

Y/ES-015

Y-12

**OAK RIDGE
Y-12
PLANT**

MARTIN MARIETTA

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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**CRITERIA FOR THE SAFE STORAGE
OF ENRICHED URANIUM
AT THE Y-12 PLANT**

JULY 1995

Compiled by S. O. Cox
Defense Programs

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ENRICHED URANIUM
AT THE Y-12 PLANT**

JULY 1995

Compiled by S. O. Cox
Defense Programs

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For the
U.S. DEPARTMENT OF ENERGY
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FOREWARD

Uranium storage practices at U.S. Department of Energy (DOE) facilities have evolved over a period spanning five decades of programmatic work in support of the nuclear deterrent mission. During this period, the Y-12 Plant in Oak Ridge, Tennessee has served as the principal enriched uranium facility for fabrication, chemical processing, metallurgical processing and storage. Recent curtailment of new nuclear weapons production and stockpile reduction has created significant amounts of enriched uranium available as a strategic resource which must be properly and safely stored. This standard specifies criteria associated with the safe storage of enriched uranium at the Y-12 Plant.

Because programmatic needs, compliance regulations and desirable materials of construction change with time, it is recommended that these standards be reviewed and amended periodically to ensure that they continue to serve their intended purpose.

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1. PURPOSE, SCOPE, AND EQUIVALENCY

1.1 PURPOSE

This standard provides criteria for the safe storage of enriched uranium metal, alloys, and stable compounds. The criteria establish acceptable forms of storage, specify the storage methods, and provide for storage of these materials in a safe, secure, and environmentally compliant form.

1.2 SCOPE

This standard applies to the safe storage of enriched uranium metal and its compounds and alloys at the Y-12 Plant. Material handling considerations are included only to the extent required to prepare the material for storage and to conduct routine inspections and investigations. The long-term storage of canned subassemblies and the storage of depleted and normal (natural) uranium are not included in this standard.

1.3 EQUIVALENCY

This standard does not prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety in the place of those that are prescribed by this standard, if technical documentation is made available to demonstrate equivalency. Also, the systems, methods, or devices must be approved for their intended purposes.

2. ACRONYMS AND DEFINITIONS

2.1 ACRONYMS

CSA	Criticality Safety Approval
CSMO	Central Scrap Management Office of the Department of Energy
DBA	Design Basis Accident
DOE	U.S. Department of Energy
DOT	Department of Transportation
DU	Depleted Uranium
EU	Enriched Uranium
HEU	Highly Enriched Uranium
IPS	In-Process Storage
IS	Interim Storage
LEU	Low Enriched Uranium
MEU	Moderately Enriched Uranium
MSDS	Material Safety Data Sheet
MSV	Modular Storage Vault
NMC&A	Nuclear Material Control and Accountability
NU	Normal (natural) Uranium
PLMS	Prolonged Low Maintenance Storage
ppm	Parts per million, or grams of designated material per megagram (metric ton) of net representative sample
SNM	Special Nuclear Materials

U	Uranium
UF ₄	Uranium Tetrafluoride
UO ₂	Uranium Dioxide
U ₃ O ₈	Triuranium Octoxide
VHEU	Very Highly Enriched Uranium

2.2 DEFINITIONS

Alloy - A substance composed of two or more metals united by being fused together and dissolving in each other when molten.

Approved - Acceptable to the "authority having jurisdiction."

Authority Having Jurisdiction - The organization, office, or individual responsible for approving equipment, installation, or procedure.

Barrier - A restraint that prevents the dispersion of stored material.

Combustible - In the form used and under the conditions anticipated, will ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat.

Conversion - An operation for changing from one material form, use, or purpose to another.

Depleted Uranium - Uranium isotope ²³⁵U assay less than 0.713 percent (see Appendix, Section 2.2).

Design Basis Accident - Accidents that are postulated for the purpose of establishing functional requirements for safety significant structures, systems, components, and equipment.

Dry Air - Air containing less than 100 ppm of moisture.

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

Enriched Uranium - Uranium isotope ^{235}U assay greater than 0.713 percent (see Appendix, Section 2.2).

Highly Enriched Uranium - Uranium isotope ^{235}U assay is 85 to 94 percent (see Appendix, Section 2.2).

In-Process, In-Use - Material that is integral to the manufacturing or recycle processes involved with continuity of operations.

Irradiated Material - Material that has been subjected to the high-neutron-flux environment existing near the core of a nuclear reactor.

Low Enriched Uranium - Uranium isotope ^{235}U assay is 0.713 to 20 percent (see Appendix, Section 2.2).

Low-Equity Material - Material that cannot be converted to a high-purity form on a cost-effective basis.

May - Denotes permission but is neither a requirement nor a recommendation.

Moderately Enriched Uranium - Uranium isotope ^{235}U assay is 20 to 85 percent (see Appendix, Section 2.2).

Modular Storage Vault - Concrete arrays that provide for the storage of enriched uranium in a highly stable criticality-safe configuration.

Normal (natural) Uranium - Uranium isotope ^{235}U assay 0.713 percent (see Appendix, Section 2.2).

Process (n) - An operation in which a material is extracted, separated, purified, or fabricated by some physical, chemical, or mechanical means.

Process (v) - To extract, separate, purify, or fabricate a material by a physical, chemical, or mechanical means.

Pyrophoric - Capable of igniting spontaneously when exposed to air.

Safety Class Item - Systems, components, and structures, including portions of process systems, whose failure could adversely affect the environment or safety and health of the public.

Shall - Indicates a mandatory requirement.

Should - Indicates a recommendation or that which is advised but not required.

Storage - Any method for maintaining items in a retrievable form for subsequent management.

Storage Facility - The building structure and outermost barrier in which the containers are housed.

Transuranic Elements - Elements having an atomic number greater than 92.

Unirradiated Material - Material that has not been subjected to the high-neutron-flux environment existing near the core of a nuclear reactor.

Very Highly Enriched Uranium - Uranium isotope ^{235}U assay greater than 94 percent (see Appendix, Section 2.2).

3. RELEVANT ORDERS, STANDARDS, AND DOCUMENTS

3.1 FEDERAL REGULATIONS

10 CFR 71, *Packaging and Transportation of Radioactive Material*
10 CFR 830.120, *Quality Assurance*
10 CFR 835, *Occupational Radiation Protection*
29 CFR 1910, *Occupational Safety and Health Standards*
40 CFR 61, Subpart H, *Emission Standards*
40 CFR 191, Subpart A, *Environmental Radiation*
49 CFR 173, *Shippers - General Requirements for Shipments and Packagings*
49 CFR 178, *Shipping Container Specifications*

3.2 DEPARTMENT OF ENERGY DOCUMENTS

3.2.1 DOE Orders

DOE 5000.3B, *Occurrence Reporting and Processing of Operations Information*, July 1993.

DOE 5400.1, *General Environmental Protection Program*, June 1990.

DOE 5400.5, *Radiation Protection of the Public and Environment*, January 1993.

DOE 5480.3, *Safety Requirements for Packaging and Transportation of Hazardous Materials*, July 1985.

DOE 5480.7A, *Fire Protection*, February 1993.

DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, May 1992.

DOE 5480.20A, *Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities*, November 1994.

DOE 5480.23, *Nuclear Safety Analysis Reports*, March 1994.

DOE 5480.24, *Nuclear Criticality Safety*, August 1992.

DOE 5500.1B, *Emergency Management System*, February 1992.

DOE 5500.2B, *Emergency Categories, Classes, and Notification and Reporting Requirements*, February 1992.

DOE 5500.3A, *Planning and Preparedness for Operational Emergencies*, February 1992.

DOE 5500.4A, *Public Affairs Policy and Planning Requirements for Emergencies*, June 1992.

DOE 5500.10, *Emergency Readiness Assurance Program*, February 1992.

DOE 5630.11B, *Safeguards and Security Program*, August 1994.

DOE 5633.3B, *Control and Accountability of Nuclear Materials*, September 1994.

DOE 6430.1A, *General Design Criteria* (especially Section 1306, *Unirradiated Uranium Storage Facilities*), October 1989.

3.2.2 Miscellaneous DOE Documents

DOE/EA-0929, *Environmental Assessment for the Proposed Interim Storage of Enriched Uranium Above the Maximum Historical Storage Level at the Y-12 Plant Oak Ridge, Tennessee*, September 1994.

DOE/EH-0256T Rev. 1, *Radiological Control Manual*, April 1994.

DOE-NE-STD-1001-91, *Guide to Good Practices for Training & Qualification of Instructors*, November 1991.

DOE-NE-STD-1002-91, *Guide to Good Practices for Training & Qualification of Chemical Operators*, November 1991.

DOE-STD-1012-92, *Guide to Good Practices for On-the-Job Training*, July 1992.

DOE-STD-1029-92, *Writer's Guide for Technical Procedures*, December 1992.

3.3 NONGOVERNMENT PUBLICATIONS

ACI 211.1, *Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete*, American Concrete Institute, 1991.

ACI 349, *Code Requirements for Nuclear Safety Related Concrete Structures*, American Concrete Institute, 1990.

ANS 8.7, *Guide to Nuclear Criticality Safety in the Storage of Fissile Materials*, 1975 (Reaffirmed 1987).

ASTM-A-240-94, *Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels*, 1994.

Criteria for Acceptance of Enriched Uranium at the Y-12 Plant, Martin Marietta Energy Systems, Inc., (Draft) May 1995.

EGG-2530, *Health Physics Manual of Good Practices for Uranium Facilities*, June 1988.

Ritchie, A. G. "A Review of the Rates of Reaction of Uranium with Oxygen and Water Vapour at Temperatures Up to 300°C," *Journal of Nuclear Materials*, **102** (1981): 170-82.

Y/ES-014, *Assessment of Enriched Uranium Storage Safety Issues at the Oak Ridge Y-12 Plant*, Lockheed Martin Energy Systems, Inc., July 1995.

4. SAFE STORAGE CRITERIA

The following safety criteria are established to minimize hazards to workers, the public, and the environment associated with the storage of enriched uranium and its alloys and compounds. Enriched uranium to be stored at the Y-12 Plant shall be assigned to one of the following storage categories: Transient Storage (TS), Interim Storage (IS), or Prolonged Low Maintenance Storage (PLMS). Each type of storage will be discussed in this section. All other enriched uranium materials are considered "in-process" and are not managed or accounted for as stored material.

Bases for the criteria are provided in Appendix A and are discussed in *Assessment of Enriched Uranium Storage Safety Issues at the Oak Ridge Y-12 Plant*, Y/ES-014 (July 1995). Additional background information on the storage of enriched uranium at the Y-12 Plant can be obtained in the *Environmental Assessment for the Proposed Interim Storage of Enriched Uranium Above the Maximum Historical Storage Level at the Y-12 Plant Oak Ridge, Tennessee*, DOE/EA-0929 (September 1994).

4.1 GENERAL

The following criteria apply to all material forms and storage durations.

- A. Enriched uranium to be stored at the Y-12 Plant shall meet the *Criteria for Acceptance of Enriched Uranium at the Y-12 Plant* (May 1995).
- B. Criticality Safety Approvals (CSA) shall be obtained for the specific enriched uranium storage configuration and on the specific operations required to store enriched uranium in that configuration.
- C. The support configuration used to obtain geometric spacing necessary to prevent criticality shall be considered an engineered safety feature.
- D. Combustible materials should not be stored with enriched uranium.
- E. Nonradioactive materials should not be stored with enriched uranium.

Additional storage criteria applicable to TS, IS, and PLMS are discussed in the following subsections. Current Y-12 Plant practices that satisfy or exceed selected criteria are printed in italics and are considered good management practices.

4.2 TRANSIENT STORAGE (TS) CRITERIA

Upon arrival at the Y-12 Plant, any material containing enriched uranium is designated as being in TS. Enriched uranium that meets the *Criteria for Acceptance of Enriched Uranium at the Y-12 Plant* is transferred into Y-12 Plant containers and subsequently designated as being IS material. Enriched uranium that does not meet the acceptance criteria remains in TS status while the disposition is negotiated with DOE and other governmental bodies having jurisdiction.

The following criteria apply to all material forms in TS.

- A. Enriched uranium in TS shall be received in shipping packages meeting the requirements of 10 CFR 71, 49 CFR 173, and 49 CFR 178.
- B. The retention time of enriched uranium in TS status shall be minimized, and shall never exceed one year.
- C. Enriched uranium in TS may be transferred into shipping packages equivalent to but not necessarily meeting the certification requirements of 10 CFR 71, 49 CFR 173, and 49 CFR 178.

4.3 INTERIM STORAGE (IS) CRITERIA

After meeting the Criteria for Acceptance of Enriched Uranium at the Y-12 Plant and transfer into Y-12 Plant containers, the enriched uranium is assigned to IS. Enriched uranium with anticipated programmatic use may also be assigned to IS. Material owned by the Central Scrap Management Office (CSMO) will often be included in this category.

The following criteria apply to all material forms in IS.

- A. Enriched uranium in IS shall be limited to ten years or less.
- B. Enriched uranium in IS shall be stored for ease of retrieval, inspection, and inventory.
- C. Enriched uranium in IS should be contained in packages equivalent to but not necessarily meeting the requirements of 10 CFR 71, 49 CFR 173, and 49 CFR 178. Certification as shipping containers is not required.

At the Y-12 Plant, enriched uranium in IS is stored in packages that enhance corrosion resistance, radiation protection, and criticality safety such as bird cages, lock boxes, and carbon steel drums. Any known

form of potentially pyrophoric material is converted into cast metal or stable oxide before transfer to IS. See DOE/EA-0929 for a discussion of these packages.

4.4 PROLONGED LOW MAINTENANCE STORAGE (PLMS) CRITERIA

Enriched uranium assigned to PLMS shall be a metal or a stable oxide and shall not be classified as "in-process." The length of time that enriched uranium is assigned to PLMS is considered indefinite.

4.4.1 General

The following criteria apply to all material forms in PLMS.

Enriched uranium in PLMS shall be stored for ease of retrieval, inspection, and inventory.

4.4.2 Enriched Uranium Metal in PLMS

Uranium alloys and intermetallics may be stored under the same standards as pure uranium metal, provided technical documentation is made available to the authority having jurisdiction to demonstrate equivalency.

The following criteria apply to enriched uranium metal in PLMS.

- A. Enriched uranium metal in PLMS shall be protected from surface corrosion or degradation that could generate airborne radioactivity.

At the Y-12 Plant, the following specifications meet the requirements for enriched uranium metal in PLMS:

- *A fully-dense, cast right-angle hollow cylinder having an inner radius of 4.45 cm and an outer radius of 6.35 cm. The mass will typically be approximately 18 kg and shall never exceed 20 kg.*
- *Material having a specific surface area greater than 1 cm²/g is not acceptable for storage. The surface area for smooth cast or machined parts may be determined geometrically, while rough surfaces such as broken metal must be determined by gas adsorption measurements.*
- *Loose surface oxide removed prior to packaging.*

Waivers to the geometry restriction are justified by demonstrating an equivalent level of nuclear criticality safety, resistance to corrosion, and ignitability.

Containers for Enriched Uranium Metal in PLMS

- B. Metal containers for enriched uranium in PLMS shall be corrosion-resistant and contain no plastic, oils, other combustible material, or substances that may initiate corrosion when in physical contact with the metal.

At the Y-12 Plant, the following specifications meet the requirements for enriched uranium PLMS containers:

- *constructed of 304-L stainless steel*
- *sealed with a commercial crimping apparatus*
- *packaged for storage in dry air or an inert atmosphere that has a moisture content of 100 ppm or less. If an inert gas is selected, oxygen is added to the extent of one plus-or-minus one-half percent*

An exception is allowed for combustible material in enriched uranium containers for the sealant compound used to crimp-seal the top and bottom of the containers.

The moisture content requirement may be waived if an inspection certifies that the ambient conditions at the time the container is sealed are sufficient to preclude condensation.

Storage Configuration for Enriched Uranium Metal in PLMS

Storage configurations meeting the requirements for enriched uranium prevent and/or mitigate the consequences of all potential accidents including bounding design basis and criticality accidents (Engineered safety feature per DOE 5480.23).

At the Y-12 Plant, moderately and highly enriched uranium is stored in vault-like cages, tube vaults, vaults, and modular storage vaults. The facilities that contain substantial quantities of enriched uranium have DOE-approved Safety Analysis Reports which are currently undergoing an SAR Upgrade Program (SARUP) to meet requirements of new DOE Orders. See DOE/EA-0929 for a discussion of vault storage.

4.4.3 Enriched Uranium Oxide in PLMS

The following enriched uranium oxides are acceptable for storage:

- the compound triuranium octoxide U_3O_8
- UO_2 and/or UO_3 , if the following criteria are met:
 - the process of conversion to U_3O_8 would result in unacceptable radiation to operating personnel or facilities,
 - the material is demonstrably not pyrophoric, and
 - the net moisture content within the container is shown to be below the level that would result in a net pressurization of one atmosphere over the maximum projected lifetime of storage

The following criteria apply to enriched uranium oxides in PLMS.

- A. Dispersible enriched uranium in PLMS shall be separated from the ambient environment by at least two physical barriers, and from the operator by at least one physical barrier.

Containers for Enriched Uranium Oxide in PLMS

- B. Polyvinyl chloride bags may be used to hold enriched uranium oxide within corrosion-resistant containers.

At the Y-12 Plant, the following specifications meet the requirements for enriched uranium PLMS containers:

- *constructed of 304-L stainless steel*
- *sealed with a commercial crimping apparatus*
- *packaged for storage in dry air or an inert atmosphere that has a moisture content of 100 ppm or less. If an inert gas is selected, oxygen is added to the extent of one plus-or-minus one-half percent*

An exception is allowed for combustible material in enriched uranium containers for the sealant compound used to crimp-seal the top and bottom of the containers.

The moisture content requirement may be waived if an inspection certifies that the ambient conditions at the time the container is sealed are sufficient to preclude condensation.

Storage Configuration for Enriched Uranium Oxide in PLMS

See the discussion presented in Subsection 4.4.2 for storage configuration.

4.5 STORAGE FACILITY

The following criteria apply to all material forms and storage durations.

- A. Enriched uranium storage facilities shall meet the requirements for stack emissions in 40 CFR 61, Subpart H.
- B. Enriched uranium storage facilities shall meet the requirements for environmental radiation protection in 40 CFR 191, Subpart A.
- C. Enriched uranium storage facilities shall meet the requirements for criticality safety in DOE 5480.24.
- D. New or modified enriched uranium storage systems, components, and structures shall meet the requirements of DOE 6430.1A.
- E. The enriched uranium storage facility criticality alarm system instrumentation shall be designated as a safety class item.
- F. Enriched uranium storage facilities shall not have fire sprinklers but shall meet all other fire protection requirements of DOE 5480.7A. DOE 5480.24, paragraph 7.2, mandates the requirement of ANS 8.7, Section 4.2.8. This section allows the installation of a sprinkler system *if* the possibility of a criticality occurring in an accumulation of runoff water has been considered. ANS 8.7, Section 4.2.7, requires that these areas be designed to prevent the accumulation of water.
- G. Enriched uranium storage facilities shall meet the requirements for security and safeguards in DOE 5630.11B.
- H. Enriched uranium storage facilities shall meet the requirements for protection of the environment in DOE 5400.1 and DOE 5400.5.
- I. Enriched uranium storage facilities shall meet the requirements for safety analysis in DOE 5480.23.
- J. Current enriched uranium storage facilities should be evaluated for compliance with DOE 6430.1A.

4.6 MATERIAL HANDLING

Material handling considerations are required to prepare the enriched uranium for storage and to conduct routine inspections and investigations. The following criteria apply to all material forms and storage durations.

- A. Material handling for enriched uranium storage shall meet the requirements for occupational radiation protection in 10 CFR 835.
- B. Material handling for enriched uranium storage shall meet the requirements for industrial safety in 29 CFR 1910.
- C. Material handling for enriched uranium storage shall meet the requirements for operations in DOE 5480.19.
- D. Material handling for enriched uranium storage shall meet the requirements for selection and training of personnel in DOE 5480.20A.

At the Y-12 Plant, instructors assigned to provide training for enriched uranium storage are trained and certified in accordance with DOE-NE-STD-1001-91. Personnel assigned to the enriched uranium storage areas are trained in accordance with DOE-NE-STD-1002-91 and DOE-STD-1012-92.

- E. Material Safety Data Sheets (MSDSs) for all materials handled in enriched uranium storage shall be maintained and made available to all personnel.
- F. Material handling for enriched uranium storage shall meet the requirements for control and accountability in DOE 5633.3B.
- G. Additional guidance on uranium storage radiological operations may be obtained in the *Radiological Control Manual*, DOE/EH-0256T (April 1994).
- H. Additional guidance on health physics practices for uranium storage may be obtained in the *Health Physics Manual of Good Practices for Uranium Facilities*, EGG-2530 (June 1988).

4.7 INSPECTION AND SURVEILLANCE

Inspection and surveillance considerations are required to ensure that container integrity is maintained with a high degree of confidence. The following criteria apply to all material forms and storage durations.

Inspection and surveillance of stored enriched uranium shall meet the requirements in DOE 5633.3B.

At the Y-12 Plant, formal procedures are issued for the inspection and evaluation of as-received material, prior to formal acceptance for storage.

- *Procedures are written to ensure that, upon implementation, any material that is accepted into storage will meet the standards.*
- *Procedures are written in accordance with DOE-STD-1029-92.*
- *An Acceptance Sampling Plan has been implemented in accordance with DOE 5633.3B.*

Procedures are developed to establish the actions to be taken when failures are detected in the initial acceptance inspection or during routine surveillance inspections.

4.8 EMERGENCY MANAGEMENT

Emergency management considerations are required in the event of an emergency for any enriched uranium storage location. The following criteria apply to all material forms and storage durations.

Enriched uranium storage shall meet the requirements for emergency management in DOE 5500.1B, DOE 5500.2B, DOE 5500.3A, DOE 5500.4A, and DOE 5500.10.

4.9 DOCUMENTATION

Documentation considerations are required to retain information about each enriched uranium storage location. The following criteria apply to all material forms and storage durations.

Enriched uranium storage records shall meet the requirements of DOE 5633.3B.

At the Y-12 Plant, a master list of relevant information for the storage of enriched uranium is maintained in a permanent repository. Although item by item values are not required, this information includes:

- *identification of the material by a serial number*
- *material type*
- *chemical analysis for key elements*

- *a general elemental analysis by an approved method, such as spark source mass spectrography or inductively coupled plasma emission spectroscopy*
- *isotopic analysis*
- *gross, tare, and net weights*
- *radiation analysis*
- *material history, including processing information for Y-12 Plant processed material*
- *log of inspection tests performed and dates of inspection*
- *inspection results*
- *container information*
- *exact, current location in the storage facility*
- *tamper-indicating device serial numbers*

4.10 QUALITY ASSURANCE

Procedures and processes that are essential for assuring compliance with these criteria shall be covered by quality assurance. The following criteria apply to all material forms and storage durations.

- A. Enriched uranium storage shall meet the requirements for quality assurance in 10 CFR 830.120.
- B. Enriched uranium storage shall meet the requirements for reporting and processing of operations information in DOE 5000.3B.

APPENDIX A

BASES FOR URANIUM STORAGE CRITERIA

The paragraphs in this Appendix briefly provide the basis for the paragraphs in the body of this Standard. For this reason, the numbering of the sections in the Appendix corresponds to that in the body of the Standard.

I. PURPOSE AND SCOPE

This standard establishes safety criteria for safe storage of enriched uranium metal and its compounds and alloys at the Y-12 Plant. Uranium materials packaged to meet PLMS criteria should not need subsequent repackaging to ensure safe storage for at least 50 years or until final disposition.

2. DEFINITIONS AND ACRONYMS

2.1 ACRONYMS

No basis necessary.

2.2 DEFINITIONS

Table 1. Standard Terminology for Uranium Isotopic Assays

Designation	Acronym	²³⁵ U Assay
Depleted Uranium	DU	<0.713 percent
Normal (natural) Uranium	NU	0.713 percent
Enriched Uranium	EU	>0.713 percent
Low Enriched Uranium	LEU	0.713 to 20 percent
Moderately Enriched Uranium*	MEU	20 to 85 percent
Highly Enriched Uranium*	HEU	85 to 94 percent
Very Highly Enriched Uranium	VHEU	> 94 percent

* Some documents use HEU as 20 to 94 percent.

3. RELEVANT ORDERS, STANDARDS, AND DOCUMENTS

3.1 FEDERAL REGULATIONS

No basis necessary.

3.2 DEPARTMENT OF ENERGY ORDERS

No basis necessary.

3.2.1 DOE Orders

No basis necessary.

3.2.2 Miscellaneous DOE Documents

No basis necessary.

3.3 NONGOVERNMENT PUBLICATIONS

No basis necessary.

4. SAFE STORAGE CRITERIA

In-Process Storage (IPS), or lag storage, is best described as a working vault. Access to a working vault may be on a daily basis. The IPS designation is utilized for material that is used frequently. NMC&A overhead associated with IPS is high because of frequency of access. This technical standard does not apply to IPS.

4.1 GENERAL

A. Basis is Y/ES-014, Section 1.0. The *Criteria for Acceptance of Enriched Uranium at the Y-12 Plant*, has been established to delineate the radiological properties of materials received from external sources that would cause their rejection by the Y-12 Plant. The following materials could be excluded by the acceptance criteria:

- All materials containing the isotopes ^{232}U , ^{233}U , and/or ^{236}U in concentrations such as to cause either radiation levels or criticality hazards significantly greater than those for ^{235}U .
- Irradiated uranium and other materials containing transuranic elements, fission products, and/or radioactive decay products in such

concentrations such as to cause either radiation levels or criticality hazards significantly greater than those for ^{235}U .

- Materials containing concentrations of any of the radionuclides mentioned in the prior two paragraphs whose decay products will generate radiation fields significantly greater than those for ^{235}U during the maximum projected lifetime of the facility.

The isotope ^{233}U and its associated sister isotope ^{232}U (both of which are synthetic isotopes formed by irradiation of natural thorium) present much more severe radiological hazards than any of the naturally occurring uranium isotopes. Similar to the SNM-version of their naturally occurring siblings, these synthetic uranium isotopes require a stable configuration to ensure nuclear safety and safeguards measures to protect and account for the material. However, ^{232}U (72-year half-life) and ^{233}U (1.6×10^5 year half-life) also require additional personnel protection due to their high alpha activities (10 million times higher and 4375 times higher than ^{235}U , respectively). In addition, they require extensive biological shielding to protect personnel from the 2.6 MeV gamma emission of one of the ^{232}U daughters, ^{208}Tl . Because of the severe radiological hazards associated with ^{232}U and ^{233}U , both isotopes must be handled under their own specific set of criteria that address the unique set of hazards that they present.

The isotope ^{236}U is formed by neutron capture of ^{235}U , and thus is present in significant concentrations in irradiated uranium.

- B. Basis is DOE 5480.24, paragraph 7.c, which requires a documented nuclear criticality safety analysis for specific operations and storage arrangements and paragraph 7.a, which mandates the requirements of ANS 8.7, Section 4.2.1.
- C. Basis is DOE 5480.24, paragraph 7.a, which mandates the requirement of ANS 8.7, Section 4.2.3. Engineered safety features are defined in DOE 5480.23, paragraph 5.g as preventing and/or mitigating the consequences of all potential accidents.
- D. Basis is DOE 5480.24, paragraph 7.a, which mandates the requirements of ANS 8.7, Section 4.2.6, and DOE/EH-0256T, Revision 1, Chapter 4, Article 414, Nos. 10 and 11.
- E. Basis is DOE/EH-0256T, Revision 1, Chapter 4, Article 414, No. 8.

4.2 TRANSIENT STORAGE (TS) CRITERIA

Upon arrival at the Y-12 Plant, any material containing enriched uranium shall be designated as being in TS. The time the material remains in this status should be minimized. While in TS, the following determinations are made:

- The shipping containers meet DOT specifications (49 CFR 173 and 178) and do not show visual signs of damage or distortion.
- The items within the shipping containers are those specified by the shipping agreement.
- The received material meets the *Criteria for Acceptance of Enriched Uranium at the Y-12 Plant*, see Section 4.1 A.
- The quantity of enriched uranium specified by the shipping agreement is, in fact, present (within measurement capabilities).

Most materials received will at this point be transferred to storage containers owned by the Y-12 Plant and placed in IS. Materials that are considered to be unsuitable for IS should be returned to the sender or transferred to enriched uranium operations for conversion to a form that is acceptable for either IS or PLMS.

- A. Basis is DOE 5480.3, paragraph 7.a.
- B. Basis is Y/ES-014, Section 4.1.
- C. Basis is 10 CFR 71, Subpart A, Section 71.0 (c).

4.3 INTERIM STORAGE (IS) CRITERIA

IS is defined as storage of inactive material for a defined use at some time in the future, a period which is to be less than 10 years. Inventories requiring periodic surveillance, maintenance, and accessibility are candidates for IS. IS facilities are designed to ensure that dispersal of nuclear material can be localized to a specific area within the facility.

In general, priority should be given to conversion of materials to forms accepted for PLMS if the material is in a form that poses health, environmental, or safety risks due to its chemical or physical state. Materials in IS should be contained in storage containers that meet the specifications for DOT Type A or Type B shipping containers (10 CFR 173 and 178). However, it is an acceptable practice to use shipping containers whose certifications have expired, or containers manufactured according to DOT specifications for use strictly for IS, which have not been certified as shipping containers. The physical configurations in which the storage containers are arrayed

must be established by operating procedures derived from formal Criticality Safety Approvals.

- A. Basis is Y/ES-014, Section 4.6.
- B. Basis is Y/ES-014, Section 4.1.
- C. Basis is 10 CFR 71, Subpart A, Section 71.0 (c).

4.4 PROLONGED LOW MAINTENANCE STORAGE (PLMS) CRITERIA

PLMS is defined as storage of material over a time period greater than 10 but less than 50 years. This is an important point because the future uses/needs for nuclear materials are not currently known. Therefore, it is impossible to predict which storage form will be most useful in the future. The objective of PLMS is to provide safe storage of enriched uranium. Secondary objectives are to provide for conversion/consolidation with low maintenance and limited access. A PLMS facility is designed for limited personnel access and low NMC&A overhead. The objective is to ensure that the material is in the same condition 50 years from now as when it was placed in storage.

All material containing isotopically enriched uranium, with the ^{235}U concentration greater than 20 percent, shall be placed in PLMS unless it fits into one of the following categories:

- Material that can be classified as in-use or in-process.
- Material that is assigned to IS because of an anticipated programmatic use.
- Low-equity material.

In order to be accepted for PLMS, the uranium materials shall be in the chemical form of metal, alloys that qualify, or a stable oxide.

- The forms shall be retrievable for future use.
- The quantity of stored uranium permitted per container shall be determined by criticality safety analysis.

Some forms of material may be unsuitable for PLMS, whereas other material forms may be uneconomical to prepare for prolonged, low-maintenance storage. Material forms that are unsuitable for long-term storage will require stabilization, concentration, or conversion to acceptable material forms. Waste minimization is also a consideration. Low-equity material will generally not be accepted for PLMS.

4.4.1 General

Basis is Y/ES-014, Section 4.1.

4.4.2 Enriched Uranium Metal in PLMS

Current practices at the Y-12 Plant involve casting the uranium into hollow, right-circular cylinders having an inner radius of 4.45 cm and an outer radius of 6.35 cm. The maximum weight of a routine casting is about 20 kg, but most of the castings are smaller. A 20 kg casting corresponds to a cylinder height of 16.5 cm and a volume of 1.06 L.

Sample Calculation 1

The specific surface areas of the hollow right circular cylinders described in Section 4.4.2 can be calculated as follows:

$$\begin{aligned}\text{Surface area} &= 2\pi \times 6.35 \times 16.5 && \text{(outer contour)} \\ &+ 2\pi \times (4.45) \times 16.5 && \text{(inner contour)} \\ &+ 2\pi \times [(6.35)^2 - (4.45)^2] && \text{(two planar ends)} \\ &= 1248 \text{ cm}^2\end{aligned}$$

Mass = 20,000 g, so the specific surface area is $1248/20,000 = 0.06 \text{ cm}^2/\text{g}$.

Sample Calculation 2

A uranium metal cube, 1.00 cm on a side has a volume of 1.00 cm^3 and a mass of about 19.0 g (depending on isotopic content). The surface area is 6.00 cm^2 . The specific surface area is then $6.00/19.0 = 0.32 \text{ cm}^2/\text{g}$.

Sample Calculation 3

A square (1×1) dimension segment of a planar uranium metal foil of 0.10 cm thickness has a surface area of 2.4 cm^2 , a volume of 0.1 cm^3 , and a mass of 1.9 g. The specific surface area is $2.4/1.9 = 1.26 \text{ cm}^2/\text{g}$.

Two of the sample calculations give specific surface areas below the standard of $1.00 \text{ cm}^2/\text{g}$, and thus are acceptable in terms of this standard. The intent of the standard is to eliminate physical forms that would be subject to ignition or rapid corrosion.

Machine turnings, thin metal foils, chips, saw fines, and any other form of high-specific surface area metal shall be converted to forms that meet the storage criteria.

A. Basis is Y/ES-014, Section 3.1.1, and 10 CFR 835, Subpart C.

The quantitative basis for minimizing corrosion of uranium by controlling the temperature and the moisture and oxygen contents within the primary containers is based on a compilation of kinetics data by A. G. Ritchie, *Journal of Nuclear Materials*, **102** (1981): 170-82.

Containers

The storage container used at the Y-12 Plant for the storage of enriched uranium metal and stable oxides is a cylindrical steel can. The can material is 304-L stainless steel meeting the standard ASTM-A-240. The low-carbon steel is required to avoid vulnerability to corrosion in the welded seam of the can. The wall is 30 gauge material, corresponding to a wall thickness of 0.01 in. (0.03 cm). The outer diameter and height of the can are 6.13 in. (15.56 cm) and 8.75 in. (22.23 cm) or 7.0 in. (17.78 cm), respectively. The internal volume of the can is 255.1 in.³, or 4180 cm³. The volume of the hollow cylindrical casting is 1064 cm³. Therefore, the free volume of the can in standard metal storage mode is 4180 - 1064 = 3116 cm³.

The mechanical strength of the can is enhanced by four concave, symmetrically spaced beads in the can wall. The bead width and inner-contour radius are 0.08 in. and 0.04 in., respectively. The top and bottom lids are attached to the wall by crimp seals. The integrity of the crimp seal is enhanced by use of a sealant applied to the perimeter of the lids prior to crimping. A commercially-available, water-based sealant consisting of an emulsion of natural rubber, pigment, and modifiers is currently used.

The cans are obtained from a commercial vendor with the bottom lids already sealed and the sealant applied to the top lids. The supplier of the sealant recommends that the lids be sealed within six months of the time of application of the sealant. All the cans are leak-tested by the vendor with the bottoms crimped. The leak tests are performed at 6 psi with the system either submerged in water or covered with detergent. Appearance of bubbles is a cause for rejection. After the charge is placed in the can at the Y-12 Plant, the top lids are sealed with a commercial crimping apparatus.

The contents of each primary container must be marked on the exterior of the container and entered into the master list of relevant information described in Section 4.9.

The storage container for any fissionable uranium shall have external dimensions that will provide criticality-safe storage for the contained material.

The container's gaseous environment shall be designed to maintain mechanical integrity, including its seal, during normal handling.

The storage container is not expected to provide protection against all perils such as major fire and earthquakes. Design of the facility and of the storage array is expected to cover these considerations.

B. Basis is Y/ES-014, Section 7.5.1, and 10 CFR 835, Subpart C.

Storage Configuration

New storage configurations or significant modifications to existing storage configurations may be either of the tube vault configuration or the MSV configuration, or equivalent.

New or modified storage facilities based on the tube vault configuration shall be designed to meet the requirements of DOE 6430.1A, especially those listed in Section 1306, *Unirradiated Enriched Uranium Storage Facilities*.

New or modified storage facilities based on the MSV configuration shall be designed to meet the following requirements:

- Modules shall be fabricated of concrete of such composition as is designated by ACI 211.1 and shall meet the code requirements specified in ACI 349.
- Physical dimensions of the modules must be such as to ensure that a criticality-safe geometry is maintained in stacking as well as in storage position.

4.4.3 Enriched Uranium Oxide in PLMS

Uranium tetrafluoride (UF_4) would be an acceptable material for PLMS storage if it could be certified to be free from chemisorbed HF. Long-term desorption of HF would cause serious corrosion problems for the container.

Sample Calculation

If 20 kg of UO_3 were stored in a can having a net internal volume of 4.22 L (see containers under Section 4.4.2), the volume occupied by the powder would be $20,000 \text{ g} / 7.30 \text{ g/cm}^3 = 2740 \text{ cm}^3 = 2.74 \text{ L}$. The residual free volume would be $4.22 \text{ L} - 2.74 \text{ L} = 1.48 \text{ L}$. Assuming ideal gas behavior, $PV = nRT$, with $P = 1 \text{ atm}$, $V = 1.48 \text{ L}$, $R = 0.08206 \text{ L atm/mole deg}$, and $T = 313.2 \text{ K}$ (40°C), the number of moles of gas that can be accommodated is 0.06. The maximum volume of gas that could be generated by the radiation-induced decay of water is determined by assuming that all of the water present is dissociated to H_2 and O_2 . Thus one mole of water yields one mole of H_2 and one-half mole of

O₂. Consequently, the allowable amount of water in the 20 kg of UO₃ is $(2/3) \times 0.06 = 0.04$ mole. The molecular weight of water is 18, so the weight of water allowed in the 20 kg of UO₃ is $0.04 \times 18 = 0.69$ g. This corresponds to 35 ppm water in the UO₃.

- A. Basis is DOE 6430.1A, Section 1306-6.1 and EGG-2530, Section 13.2.1.

Containers

- B. Basis is Y/ES-014, Section 7.5.1.

Storage Configuration

Same basis as for metal.

4.5 STORAGE FACILITY

Storage facilities shall be designed and constructed to maintain their integrity during DBA they are required to withstand and to minimize the possibility of fire.

- The facility will be constructed of non-combustible materials, primarily concrete.
- Fire sprinklers will not be incorporated because of the need to avoid criticality hazards associated with the neutron-moderating and neutron-reflecting properties of water.
- With the exception of the exclusion of fire sprinklers, the facility will be constructed and operated according to DOE Order 5480.7A.

In accordance with DOE 5480.24, the basic elements and control parameters of the facility shall satisfy the requirements of nuclear criticality. Radiation warning symbols shall be posted in accordance with 10 CFR 835, Subpart G.

- A. Basis is 40 CFR 61, Subpart H, Sections 61.92 and 61.93.
- B. Basis is 40 CFR 191, Subpart A, Section 191.03 (b).
- C. Basis is DOE 5480.24, paragraph 7.a, which mandates the requirements of ANS 8.7, Sections 4.1 and 4.2.
- D. Basis is DOE 6430.1A, Section 1306.

- E. Basis is DOE 5480.24, paragraph 7.a, which mandates the requirements of ANS 8.7, Section 4.2.9. Safety class items defined in DOE 6430.1A, Section 1300-3 include those required for nuclear criticality safety.
- F. Basis is DOE 5480.7A, paragraphs 5 and 9 and Y/ES-014, Subsection 7.6.3, Fire Safety.
- G. Basis is DOE 5630.11B, paragraphs 7 and 9. DOE 5480.24, paragraph 7.a, mandates the requirements of ANS 8.7, Section 4.1.4, for access control.
- H. Basis is DOE 5400.1, Chapter IV, paragraphs 7, 8.a, and 8.b, and DOE 5400.5, Chapter II, paragraph 1.c.
- I. Basis is DOE 5480.23, paragraphs 8 and 9. If a safety analysis report is required, Attachment I, paragraph 4.f presents the scope and content.
- J. Basis is DOE 6430.1A, Division 1, paragraph 0101-1.

4.6 MATERIAL HANDLING

Formal operating procedures shall be developed to govern all facets of materials handling that pertain to operation of any storage facility:

- Procedures shall be adequate to ensure that the safety requirements of DOE 5480.23 are fulfilled.
 - Procedures shall meet the nuclear criticality safety criteria set forth in DOE 5480.24.
 - Procedures shall be adequate to maintain radiological protection in accordance with 10 CFR 835.
- A. Basis is 10 CFR 835, Subpart C, *Standards for Internal and External Exposure*; Subpart F, *Entry Control Program*; Subpart G, *Posting and Labeling*; Subpart H, *Records*; Subpart J, *Radiation Safety Training*; and Subpart N, *Accidents and Emergencies*.
 - B. Basis is 29 CFR 1910.120, *Hazardous Waste Operations and Emergency Response* and 29 CFR 1910, Subpart N, *Material Handling and Storage*.
 - C. Basis is DOE 5480.19, paragraph 5. DOE 5480.24, paragraph 7.a, mandates ANS 8.7, Sections 4.1.1 and 4.1.2, to require written procedures for all operations.

- D. Basis is DOE 5480.20A, paragraph 6. DOE 5480.24, paragraph 7.a, mandates ANS 8.7, Section 4.1.2, to require that all personnel be familiar with the operating procedures.
- E. Basis is 29 CFR 1910.1200 (b) (4) (ii).
- F. Basis is 10 CFR 835, *Supplementary Information*, III.B.
- G. Basis is Y/ES-014, Reference 27.

4.7 INSPECTION AND SURVEILLANCE

The accountable material in the facility shall be inventoried on a routine basis as specified by procedures, in accordance with DOE 5633.3B. Formal methods and responsibilities are to be documented and maintained for independent review and evaluation.

Basis is DOE 5633.3B, Chapter II, 3.a (4), Chapter II, 3.a (5), Chapter II, 3.b, and Chapter II, 3.c.

4.8 EMERGENCY MANAGEMENT

Basis is DOE 5500.1B, paragraph 9; DOE 5500.2B, paragraphs 9 and 11.a; DOE 5500.3A, paragraph 11; DOE 5500.4A, paragraph 7.a; and DOE 5500.10, paragraphs 9 and 10.

4.9 DOCUMENTATION

Basis is DOE 5633.3B, Chapter II, 2.c.

4.10 QUALITY ASSURANCE

- A. Basis is 10 CFR 830.120, Quality Assurance Requirements.
- B. Basis is DOE 5000.3B, paragraphs 6, 7, and 8.