12.f							1.I
NS 2.3.i	CP 2.5.i										1.J
NS 2.3.j	CP 2.5.j										1.K
					*					RP 2.11.a	1.L
										RP 2.11.b	1.M
										RP 2.11.c	1.N

Technical Safety Requirements

Section 4

OBJECTIVE

1. Demonstrate knowledge of the technical safety requirements as described in DOE Order 5480.22, Technical Safety Requirements (TSRs), with respect to its impact on Department nuclear safety.

4-1

1. Demonstrate knowledge of the technical safety requirements as described in DOE Order 5480.22, Technical Safety Requirements (TSRs), with respect to its impact on Department nuclear safety.

A. Discuss the purpose of the Technical Safety Requirements (TSRs).

Technical Safety Requirements (TSRs) define the conditions, safe boundaries, and the management or administrative controls necessary to:

- ensure the safe operation of a nuclear facility; and
- reduce the potential risk to the public and facility workers from uncontrolled releases of radioactive materials or from radiation exposures due to inadvertent criticality.

TSRs were formerly known as OSRs for nonreactor nuclear facilities and technical specifications for reactor facilities. In general, TSRs define the conditions, controls and boundaries that ensure facility operation within a safe “envelope”.

B. Describe the responsibilities, regarding the technical safety requirements, of contractors authorized to operate defense nuclear facilities.

A contractor responsible for the operation of a DOE nuclear facility shall:

- Prepare Technical Safety Requirements for the facility;
- Submit the Technical Safety Requirements to the Program Secretarial Officer (PSO) for approval; and,
- Operate the facility in accordance with the Technical Safety Requirements as approved by the PSO, including any modification by the PSO.

C. Define the following terms and discuss the purpose of each:

Safety Limits(SL): 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 material.

Limiting Control Settings (LCS): The settings on safety systems that control process variables associated with the facility function to prevent exceeding the associated safety limits.

Limiting Conditions for Operations (LCO): The limits that represent the lowest functional capability or performance level of safety-related items required for the safe operation of a facility.

Surveillance Requirements: (SR) Requirements relating to test, calibration, or inspection, to ensure that the necessary operability and quality of safety-related structures, systems, components (SSCs), and their support systems required for safe operation of the facility are maintained.

D. Describe the general content of each of the following sections of the technical safety requirements:

Use and Application

This section of the TSR shall contain the basic instructions for using and applying the safety restrictions contained in the TSR. Included in this section are:

- Definitions of terms;
- Operating modes;
- Frequency notations; and
- Actions to be taken in the event of violation of TSR operating limits or surveillance requirements.

Safety Limits

Safety limits are limits on process variables associated with those physical barriers, generally passive, that are necessary for the intended facility function and are found to be required to guard against the uncontrolled release of radioactivity and other hazardous materials.

- If any Safety Limit is exceeded at any reactor or nonreactor nuclear facility, action shall begin immediately to place the facility in the most stable, safe condition attainable. This action would generally include total shutdown of either reactor or nonreactor nuclear facilities, unless a prior exception was granted for the condition in question.
- The appropriate time frame for the completion of any corrective action performed in response to an SL violation has to be developed and justified by the contractor for each nuclear facility, as appropriate, in the TSR.
- The TSR shall describe the action to be taken when an SL is exceeded. If an SL is exceeded, the contractor shall:
  - Notify DOE in accordance with DOE Order 232.1;
  - Review the matter, and record the results of the review. The review shall include the cause of the condition and the basis for any corrective action taken to preclude reoccurrence; and

- Maintain the safe, stable condition achieved as a result of the corrective action until the cognizant Program Manager authorizes further operations.

Operating Limits

Limiting Control Settings (LCS)

This subsection of the TSR shall contain the settings for automatic alarms and automatic or non-automatic initiation of protective actions related to those variables having significant safety functions including provisions for the following:

- The specific settings shall be chosen such that if exceeded, sufficient time is available to automatically or manually correct the condition prior to exceeding Safety Limits.
- If the automatic alarms or protective devices do not function as required during applicable operating modes, the contractor shall take action to maintain the variables within requirements and to promptly repair the automatic devices of the affected part of the process. If required, the facility shall be placed in a stable shutdown condition. This action shall be described within each individual LCS.
- Notification of DOE in accordance with DOE O 232.1; and
- Reviewing and recording the results, including the cause of the condition, corrective actions taken and associated basis.

Limiting Conditions for Operation (LCO)

Limiting conditions for operation are the lowest functional capability or performance level of safety-related SSCs and their support systems required for safe, normal operation of the facility. This subsection of the TSR shall contain the limits on functional capability or performance level including provisions for:

- Directing remedial actions to be taken when a LCO cannot be met during facility normal operations; and
- Describing the action to be taken when a LCO cannot be met.

Surveillance Requirements

Surveillance Requirements are requirements relating to test, calibration, or inspection to ensure that the necessary operability and quality of safety-related SSCs and their support systems required for safe operation of the facility are maintained. The requirements statements consist of short descriptions of each requirement and its frequency of performance. A frequency of performance is mandatory. These statements should be as brief as possible but should identify those elements needed to ensure compliance with the LCS or LCO.

Administrative Controls

Administrative controls are the provisions relating to organization and management, procedures, record keeping, reviews, and audits necessary to ensure safe operation of the facility. This section of the TSRs shall contain the requirements associated with administrative controls including:

- Reporting deviations from TSRs (i.e., exceeding an LCO, LCS, or SR, or violation of a TSR);
- Staffing requirements for facility positions important to safe operation; and,
- Physical and administrative controls of the criticality safety program.

Basis

This appendix to the TSR shall provide summary statements of the reasons for the operating limits and associated surveillance requirements. The basis shall show how the numeric value, the condition, or the surveillance, fulfills the requirement derived from the safety documentation.

Design Features

This appendix shall describe passive design features of the facility which, if altered or modified, would have a significant effect on safe operation. If design features are in a DOE-approved Safety Analysis Report, this appendix is not required.

E. Discuss the required approvals for the technical safety requirements for new facilities and, subsequent changes to the technical safety requirements.

Program Secretarial Officers (PSOs) or their designee shall:

- Review and approve schedules for preparing new Technical Safety Requirements in accordance with the Order; and
- Review and approve new TSRs and revisions thereto for all nuclear facilities.

Heads of Field Offices or their designee shall:

- Review all new TSRs and revisions to existing TSRs submitted by contractors under their cognizance and assume review responsibilities as directed by the cognizant PSO.

F. Discuss the requirements for administrative control of the technical safety requirements.

The facility must be operated in accordance with the provisions of a current DOE-approved TSR. Thus, the TSR and its appendices must be an administratively controlled document so that only current copies of the DOE-approved TSR are used for operation of the facility.

Controlling the TSR involves establishing a list of official copies, and then instituting a formal process of issuing copies and installing DOE-approved changes in those copies.

G. Discuss the possible source documents that may be used in developing the technical safety requirements.

The site-specific Safety Analysis Report (SAR), serves as the source document for the development of controls, setpoints, limits, staffing requirements, and other parameters which input to the TSR.

The site-specific safety analysis considers:

- All credible accidents;
- All site specific hazards;
- Significant possible releases of radioactive and other hazardous materials, and
- Criticality scenarios.

An examination of the accident analyses will yield:

- The operational limits and administrative controls necessary to assure that facility operation does not occur outside the bounds assumed in the analyses;
- The parameters and operating conditions that should be limited in order to reduce, provide warning of, and mitigate the uncontrolled release of hazardous materials;
- The technical and administrative conditions that must be met;
- The requirements for availability of safety equipment and systems; and
- The critical functions of instrumentation and controls.

Operation within the bounds of the resulting requirements will provide reasonable assurance that the nuclear facility will not threaten the health and safety of the public or pose an undue risk to workers.

H. Discuss the definition and implementation principles for the term "operability" as used in a technical safety requirement.

A system, subsystem, train, component, or device shall be operable or have operability when it is capable of performing its specified function(s), and when all necessary attendant instrumentation, controls, electrical power, cooling or seal water, lubrication, or other auxiliary equipment that are required for the system, subsystem, train, component, or device to perform its function(s) are also capable of performing their related support function(s) for an adequate duration to address the accident or condition of concern.

General Principle 1: A system is considered operable as long as there is assurance that it is capable of performing its specified safety function(s) for the specified duration.

General Principle 2: A system can perform its specified safety function(s) only when all of its necessary support systems are capable of performing their related support functions.

General Principle 3: Assuring the capability to perform a safety function is an ongoing and continuous process.

General Principle 4: When all systems designed to perform a certain safety function are not capable of performing that safety function, a loss of function condition exists. Facility operation with such a condition may not continue.

General Principle 5: When a system is determined to be incapable of performing its intended safety function(s), the declaration of inoperability shall be immediate.

General Principle 6: Any exception to an immediate determination of inoperability must be justified.

I. Discuss the conditions that constitute a violation of the technical safety requirements and state the reporting requirements should a violation occur.

Violations of the TSR occur as the result of four circumstances:

(1) Exceeding a Safety Limit (SL);

(2) Failure to take the required actions within the required time limit in conjunction with one of the following:

- (a) Exceeding a Limiting Control Setting (LCS)
- (b) Failure to meet Limiting Conditions for Operation (LCO) or,
- (c) Failure to meet a Surveillance Requirement (SR);

(3) Failure to perform surveillance within the required time limit; or,

(4) Failure to comply with an administrative control requirement.

Reporting TSR violations is mandated by DOE and must be done in accordance with DOE Order 232.1. In addition, contractors responsible for operation of nuclear facilities with TSRs must outline facility specific procedures for reporting TSR violations within their TSR submittals.

J. Differentiate between the following facility designations:

Category A Reactor Facilities are those production, test, and research reactors designated by DOE based on power level (e.g., **design thermal power rating of <u>20 megawatts</u> steady state <u>and higher</u>**), potential fission product inventory, and experimental capability.

Category B Reactor Facilities are those test and research reactors designated by DOE based on power level (e.g., **design thermal power rating of <u>less than</u> <u>20 megawatts</u> steady state**), potential fission product inventory, and experimental capability.

K. Discuss the requirements for emergency actions that depart from the approved technical safety requirements.

- If a situation develops during an emergency, which is not addressed by the TSR, site personnel are expected to use their training and expertise to take actions to correct or mitigate the situation. Also, site personnel may take actions that depart from a requirement in the TSR provided that:
  - An emergency situation exists;
  - Actions are needed immediately to protect the public health and safety; or
  - No action consistent with the TSR can provide adequate or equivalent protection.

- Such action must be approved minimally by an operator or supervisor who is certified on the system or reactor through a DOE-approved training program.

- If emergency action is taken, a verbal notification shall be made to the responsible Head of the Field Element and a written report shall be provided to the Program Secretarial Officer (PSO) within 24 hours.

L. Discuss the role of the technical safety requirements as they relate to the site/facility radiological control operations and activities.

- Risk to workers is reduced through the reduction of the likelihood and potential impact of events, such as an uncontrolled release of hazardous material or inadvertent criticality. This reduction is accomplished by the development of safety requirements in the TSR for those SSCs that:
  (1) Act as barriers to prevent the uncontrolled release of radioactive and other hazardous materials;
  (2) Prevent inadvertent criticality; or
  (3) Mitigate such releases.

- It should be noted that the impact from release of hazardous materials is also reduced through industrial hygiene and radiation protection oversight (e.g., monitoring of worker exposures, use of personal protective clothing and equipment, and emergency evacuation planning), as well as the use of TSRs.
- Consistent with relevant DOE Orders, the control of the levels of hazardous materials to which workers may, at any time, be exposed is addressed in each facility's safety and health program. These programs are required to be referenced in the Administrative Control Section of the TSR.

M. Discuss criteria for identifying problems in meeting technical safety requirements (TSRs) and for identifying violations.

The criteria for identifying problems in meeting TSRs and identifying violations are founded in the process of performing and documenting the results of a thorough safety analysis in the SAR. From this analysis, TSRs will be established by the contractor and submitted to the DOE for review and approval. The approved TSRs establish an agreed upon basis for the safe operation of the facility. If at any point in time, the facility management believes a potential TSR violation has occurred, the facility should be placed in a safe condition (up to and including facility shutdown as appropriate) and the DOE shall be notified promptly.

If conditions or tasking which require temporary or permanent changes in the facility, temporary or permanent changes in procedures, or tests or experiments not described in existing safety analyses, or a potential inadequacy is discovered in the previous SAR these form the basis for an Unreviewed Safety Question (USQ). These issues should be pointed out to the DOE through the USQ process. The USQ process will be covered in detail in Section 5.

Through the effective implementation of a comprehensive conduct of operations program, which conveys the importance of maintaining the safety conditions outlined in the SAR through implementation of the TSRs, the DOE nuclear facility demonstrates the importance that TSRs play in protecting the health and safety of the worker and the public.

Additionally, through effective use and emphasis on management involvement and review of self-audits, surveillances, assessments, training and qualification, maintenance and calibration programs, and log and record keeping (as they relate to TSR implementation and validation) the facility establishes the basis for identifying and correcting potential TSR violations before they occur as well as those that may occur.

N. Discuss the requirements for reporting technical safety requirements (TSRs) violations.

Reporting TSR violations is mandated by DOE and must be done in accordance with DOE Order 232.1. In addition, contractors responsible for operation of nuclear facilities with TSRs must outline facility specific procedures for reporting TSR violations within their TSR submittals.

References and Suggested Reading

Section 4 References and Suggested Reading

Department of Energy, DOE Order 5480.22 Technical Safety Requirements, DOE, 1992

Department of Energy, DOE Order 5480.23 Nuclear Safety Analysis Reports, DOE, 1992

Department of Energy, DOE Order 5480.21 Unreviewed Safety Questions, DOE, 1991

Department of Energy, DOE Order 5481.1 Safety Analysis and Review Systems, DOE, 1986

Department of Energy, DOE Order 232.1 Occurrence Reporting and Processing of Operations Information, DOE, 1996

Department of Energy, DOE Standard 3009-94 Non-Reactor Nuclear Facility Safety Analysis Reports, DOE, 1994

Department of Energy, DOE Standard 1027-92 Hazard Categorization and Accident Analysis Techniques, DOE, 1992

Department of Energy-Albuquerque Operations Office, Safety Documentation; Authorization Basis for Facility Representatives, Course Workbook, DOE, 1996
Department of Energy-Systems Analysis and Standards (EH-64), Safety Analysis Report Preparation, Course workbook, DOE, 1993

Department of Energy-Environmental Management (EM-4), Authorization Basis, Course instructor guide, DOE, 1993

Unreviewed Safety Questions
Cross-Competency Listing

The following matrix shows where the Unreviewed Safety Questions portion of the Study Guide addresses particular qualification standard competencies.

DOE Qualification Standard(s)											Study Guide
Nuclear Safety Systems	Chemical Processing	Instrum-entation and Control	Project Manage-ment	Electrical Systems	Facility Mainten-ance	Construction Management	Mechanical Systems	Nuclear Explosives Safety	Technical Manager	Waste Manage-ment	
NS 2.2	**CP 2.4**	**IC 2.11**	**PM 2.4**	**ES 2.6**	**FM 2.7**	**CM 2.6**	**MS 2.4**	**NES 2.7**			**Section 5-1**
NS 2.2.a	CP 2.4.a	IC 2.11.a	PM 2.4.a	ES 2.6.a	FM 2.7.a	CM 2.6.a	MS 2.4.a	NES 2.7.a			Parts 1.A
NS 2.2.b	CP 2.4.b	IC 2.11.b	PM 2.4.b	ES 2.6.b	FM 2.7.b	CM 2.6.b	MS 2.4.b	NES 2.7.b			1.B
NS 2.2.c	CP 2.4.c	IC 2.11.c	PM 2.4.c	ES 2.6.c	FM 2.7.c	CM 2.6.c	MS 2.4.c	NES 2.7.c			1.C
NS 2.2.d	CP 2.4.d	IC 2.11.d	PM 2.4.d	ES 2.6.d	FM 2.7.d	CM 2.6.d	MS 2.4.d	NES 2.7.d			1.C
											1.D
NS 2.2.e	CP 2.4.e	IC 2.11.e	PM 2.4.e	ES 2.6.e	FM 2.7.e						1.E
NS 2.2.f	CP 2.4.f	IC 2.11.f	PM 2.4.f	ES 2.6.f	FM 2.7.f						1.F
NS 2.2.g	CP 2.4.g	IC 2.11.h	PM 2.4.h								1.H
NS 2.2.h	CP 2.4.h	IC 2.11.g	PM 2.4.g			CM 2.6.e		NES 2.7.e			1.G
NS 2.2.i	CP 2.5.i								TM 1.6.d	WM 1.7.d	1.I
									TM 1.6	**WM 1.7**	**Section 5-2**
									TM 1.6.a		Parts 2.A
										WM 1.7.a	2.B
									TM 1.6.b	WM 1.7.b	2.C
									TM 1.6.c	WM 1.7.c	2.D
									TM 1.6.e	WM 1.7.e	2.E
									TM 1.6.f	WM 1.7.f	Section 5-3.A
									TM 1.6.g	WM. 1.7.g	2.F
									TM 1.6.h	WM 1.7.h	2.H
									TM 1.6.i	WM 1.7.i	2.G

Unreviewed Safety Questions

Section 5

OBJECTIVES

1. Demonstrate knowledge of the safety evaluation process, and of DOE Order 5480.21, Unreviewed Safety Questions (USQs), with respect to its impact on Department nuclear safety.
2. Demonstrate knowledge of unreviewed safety questions to ensure that program priorities are established, formal process requirements are met, and resources are applied to ensure safety of operations.
3. Demonstrate the ability to determine the existence of an unreviewed safety question (USQ) in accordance with DOE Order 5480.21.

5-1

1. Demonstrate knowledge of the safety evaluation process, and of DOE Order 5480.21, Unreviewed Safety Questions (USQs), with respect to its impact on Department nuclear safety.

A. Discuss the reasons for performing an unreviewed safety question determination.

- The USQ process allows contractors to make certain physical and procedural changes without prior DOE approval. The changes must not affect any items explicitly or implicitly identified in the facility authorization basis, or result in the need for a Technical Safety Requirement (TSR) modification.
- The USQ process provides contractors with needed operational flexibility, while ensuring that issues with a potential impact on safety, as defined in the facility authorization basis, are brought to attention.

B. Define the following terms:

Accident analysis: Those bounding analyses selected for inclusion in the SAR. These analyses refer to design basis accidents only.

Safety evaluation: A record of the review of a "change" as required by DOE 5480.21. This document records the scope of the evaluation and the logic used when determining whether or not an Unreviewed Safety Question exists.

Technical Safety Requirements (TSRs): Those requirements that define:

1) The bounding conditions for safe operation;
2) The bases of those bounding conditions; and,
3) The management and administrative controls required to ensure safe operation of a nuclear facility.

C. Describe the situations or conditions for which a USQ safety evaluation is required to be performed.

A safety evaluation shall be performed for:

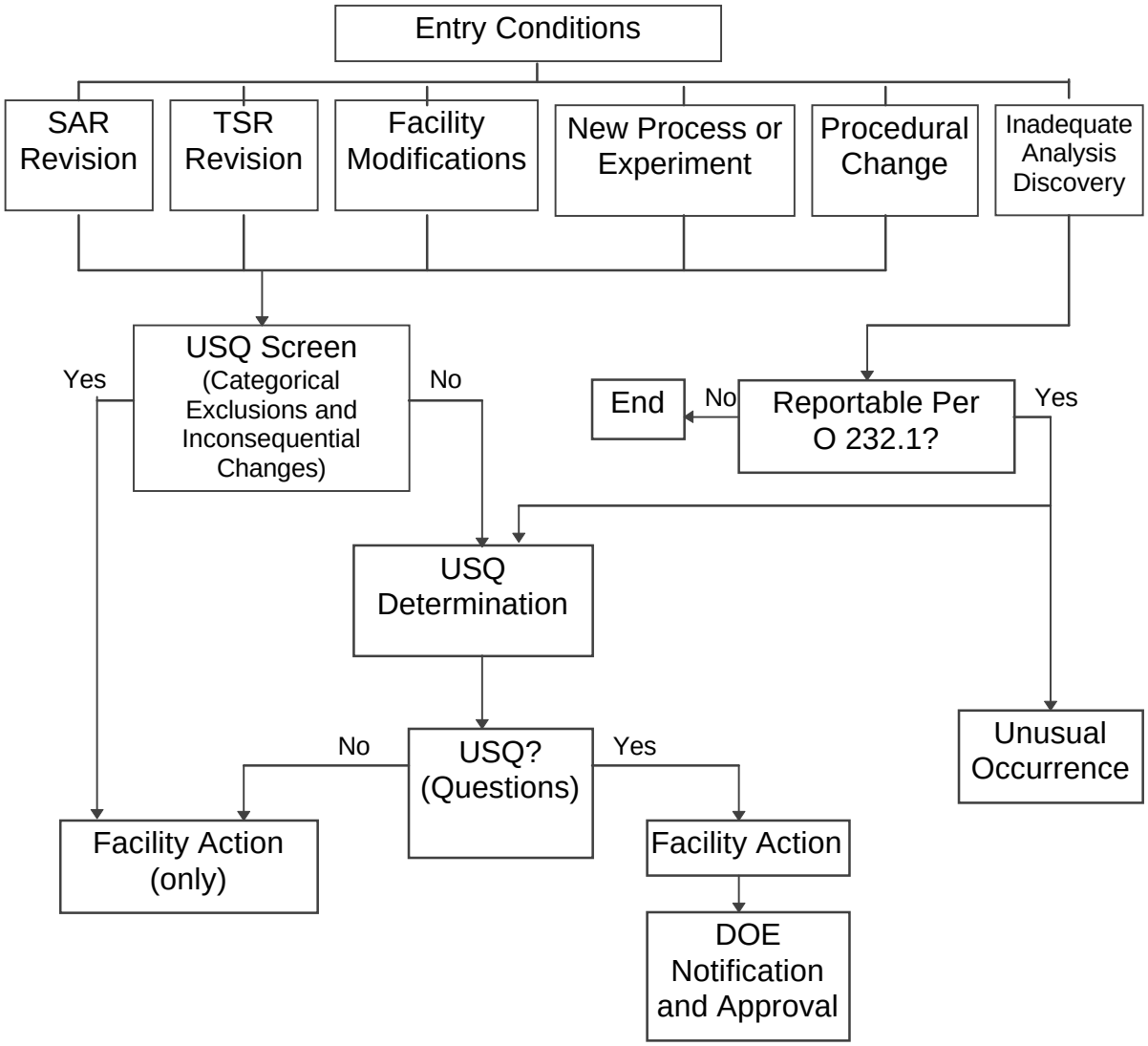
1) Temporary or permanent changes in the facility, or changes that could potentially affect facility structures, systems, and components (SSCs) or associated support systems as described in the existing safety analyses;
2) Temporary or permanent changes in procedures or routine operations as described in existing safety analyses; and
3) Tests or experiments not described in the existing safety analyses.

D. Describe the process for conducting an unreviewed safety question safety evaluation.

Please see figure 5-1.

Figure 5-1

Safety Evaluation Process



The figure above depicts the entry conditions and safety evaluation process. Briefly, entry conditions are screened to remove certain changes from the process. Remaining changes are evaluated for safety implications. DOE is promptly notified of changes not already covered under by existing safety analyses. More detailed descriptions of the process and associated determination criteria are provided later in this module.

E. Describe the responsibilities of contractors authorized to operate defense nuclear facilities regarding the performance of safety evaluations.

A contractor authorized to operate DOE nuclear facilities shall:

1) Perform all required safety evaluations to determine whether a situation involves a USQ;
2) Prior to implementation of a proposed action, obtain Program Secretarial Officer (PSO) approval for situations determined to involve a USQ or a Technical Safety Requirement (TSR) change; and
3) Develop and implement procedures to govern the need for, and the performance of, safety evaluations.

F. Describe the action taken by a contractor upon identifying information indicating potential inadequacy of previous safety analyses, or a possible reduction in the margin of safety as defined in the Technical Safety Requirements.

A contractor authorized to operate DOE nuclear facilities shall:

1. Notify the PSO of the situation upon discovery of the information;
2. Make a safety evaluation and a USQ determination in accordance with DOE 5480.21;
3. Take action to place the facility in a safe condition until the safety evaluation is completed; and
4. Submit the completed safety evaluation to DOE prior to removing any operational restrictions.

G. Discuss the action(s) to be taken if it is determined that an unreviewed safety question is involved.

A contractor authorized to operate DOE nuclear facilities shall:

1) Document the basis for the USQ determination;
2) Incorporate in the existing SAR, any changes that are needed as a result of the safety evaluation or any action taken; and

3) Submit to the PSO, on a schedule corresponding to the periodic updates of the SAR, a report summarizing all situations for which a safety evaluation was required by this section. In addition, the report should indicate all "changes" which are considered in a safety evaluation and were implemented 6 months or more before the submittal date of the report.

H. Discuss the qualification and training requirements for personnel who perform safety evaluations.

All personnel responsible for performing, reviewing, or approving USQ determinations should receive initial training on the application of DOE 5480.21, and facility-specific safety evaluation procedures. Retraining is recommended every 2 years.

I. Discuss the following terms as they apply to USQ:

One of the first steps in the USQ process is to screen proposed changes. The screening process eliminates insignificant changes and changes that clearly fall within the existing authorization basis. Two criteria used to exclude proposed changes during the screening process are:

Categorical Exclusions: Are used to eliminate from further review certain groups of administrative/procedural changes. The excludable groups and the change must not significantly alter the likelihood or consequences of analyzed hazard, or introduce a new hazard.

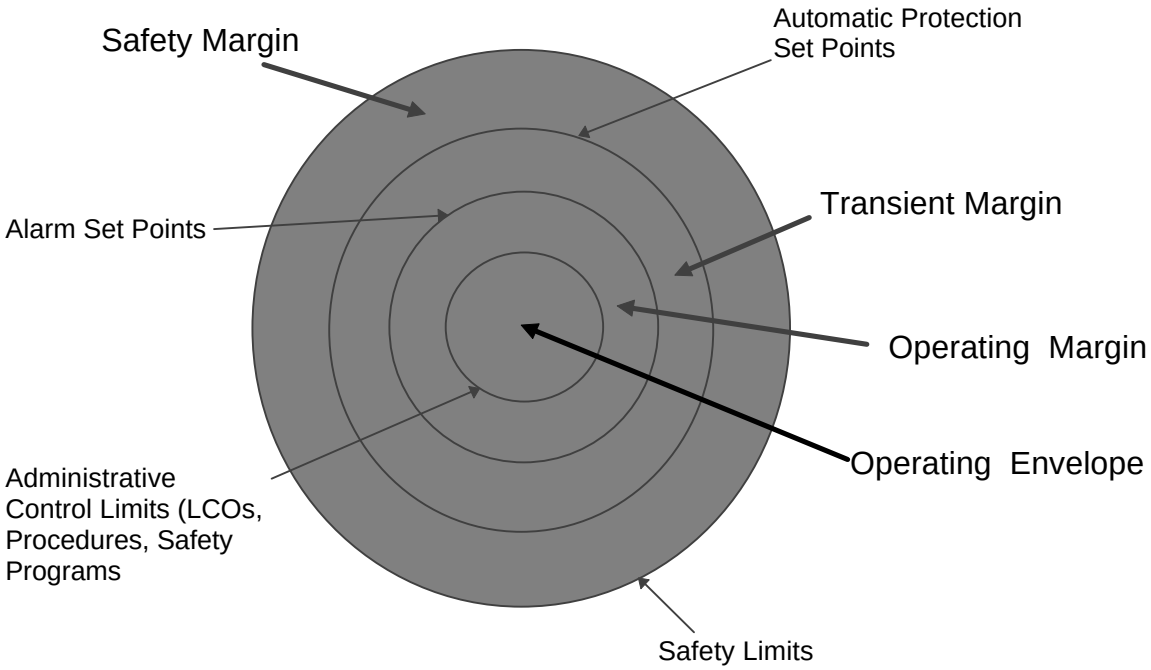
Inconsequential Changes: Are administrative/procedural items that pertain directly to the authorization basis. However, the change is of such a nature that it does not affect the authorization basis. Examples could include typographical or spelling errors contained in a procedure.

The above screening criteria apply solely to administrative changes and must not inappropriately screen out changes that require safety evaluations. Screening will NOT be used for any physical facility modifications.

Prior Unreviewed Safety Question Safety Evaluations: Should be referenced to determine similarity to current USQ evaluations. This action could result in resource savings. USQ evaluations also provide a constant source of feedback to the current facility authorization basis.

Margin of Safety: That margin built into the safety analyses of the facility as set forth in the authorization basis acceptance limits. The facility's safety envelope can be graphically represented as:

Figure 5-2



Design Basis Accidents: Those accidents that are considered credible enough to be postulated for the purpose of establishing design and performance requirements for SSCs important to safety.

Equipment Important to Safety: Any equipment whose function can impact safety either directly or indirectly. This includes safety-related equipment, equipment relied upon for safe shutdown, and in some instances, balance-of-plant equipment.

Authorization Basis: Those aspects of the facility design basis and operational requirements relied upon by DOE to authorize operation. These aspects are considered to be important to the safety of facility operations. The authorization basis is described in documents such as the facility Safety Analysis Report and other safety analyses.

2. Demonstrate knowledge of unreviewed safety questions to ensure program priorities are established, formal process requirements are met, and resources are applied to ensure safety of operations.

5-2

A. Discuss the technical manager's purpose, roles, and responsibilities as they pertain to DOE 5480.21, Unreviewed Safety Questions.

Under direction and delegation of the Head of the Field Organization, the technical manager shall:

1) Ensure that adequate and effective contractor procedures are implemented, consistent with the provisions of DOE 5480.21;
2) Approve documentation prepared by the contractor demonstrating compliance with DOE 5480.21;
3) Actively monitor the USQ identification, review, and decision making process of contractors to determine whether an incident, analysis, or proposed change/modification to systems, components, processes, operations, tests, or experiments involves a USQ;
4) Declare the existence of a USQ, when discovered, and direct the contractor to curtail or suspend operations, tests, experiments, or actions to implement the proposed changes/ modifications pending resolution of the USQ concern, or take other actions as appropriate to reduce the risk;
5) Assure contractors implement the requirements of paragraph 10 of DOE 5480.21; and
6) Bring to the attention of the contracting officer each procurement for which DOE 5480.21 is part of the statement of work.

B. Discuss the purpose, roles, and responsibilities of waste management personnel as they pertain to DOE 5480.21, Unreviewed Safety Questions.

Waste management and other facility support personnel must be sure their actions are within the scope of the authorization basis. Special attention should be directed to waste treatment, storage, and transportation activities that may not be identified in older safety analyses.

C. Discuss the conditions that require an unreviewed safety question safety evaluation.

1) Changes in the Facility as Described in Safety Analyses.

To determine whether the proposed change alters the design, function, or method of performing the function of the SSC, an engineering evaluation and a thorough understanding of the design basis of the system is essential. The following are general guidelines for situations and conditions that require an evaluation:

a) DOE 5480.21 requires safety evaluations for changes to the facility that alter the design, function, or method of performing the function of a SSC described in the safety analyses either by text, drawing, or other information relied upon as the authorization basis. Changes to components or sub-components not explicitly described in the safety analysis that have the potential for altering the function of an explicitly described SSC must be evaluated.

b) Routine maintenance activities, as opposed to changes, do not require review under DOE 5480.21, with the exception of activities not addressed by current analyses or activities that could violate a TSR.

Allowable outage time, permissible mode conditions, and permitted reductions in redundancy of systems or components removed from service for maintenance should be accounted for by TSRs. A safety evaluation need not be performed for routine, maintenance activities accounted for by TSRs.

c) Temporary changes to the facility should be evaluated to determine whether a USQ exists. Changes to non-safety related equipment which are not described in the safety analyses, but can indirectly affect the intended performance of safety equipment should also be evaluated.

d) The actual modification implementation process (e.g., work authorization system) used in the field should be reviewed for possible development of USQs. Changing plant configurations while work is in progress may involve an USQ even though the completed modification, may not.

e) For any nuclear facility in which the design basis was changed to make it agree with the as-built condition, the change could constitute a change to the facility as described in the safety analyses and may require a safety evaluation, even though no physical change took place in the facility.

2) Changes in the Procedures as Described in Safety Analyses. Procedures are not limited to those items specifically identified as procedure types (e.g., operating, chemistry, system, test, surveillance, and emergency plan), but could include anything described in the safety analyses that defines or describes activities or controls over the conduct of work. If changes to these activities or controls are made, such changes qualify as changes to procedures as described in the safety analyses, and must be evaluated.

- There are three types of procedure changes to be considered:

  a) **Procedures not contained in the safety analyses.** Changes to these procedures would not require a USQ evaluation to be performed prior to implementation.

b) **Procedures simply listed, and not outlined, summarized, or described in the safety analyses.** Changes to these procedures do not require evaluation in accordance with 5480.21.

c) **Procedures that are outlined, summarized, or described in the safety analyses.** Changes to these procedures must be evaluated if the outline, summary, or description in the safety analyses are impacted.

- Certain procedural modifications may implement operational changes, such as setpoint changes. The actual procedure may not meet evaluation requirements but the operational change should be evaluated to assure it does not impact authorization basis limits or supporting safety analyses.

3) **Conduct of Tests or Experiments Not Described in Safety Analyses.** By definition, tests and experiments requiring safety evaluation could degrade the margins of safety during normal operations or during anticipated transients, or they could reduce the ability of SSCs to prevent or mitigate accident conditions.

- Safety evaluations are required for tests or experiments not described in the current safety analyses or other approved documentation providing the authorization basis of the nuclear facility. Previously evaluated tests do not require safety evaluations under 5480.21, unless there are changes that exceed the approved envelope evaluated in the existing safety analyses.

4) **Discovery of Analytic Errors, Omission, or Inadequacies.** Safety evaluations are required for discoveries of analytical errors, omissions, or inadequacies which present the potential for a USQ. The analytic errors, omissions, or inadequacies may also have the potential for reducing the margins of safety as defined in TSRs.

- Because an analytical error, omission, or inadequacy has the potential to cast doubt on information relied upon for authorization of operations, DOE requires the following:

a) The contractor shall immediately notify the PSO;

b) The contractor shall take steps to assure that operations are conducted in a mode or manner within the authorization basis, despite the analytical discrepancy; and

c) The contractor shall immediately complete and submit to the PSO a safety evaluation prior to removing any operational restrictions implemented to compensate for the analytical discrepancy.

D. Describe the process for USQ safety evaluation. The safety evaluation must provide comprehensive justification for the USQ determination. These explanations should be complete so that a qualified independent reviewer could draw the same conclusion. The process essentially consists of:

Identification of a potential safety issue. Discovery or identification of issues or conditions previously identified and detailed under part C require application of the USQ safety evaluation process.

Screening the safety issue for USQ potential. The safety evaluation screening process can be approached by providing answers to seven questions which will be covered in more detail later in this section. A "yes," response to any questions indicates the change is an Unreviewed Safety Question.

Performing/determining the safety significance of the USQ. Various analytic and subjective, “expert opinion” evaluation processes may be used to determine the impact of the issue on safety and to compare the results against those previously documented in the existing SAR. This is essentially the process of demonstrating that the authorization basis currently defined in the SAR is being maintained. If not, the USQ requires modification of the SAR (and perhaps TSRs) to ensure safety is adequately addressed prior to further facility operations. These modifications must be approved by the DOE.

Documentation of the safety evaluation and USQ process. Proper documentation is extremely important because experience and engineering knowledge other than models and experimental data are frequently relied upon in the safety evaluation. An important goal of the safety evaluation is to demonstrate that the authorization basis is being maintained. By documenting the effects that were considered, independent reviewers will be able to assess the adequacy of the review and its conclusions.

E. Identify and explain the seven criteria of a USQ safety evaluation.

DOE 5480.21 requires that a proposed change, test, experiment or the identification of an analytic inadequacy shall be deemed to involve an USQ under any of the following circumstances:

1) If the frequency of occurrence, or the consequences of an accident or malfunction of equipment important to safety (previously evaluated by the safety analyses) could be increased;
2) If the possibility for an accident or malfunction of a different type than any evaluated previously by safety analyses could be created; or
3) If any margin of safety, as defined in the basis for any TSR, could be reduced.

For the purpose of performing safety evaluations, the criteria above can be broken down into seven separate questions:

1) Could the proposed activity increase the frequency of occurrence of an accident previously evaluated in the safety analyses?

- Determine what accidents, evaluated in the previously approved safety analyses, may be affected by the proposed activity. A determination is made as to whether the likelihood of the accident occurring would be increased.

  Two questions to ask that may help make the determination:

* Will the proposed activity fail to meet the design, material, and construction standards applicable to the system or equipment being modified?

  If the answer is "yes," this aspect of the proposed change might increase the likelihood of accident occurrence.

* Will the proposed activity affect overall system performance in a manner that could increase the probability of an accident?

  If the proposed activity affects overall system performance in a manner that could lead to an accident, or cause an accident previously evaluated to shift to a higher frequency category, then the proposed activity is elevated to USQ status.

2) Could the proposed activity increase the consequences of an accident previously evaluated in the safety analyses?

- Determine which accidents evaluated in the safety analyses may have associated radiological and hazardous material consequences altered as a direct result of the issue or change. Then determine whether or not the issue increases the consequences of any of the accidents evaluated in the safety analyses. Examples of questions that assist in this determination are as follows:

  a) Will the proposed activity change, degrade, or prevent mitigative or recovery actions described or assumed in the accident analyses?

  b) Will the proposed activity alter any assumptions previously made in evaluating the radiological and hazardous material consequences in the accident analyses?

  c) Will the proposed activity play a direct role in mitigating the radiological or hazardous material consequences assumed in the accident analyses?

  d) Will the proposed activity affect any fission product or any radioactive or hazardous material barriers?

- If it is determined that the issue does have an effect on the consequences of any accident analysis previously described in safety analyses, then the contractor should either:

  * Demonstrate and document that the safety consequences of the accident described in the safety analyses are bounding for the proposed activity (e.g., by showing that the results of the previous analyses bound those that would be associated with the issue); or
  * Revise and document the analysis, taking into account the proposed activity and compare the consequences to the acceptance limits in the prior analyses.

3) Could the proposed activity increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the safety analyses?

- Determine what important to safety (ITS) equipment could be impacted by the proposed activity. Then evaluate the effects of this activity on ITS equipment. This evaluation should include both direct and indirect effects.
- Will the issue increase the probability of a malfunction of the ITS equipment? The following are examples of questions that may be used in making the determination:

  (a) Will the proposed activity meet the original design specifications for materials and construction practices when the following questions are considered:

  (1) Are the seismic specifications met (e.g., use of proper supports, proper lugging at terminals, and isolation of lifted leads);

  (2) Are separation criteria met (e.g., minimum distance between circuits in separate divisions, channels in the same division, and jumpers run in conduit); or

  (3) Are the environmental qualification criteria met (e.g., use of materials qualified for the radiation or thermal environment in which they will be used)?

(b) Will the proposed activity degrade SSC reliability by:

(1) Imposing additional loads not analyzed in the original design;

(2) Deleting or modifying system/equipment protection features;

(3) Downgrading the support system performance necessary for reliable operation of the ITS equipment;

(4) Reducing system/equipment redundancy or independence;

(5) Increasing the frequency of operation of ITS system/equipment; or

(6) Imposing increased or more severe testing requirements on ITS systems/equipment?

A "yes" answer to any question in (b) above does not mean that there is a negative impact on safety. However, it would indicate the existence of a USQ and the need for justification that the equipment can provide or perform its intended safety function.

- If the issue or change adversely impacts the ITS equipment, the likelihood of equipment malfunction may be increased.

4) Could the proposed activity increase the consequences of a malfunction of equipment important to safety previously evaluated in the safety analyses?

- Assuming a malfunction of ITS equipment, would the issue or change result in increased hazardous material or radiological consequences?

5) Could the proposed activity create the possibility of an accident of a different type than any previously evaluated in the safety analyses?

- An accident or malfunction that involves an initiator or failure not considered in the nuclear facility safety analyses is potentially an accident or malfunction of a different type.

- The possible malfunctions or accidents of a different type are limited to those that are considered to be as likely to happen or those with unacceptably high consequences as compared to those considered in the authorization basis.

- Determine the types of accidents that have been evaluated in the prior safety analyses. The types of credible accidents that the issue or change could create can then be identified. Comparing the two lists will determine the answer to the question.

6) Could the proposed activity create the possibility of a malfunction of equipment important to safety of a different type than any previously evaluated in the safety analyses?

- Could the issue lead to a failure mode of a different type than the types evaluated in previous safety analyses? An example that might create a malfunction of a different type could be the relocation of equipment so that it now becomes susceptible to flooding, where previously there was no credible danger. Another more subtle example would be the introduction of the potential for common cause or common mode failure within a given system or across redundant systems.
- The types of failure modes of ITS equipment that have previously been evaluated in safety analyses affected by the issue are compared to the types of failure modes that the issue could create.

7) Does the proposed activity reduce the margin of safety as defined in the basis for any technical safety requirement?

a) TSRs set forth the minimum acceptable limits for operation under normal and specified failure conditions. They ensure that the available equipment and initial conditions meet the assumptions in the accident analysis. The bases for TSRs define the acceptance limits from which margins of safety may be determined.

b) Determine whether the proposed change, test, experiment, or new information, would result in a reduction in a margin of safety. The margin may be implicitly expressed rather than explicitly expressed as a numerical value. A margin of safety defined in the Bases Section of a TSR document may depend on a parameter other than one of the process variables.

c) The margin of safety is the range above the acceptance limit reviewed and approved by the DOE as part of the authorization process. In making the judgment on whether the margin is reduced, the decision should be based on physical parameters or conditions that can be observed or calculated. Where a change in margin is so small (relative to the magnitude of the margin), or if there are uncertainties in determining whether a change in margin has occurred and the overall effect is estimated to be negligible, the change need not be considered a reduction in margin.

d) The change, test, experiment, or new information should be evaluated with respect to safety limits, limiting control settings (LCS), limiting conditions of operation (LCO), and design parameters for systems and individual components. Various margins exist between unacceptable conditions or failure, and a TSR safety limit.

e) A change in initial conditions, in a system response time, or in some other parameter affecting the course of an accident analysis supporting the bases of TSRs must be evaluated to determine whether the change causes the acceptance limit to be exceeded for that analysis. If the limit is exceeded, the change would involve a reduction in the margin of safety.

F. Identify who must approve changes involving a USQ.

- Program Secretarial Officers (PSOs), shall be responsible for approval of changes determined to involve a USQ prior to implementation, and approve operations when a USQ has been determined to exist for all nuclear facilities under their responsibility.

- Heads of Field Organizations shall actively monitor the USQ identification, review, and decision making processes of contractors under their cognizance to determine whether an incident, analysis, or proposed change/modification to systems, components, processes, operations, tests, or experiments involves a USQ.

G. Identify the documentation, records, and reporting requirements for proper USQ management.

Responsible contractors must:

- Submit to the PSO, on a schedule corresponding to the periodic updates of the SAR, a report summarizing all situations for which a safety evaluation was required by this section. In addition, the report should indicate all "changes" which are considered in a safety evaluation and were implemented 6 months or more before the submittal date of the report.
- Provide a comprehensive justification for the USQ determination; and,
- Incorporate into the existing SAR, any changes that are needed as a result of the safety evaluation or any other action taken.

H. Query the Occurrence Reporting and Processing System (ORPS) and select a number of incident reports that deal with unreviewed safety questions. Discuss the appropriateness of corrective actions, and identify if actions were omitted.

The following is an example from the ORPS:

1) POTENTIAL UNREVIEWED SAFETY QUESTION ON OFF-SITE RELEASE

On December 8, 1995, a team of safety analysis experts working on a new Pantex Environmental Impact Statement notified the DOE Amarillo Area Office that the present analysis may not correctly postulate the plutonium dispersal for a high-explosive detonation because of the as-found configuration of the assembly cells. The team identified a scenario that could result in significantly higher radiation doses at the site boundary than previously calculated. The increased doses resulted from a different dispersal path than previously analyzed combined with large vent areas, consisting of penetrations and gaps, around personnel and equipment blast doors in the cells. The operating contractor determined that an unreviewed safety question existed and submitted a justification for continued operation while the issue is resolved. (ORPS Report ALO-AO-MHSM-PANTEX-1995-0216)

The 1983 Environmental Impact Statement analyzed the effect of a plutonium release from a high-explosive detonation in the assembly cells. During the detonation, the plutonium converts to an aerosol in the cell, which is pressurized by the blast. The pressure is sufficient to raise the gravel roof on the bay allowing the airborne plutonium to disperse by interaction with the gravel. However, if the volume of high-explosive is less than the quantity needed to raise the roof, the resulting cell pressure would bleed down through the gaps. In this case, the dose release at the site boundary would exceed all previous projections. The authors expressed concern with the gaps around the personnel and equipment blast doors. The gaps were not repaired at that time.

The accident scenario with the highest potential for off-site release involves insufficient high-explosives to raise the gravel roof. In this scenario, dose at the site boundary could exceed previous analyzed projections. The Safety Analysis Report estimated the probability of this accident to be once every one hundred thousand years.

Between 1983 and 1994, engineers re-analyzed the problem several times to assess the impact of larger gap sizes than those stated in the environmental impact statement. As a result of a 1994 study of the analysis report, planners added a major repair item to fix the personnel door problems. This activity is still pending.

During preparation of safety documentation for the site-wide environmental impact statement, the group of analysts determined that the off-site dose at the site boundary would exceed previous analyzed projections. After quantifying their results, they notified the DOE Area Office on December 8 and provided a list of actions to reduce the offsite dose.

On December 9, 1995, the operating contractor assembled a team to accurately measure gaps and penetrations around the cell doors, to identify short-term options for reducing off-site dosage, and to begin planning a long-term solution. They also limited plutonium loading in cells. These actions reduced the largest mean dose at the site boundary to less than 100 rem. On December 12, 1995, the operating contractor received approval for the justification for continued operation of the cells for 60 days allowing time to plug leakage paths and better assess the hazards.

Comments:

This event underscores the importance of timely response to problems identified in the safety analysis. DOE 5480.21, *Unreviewed Safety Questions,* section 10.d, requires that a contractor must notify the appropriate DOE office upon discovery of a potential inadequacy in a safety analysis, perform a safety evaluation, keep the facility in a safe condition while the evaluation is performed, and submit the completed evaluation before removing any operational restrictions. Managers at DOE facilities should review their programs for compliance with this Order.

2) POSSIBLE USQ IDENTIFIED DUE TO THE PRESENCE OF HYDROGEN GAS IN TRANSURANIC SOLUTION TANKS

A potential unresolved safety question (a hazard) has been identified associated with the generation and presence of hydrogen gas in Rocky Flats Plant (RFP) Buildings 371 and 771 transuranic solution tanks. The source is radiolytic gas build-up since curtailment of operations at RFP in December of 1989. The principal gaseous products are hydrogen and oxygen. Currently, an explosive hazard was identified based on predictive calculations of hydrogen gas concentration in the tank void spaces. All of the susceptible tanks in Building 771 are vented. Venting of the tanks in Building 371 has not been verified because of inaccessibility. Nuclear Safety Calculations identified actinide solutions in Building 771 tanks which, even when vented, may contain explosive mixtures of hydrogen and oxygen. Sampling results from nine of the ten tanks in Building 771 indicate levels of hydrogen that range from .0036% to 49.9%. The rate of hydrogen production in the subject Building 371 tanks is such that these tanks can remain unvented for an additional two years without requiring re-evaluation. Potential explosion(s) in these tanks is not considered in the existing safety analysis. Normal operations were in progress at the time of occurrence.

The Operations Manager generated an Operations Order (OO) on January 27, 1995, to provide direction for personnel until this condition is resolved. The Operations Order allows only required surveillance, inspections, maintenance, and safety-related activities in these identified areas, and that all ignition sources, including welding equipment, be prohibited within approximately six feet of the tanks.

The root and direct causes were attributed to a management problem. When operations ceased in December of 1989, the potential effects of long term storage of actinide solutions was not considered. Because of the potential explosive hazard, unresolved safety question determination (Corrective Action #1), and the Operations Order (Corrective Action #2) will remain in effect to provide direction for building personnel until the tanks are drained. In addition to the welding restriction in the Operations Order, any work involving the breach of any piping system known or suspected of containing actinide solution shall be reviewed by Industrial Hygiene & Safety personnel for the application of appropriate precautions/controls regarding hydrogen. The evolution supervisor shall ensure that this review is obtained and any special precautions are discussed as part of the Pre-Evolution briefing and that the Industrial Hygiene & Safety and Shift Manager approval be obtained prior to initiation of any work. A Site plan has been developed to purge the tanks suspected of containing hydrogen. Building 371 has a clearly identified plan and schedule for hydrogen activities. (Corrective Action #3). The building activities are on-going and are not scheduled for completion until November, 2000.

Corrective Actions:

1) Unreviewed Safety Question Determination USQD-RFP-95.0387-CAS was completed regarding the potential hazards from the presence of hydrogen gas.

2) Operations Order, OO-371-39 was initiated to provide direction for operations until the condition is resolved.

3) Building 371 has developed a clearly identified plan and scheduled to complete purging of tanks suspected of containing hydrogen.

This event illustrates the importance of analyzing the changes caused by long-term storage of materials used in processing activities before terminating or curtailing processing operations.

3) DEGRADED LOW TEMPERATURE ALARM

During normal operations, the low temperature (55 degrees F) detection system for the Material Access Area, Room 103, went into alarm condition.

Please Note: This occurrence report will address three separate occurrences concerning the low temperature detection alarm system activation. Information throughout the report supporting each individual occurrence will be represented by using, 1, 2, and 3.

1) The first temperature alarm activation occurred on, December 23, 1995, at 0833 hours.
2) The second temperature alarm activation occurred on, January 2, 1996, at 1540 hours.
3) The third temperature alarm activation occurred on, January 5, 1996, at 0238 hours.

Note: Each immediate action listed below was initiated as a result of each individual occurrence listed above.

1. Verification was made that the temperature was indeed within acceptable limits (71 degrees F).
2. The facility was evacuated of all non-essential personnel as a precaution as outlined in the Basis of Interim Operation procedure for Building 886.
3. Two hour watches were established to verify proper room temperature until the alarm system could be investigated and repair/corrected. Watches were established as outlined in the Basis of Interim Operation procedure for Building 886.

The direct and root cause of this occurrence pertains to a design problem in the selection and placement of the indicating temperature probe. The selected location of the probe is not representative of the overall room/area temperature.

A temperature alarm was installed in Building 886, room 103 on December 13, 1995. The purpose of the alarm is to notify Building Operations personnel if the temperature drops below 55 degrees Fahrenheit in room 103. Located in room 103 are several tanks containing Highly Enriched Uranyl Nitrate. An unresolved safety question determination existed concerning room temperature reducing to levels that could potentially cause precipitation within the tanks. The location of the probe (alarm), is on the west wall of room 103, near a stainless steel air lock door. The alarm is located behind the door where the cold air seems to permeate through the west wall and subsequently is trapped behind the door. The purpose of placing the temperature alarm on the west wall was because the area near the west wall was the coldest area of the room, thus, a conservative approach was taken in determining probe location. However, the location of the alarm probe is not representative of the overall room temperature. On December 23, 1995, at 0833, the alarm activated the first time. An electrical power bump was thought to have possibly caused the system to alarm. However, alarm technicians explained that the system is primarily mechanical and an electrical power bump would not have caused activation of the system.

On January 2, 1996, the alarm activated for the second time. Between January 2, and January 5, 1996, building management generated a work order to remove the glass panel in the door to equalize room temperature with associated areas. When the alarm activated, the door was found open and the temperature behind the door was approximately 50 degrees Fahrenheit. With the door open, normal supply air flow is restricted from heating the west wall area.

On January 5, 1996, due to extremely cold outdoor ambient air temperature, the system went into alarm for the third time. It was determined that directly above the temperature probe in room 103, seemed to be a down draft of cold air coming from holes around the ceiling support beams. Remedial action was initiated to place insulation materials around the ceiling supports, until permanent repair could be completed. As of the date of this occurrence, this has proven to be adequate in solving the problem.

Corrective Actions:

Generate a work order to remove the glass panel from door located near the temperature probe in room 103. Place insulation material around ceiling supports and generate a work order to properly insulate/repair the ceiling area above the temperature probe that creates the down draft of cold air condition.

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3. Given a situation relating to USQ, determine if a USQ exists, and the subsequent actions required.

The following is an example of an USQ Determination. The first part is the preliminary information and background. The second part is the determination.

Preliminary Material

Hot Cell Exhaust Example

The change to be evaluated is to add an additional exhaust fan and filter to the ventilation system that maintains a hot cell at a negative pressure with respect to the atmosphere. The ventilation system currently consists of one exhaust fan and filter. The existing exhaust fan and filter cannot maintain the hot cell at a sufficiently negative pressure. It has been determined that the ventilation system should have a second fan and filter added to it.

Define the Change

The change is to add an exhaust fan and filter to a ventilation system in parallel with an existing exhaust fan and filter. To accomplish this addition, the existing ductwork will have to be cut to allow the ductwork associated with the new fan and filter to be welded in. The new fan, filter, and ductwork will be of the same materials and designed to the same codes and standards as the existing ductwork. The new fans, filters, and ductwork will have the same capacities as the existing components. The new fan and filter will be supplied from the same manufacturer and consequently will be the same model as the existing components. The new fan will be powered from the same electrical distribution board as the existing fan. Backdraft dampers are provided with the new and existing fans.

Determine the Potential Effects of the Change on the Facility

The potential effects of this change on the facility are to increase the flow rate out of the hot cell, to decrease the pressure within the hot cell, and to increase the off-site dose. The magnitude of the changes in pressure and doses needs to be determined or bounded. The ability of the hot cell and ductwork to withstand the increased negative pressure should be demonstrated. The addition of the exhaust fan will increase the loading on the electrical distribution board. The addition of the exhaust fan would result in an increased thermal loading in the room that contains the fans and filters. The added components may also increase the radiation levels from the radioactive materials flowing through, as well as from those deposited on the components.

The above material is not a part of the USQD documentation. It has been included to illustrate the thought process that should be applied in considering a change. The following material is an example of the suggested format and content of a USQD.

Unreviewed Safety Question Determination
Hot Cell Exhaust Example

Introduction

The change being evaluated is the addition of an exhaust fan, filter, and associated ductwork in parallel with the existing fan and filter for hot cell “A” in Building XXXX. The system requirements document indicates that the added components will have capabilities identical to the existing components. The new components will be designed and procured to the same codes, standards, and loadings as the existing components. The new fan and filter will be supplied from the same manufacturer and consequently will be the same model as the existing components.

These exhaust fans maintain hot cell “A” at a negative pressure with respect to atmosphere during normal operations and accidents. Keeping hot cell “A” at a negative pressure ensures that any air leakage is into and not out of the hot cell. The filters in the ventilation system will remove most of the radioactive powder that could be released in an accident.

Safety Evaluation

The addition of an exhaust fan, filter, and associated ductwork to hot cell "A" will be evaluated with respect to its effects on the authorization basis in this safety evaluation.

Part I: Impact on the Accidents and Malfunctions Considered in the Authorization Basis

The authorization basis for this facility consists only of the hazard screening document for Building XXXX, HS/XXXX/F/0001/R2.

1. Identify the design basis accidents reviewed for potential impact by the change.

The hazard screening document was reviewed to determine which bounding accidents could be impacted by the change. Since the hot cell exhaust system maintains the hot cell at a negative pressure with respect to atmosphere and exhausts air from the hot cell, only accidents that result in radioactive material becoming airborne could be impacted by this change. In the hazard screening document for Building XXXX the bounding accident for radioactive material becoming airborne in hot cell "A" is the dropping of a container containing 100 grams of Cs^{137} in powder form. The analysis in the hazard screening document does not take credit for the exhaust system.

2. Discuss how the parameters and systems, affected by the change, impact the consequences of these accidents.

The addition of another exhaust fan could increase the exhaust flow rate out of hot cell "A:". If a container of Cs^{l37} powder were dropped, the powder could become airborne in hot cell "A". Even though the increased exhaust air flow is filtered, higher radiation doses to off-site and on-site people could result from the increased flow. These radiation doses are shown on the attached map. The increase in radiation dose is small on-site and off-site, i.e., less than 3%, and well within the acceptance limit given in DOE Order ZZZZ.ZZ.

The dose in the immediate vicinity of the hot cell would be reduced by the increased exhaust flow since there would be less air leakage out of the hot cell. In addition, a procedure will be written to direct the operators to monitor and adjust the air flow rate out of the hot cell if a spill of radioactive material has occurred.

3. Identify the design basis accidents, if any, for which failure modes associated with the changes can be an initiating event.

The components being added will be designed and procured to the same codes and standards as the ousting components. Handling of powdered radioactive material will be halted while the assisting exhaust system is out-of-service for this modification. See special requirement 3.
The new fan and filter will be supplied from the same manufacturer and will also be the same model as the existing components. Therefore, there are no new failure modes associated with the change that can be an initiating event for design basis accidents.

4. Discuss the impact of the change on the probability of occurrence of the design basis accidents identified in 3.

In Item 3 there were no design basis accidents identified for which a failure mode associated with the change could be an initiating event.

5. Identify the safety systems and systems important-to-safety affected by the change.

Although not explicitly identified in the authorization basis as such, the exhaust system was considered as the system important-to-safety that could be affected by the change. The exhaust system (fans, filter, and ductwork) is required to mitigate the drop of a container of CS137 powder. Any equipment located in the same room as the existing and the new exhaust fans, filters and ductwork could be affected by increased room temperature and increased radiation resulting from the new equipment. Thermal and radiation dose calculations were performed that demonstrate the added equipment will not increase the room temperature or radiation above the values used for design. Therefore, the only system important-to-safety that could be affected by this change is the exhaust system.

With both fans operating, the ductwork and hot cell “A” structure could be subjected to slightly more negative pressures. The effect of this slight increase in negative pressure on the structure would be negligible.

6. Discuss the impact of the change and/or the failure modes associated with the change on the probability of failure of the systems identified.

The added components will be designed and procured to the same criteria as the existing components and will be functionally identical to them. The presence of back draft dampers, that are associated with the fans, will prevent any backflow through an inoperative fan.

The calculated maximum negative pressure that the exhaust ductwork and hot cell “A” structure would see with both fans running would be 1/2 in. of water. This value was determined to be well within the design exhaust ductwork structural capabilities.

The plan for accomplishing this modification has not yet been developed. The modification plan must be reviewed and this USQD revised to reflect that review before any physical modification is allowed. Obviously, the existing ductwork will have to be cut in the process of adding these additional components. Section Y.Y.Y. of the Technical Safety Requirements (or Operational Safety Requirements) for Building XXXX requires that handling of powdered radioactive material must stop if the cell exhaust system is inoperative. Therefore, no radioactive material in powdered form may be handled while the existing exhaust system is out-of-service for construction. Otherwise, there will be no increase in the probability of failure of any systems important-to-safety.

7. Discuss the impact of the change on the performance of the safety systems.

The completed modification will increase the probability that at least one exhaust fan will be operating after a spill of radioactive material in hot cell “A”. On-site and off-site doses could be slightly increased but are still well within acceptance limits specified in DOE Order ZZZZ.ZZ.

- The added components will not result in the thermal or radiation environment exceeding that for which any important-to-safety equipment is designed.
- The increased negative pressure resulting from the added exhaust fan will be easily withstood by the ductwork and hot cell structure.
- Therefore, there are no negative effects on the performance of any safety system resulting from this change.

	Yes	No
Based upon 2, does the change increase the consequences of a design accident?	_____	___X__
Based upon 4, does the change increase the probability of a design basis accident?	_____	___X__
Based upon 6 does the change increase the probability of a malfunction of equipment important-to-safety evaluated in the authorization basis?	_____	___X__
Based upon 7, does the change degrade the performance (i.e., increase the consequences of a malfunction) of equipment important to safety evaluated in the authorization basis?	_____	___X__

If any of the above is answered yes, the change is a USQ.

Part II: Potential for Creation of A New Type of Unanalyzed Event

1. Based upon Part I, assess the impact of the change and/or failure modes associated with the change, to determine if the change has modified the facility response to the point where it can be considered a new type of accident. Discuss the basis for this determination.

The addition of an exhaust fan, filter, and associated ductwork will not change the response of the facility to the point where it can be considered a new type accident. The only effects of the modification are to increase the flow rate of air being exhausted

from the hot cell. Part I addressed the potential for increased on-site and off-site radiation doses, increased radiation dose rate and increased thermal loading in the room that contains the new and existing exhaust equipment, and increased negative pressure in the hot cell and exhaust ductwork. All of these potential problems were shown not to cause the facility to exceed design basis.

Item 6 of Part 1 points out that handling of radioactive powders will have to be stopped when the existing exhaust system is out-of-service for construction during this modification.

2. Determine if the failure modes of equipment important-to-safety associated with the change represent a new unanalyzed type of malfunction. Discuss the basis for this determination.

The equipment to be added is functionally identical to the existing equipment. No new type of malfunction is introduced.

3. Determine if the change, or a failure mode associated with the change increases the probability of an accident to the point where it should be considered within the design basis.

The components being added are designed and procured to the same requirement as the existing components. No new failure modes are created. No equipment important-to-safety will be negatively affected by this change. As noted in Item 6 of Part I, the modification plan must be reviewed and this USQD revised to reflect that review before any physical modification is allowed.

	Yes	**No**
Based upon 1, 2, and 3 does the change create the potential for a new type of unanalyzed accident or a new type of malfunction?	_____	___X__

If the answer is yes, the change is an unreviewed safety question.

Part III: Impact on the Margin of Safety

1. Based on the results identified in the discussion on the change's impact on previously analyzed accidents and malfunctions, discuss the impact of the consequences on the protective boundaries.

Item 2 of Part I indicates this change could slightly increase the on-site and off-site dose but that this increase is well within the acceptance limit.

Item 5 of Part I indicates that the added components will not negatively affect other components important-to-safety, and that the ductwork and hot cell structure will withstand the slightly increased negative pressure.

Item 6 of Part I indicates that there will be no increase in the probability of failure of any system important-to-safety resulting from this modification

Item 7 of Part I indicates the change will not result in negative effects on the performance of any safety system.

2. Identify how the protective boundaries, if any, are directly affected by the change or a failure mode of the change.

As discussed above, the change will not negatively affect the hot cell structure or the ductwork. Handling of powdered radioactive material will be stopped while the existing ductwork is compromised during this modification. The added components will be designed and procured to the same criteria as the existing components. The new components will be functionally identical to the existing components. Therefore, there will be no negative effects on any protective boundaries.

3. Discuss the impact of the change on the acceptance limits for the protective boundary identified above.

As discussed in 2, above, there are no negative effects on any protective boundary.

4. Identify the margins of safety related to this change that are defined in the bases of Technical Safety Requirements.

The bases for Sect. Y.Y.Y of the Technical Safety Requirements for Building XXXX state that hot cell "A" must be maintained at a negative pressure at or below - 1/4 in. of water anytime powdered radioactive material is being handled. This change will help to ensure that this margin is met.

	Yes	No
1. Based upon 1, do the consequences of the design basis accidents exceed the limits for an acceptable change?	_____	___X__
2. Based upon 2, 3, and 4 does the change reduce the margin of safety provided for the protection boundaries?	_____	___X__
3. Based upon 4, does the change reduce other margins of safety in the bases for the Technical Safety Requirements that are not related to the boundaries?	_____	___X__

Part IV: Safety Evaluation Conclusions

Based upon the safety evaluation the change.

___X__ Does not constitute an unreviewed safety question

_____ Does constitute an unreviewed safety question

Part V: Special Requirements

1. A procedure will be written to direct the operators to monitor and adjust the air-flow rate out of the hot cell if a radioactive material spill has occurred.

2. After it is developed, the modification plan for this change must be reviewed and this USQD revised to reflect that review before any physical modification is allowed.

3. Handling of powdered radioactive material will be stopped while the existing exhaust system is out-of-service for construction during this modification.

Following the methodology outlined in the Hot Cell Exhaust example, (pp. 5-23), determine if a USQ exists.

Section 5
Exercise

GLOVE BOX PRESSURE CHANGE

You are the manger of a facility that produces plutonium. Material production occurs in a glove box system. One of the facility safety systems is a ventilation system that maintains negative pressure in the glove boxes to assist in preventing dispersal of Plutonium. One associated Operational Safety Requirement (OSR) is to maintain -0.6 inch glove box pressure.

Recently, fine Pu-238 particles have been migrating from glove boxes during window and glove changes. Actinide ceramics and fabrication operators have requested an increase in the negative pressure for several glove boxes containing fine Pu-238 oxide particles. The intent of the change is to improve Pu-238 confinement by minimizing migration of the particles during window and glove changes. The operators are aware of the OSR requirements, but they do not know all the specific parameters under OSR jurisdiction.

The request is forwarded to a facilities management engineer who is responsible for ensuring compliance with the OSRs. He grants approval for the increase.

Shortly thereafter, an occurrence investigator and an assistant DOE facility representative noticed that several magnehelic gages on glove boxes in your facility are pegged at -1.0 inch negative pressure, which is greater than the -0.6 inch specified in the Operational Safety Requirements (OSRs). They inform you of their discovery. What are your actions?

First, you should direct operators to immediately return the glove box pressure to the required -0.6 inches.

Secondly, you start an investigation of this event, and concurrently you direct safety engineers to perform an unreviewed safety question determination to evaluate the safety significance of the glove box pressure change. Of particular concern is that the gages were pegged at -1.0 inches and it is unknown how negative the pressure in the glove boxes became.

Your investigation indicates the pressures were changed without proper review and approval and were in violation of the OSRs.

The facilities management engineer approved the change without verifying that the change would not violate OSRs and without submitting the change to the Configuration Change Team for a safety evaluation. Either review would have identified the violation and triggered an unreviewed safety question determination that would have properly evaluated the change.

An occurrence investigator reported that similar pressure changes had been made in past years before the recent emphasis on compliance with the OSRs and other safety authorization basis documents. These past practices may have contributed to the belief that the change was acceptable. In addition, the OSR did not provide a range of acceptable pressures, only the -0.6-inch number, making it difficult to comply with and somewhat open to interpretation. This lack of clarity in the OSRs could have contributed to a belief that, because negative pressure provides glove box confinement, a greater negative pressure is acceptable.

Section 5 References and Suggested Reading

References and Suggested Reading

Department of Energy, DOE Order 5480.23 Nuclear Safety Analysis Reports, DOE, 1992

Department of Energy, DOE Order 5480.21 Unreviewed Safety Questions, DOE, 1986

Department of Energy, DOE Standard 3009-94 Non-Reactor Nuclear Facility Safety Analysis Reports, DOE, 1994

Department of Energy, DOE Standard 1027-92 Hazard Categorization and Accident Analysis Techniques, DOE, 1992

Department of Energy-Albuquerque Operations Office, Safety Documentation; Authorization Basis for Facility Representatives, Course workbook, DOE, 1996

Department of Energy-Systems Analysis and Standards (EH-64), Safety Analysis Report Preparation, Course instructor guide, DOE, 1993

Department of Energy-Environmental Management (EM-4), Authorization Basis, Course workbook, DOE, 1993

SECTION 5 QUIZ

Section 5 Quiz

1. What are some documents where the facility's safety basis is described?

2. What is an Unreviewed Safety Question?

3. What is an Unreviewed Safety Question Screening ?

4. What is an Unreviewed Safety Question Determination?

5. Why does the Unreviewed Safety Question Process exist?

6. What might prompt a change review?

Section 5
Solutions

SECTION 5 QUIZ SOLUTIONS

1. What are some documents where the facility's safety basis is described?

- SAR;
- Facility Description;
- Hazard & Accident Analysis; and,
- TSRs, OSRs.

2. What is an Unreviewed Safety Question?

Unreviewed Safety Question**:** a proposed change or existing condition that could:
1) significantly increase the probability of, or the consequences of an accident or malfunction of any safety-related equipment;
2) create the possibility for an accident or for the malfunction of safety-related equipment different than previously (determined-mined in the SAR and/or TSR; or,
3) reduce the safety margin (envelope).

This change or modification could be a new activity or identification of an existing condition that presently is not covered in the facility authorization basis documents.

3. What is an Unreviewed Safety Question Screening?

An Unreviewed Safety Question Screening is the preliminary review of any proposed change or existing change of an "administrative" nature to determine if this change is either inconsequential and does not require any further evaluation or whether the change is technically significant and requires an Unresolved Safety Question Determination.

4. What is an Unreviewed Safety Question Determination?

An Unreviewed Safety Question Determination is the resulting record of a review of any technically significant proposed change or existing condition not included in any previous safety analysis (Facility SAR/TSR). The determination process follows a USQ Screening that has resulted in affirmative responses to criteria questions.

5. Why does the Unreviewed Safety Question Process exist?

There are three main reasons for the USQ process:
1) to permit contractors the operational flexibility to approve changes to facilities or procedures that do NOT impact the authorization basis;
2) to determine whether a problem (USQ) exists with the authorization basis; and,

3) to alert DOE of events, conditions, or actions that affect DOE approved authorization basis of the facility or operation.

6. What might prompt a change review?

1) Revision to the SAR (FSAR);
2) Charge to the basis of the TSR;
3) Temporary or permanent change to the facility;
4) Temporary or permanent change to procedures;
5) New tests or experiments in facility; or,
6) Exploration of safety analysis for perceived inadequacy/shortfall.

Startup and Restart of Nuclear Facilities
Cross-Competency Listing

The following matrix shows where the Startup and Restart of Nuclear Facilities portion of the Study Guide addresses particular qualification standard competencies.

DOE Qualification Standard(s)				**Study Guide**
Nuclear Safety Systems	Environment Safety & Health Resident	Environmental Restoration	Chemical Processing	
NS 2.7	**EH 2.4**			**Section 6-1**
NS 2.7.a	EH 2.4.a		CP 2.12.a	Parts 1.A
	EH 2.4.b			1.A
NS 2.7.b				1.B
NS 2.7.c		ER 4.8.c		1.C
NS 2.7.d			CP 2.12.c	1.D
NS 2.7.e				1.E
NS 2.7.f	EH 2.4.c		CP 2.12.d	1.F

Startup and Restart of Nuclear Facilities

Section 6

OBJECTIVE

1. Demonstrate knowledge of DOE Order 425.1 (replacement for DOE Order 5480.31), Startup and Restart of Nuclear Facilities, with respect to nuclear safety issues.

Introduction

Ensuring that every nuclear facility is operated safely within its approved safety envelope, as defined in the facility safety basis, is paramount to the DOE. In support of this objective, the Department has established DOE Order 425.1 to standardize and promote consistency and quality of the reviews, which are used to assess the operational readiness of both new startup and existing restart nuclear facilities.

1. Demonstrate knowledge of DOE Order 425.1 (replacement for DOE Order 5480.31), Startup and Restart of Nuclear Facilities, with respect to nuclear safety issues. **6-1**

A. Discuss the purpose, scope, and applicability of DOE O 425.1.

Purpose

The purpose of DOE O 425.1 is to establish the requirements for new startup nuclear facilities and the restart of existing nuclear facilities that have been shutdown. These requirements delineate a review process which, when applied properly, will demonstrate that it is safe to startup or restart the nuclear facility.

The facility shall startup or restart, only after independent readiness reviews have been conducted, documented, and the approvals specified in DOE O 425.1 have been received.

Scope and Applicability

The provisions of DOE O 425.1 apply to all Departmental nuclear facilities except for the following exclusions:

- The Naval Nuclear Propulsion Program;
- Those activities regulated through a license by the Nuclear Regulatory Commission (NRC) or a State under an agreement with NRC;
- Nuclear explosive operations and processes (including nuclear weapons assembly and disassembly);
- Activities regulated by Department of Transportation; and,
- DOE nuclear facilities that are classified as below hazard category 3.

B. Discuss the content of the requirements section of DOE Order 425.1.

I. Overview

There are three types of readiness reviews that are conducted by the DOE: Operational Readiness Review (ORR), Readiness Assessment (RA), and Safety Evaluation (SE). (For the purpose of this module, SE will not be addressed.)

1) Operational Readiness Review (ORR)

DOE line management shall determine if ORRs are required for startup of new nuclear facilities or restart of existing nuclear facilities. DOE shall conduct an ORR, in accordance with DOE O 425.1, under the following conditions:

a) Initial startups of new nuclear facilities classified as hazard categories 1, 2, or 3;

b) Restart of a nuclear facility after an unplanned shutdown directed by DOE for safety or other appropriate reasons;

c) Restart of hazard category 1 or 2 nuclear facilities following an extended shutdown.;

d) Restart of hazard category 1 or 2 nuclear facilities following substantial process, system, or facility modifications that require changes in the safety basis previously approved by DOE;

e) Restart of a nuclear facility, which was shutdown because of operations outside the safety basis; or,

f) When deemed appropriate by DOE management officials, including restart of hazard category 3 nuclear facilities.

2) Readiness Assessment (RA)

A RA will be conducted vice an ORR when startup or restart of a program within an operating facility does not require DOE approval of changes to facility limits or requirements, as stated in Operational Safety Requirements/Technical Safety Requirements, Basis for Interim Operations/Safety Analysis Reports, or other equivalent authorization basis documents. RA protocol requires:

- DOE line management to evaluate the need for performing a RA prior to restart; and,
- Operations Offices to develop procedures and ensure that the contractors use these procedures to gain Operations Office approval prior to the startup or restart of nuclear facilities.

II. Authorization Authority

The authorization authority for startup or restart of nuclear facility shall be as follows:

Please see the table on the following page.

Figure 6-1

Startup or Restart Approval Authority

Type	Hazard Category 1	Hazard Category 2	Hazard Category 3
New Start	Secretary or Designee	Secretary or Designee	Secretarial Officer or Designee
Restart after shut-down directed by DOE management official	Commensurate with level of Official ordering Shutdown	Commensurate with level of Official ordering Shutdown	Commensurate with level of Official ordering Shutdown
Restart after extended shutdown	Secretarial Officer	Secretarial Officer or Designee	Operations Office Manager or Designee
Restart after modifications that result in change to safety basis	Secretarial Officer	Secretarial Officer or Designee	Operations Office Manager or Designee
Restart after operations outside safety basis	Approval Authority of Safety Basis	Approval Authority of Safety Basis	Approval Authority of Safety Basis

III. Operational Readiness Reviews (ORR) Requirements

(1) ORR Documentation

For ORRs, DOE line management shall require contractors to prepare the following documents:

- Startup/restart notification reports;
- Plans-of-Action;
- Operational Readiness Reviews Implementation Plans; and,
- Final reports.

DOE line management shall also prepare its own Plans-of-Action, ORR Implementation Plans, and final reports.

(2) Plan of Action (POA)

In developing the POA, the ORR team should focus on the safety envelope as defined in the FSAR/TSR. In addition, each member of the team should become familiar with the process, hazards, and controls of the facility.

DOE line management shall develop the breadth and depth of the ORR and document these elements of the review in the POA. The POA will ensure a timely, cross-cutting, independent review that addresses the requirements in a technically satisfactory manner.

During the ORR, the breadth may be expanded by the ORR team, if necessary.

The diagram illustrates the concept of breadth and depth.

Plan of Action, Breadth and Depth

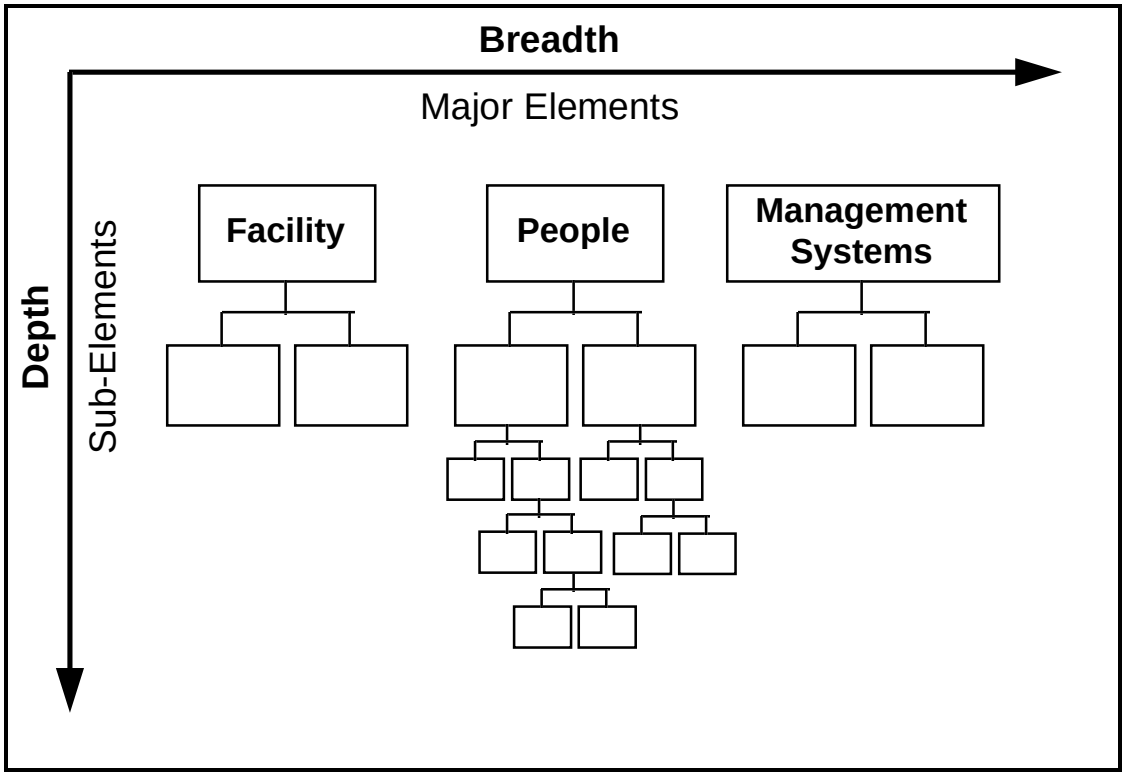


Figure 6-2

(3) Approval and Content

- The contractor and DOE ORR POA shall be approved by the startup or restart authorities.
- DOE line management shall ensure the contractor's POA specifies the prerequisites for starting the responsible contractor's ORR.
- The prerequisites shall address each element of the program determined to be applicable when developing the scope of the ORR.
- The DOE POA shall specify additional prerequisites, such as certification of readiness to oversee facility operations by Operations Office and Headquarters management.
- The DOE and contractor POA shall be provided to EH for review and comment.

The following is a list of the minimum core requirements which must be addressed when developing the breadth of an ORR. Justification shall be provided in the POA if it is determined that a particular core requirement will not be reviewed.

(1) There are adequate and correct procedures and safety limits for operating the process and utility systems.

(2) Training and qualification programs for operations and operations support personnel have been established, documented, and implemented.

(3) Level of knowledge of operations and operations support personnel is adequate.

(4) Facility safety documentation is in place that describes the safety envelope of the facility.

(5) A program is in place to confirm and periodically reconfirm the condition and operability of safety systems.

(6) A process has been established to identify, evaluate, and resolve deficiencies and recommendations made by oversight groups, official review teams, audit organizations, and the operating contractor.

(7) A systematic review of the facility's conformance to applicable DOE Orders has been performed, non-conformance identified, and schedules for compliance have been justified in writing and formally approved.

(8) Management programs are established, sufficient numbers of qualified personnel are provided, and adequate facilities and equipment are available to ensure operational support services are adequate for operations.

(9) A routine and emergency operations drill program, including program records, has been established and implemented.

(10) An adequate startup or restart test program has been developed that includes adequate plans for graded operations testing to simultaneously confirm operability of equipment, the viability of procedures, and the training of operators.

(11) Functions, assignments, responsibilities, and reporting relationships are clearly defined, understood, and effectively implemented with line management responsible for control of safety.

(12) The implementation status for DOE 5480.19, Conduct Of Operations Requirements for DOE Facilities, is adequate for operations.

(13) There are sufficient numbers of qualified personnel to support safe operations.

(14) A program is established to promote a site-wide culture in which personnel exhibit an awareness of public and worker safety, health, and environmental protection requirements and, through their actions, demonstrate a high-priority commitment to comply with these requirements.

(15) The facility systems and procedures, as affected by facility modifications, are consistent with the description of the facility, procedures, and accident analysis included in the safety basis.

(16) The technical and managerial qualifications of those personnel at the DOE Field organization and at DOE Headquarters who have been assigned responsibilities for providing direction and guidance to the contractor, including the Facility Representatives, are adequate (DOE ORR only).

(17) The breadth, depth, and results of the responsible contractor ORR are adequate to verify the readiness of hardware, personnel, and management programs for operations (DOE ORR only).

(18) Modifications to the facility have been reviewed for potential impact on procedures and training and qualification. Procedures have been revised to reflect these modifications and training has been performed to these revised procedures.

(19) The technical and management qualifications of contractor personnel responsible for facility operations are adequate.

(20) DOE Operations Office Oversight Programs, such as Occurrence Reporting, Facility Representative, Corrective Action, and Quality Assurance Programs, are adequate (DOE ORR only).

(4) ORR Teams

DOE line management shall appoint ORR teams in accordance with the following qualifications and training requirements:

- Technical knowledge of the area assigned for evaluation, including experience working in the technical area;
- Knowledge of performance-based assessment processes and methods; and,
- Knowledge of facility-specific information.

The ORR teams shall not include as senior members (including team leader), individuals from offices assigned direct line management responsibility for the work being reviewed. Additionally, no ORR team member should review work for which he or she is directly responsible.

The ORR team leaders shall determine and document qualifications of ORR team members.

(5) Criteria and Review Approaches

The DOE ORR team shall identify the criteria and review approach to be used for conducting the assessment based on the ORR breadth and depth provided in the POA. This criteria and review approach will be documented in the ORR Implementation Plan.

(6) Approve and Use of Implementation Plans

The ORR team leader shall approve the implementation plan. This plan shall be used to conduct the ORR. The implementation plan shall be provided to EH for review and comment.

(7) Certification and Verification

a) The prerequisites for starting the DOE ORR include:

- DOE line management has received correspondence from the responsible contractor certifying that the facility is ready for startup or restart and this has been verified via the contractor ORR;
- DOE line management has verified that the contractor's preparations for startup or restart have been completed; and,
- DOE line management has certified that it meets the DOE POA.

b) At the start of the DOE ORR, all actions required for startup or restart shall be complete with the exception of a manageable list of open prestart findings that have a well-defined schedule for closure. This corrective action and schedule should be reviewed by the DOE ORR team to ensure adequate closure of the findings.

During the certification and verification process, DOE Operations Office line management shall document their actions taken to verify Operations Office and contractor readiness.

c) All events significant to the startup and restart process, that occur prior to the formal commencement of the DOE ORR, shall be reviewed by the team when they are conducted.

(8) Final Report

a) Upon completion of the contractor or DOE ORR, DOE line management shall ensure a final report is prepared and approved by the ORR team leader. The final report shall document the logic of the review, convey the results of the ORR, and form the basis for recommendations and conclusions as to the readiness of the activity to proceed with the startup or restart as well as the readiness of the management system to manage and oversee the activity.

This conclusion shall be based on:

* Review of the program to document conformance with applicable DOE requirements, including a process to address new requirements; and,
* Extensive use of references to DOE requirements in the ORR documentation.

b) There shall be a “Lessons Learned" section of the final report that may relate to design, construction, operation, and decommissioning of similar facilities and future ORR efforts.

c) A sample outline of the report is as follows:

* Title Page
* Signature Page
* Table of Contents
* Executive Summary
* Introduction
* Scope
* Objective and Approach
* Findings and Conclusions
* Lessons Learned
* Appendix: Criteria for Assessment

(9) Closure of Prestart Findings

The mechanism for closure of prestart findings shall include the following:

a) Development of plans-of-action approved by DOE to correct the findings. Action plans shall provide evaluation of any overall programmatic deficiencies or root causes.

b) Documentation of completion of response actions responding to the findings in a closure package. Closure packages shall include a brief description of actual corrective actions taken and reasons for concluding that closure has been achieved.

c) DOE verification of closure of prestart findings. The organization verifying the closure will be designated by the startup or restart authority.

(10) Resolution of Prestart Findings

DOE line management shall ensure the contractor has satisfactorily resolved all prestart findings prior to startup or restart of the facility.

(11) Submit Final Report

The final report shall be submitted to the startup/restart authority to be used as basis to grant approval of the start or restart of the facility. A copy of the final report shall be provided to EH for review and comment.

IV. Readiness Assessment (RA) Requirements

(1) RA Procedures.

- Operations Offices shall establish procedures for their offices that define when a RA is required. Also, Operations Offices shall provide requirements for conducting a RA, including procedures by which contractors will gain Operations Office approval for the startup or restart of nuclear facilities.

- The procedures shall require submittal of a startup notification report for approval. Preparation of a formal POA that includes, as a minimum, the breadth of the assessment, team leader designation, and prerequisites for the assessment shall be approved by the startup or restart authority.

- For shutdowns directed by contractor management, these procedures may indicate that, except for serious safety reasons, the contractor management may be the startup or restart authority.

(2) Graded Approach

- The RA procedures shall specify a graded approach to the tenets of operational readiness requirements. The procedures should indicate that the RA may be as short and simple as a restart check procedure, or that it may approach the breadth and depth of an ORR, depending on the causes and duration of the shutdown and the modifications accomplished during the shutdown.

(3) Approval

- The startup or restart authority, the Operations Office Manager (or designee), may approve the startups or restarts after any prestart findings are corrected.

C. Discuss the responsibilities and authorities section of DOE O 425.1, with respect to implementation.

<u>Responsibilities</u>

DOE Line Management.

(1) Establish procedures as necessary to manage startup and restart actions in accordance with the requirements of the Order.

(2) Exercise delegation of authority and document all delegations of authority made under the provisions granted by the Order.

(3) Determine whether adequate protection can most effectively be achieved by continuing to operate under the terms of existing contracts, or modify the contract to incorporate the requirements of the revised Order.

(4) Determine whether implementation of new rule or Order requirements will provide adequate protection prior to requesting contract modification, which may delete some of the old Order requirements from the contract.

Assistant Secretary for Environment, Safety and Health (EH-1)

The Assistant Secretary for ES&H is to exercise independent oversight of the startup and restart process for nuclear facilities. This responsibility specifically entails the following:

(1) In coordination with the Cognizant Secretarial Officer (CSO), perform independent reviews of startup and restart activities, as appropriate. Also, provide results of these reviews to DOE ORR team leaders, Cognizant Operations Office Managers, and Cognizant Secretarial Officers for resolution.

(2) Assess the Secretarial Officer, Operations Office, and contractor procedures for startup or restart of nuclear facilities. Also, provide periodic reports to the Secretary on their effectiveness.

(3) Review and comment on contractor and DOE POA and ORR Implementation Plans for startup or restart of nuclear facilities.

(4) Review and comment on the ORR final report, and provide recommendations regarding startup or restart to the DOE startup or restart approving official.

(5) Provide opinions on the readiness of a facility to startup or restart to DOE line management or the Secretary, if a significant safety concern is not being properly corrected.

(6) If requested by the Secretary, review and concur in the final decision to startup or restart a nuclear facility.

D. Define the following terms as they relate to DOE O 425.1 and nuclear safety:

Facility Shutdown: The situation in which the reactor is taken subcritical either manually or automatically to a safe shutdown condition; or the condition in which a nonreactor nuclear facility ceases operations for which the facility was being operated and is placed in a safe condition (i.e., program work ceases).

Operational Readiness Review (ORR): A disciplined, systematic, documented, performance based examination of facilities, equipment, personnel, procedures, and management control systems to ensure that a facility will be operated safely within its approved safety envelope as defined by the facility safety basis.

Operational Readiness Review Breadth: The set of core requirements which will be evaluated by the ORR team during conduct of the ORR. (See figure 6-2 provided within the study guide under Section 6, page 6-5)

Operational Readiness Review Depth: The level of analysis, documentation, and/or actions necessary to evaluate an applicable core requirement. (See figure 6-2 provided within the study guide under Section 6, page 6-5)

Operational Readiness Review Implementation Plan: The plan developed by the ORR team describing the specifics of the approach, methodology and reporting requirements of the ORR.

Operational Readiness Review Scope: The overall magnitude of the ORR as defined by the breadth of core requirements selected and the depth of evaluation of these core requirements during conduct of the ORR.

Plan-of-Action: The high level document describing the breadth and pre-requisites of the Operational Readiness Review, the composition of the team performing the review, and the designated startup or restart authority.

Prestart Finding: A finding that must be corrected before an activity can be started. This will have first order impact on operational safety.

Readiness Assessment: A review that is conducted to determine a facility's readiness to startup or restart when an Operational Readiness Review is not required.

Unplanned Shutdown: An unplanned facility shutdown for any cause, such as equipment malfunction, personal error, on-shift operator response to indications of an unsatisfactory situation, or a situation that would have had unsafe consequences without shutdown. Also, an unplanned shutdown directed by contractor management, local DOE officials, or by Headquarters.

E. Discuss management and operating contractor responsibilities for implementing DOE Order 425.1.

DOE O 425.1 and its attachments include requirements that are to be applied to the universe of contractors involved with the startup or restart of a nuclear facility and awarded a procurement contract or a subcontract.

Contractor shall be required to establish procedures as necessary to manage startup and restart actions in accordance with the Contractor Requirements Document (CRD). DOE-STD-95 provides guidance on approaches and methods approved a acceptable for implementing the requirements of this CRD. Other approaches and methods may be used, provided that they are justified, documented, and approved as being in accordance with the requirements of this CRD by the authorization authority for startup and restart.

F. Discuss the role of Department nuclear safety personnel in implementing the requirements of DOE O 425.1.

This Order is applicable to all nuclear safety personnel who participate in an ORR or a RA as well as those who participate in the development, review, approval, and interpretation of DOE O 425.1. (Nuclear Safety personnel, as defined in this nuclear safety systems qualification standard, is anyone who provides management oversight or direction that could impact the safe operation of defense nuclear facilities.) All DOE and contractor personnel who will be a member of the readiness review teams should understand the requirements and processes outlined in this Order.

Section 6 References and Suggested Reading

References and Suggested Reading

Department of Energy, DOE Order 425.1, Startup and Restart of Nuclear Facilities, DOE, 1995

General Design Criteria
Cross-Competency Listing

The following matrix shows where the General Design Criteria portion of the Study Guide addresses particular qualification standard competencies.

DOE Qualification Standard(s)									Study Guide
Nuclear Safety Systems	Facility Mainten-ance	Electrical Systems	Mechanical Systems	Construc-tion Manage-ment	Chemical Processing	Instrum-entation and Control	Safegurds and Security	Waste Management	
NS 2.6									**Module 7-1**
NS 2.6.a						IC 2.1.a	SS 2.28.a	WM 2.5.a	Sections 1.A
NS 2.6.b		ES 2.1.f	MS 2.1.f	CM 2.1.f	CP 2.1.c	IC 2.1.b	SS 2.28.b	WM 2.5.a	1.B
NS 2.6.c									1.C
NS 2.6.d									1.D
	FM 1.22								**Module 7-2**
	FM 1.22.a								2.A
	FM 1.22.b								2.B
	FM 1.22.c								2.C

General Design Criteria

Section 7

OBJECTIVE

1. Demonstrate knowledge of the nuclear safety-related General Design Criteria requirements in DOE O 420.1 Facility Safety. (Formerly DOE 6430.1A) .
2. Demonstrate familiarity-level knowledge of safety documentation and safety-related structures, systems, and components

Introduction

The General Design Criteria section of DOE 420.1, Facility Safety (Formerly DOE Order 6430.1A), covers the specifications and industry standards for DOE facility design and construction. This Order is useful as a reference for both Contractors, and DOE personnel.

1. Demonstrate knowledge of the nuclear safety-related General Design Criteria requirements in DOE 420.1, Facility Safety (Formerly DOE Order 6430.1A)

7-1

A. Discuss the purpose, scope, and applicability of the General Design Criteria section of DOE 420.1, Facility Safety (Formerly DOE Order 6430.1A).

Purpose

The general design criteria (GDC) Order was established to provide and outline the design criteria for Departmental facilities. The Order was comprised of 16 divisions that cover the criteria that must be used in the design, construction, acquisition, or modification of all DOE owned or leased facilities. The order generally referenced accepted construction and design industry standards. The Order also outlined the responsibilities and authorities for the development and maintenance of the criteria.

Scope and Applicability

The provisions of the GDC Section apply to all Departmental Elements, and all contractors and subcontractors performing work whose contract may involve planning, design, or facility acquisitions, except as otherwise provided by statute or by specific delegation of authority from the Secretary of Energy.

B. Discuss the Department policy and objectives with respect to safety-class criteria.

The Department's policy regarding safety class items, highlights their importance. It states that:

- Safety class items shall be subject to appropriately higher-quality design, fabrication, and industrial test standards and codes, to increase the reliability of the item and allow credit to be taken for its capabilities in a safety analysis.
- Safety class items shall be designed to the ASME Boiler and Pressure Vessel Code (Section III, Class II) or to other comparable safety-related codes and standards that are appropriate for the system being designed.
- Safety class and non-safety class items shall comply with the Quality Assurance Section 0140.
- Failure of non-safety class items shall not adversely affect the environment or the safety and health of the public. In addition, their failure shall not prevent safety class items from performing their required functions.

C. Discuss the responsibilities and authorities section of the General Design Criteria section of DOE 420.1, Facility Safety (Formerly DOE Order 6430.1A), with respect to implementation.

Since the Assistant Secretary if Management and Administration is responsible for the development of budget, accounting, procurement, cost estimating, construction, facilities management, site development, real estate, project management, and business related policy, the GDC implementations fall under his or her responsibilities. These responsibilities are typically carried out by the Deputy Assistant Secretary for Administration through the Director of Project and Facilities Management, and include:

1) Establishing the GDC Planning Board, the DOE advisory group of major Headquarters and field organizations involved in the construction of facility acquisitions, which includes those organizations having planning, design, construction, environmental, safety and health, research, operations, and maintenance functions.

2) Serving as the Department's focal point for the development, maintenance, and interpretation of the GDC.

3) Utilizing, as needed, technical advice and assistance of criteria users, support contractors, and consultants to develop and maintain criteria for specialized areas.

4) Providing, when requested, technical advice and assistance to other Departmental organizations on matters relating to planning, design, and construction of facilities.

5) Assuring, through the GDC Planning Board, that proposed criteria revisions and additions of a substantive nature are reviewed with all appropriate Headquarters and field organizations.

6) Participating with responsible Headquarters organizations, in reviewing and adopting comments received on their particular areas of responsibility.

7) Maintaining liaison with other Federal agencies, the architect-engineer professions, and the construction industries on current practices, procedures, criteria, and standards being applied to facility design and construction.

Others in the Department also have responsibilities for GDC implementation including those Heads of Headquarters and Field Organizations having responsibilities for construction project planning and design, or facility acquisitions. These responsibilities include:

- Assuring that the GDC are applied throughout the planning and design of each construction project under his or her cognizance, whether contracted for by the Department or through the Department's management and operating contractors. The GDC shall be applied in the development of site-specific general design criteria, specific project design criteria, and technical specifications for facilities.
- Serving or appointing a member on the GDC Planning Board, and through that advisory body:
  - ◊ Recommends criteria revisions and additions to the Director of Project and Facilities Management; and
  - ◊ Provides technical input, advice, and assistance during revision or expansion of the criteria.

D. Discuss the content of the general requirements section of Division 13 - Special Facilities of the General Design Criteria section of DOE 420.1, Facility Safety (Formerly DOE Order 6430.1A).

The general requirements section of Division 13 of the GDC includes the following subsections:

- Coverage
- Using Division 13
- Objectives
- Guidance on Limiting Exposure to the Public

Coverage
Coverage of the GDC Special facilities as used in Division 13 include the following:

- Nuclear facilities as defined in DOE 5480.5; and,
- Explosives facilities.

The criteria in the General Requirements section of Division 13, apply to all nonreactor nuclear facilities and to explosives facilities. Subsequent sections provide additional criteria that are applicable to specific types of nonreactor nuclear facilities and to explosives facilities. Reactors and their safety systems shall be cited and designed according to DOE 5480.6.

There may be some facilities for which these criteria are not sufficient and for which additional criteria must be satisfied in the interest of safety.

Some criteria may be determined by safety analysis to be unnecessary or inappropriate for a specific facility. For facilities such as these, departures from the criteria shall be identified and justified.

Using Division 13

Guidelines and codification notes for using Division 13 are also included in the general requirements section. The other divisions of the GDC correspond to the CSI MASTERFORMAT organization, which reflects the major building systems and design specialties. Criteria for special facilities in other divisions are noted with a numerical designation of "-99."

For example, Division 15, Mechanical, contains mechanical criteria that apply to all DOE facilities, both non-special and special. Mechanical criteria for all facilities are numbered 15xx. In addition, mechanical criteria that apply only to special facilities are numbered 15xx-99. For the specific numerical designations for each type of special facility please refer to section 1300.1.2 of the GDC.

The remaining sections of Division 13 cover nonreactor nuclear facilities and explosives facilities criteria that do not relate to the major building systems or other design specialties covered in the other divisions. When designing these facilities, Division 13 criteria shall be applied in addition to applicable criteria in other divisions.

Objectives

The objectives section of general requirements outlines general guidelines and statements with regard to safety of special facilities. This includes:

1) The protection of the public and facility personnel from hazards associated with the use of radioactive and other hazardous materials as a result of normal operations, anticipated operational occurrences, and DBA (Design Basis Accidents) conditions, including the effects of natural phenomena pertinent to the site, and maintain these effects ALARA (as low as reasonably achievable).

2) Ensuring compliance with DOE policies regarding nuclear safety, criticality safety, radiation safety, explosives safety, industrial safety, fire protection, environmental protection, and Safeguards and Security (S&S) protection for special nuclear material.

3) The protection of government property and essential operations from the effects of potential accidents.

4) The minimization of personnel and the general public exposure to hazardous materials by emphasizing ALARA concerns during all design, construction, and operational phases of special facilities.

5) The design of new or modification of existing special facilities shall address the health hazards represented by all hazardous materials in enclosures, general work areas, and non-contaminated areas.

6) The release of hazardous materials under normal operating conditions and anticipated operational upset occurrences shall be designed to be less than release guideline limits contained in applicable orders, regulations, and requirements. In addition, to the extent practical, such releases shall be maintained ALARA.

7) Consideration shall be given to the frequency of occurrence and the effects of DBAs in the design features of special facilities. The depth of the risk analysis involved in this consideration should be in some measure proportional to the level of risk at the facility under consideration.

8) Protection of employees within the facility and at nearby facilities shall be a requirement in all aspects of the design.

9) Design goals shall be established to maintain radiation exposure of employees ALARA. The nature of the hazardous materials in the facility, including radionuclides, shall be considered in the assessment of potential employee exposure.

Guidance on Limiting Exposure to the Public

GDC, Division 13, General Requirements section outlines basics for limiting exposure to the public, including the following:

General: The confinement of hazardous materials produced, processed, or stored in special facilities shall be designed to minimize dose to a maximally exposed member of the public.

Accidental Releases: Releases of hazardous materials as a result of DBAs shall be limited by designing facilities such that at least one confinement system remains fully functional following any credible DBA. To the extent practical, ALARA concepts shall be applied when designing special facilities to mitigate post-DBA releases of hazardous materials. For facilities whose hazard potential is determined to be extremely low, deviations from the criteria of this section may be considered in accordance with GDC Section 0101-2, Criteria Deviations.

Routine Releases: The annual dose resulting from postulated, planned, or expected releases from the proposed facility shall be considered in combination with the annual doses resulting from planned or expected releases from other facilities at the same site. The sum of the doses from the site shall be limited according to DOE Radiation Standards of Protection of the Public in the Vicinity of DOE Facilities or subsequent guidance included in the directive on Radiation Protection of the Public and the Environment in the DOE 5400 series.

Monitoring of Releases: Releases shall be monitored in accordance with the directive on Radiological Effluent Monitoring and Environmental Surveillance in the DOE 5400 series.

7-2

2. Demonstrate knowledge of safety documentation and safety-related structures, systems, and components.

A. Identify safety-related structures and systems.

Safety-Class Structures Systems, and Components (SSCs):

Safety Class Systems, structures, or components are those items whose failure could adversely affect the environment or safety and health of the public as identified by the safety analysis. Specifically, safety class items are those SSCs with the following characteristics:

1) Those whose failure would produce exposure consequences that would exceed the guidelines in GDC Section 1300-1.4, Guidance on Limiting Exposure of the Public, at the site boundary or nearest point of public access;
2) Those required to maintain operating parameters within the safety limits specified in the OSRs during normal operations and anticipated operational occurrences;
3) Those required for nuclear criticality safety;
4) Those required to monitor the release of radioactive materials to the environment during and after a DBA;
5) Those required to achieve and maintain the facility in a safe shutdown condition; and
6) Those that control the safety class items described above.

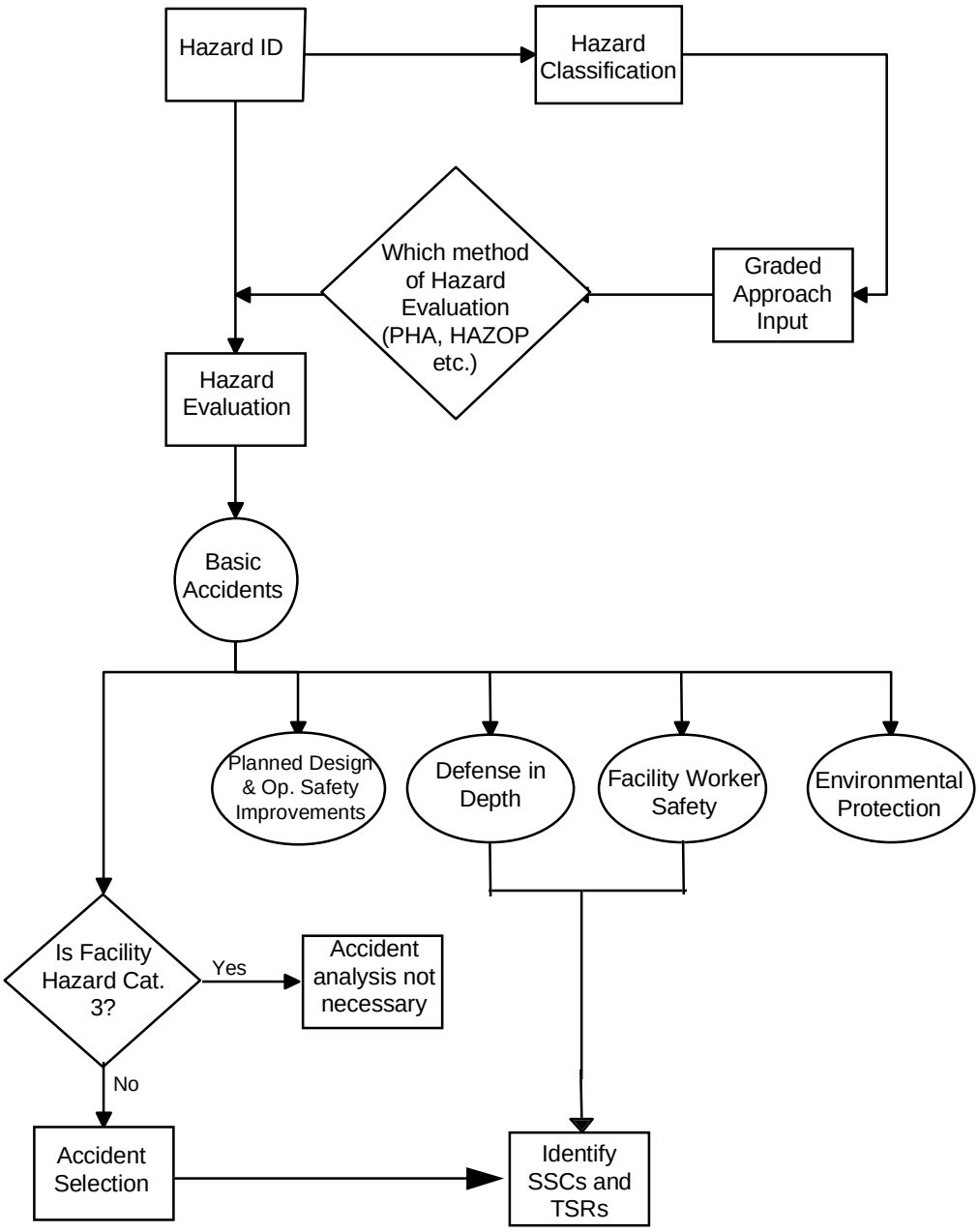
Safety-Significant Structures, Systems and Components:
Those systems not designated as safety-class, but whose preventive or mitigative function is a major contributor to defense in depth (i.e., prevention of uncontrolled material releases) and/or worker safety as determined from hazard analysis. As a general rule of thumb, safety-significant SSC designations based on worker safety are limited to those structures, systems, or components whose failure is estimated to result in an acute worker fatality or serious injuries to workers. Considerations should be based on engineering judgment of possible effects and the potential added value of safety-significant SSC designation.

B. Describe the process used to identify safety-related structures, systems, and/or components.

Safety related items are identified from an analysis of the hazard and accidents associated with a particular facility and its requisite operations. The following chart demonstrates a simplified version of the process.

Hazard Analysis and SSC Identification

Figure 7-1



C. Discuss the special requirements placed on safety-related structures, systems, and components.

Requirements imposed by DOE Order 6430.1A - 1300-3.0 Include:

Single Failure Criterion and Redundancy

The design shall ensure that a single failure does not result in the loss of capability of a safety class system to accomplish its required safety functions. A single failure is an occurrence that results in the loss of capability of a SSC to perform its intended safety function(s). The loss of capability of several components, resulting from a single occurrence are considered to be a single failure. To protect against single failures, the design shall include appropriate redundancy and shall consider diversity to minimize the possibility of concurrent common-mode failures.

Equipment Environment Considerations

General

Safety class items shall be designed to withstand the effects of, and be compatible with, the environmental conditions associated with operation, maintenance, shutdown, testing, and accidents. The environmental capability of equipment shall be demonstrated by appropriate testing.

Environmental Qualification of Equipment

Equipment qualification shall provide assurance that safety class items will be capable of performing required safety functions under DBA conditions. The qualification shall demonstrate that the equipment can, at minimum, perform for the period of time that its safety functions are required. Temperature, pressure, and humidity environments shall be based on the most severe postulated accident affecting the particular item.

Equipment Operability Qualification

Testing or a combination of testing and analysis shall be the preferred method of demonstrating the operability of fluid system components, mechanical equipment, instrumentation, and electrical equipment that are required to operate during and following a DBA. Seismic experience data maybe used as an alternative to testing or dynamic analysis where such data have been documented and validated.

Maintenance

The design shall consider the maintainability factors peculiar to the specific equipment to be used in the facility. Facility design shall provide for routine maintenance, repair, or replacement of equipment subject to failure.

Safety class items shall be designed to allow:

- inspection;
- maintenance; and
- testing to ensure functionality, readiness for operation, and accuracy.

Ancillary equipment, such as pumps, blowers, motors, compressors, gear trains, and controls, shall be located in an area least likely to be contaminated.

The design of equipment that must be located within confinement systems shall allow for in-place maintenance or replacement. This capability shall include the necessary provisions for confinement, ventilation, and waste control.

Testing

The design shall include provisions for periodic:

- Monitoring;
- Surveillance; and
- Testing of alarm systems.

The design shall provide a means for periodic testing of those safety class SSCs, that are required to function during emergency conditions, under simulated emergency conditions.

Section 7 References and Suggested Reading

References and Suggested Reading

Department of Energy, DOE Order 6430.1A General Design Criteria, DOE, 1989

Department of Energy, DOE Order 5481.1 Safety Analysis and Review Systems, DOE, 1986

Department of Energy, DOE Standard 1027-92 Hazard Categorization and Accident Analysis Techniques, DOE, 1992

Department of Energy-Albuquerque Operations Office, Safety Documentation; Authorization Basis for Facility Representatives, Course workbook, DOE, 1996

Manual of Functions, Assignments, and Responsibilities Cross Competency Listing

The following matrix shows where the FAR Manual portion of the Study Guide addresses particular qualification standard competencies.

DOE Qualification Standard	Study Guide
Environment Safety & Health Resident	
EH 2.21	**Section 8-1**
EH 2.21.a	Parts 1.A
EH 2.21.b	1.B
EH 2.21.c	1.C
EH 2.21.d	1.D
EH 2.21.e	1.E
EH 2.21.f	1.F

Manual of Functions, Assignments, and Responsibilities

Section 8

OBJECTIVE

1. Demonstrate knowledge of the functions, assignments, and responsibilities of all levels of DOE personnel as defined in the Manual of Functions, Assignments, and Responsibilities for Nuclear Safety.

Introduction

The Manual of Functions, Assignments, and Responsibilities (FARs) is a resource that can be used to reference duties relating to nuclear safety for specific positions in the Department. The manual is primarily a compilation of the Responsibilities and Authorities sections of DOE nuclear safety Orders.

1. Demonstrate knowledge of the functions, assignments, and responsibilities of all levels of DOE personnel as defined in the Manual of Functions, Assignments, and Responsibilities for Nuclear Safety.

8-1

A. Discuss the purpose of the Manual of Functions, Assignments, and Responsibilities (FAR) for Nuclear Safety.

Purpose

The FAR Manual identifies DOE directives that relate to nuclear safety and the specific DOE personnel who are responsible for implementing them. The manual includes only FARs that have been extracted from active directives that have been approved in accordance with the procedures contained in DOE Order 1321.1B.

Current DOE directives, including Orders, Secretary of Energy Notices, and other assorted policy memoranda, are the source of this information and form the basis of the FAR Manual.

B. Given a copy of this manual, discuss the format and content of the manual.

The FAR Manual is organized into 11 sections. Within each category/section, the FARs are arranged alphabetically by individual and numerically by DOE Order number. Because of its central importance to nuclear safety, DOE 5480.1B appears at the beginning of every section to which it applies.

Figure 8-1

Manual of Functions, Assignments, and Responsibilities for Nuclear Safety

Section	Title	Contents
1.	Introduction	Information about the FAR Manual and its contents
2.	Under Secretary	Responsibilities assigned to the Under Secretary of Energy
3.	All Cognizant Secretarial Officers	Responsibilities common to all CSOs
4.	Specific Cognizant Secretarial Officers	Responsibilities assigned to particular CSOs
5.	Other Headquarters Elements	Responsibilities assigned to Headquarters Elements other than CSOs
6.	Assistant Secretary for Environment, Safety, and Health	Responsibilities assigned to the Assistant Secretary
7.	All Managers of Field Offices	Responsibilities common to all managers of DOE field offices (M-FOs)
8.	Specific Managers of Field Offices	Responsibilities assigned to the particular M-FOs
9.	Other Field Elements	Responsibilities assigned to field elements other than M-FOs
10.	Citations	Cross-reference to the sources of the citations FAR for nuclear safety
11.	Appendices Appendix A Appendix B Appendix C Appendix D	Appendix A - DOE Orders included in the Manual. Appendix B - Sources, other than DOE Orders. Appendix C - Verbs used in the text and their restricted definitions. Appendix D - Procedures for submitting comments on the FAR Manual.

C. Given a copy of the manual, identify the sources used to compile the manual.

Appendix A and B contain the references and sources used to compile the manual.

Section 10, Citations, contains each category cross-referenced with the source materials.

D. Describe the procedure for submitting comments to the manual.

The FAR Manual will be periodically reviewed and updated, and revised versions will be published on a regular basis. The manual will provide DOE managers with an up-to-date, published record of nuclear safety functions, assignments, and responsibilities (FARs).

To submit comments regarding the FAR Manual, complete the Comment Form provided in the manual (Appendix D), and mail or fax it directly to the Office of Organization and Management, HR-6.

Comments that address the following issues are of particular interest:

- Additional DOE Orders or other documents to be considered as sources of nuclear safety FARs.
- Contribution of a specific nuclear safety FAR. Submit references citing the source of any new FAR submitted for consideration.
- Comments on a published FAR. Cite the number of the FAR to which your comment pertains.
- Comments on Terminology. The terminology in the manual has been standardized. The FAR Manual contains lists of abbreviations and acronyms and definitions of initial verbs to assist the reader. Comments on terminology should cite the number of the FAR to which it pertains.

E. Given a specific Department position and the manual, identify that person's function, assignment, and responsibility with regard to a specific DOE Order or other source contained in the manual.

Since the manual is arranged into sections by position, it is not difficult to locate a position and refer to its FARs. The FARs are listed numerically by source. For example:

Determine the responsibilities of the Field Manager of the Albuquerque Operations Office regarding DOE Order 5610.11 Nuclear Explosive Safety.

- Use the table of contents and note that there are two sections that should be referenced: Section 7, Responsibilities of All Field Office Managers, and Section 8, Responsibilities of Specific Field Office Managers.

- Turning to Section 7, follow the section table of contents (organized numerically by DOE Order) and see if 5610.11 is listed. It is not, so there is no FAR in 5610.11 applicable to all Field Office Managers.

- Now using the table of contents for Section 8, find the Albuquerque Operations Office Field Manager heading. Finding the sub-heading 5610.11 note that those FARs can be found on page 10.

F. Given a scenario concerning an issue and a copy of the manual, determine the responsibilities of each Departmental management position.

Section 10 Citations, provides a cross-reference to the sources of the citations for each FAR. The section contains a table with the first column, listing the serial number of the FAR and the position to which the FAR is assigned. The second column lists the sources for each FAR, and the third column lists the page of the manual where the FAR appears.

If an electronic copy of the manual is available, a simple sort of the second column will arrange the table by DOE Order. If only a hard copy is available, use the table to find which specific Order is listed for each position.

If given a situation, for example, who approves the Authorization Basis for a DOE non-reactor nuclear facility, one must first determine which DOE directives pertain to that subject. To simplify this example, assume the Authorization Basis is documented by the Safety Analysis Report (SAR), The Technical Safety Requirements (TSR) and Unreviewed Safety Questions (USQ). Determine which Orders pertain to those items (SAR= 5480.23, TSR= 5480.22, and USQ= 5480.21). Use the table in section 10 to find all the FARs relating to those Orders. Turn to the noted pages and compile the information.

References and Suggested Reading

Department of Energy, The DOE Manual of Functions, Assignments, and Responsibilities, DOE, 1994

Section 8 References and Suggested Reading

Related Regulations
Cross-Competency Listing

The following matrix shows where the Related Regulations portion of the Study Guide addresses particular qualification standard competencies.

DOE Qualification Standard(s)			Study Guide
Nuclear Safety Systems	Facility Maintenance	Waste Management	
NS 3.3			**Section 9-1**
NS 3.3.a	FM 3.2.a		Parts 1.A
NS 3.3.b	FM 3.2.d		1.B
NS 3.3.c			1.C
NS 3.3.d			
NS 3.3.e			
NS 2.11			**Section 9-2**
NS 2.11.a			Parts 2.A
NS 2.11.b			
NS 2.11.c			
NS 2.11.d			
NS 2.11.e			
NS 3.2		**WM 2.10**	**Section 9-3**
NS 3.2.a		WM 2.10.a	Parts 3.A
NS 3.2.b		WM 2.10.b	3.B
NS 3.2.c			3.C

Nuclear Safety Related Regulations, Rules, Orders, and Agreements

Section 9

OBJECTIVES

1. Demonstrate knowledge of nuclear safety-related data and information management requirements in accordance with the requirements of applicable DOE Orders.
2. Demonstrate knowledge of the Price-Anderson Amendment Act of 1988 and its impact on DOE nuclear safety activities.
3. Demonstrate knowledge of the general principles associated with the development, negotiation, and management of agreements.

Introduction

There are several related Rules, Regulations and Orders that apply to nuclear safety and nuclear safety documentation. It is important to understand all of these interrelated requirements, and how they apply to the Department.

9-1

1. Demonstrate knowledge of nuclear safety-related data and information management requirements in accordance with the requirements of applicable DOE Orders.

A. Describe the authorized disposition requirements for nuclear safety-related records in DOE Order 1324.2B, Records Disposition.

The disposition of records involving safety-related issues must be executed according to DOE Order 1324.2B.

Occurrence report files maintained by HQ of considerable public or congressional interest are considered permanent records and can not be destroyed. They must be transferred to the National

Glossary of Terms

Glossary of Terms

Absorption Reactions	Neutron-nucleus interactions that result in the capture of a neutron into a nucleus, coupled with the emission of a charged particle or gamma ray. Capture, particle ejection, and fission are all categorized as absorption reactions.
Alpha Decay	Occurs with the ejection of an alpha particle (energetic helium nucleus) from the parent nucleus, causing the parent nucleus mass number (A) to decrease by 4 and the atomic number (Z) to decrease by 2.
Atomic Number	The number of protons in the nucleus of an atom. The symbol for atomic number is Z.
Authorization Basis	Those aspects of the facility design basis and operational requirements relied upon by DOE to authorize operation. The Authorization Basis is described in documents such as the facility SAR and other safety analysis documentation
Beta-Minus Decay	The emission of Beta minus particle or a negatively charged electron from the nucleus.
Beta-Plus Decay	The emission of a positively charged electron (also known as a positron) from the nucleus of an atom.
Beyond Design Basis Accident	An accident of the same type as a design basis accident, but defined by parameters that exceed in severity the parameters defined for the design basis accident. The same correlation applies to beyond derivative design basis accidents with regard to derivative design basis accidents.
Binding Energy	The energy required to break up a nucleus into its component protons and neutrons.
Burnable Neutron Poison	A material that has a high neutron absorption cross section that is converted into a material of relatively low absorption cross section as the result of neutron absorption.

Learning Activity to Competency Matrix

Learning Activity-to-Competency Matrix

Study Guide Section	Functional Area Competency	Activity Title	Activity Source
1-1 1-2 1-3 Nuclear Fundamentals	GTB 1.1, GTB 1.2, GTB 1.3	Facility Representative Technical Training	DOE, Albuquerque Operations, Qualification and Training Division
2-1 2-2 2-3 2-4 Nuclear Criticality Safety	NS 1.3, NS 1.4, NS 2.5, NS 2.9, NES 2.10	Criticality Safety	Brookhaven National Lab (Engineering)
		Fundamentals of Criticality Safety for Plutonium Handlers	Lawrence Livermore National Laboratory
		Nuclear Criticality Safety (24 Hrs)	DOE, HR-21 HQ Washington DC.
		Nuclear Criticality Safety for Fissile Material Handlers	FERMCO
		Nuclear Criticality Safety Short Course	Savannah River Operations Office
2-1 2-3 2-4 Nuclear Criticality Safety	NS 1.3, NS 1.4, NS 2.9	Nuclear Criticality (24 Hrs)	Los Alamos National Laboratory
2-5 Criticality and Nuclear Explosive Applications	NES 1.3	Nuclear Explosive Oriented Nuclear Criticality Safety (8 Hrs)	DOE, Albuquerque Operations, Qualification and Training Division.

Study Guide Section	Functional Area Competency	Activity Title	Activity Source
3-1 3-2 3-4 SARs	NS 1.6, NS 2.4, GTB 7.1, CM 2.8, ES 2.8, FM 2.9, I&C 2.13, MS 2.6, PM 2.6, CP 2.6, RP 2.4	Safety Analysis Report for Defense Waste Process Facility (DWPF)	Savannah River Operations Office
		SRSPO Self Study of the Safety Analysis Report	Savannah River Operations Office
3-1 3-2 SARs	NS 1.6, NS 2.4, GTB 7.1, NES 2.9, CM 2.8, ES 2.8, FM 2.9, I&C 2.13, MS 2.6, NS 2.5, PM 2.6, CP 2.6	Annual Safety Analysis Workshop (40 Hrs.)	Lockheed Martin Idaho Technologies
3-2 3-3 3-4 4-1 7-2	NS 1.7, GTB 7.1, FM 1.22	DOE Standard 3009-94: Conceptual Basis and Hazard and Accident Analysis Processes (24 Hrs)	DOE Defense Programs (DP-31)
3-2 3-3 3-4 4-1 7-2	NS 1.7, GTB 7.1, FM 1.22	Hazard /Accident Analysis to Meet Nonreactor Nuclear Safety Analysis Requirements (24 Hrs)	Technology and Safety Assessment Div. Los Alamos National Lab.
3-2 3-3 SARs and Haz./Accident Analysis	NS 1.7	Hazard and Accident Analysis (24 Hrs.)	Technology and Safety Assessment Div. Los Alamos National Lab.
4-1 3-4 2-3 5-1	GTB 7.1, NES 2.8, CM 2.7, ES 2.7, FM 2.8, I&C 2.12, MS 2.5, NS 2.3, PM 2.5, RP 2.11, CP 2.5, RP 2.4, NS 2.9	Applying Codes and Standards at DOE Facilities	General Physics Corporation

Study Guide Section	Functional Area Competency	Activity Title	Activity Source
4-1 TSR's	NES 2.8, CM 2.7, ES 2.7, FM 2.8, I&C 2.12, MS 2.5, NS 2.3, PM 2.5, RP 2.11	Preparing and Reviewing Technical Safety Requirements (TSR) Training Course	Savannah River Operations Office
		Technical Safety Requirements Course "TSR"	Trainer Net # TNID1103
5-1 5-2 5-3 USQs	NES 2.7, CM 2.6, ES 2.6, FM 2.7, I&C 2.11, MS 2.4, NS 2.2, PM 2.4, CP 2.4, TM 1.6, WM 1.7, GTB 7.1	Unreviewed Safety Question Training Course	DOE-HQ (NE-73) {Westinghouse Savannah River Corp.}
		Unreviewed Safety Questions (24 Hrs)	DOE, Albuquerque Operations, Qualification and Training Division.
		Unreviewed Safety Questions - USQD	Savannah River Operations Office
6-1 Start-up and Restart	NS 2.7	Operational Readiness Evaluation	EG&G Idaho, Inc. Systems Safety Development Center (SSDC)
		Operational Readiness Review	Lockheed Martin Idaho Technologies
		Operational Readiness Review (8 Hrs)	Jason Associates Corporation, Idaho Falls, ID.
		Operational Safety Requirements and Technical Specifications	Savannah River Operations Office

Study Guide Section	Functional Area Competency	Activity Title	Activity Source
7-1 7-2 General Design Criteria	NS 2.6, FM 1.22	An overview of DOE Order 6430.1A General Design Criteria (GDC)	Westinghouse Hanford Corp
8-1 FAR Manual	EH 2.21	Manual of Functions, Assignments and Responsibilities (FAR)	DOE Office of Organization and Management (HR-6)
9-1 ,9-3	NS 3.2, NS 3.3	Records Disposition	Federal Records Center

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Chemical Shim	A soluble neutron poison that is circulated in the coolant during normal operation.
Critical Energy (for fission)	The minimum excitation energy required for fission to occur.
Criticality	The state of a system of fissionable material where on average exactly one of the several neutrons emitted during a fission event causes another fission event to occur.
Criticality Accident	The release of energy as a result of accidentally producing a self sustaining or divergent neutron chain reaction; or, an inadvertent nuclear chain reaction in a non-reactor environment.
Criticality Incident	The release of energy as a result of accidentally producing a self sustaining or divergent neutron chain reaction.
Criticality Safety Evaluations	M&O contractors responsible for their nuclear facilities are required to perform and document detailed nuclear criticality safety analysis. The facility SAR shall contain a criticality safety section including the following: Detailed descriptions of all equipment and facilities in which a criticality hazard may exist; Descriptions of all the fissionable materials and process to be used including; maximum quantities, collection, handling, and transportation; Analysis of all criticality scenarios and their safety control parameters; Descriptions of all criticality alarm systems (CAS) and emergency procedures.
Curie (Ci)	A unit of measure used to describe the actively (A) of atoms in a specimen.
Design Basis	The set of requirements that bound the design of structures, systems and components within a facility. Areas included are; seismic qualifications, fire protection, and safe shutdown.
Design Basis Accidents (DBA)	A postulated accident that establishes design and performance requirements for systems, structures, and components important to safety.

Double Contingency Principle	Process designs must incorporate sufficient safety factors so that at least two unlikely, independent and concurrent changes in process conditions must occur before accidental nuclear criticality is possible.
Elastic Scattering	A reaction between a neutron (or another nucleus) and a target nucleus, where there is no energy transferred into nuclear excitation. Momentum and kinetic energy of the system are conserved.
Electron Capture	Occurs when a nucleus absorbs or captures an electron from one of the inner orbits of the atom and the electron combines with a proton to form a neutron.
Electrostatic Forces	As described by Coulomb's Law, exist between charged particles (protons +1) within a nucleus
Engineered Safety Features	Systems, components, or structures that prevent and/or mitigate the consequences of all potential accidents including the bounding design basis accidents.
Enrichment	The percentage of a fissile isotope contained in the nuclear material to be used as fuel or critical mass; or, the process of increasing the percentage of a fissile isotope to create fuel or a critical mass.
Evaluation Guidelines	Hazardous material dose/exposure values that the safety analysis is evaluated against. Theoretically, individual doses/exposures exceeding the Evaluation Guideline should not occur at a given point inside the evaluation area.
Excitation Energy	The measure of how far the energy level of a nucleus is above its ground state.
Fertile Material	Materials that can undergo transmutation to become fissile materials.
Fissile Material	Material for which exhibit a preference for fission by slow or thermal neutrons. Fission with fast neutrons is also possible but is less likely than with slow neutrons.
Fission	An absorption reaction in which the nucleus that absorbs the neutron splits into two similarly sized parts.

Fissionable Material	Materials composed of nuclides for which fission is possible with neutrons of any energy level.
General Design Criteria (GDC)	DOE Order 6430.1A, General Design Criteria, covers the specifications and industry standards for DOE facility design and construction. This Order is useful as reference for both Contractors, and DOE personnel.
Graded Approach	Application of guidelines 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 environment, safety, and health impact.
Hazard	The existence of a source of danger which could cause illness, injury, or death to personnel, or, damage to a facility, or the environment.
Hazard Category 1	A hazard analysis shows the potential for significant offsite consequences. This classification is primarily reactors capable of operating at a steady state power level greater than 20 megawatts.(Class A reactor)
Hazard Category 2	A hazard analysis shows the potential for significant onsite consequences. A release of materials from a category 2 facility would result in exposures greater than that of 1 REM at 100 meters.
Hazard Category 3	A hazard analysis shows the potential for only significant localized consequences. Minimum threshold values for a category 3 facility would result in less than a 10 REM exposure at 30 meters over a 24 hour period.
Heterogeneity	An alloy or solution containing different fissionable materials. Heterogeneous materials typically have a higher critical mass than do homogenous materials.
Inelastic Scattering	An absorption reaction in the incident neutron is absorbed by the target nucleus, forming a compound nucleus. The compound nucleus will then emit a neutron of lower kinetic energy which leaves the original nucleus in an excited state. The nucleus typically undergoes one or more gamma emissions to drop from its excited state to its ground state.

Interaction	Occurs when neutrons from one fissionable system can travel into and interact with another fissionable system.
Isotope	Nuclides with the same atomic number (protons) but a different number of neutrons are isotopes of the same element.
Limiting Conditions for Operations (LCO)	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.
Limiting Control Settings (LCS)	The settings on process variables associated with safety systems that control the facility function and will prevent exceeding the associated safety limits.
Manual of Functions, Assignments and Responsibilities (FAR)	The Manual of Functions, Assignments, and Responsibilities (FARs) is a resource that can be used to reference duties relating to nuclear safety for specific positions in the Department. The manual is primarily a compilation of the Responsibilities and Authorities sections of DOE nuclear safety Orders.
Margin of Safety	That margin built into the safety analyses of the facility as set forth in the authorization basis acceptance limits. The facility's safety envelope can be graphically represented as:
Mass Defect	The sum of the mass of nucleons and electrons of an atom is greater than the actual mass of the atom, which is due to the conversion of mass into binding energy when the nucleus is formed.
Mass Number	The number of protons and neutrons in the nucleus of an atom. The symbol for mass number is A.
MeV	Mega Electron Volts
Minimum accident of concern	A smallest accident a criticality alarm system is required to detect; a criticality accident such as this would produce ~10^{15} fissions in its first minute and provide an absorbed dose in free air of 20 rad at 2 meters if no significant shielding were present.

Mitigating Features	Any structure, system, or component that serves to mitigate the consequences of a release of radioactive or other hazardous materials in an accident scenario.
Moderation	The slowing down of neutrons to thermal velocities.
Neutron Poisons	Are non-fissionable atoms that are effective at capturing or absorbing neutrons.
Non-Burnable Neutron Poison	Is a material that has relatively constant neutron absorption characteristics over core life. The absorption of a neutron by one isotope in the material produces another isotope that also has a high absorption cross section.
Non-Reactor Nuclear Facility	A nuclear facility excluding reactors and accelerators.
Nuclear Criticality Accident	An unintentional, uncontrolled nuclear fission chain reaction.
Nuclear Criticality Safety	The prevention or termination of inadvertent nuclear criticality and protection against injury or damage due to an accidental nuclear criticality.
Nuclear Facility	A facility that conducts activities or operations that involve radioactive and/or fissionable materials in such form and quantity that a nuclear hazard potentially exists to the employees or the general public. Included are reactors and accelerators.
Nuclear forces	A strong attractive nuclear force exists between all nucleons regardless of charge. The strong nuclear force has a very short range and acts over distances approximately equal to the diameter of a nucleus, is non-central and exhibits saturation.
Nuclide	Each type of atom that contains a unique combination of protons and neutrons is call a nuclide.
Operational Readiness Review (ORR)	A disciplined, systematic, documented, performance based examination of facilities, equipment, personnel, procedures, and management control systems to ensure that a facility will be operated safely within its approved safety envelope as defined by the facility safety basis.

Preventive Features	Any structure, system, or component that serves to prevent the release of radioactive or other hazardous material in an accident scenario.
Radioactive Equilibrium	Radioactive equilibrium exists when a radioactive nuclide is decaying at the same rate at which its being produced. Since the production rate and the decay rate are equal, the number of atoms remains constant over time.
Radioactive Half Life	The radioactive half life of a specific isotope is the amount of time required for half of the atoms of the isotope to undergo radioactive decay. After half of the atoms have decayed the activity will also be half of the original activity.
Radioactivity	A property of some nuclides characterized by the spontaneous emission of particles (Alpha, Beta or Neutron) and/or electromagnetic particles.
Readiness Assessment (RA)	A review that is conducted to determine a facility's readiness to startup or restart when an Operational Readiness Review is not required.
Risk	The quantitative or qualitative expression of possible loss that considers both the probability that hazard will cause harm and consequences of that event.
Safety Analysis	A Safety Analysis is a process to: systematically identify hazards of a DOE operation, analyze and evaluate potential accidents and their risks, and describe and analyze the adequacy of hazard control measures.
Safety Analysis Report (SAR)	SAR Documents the results of the safety analysis and describes the facility or activity; its design features, construction standards, operational modes; and accident analysis.
Safety Basis	The information relating to the control of hazards at a nuclear facility upon which DOE depends for its conclusion that activities at the facility can be conducted safely.

Safety Evaluation Report (SER)	A record of the review of a "change" as required by DOE 5480.21. This document records the scope of the evaluation and the logic used when determining whether or not an Unreviewed Safety Question exists.
Safety Limits (SL)	A limit 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 material.
Safety-Class Structures Systems, and Components (SSCs)	Systems, structures, or components whose failure could adversely affect the environment or safety and health of the public as identified by the safety analysis.
Single Failure Criterion and Redundancy	The design shall ensure that a single failure does not result in the loss of capability of a safety class system to accomplish its required safety functions.
Technical Safety Requirements (TSR)	TSRs define the conditions, safe boundaries, and management or administrative controls necessary to ensure the safe operation of a nuclear facility.
Unplanned Shutdown	An unplanned facility shutdown for any cause, such as equipment malfunction, personal error, or on-shift operator response to indications of an unsatisfactory situation, or a situation that would have had unsafe consequences without shutdown. Also, an unplanned shutdown directed by contractor management, local DOE officials, or by Headquarters.
Unreviewed Safety Questions (USQs)	The Unreviewed Safety Question Process allows contractors to make certain physical and procedural changes without prior DOE approval. The changes must not affect any items explicitly or implicitly identified in the facility authorization basis, or result in a TSR modification. This provides contractors with needed operational flexibility, while ensuring that issues with a potential impact on safety, as defined in the facility authorization basis, are brought to attention.

Archives and Records Administration (NARA) 25 years after the case is closed.

- All other occurrence report files maintained by HQ are destroyed 80 years after the close of the case.

Occurrence report files maintained by a field office must be destroyed 15 years after the case is closed.

Correspondence files of organizational units responsible for facility safety, must be destroyed after ten years. Correspondence files may include but are not limited to:

- Safety Reports;
- Memoranda; and
- Statistics

B. Describe the requirements for documents and records in DOE Order 5700.6C, Quality Assurance; Criterion Four, Documents and Records.

DOE Order 5700.6C, Criterion 4 outlines the quality assurance requirements of documents and records.

<u>Documents</u>

1) A process should be established and implemented to control preparation, review, approval, issuance, use, and revision of documents that establish policies, prescribe work, specify requirements, or establish design.

2) The scope of the document control system should be defined. Examples of documents to be controlled include drawings, data files (including various media), calculations, specifications, computer codes, vendor-supplied documents, procedures, work instructions, operator aids, and data sheets.

3) Revisions to controlled documents should be reviewed and approved by the organization that originally reviewed and approved the documents. An alternative organization may be designated based on technical competence and capability. Timeliness guidelines should be implemented for distribution of new or revised controlled documents.

4) Controlled documents should be distributed to and used by personnel performing work.

5) Control of superseded and canceled documents should include measures to ensure that only correct documents are in use. Record copies should be marked "superseded" or "canceled" and kept for a specified retention period.

Records

1) A process should be established and implemented to ensure that sufficient records are specified, prepared, reviewed, approved, and maintained to accurately reflect completed work (e.g., records of design, environmental conditions, applied research and development, procurement, construction, data acquisition, assessments, inspection, testing, maintenance, and modification). The maintenance of records should include provisions for retention, protection, preservation, traceability, accountability, and retrievability.

2) For records that require special processing and control, such as computer codes or information on high density media or optical disks, hardware and software required to maintain and access records should be controlled to ensure records are useable.

3) Records holding facilities are reserved for storage of inactive records and may not meet the physical requirements or have appropriate staff to maintain active records. Active records requiring special handling, storage, and processing should not be sent to records holding facilities. Reference the General Records Schedule (GRS) or DOE Order 1324.2A for retention and disposition of records.

4) The National Archives and Records Administration (NARA) exercises final authority for approving the disposition of Government records. Use of the GRS, which is published by the NARA, and the DOE unique schedules approved by the NARA are mandatory.

5) Some standards which provide interpretive quality assurance guidance may differ in records management terminology from the NARA requirements. In those instances, care should be taken to ensure that the requirements of both the NARA and standards are followed.

C. Describe the purpose, scope, contents, and requirements in DOE Orders; 1324.2B, Records Disposition, 5700.6C, Quality Assurance (QA), 1430.1D, Scientific and Technical Information Management.

DOE Order 1324.2B, Records Disposition: This Order outlines the requirements of all Departmental elements and M&O contractors regarding the creation and disposition of records. The Order defines records and retention/destruction schedules for general records.(see A above)

DOE Order 5700.6C, Quality Assurance: The QA Order requires the creation and implementation of a process related to documents and records. (see B above) It does not apply to all Department elements, but it is applicable to M&O contractors.

DOE Order 1430.1D, Scientific and Technical Information Management: This Order establishes the Departmental Policy and contractor requirements for the release of information related to Departmental research activities.

2 9-2 Demonstrate knowledge of the Price-Anderson Amendment Act of 1988 and its impact on DOE nuclear safety activities.

A. Describe the purpose and scope of the Price-Anderson Amendment Act.

Purpose and Scope
The Price Anderson Amendment Act (PAAA) of 1988 provides incentives for DOE contractors to abide by nuclear facility safety and operations requirements as set forth by DOE in such documents as 10CFR830. The 10CFR830 regulatory requirements are intended to revise and supplement the existing provisions in DOE Orders for nuclear safety and will provide a more direct means to implement the civil penalty provisions of the PAAA.

The PAAA provides a reimbursement incentive to DOE contractors (and their subcontractors and suppliers) for conducting activities that involve source, special nuclear, or byproduct material in response to public liability penalties associated with the consequences of those activities.

The PAAA also made DOE contractors (and their subcontractors and suppliers) subject to civil penalties for violations of DOE rules, and regulations, or orders related to nuclear safety.

The intent of this Act is that it will enhance compliance with such rules as 10CFR830 including programs that contribute to an effective and safe work environment at nuclear facilities.

3. Demonstrate knowledge of the general principles associated with the development, negotiation, and management of agreements, including Memoranda of Agreement (MOAs), Memoranda of Understanding (MOUs), and Agreements in Principle (AIPs). **9-3**

A. Define and compare the following types of agreements: Agreement in principle, Memorandum of agreement, Memorandum of understanding

Agreements in Principle: AIPs outline the general points of understanding or boundaries between DOE and other parties, including M&O contractors. AIPs set forth the macro level agreements, and lay out the foundation for more specific detailed negotiations on the finer points of the covenant. AIPs are often precursors to MOUs, MOAs or actual contracts.

Memorandum of Understanding: An MOU is a written agreement broadly stating basic understandings of tasks and describing a method for performing these tasks between the Department and other Governmental entities, the private sector, and educational institutions. A MOU is not a binding contract, nor can it be used to obligate, transfer, or commit funds. Interagency Agreements (IA), not MOUs, are used for monetary exchanges between DOE and other federal agencies.

Memorandum of Agreement: MOAs are usually used to document the understandings and transfer of funds between departmental elements. Usually the parties affected by MOAs receive a benefit. (i.e. monetary, services, products, etc.)

B. Discuss the role of nuclear safety personnel in the development, negotiation, and approval of AIPs.

Nuclear safety personnel should play an active role in the negotiation and approval of management agreements that affect nuclear facilities. Additional responsibilities include:

- Reviewing applicable AIPs to ensures the safety basis is not altered.
- If a safety consideration is involved, review the purposed agreement and make recommendations to the approval authority on the necessary requirements.
- Supply information on applicable laws, regulations, and Orders to those negotiating AIPs.

C. Using a copy of an MOA/MOU/AIP related to nuclear safety issues, review the document and discuss its adequacy in meeting the Department's needs.

As part of an exercise for this section, access a copy of an MOA/MOU/AIP related to nuclear safety from the local DOE Contracts Office. Review the documents and discuss it with your supervisor as part of completing this competency.

Section 9 References and Suggested Reading

References and Suggested Reading

Department of Energy, DOE Order 1324.2B, Records Disposition, DOE, 1992

Department of Energy, DOE Order 5700.6C, Quality Assurance DOE, 1991

Department of Energy, DOE Order 1430.1D, Scientific and Technical Information Management, DOE, 1991

Department of Energy, DOE Order 1240.A Memorandum of Agreements, DOE, 1989