Technical Standard

NUCLEAR CRITICALITY SAFETY - 300 AREA

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Approved: July 31, 1991
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NUCLEAR CRITICALITY SAFETY - 300 AREA

A. APPLICABILITY AND SCOPE

This Standard applies to the receipt, processing, storage, and shipment of fissionable material in the 300 Area and in any other facility under the control of the Reactor Materials Project Management Team (PMT).

B. OBJECTIVES

The objective is to establish practices and process conditions for the storage and handling of fissionable material that prevent the accidental assembly of a critical mass and that comply with DOE Orders as well as accepted industry practice.

C. LIMITS AND REQUIREMENTS

Specific limits for the handling and storage of fissionable material that are directly measurable and controllable shall be approved by operating procedures, Test Authorizations, and Supplements to this Standard. Such limits shall be at or within the limits of Operational Safety Requirements. Operating procedure limits shall be at or within the limits of either Test Authorizations or Supplements to this Technical Standard.

The approval process is defined elsewhere for Test Authorizations, Supplements to this Technical Standard, and Operational Safety Requirements. The approval process for operating procedures is established per 300 Area policies.

Practices and process condition requirements established by this Technical Standard follow.

1. Practices

a. All 300 Area operations involving fissionable material shall be reviewed in advance to ensure that no single event can result in a critical excursion. A single event is a single hardware failure, occurrence of a single process upset condition, or a departure from a procedural requirement.

b. A written report of the calculations, limits, and judgements that establish the criticality safety of an operation, called a Nuclear Criticality Safety Analysis (NCSA), shall be prepared. NCSAs shall be independently reviewed by SRL Scientific Computations. NCSAs shall be used as the bases for documenting derivation of all criticality safety limits. It is noted that prior to the issuance of this Technical Standard revision that some NCSAs were not independently reviewed by SRL nor are NCSAs always the basis for prior established criticality safety limits.
c. Specific limits shall ensure the minimum $\kappa_{\text{eff}}$ subcritical margin for normal operation and any single event. Such limits shall be established and appropriate training provided prior to starting any operation involving fissionable material or if there is a significant probability that fissionable material might be erroneously used/present in an operation. These specific limits, with appropriate additional safety margins, shall be incorporated into operating procedures as relevant to operations.

d. The 322-M and the three 321-M (Oralloy, Scrap, and Core) vaults shall be designated for the storage of excess fissionable material in 300 Area. All other areas approved for fissionable material shall either be considered process areas or areas approved for fissionable material receipt/shipment. Fissionable material placed into shipping containers that are kept within 300 Area Buildings shall be considered in process of being shipped and not in storage.

e. All fixtures approved for fissionable material should be designed to ensure the required spacing between the most reactive units that could reasonably be argued to fit into the fixtures. However, fixtures intended for storage/processing of uranium-aluminum alloy do not have to be designed for mistaken storage of enriched uranium metal containers.

f. Fissionable material stored in the vaults and in process shall have labeling appropriate to providing information needed to ensure criticality safety limits. Use of process cards or container numbers that can be traced back to a listing of contents documenting enrichment, mass, chemical composition, degree of moderation, etc. shall be considered acceptable if such data are not used for ensuring criticality safety limits.

g. All operations involving fissionable material shall be reviewed on an annual basis by the 300 Area Criticality Audit Committee (CAC) and documented as described in that committee's charter. At least half of the voting membership of the 300 Area CAC shall be independent of the 300 Area PMT management.

2. Process Condition Requirements

a. The actual Minimum Subcritical Margin shall be 0.02 with additional correction for computational method Bias, Bias Uncertainty, and any quantifiable approximations that tend towards underestimating the true $\kappa_{\text{eff}}$ value. Calculated values of $\kappa_{\text{eff}}$ shall be established to at least 95.45% confidence (2 standard deviations).

b. All storage in the vaults shall require the use of fixtures which provide physical barriers to ensure that spacing limits are met.

c. Neutron absorbers, such as boron and cadmium, may be used to reduce $\kappa_{\text{eff}}$ in storage arrays. If used, the effectiveness of the absorber shall be directly confirmed by neutron measurements. The design of the absorbers shall ensure continuous presence and intended distribution of the absorber.
D. BASES

Because fissionable material is handled and stored in a variety of shapes and concentrations in the fuel fabrication process, operating procedures, Supplements to this Technical Standard, and Test Authorizations are required to describe specific criticality safety limits for various process steps. The discussion in this section is hence limited to the practices and process conditions presented under "Limits and Requirements"; it will not present the bases for Supplements and Test Authorizations. There is a one to one correspondence between the limits and requirements in Section C and their bases below.

1. Practices

a. The probability of a critical excursion has been generally regarded as acceptable if more than a single failure event must occur before a critical excursion is possible. It is preferred that equipment/process design rely upon control over two parameters (e.g., mass and moderation) that will, independently of each other, ensure the Minimum Subcritical Margin. However, as this preference is not always practical, use of multiple controls on a single parameter is acceptable. Multiple controls take the form of diverse or like-redundant means of control. Diverse control is preferred when practical.

b. Independent review of all limits upon which criticality safety is dependent is necessary to avoid situations where a single error in setting a limit could result in a critical excursion. NCSAs are to be sufficiently detailed to permit independent evaluation by individuals competent in criticality safety analyses. It is required that NCSAs used to generate limits be reviewed by Scientific Computations (SRL). When there are sufficient qualified criticality safety personnel within 300 Area, NCSAs should be independently reviewed prior to forwarding them to Scientific Computations. NCSAs, after issuance, are distributed to all members of the 300 Area CAC as well as affected operations supervision.

c. Specific limits are generated and available before any procedure/equipment is used to store, move, or process fissionable material. Specific limits are extracted from NCSAs and formally approved as operating procedure limits that are within the limits of Supplements or Test Authorizations. 300 Area designates personnel qualified to review procedure/equipment changes to ensure that these limits are either satisfied or new limits generated before the change is approved. These designated personnel have review/approval authority over procedure/equipment changes that have been prior screened for criticality safety impact. The appropriate Technical Manager is responsible for the adequacy of this screening process.

d. DOE Order 5480.5 differentiates its requirements in terms of receipt, processing, and storage of fissipable materials. In 300 Area, all storage of fissionable material in vaults is considered material in storage. Any vault equipment/operations presenting risks not necessary to support such storage are specifically exempted by written request from the Order. In event restrictions placed upon shipments require prepackaging of shipping containers, their contents are regarded as in the process of being shipped and not stored if applicable shipping container requirements are met.

e. In storage areas, storage of fissionable material requires the use of fixtures to ensure such material is placed in approved locations. It is preferred, but not mandatory, that such fixtures also be used for fissionable material in process outside the vaults. Due to the extensive security measures taken and specific criticality safety storage directions provided for handling uranium metal, fixtures for uranium-aluminum are not required analyzed for inadvertent storage of uranium metal. Such an event would likely be a deliberate act.
f. The extensive labeling described in DOE Order 5480.5 for criticality safety is not required whenever fixtures (either in storage or in process areas) are demonstrated acceptably subcritical for the most reactive unit that might credibly fit into a fixture. In such cases, neither labeling of the fissionable material nor its container are relied upon for criticality safety.

g. It is required\textsuperscript{6} that all operations with fissionable material be at least annually reviewed by individuals knowledgeable in criticality safety and not immediately responsible for the process. In addition to being knowledgeable in criticality safety, it is required that these individuals have an understanding of the operations that extends to the bases for the limits. The 300 Area CAC is the only body of knowledgeable individuals that have this level of understanding of the operations and to the extent practical are not immediately responsible for operations. The review provided by the 300 CAC is of the internal 300 Area criticality safety auditing function.

2. Process Condition Requirements

a. There are four bases for subcritical limits.

The first is by citation of subcritical limits established in accepted industry references\textsuperscript{6,10,11,12,13}.

The second is by means of subcritical limits extended by accepted techniques (e.g., surface density\textsuperscript{12}).

The third is by means of controlled copies of computer diffusion/transport theory codes for which estimates of the bias and bias uncertainty are established or derivable.

The fourth is by subcritical measurements.

Neither experimental data nor calculations used to extend the data are considered exact and the Minimum Subcritical Margin makes appropriate allowances. The Minimum Subcritical Margin used in the derivation of subcritical limits are to be stated in the applicable NCSAs.

b. See D.1.e.

c. Any material intentionally included in the derivation of subcritical limits for the purpose of neutron absorption is considered a neutron absorber. ANS Standards establish recommended practices\textsuperscript{14} for ensuring the continued effectiveness of such absorbers.

\section*{E. UNCERTAINTIES}

The significant nuclear criticality hazard in 300 Area is enriched uranium metal and various forms of uranium-aluminum alloy produced during fuel fabrication operations and laboratory analyses. These materials could conceivably be brought together as a critical configuration. The risk of such a critical excursion is reduced to an acceptable level with the requirements imposed by this Standard which are incorporated into limits approved by means of operating procedures, Test Authorizations, Supplements to this Technical Standard, and the Operational Safety Requirements.
Equipment approved as specified in this standard provides a substantial degree of protection in event of disasters such as fire and earthquake. For example, the Scrap Can Rack is designed to allow an operator to lift a Scrap Can up and out of the Rack, but to prevent a Can from falling out of the Rack by the action of an earthquake or an inadvertently directed fire hose.

This Technical Standard does not address practices nor requirements that are effective against deliberate acts. Measures to prevent such acts are beyond the scope of this Standard and addressed elsewhere.  

F. REFERENCES

1. DPSTS-300-SUPP, Nuclear Criticality Safety Supplements, 300 Area.
3. WSRC-11Q, Westinghouse Savannah River Company Procedures for Control of Nuclear Safety Documents (U), 8/1/90.
4. ESH-SD-890130, Revision 1: Administrative and Procedural Controls System for SRS Non-Reactor Nuclear Facilities, 7/10/89.
5. SOP 300-235, Procedure Handling - Reactor Materials PMT.
8. DOE Order 5480.5, Safety of Nuclear Facilities, 9-23-86.
9. SOP 300-975C, 300 Area Criticality Audit Committee Charter.
11. ANSI/ANS 8.15, Nuclear Criticality Control of Special Actinide Elements.
1. **Bias**: estimated error in calculated $\kappa_{\text{eff}}$ for configurations where $\kappa_{\text{eff}}$ has been experimentally determined. Bias is expressed as a correlation dependent upon stated indices under defined neutronic conditions. The Bias is applicable only to controlled copies of executable code for which it was established or detailed formulas/specific data for hand calculations.

The range of experimental neutronic conditions for which errors are estimated, the error/indice relation, and calculational options used comprise the Bias. The range of neutronic conditions must be detailed enough to permit consideration of effects that might arise such as differences in materials causing reflection, the presence of different neutron absorbers, spectral effects due to significantly different neutron leakage geometries, etc..

As used in discussion of the Minimum Subcritical Margin, the underprediction of $\kappa_{\text{eff}}$ by a calculational method results in a positive bias.

2. **Bias Uncertainty**: statistical uncertainty to which the Bias is known with some expressed degree of confidence.

Extrapolations reflect large Bias Uncertainties when made beyond the neutronic conditions for which the Bias is solidly established or if experimental data are not adequate. In these cases, an alternate, independent, and validated methodology should be used to provide a second estimate of the calculated $\kappa_{\text{eff}}$ value.

3. **Critical Excursion**: an uncontrolled self-sustaining or divergent neutron chain reaction outside a shielded reactor.

4. **Diverse Means of Control**: when two independent mechanisms for implementing criticality safety control are based upon different physical principles of operation or when one control is mainly engineered by nature and the other procedural.

5. **Fissionable**: any single or mixture of isotopes capable of sustaining a neutron chain reaction at some neutron energy (U-235, Np-237, Pu-238, Pu-239, Pu-240, etc.).

6. **Fissile**: any single or mixture of isotopes capable of sustaining a neutron chain reaction at all neutron energies (U-235, Pu-239, etc.).

7. **Fissile Unit**: any single accumulation of plutonium or enriched uranium (> 0.72 weight percent U-235) containing more than 15 grams of fissile isotopes.

8. $\kappa_{\text{eff}}$: effective neutron multiplication factor for a finite collection of fissionable material. It is also the ratio of the total number of neutrons produced during a time interval (excluding neutrons produced by sources whose strengths are not a function of fission rate) to the total number of neutrons lost by absorption and leakage during the same interval.

9. **Like-Redundant Means of Control**: when two independent means of control function by exactly/almost exactly the same physical principles. However, the same operator performing multiple, administrative, Like-Redundant checks is not Like-Redundant control as such a practice does not satisfy the independency requirement.

10. **Shall**: used to denote a requirement.

11. **Should**: used to denote a recommended practice but not a requirement.
NUCLEAR CRITICALITY
SAFETY SUPPLEMENTS
300 AREA

Revised September 1988

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Aiken, SC 29808

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09-76SR00001
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The Nuclear Criticality Safety Supplements in this volume are required by the Nuclear Safety Standard, DPSTS-300, to list process conditions and limitations, calculations, and references for processing and storage of fissile materials in the 300 Area. At the time of original issue, Supplement No. 1 was identical with the former 300 Area Technical Standard, DPSTS-300-1.03, except for changes authorized by Supplement 2 and for wording changes to conform with the new Technical Standard.

Proposed new supplements and revisions to Supplement No. 1 will be circulated by Reactor and Reactor Materials Technology Department for review and approval. New supplements will follow the format:

- Title
- Description
- Process Analysis
- Limits

After approval, they will be issued by the Publications Division for inclusion in this binder under a document control system designed to ensure that all bound copies are always up-to-date.
A. APPLICABILITY

This supplement provides general nuclear criticality safety limits for processing and storing enriched uranium (>0.96 wt % \(^{235}\text{U}\)) in any form encountered in the fabrication of reactor fuel elements. These limits apply everywhere in the 300 Area, and in any other facilities under the control of the Raw Materials Department. (Additional supplements provide limits for special processing and storage conditions not within the scope of this general supplement.)

B. PROCESS ANALYSIS

All permitted arrays in this Supplement are subcritical:

- In air, and
- Moderated by 1 volume % water (or other hydrogenous material) homogeneously distributed in all void spaces within the array, and
- Moderated by 100% water (or other hydrogenous material) in all void spaces within the array, when this condition is judged to be credible, and
- Moderated by other more favorable homogeneous mixtures, when such conditions are judged to be credible, and
- Reflected by water (or other hydrogenous material) to the most nearly optimum extent that is judged to be credible.

The bases for judgments of the most reactive credible conditions of moderation and reflection, the margin by which these arrays are calculated to be subcritical, and any supporting experimental measurements, are documented in the references for each set of limits in this supplement.

C. LIMITS

1. Enriched Uranium Metal
   a. Arrays of Containers \((2.4.6.7)\)
      1) The containers authorized for processing and storage of uranium metal, and their dimensional limits, are:
• Tare pans, with a minimum inside diameter of 22.5 cm and maximum height of 12.4 cm.
• Charge cans, with a maximum inside diameter of 15.2 cm and maximum height of 17.8 cm. The bottom shall have at least three holes, with minimum diameters of 0.635 cm.
• Balance pans.
• Storage cans, with a maximum volume of 5.0 liters. Except while being loaded and unloaded, these cans shall be sealed when they contain uranium.

2) The maximum amounts of $^{235}\text{U}$ that may be in these containers are:
• Tare Pans - 19 kg $^{235}\text{U}$
• Charge Cans - 8 kg $^{235}\text{U}$
• Balance Pans - 19 kg $^{235}\text{U}$
• Storage Cans - 18 kg $^{235}\text{U}$

3) The minimum edge-edge spacing in unlimited planar horizontal rectangular arrays of tare pans shall be 10 cm.

4) Tare pans may be replaced by charge cans at any fixed position in arrays meeting the above spacing limits.

5) The minimum center-center spacings in two-high vertical planar arrays of charge cans shall be 45 cm both horizontally and vertically (see Supplement No. 7).

6) Storage cans of uranium may be stored only in shipping containers as specified in SUP-7 and SUP-13.

7) Arrays of two or more containers may not be placed on any surface that is a better neutron reflector than a 6.5-cm-thick layer of water.

b. Uncontained Enriched Uranium Metal\textsuperscript{10, 11}

Up to 600 grams of $^{235}\text{U}$ in metal form may be accumulated in one location without physically confining the metal to containers as described in Section C.1.a. Restrictions on the spacing of such accumulations are in Section C.9.

* "Shall" denotes a requirement, and "may" a permission.
c. Enriched Uranium in Liquid\textsuperscript{10, 11}

1) **Mass Limit**

Up to 600 g of \(^{235}\text{U}\) may be in any liquid that is not a better moderator than \(\text{H}_2\text{O}\); i.e., the minimum critical mass of \(^{235}\text{U}\) in the liquid is no less than it is in \(\text{H}_2\text{O}\). The \(^{235}\text{U}\) may be in pieces of any size and shall include any \(^{235}\text{U}\) in solution. Restrictions on the number and spacing of such accumulations are in Section C.9.

2) **Concentration Limit**

An unlimited volume of an aqueous solution containing \(^{235}\text{U}\) may be accumulated provided that

- The concentration is maintained uniformly at no more than 11 g \(^{235}\text{U}\)/liter of solution,
- Uranium precipitation is precluded, and
- The accumulation conforms to spacing limitations in Section C.9.

2. \(^{235}\text{U}\) Concentration in U-Al Alloy

The U-Al alloy shall contain no more than 1.23 g \(^{235}\text{U}\)/cc.

3. **Storage and Handling of Massive Pieces of U-Al Alloy**

Massive pieces of U-Al alloy are hollow or solid cylinders, including cast ingots, pre-extruded logs, machined cores, assembled extrusion billets, or cylindrical pieces of any of these.

a. **Massive Pieces in Racks, Carts or Processing Equipment\textsuperscript{1, 13, 16}**

All racks, carts or processing equipment designed to hold two or more cylinders of U-Al alloy must meet the following criteria:

- The axes of all cylinders within each array must be either all horizontal or all vertical. The locations in which the cylinders are placed must be in a regular rectangular array.

- Within each array of horizontal cylinders, the minimum axis-axis spacing of adjacent cylinders is given in Table III as a function of the height of the array, expressed as the number of layers.

- The cylinders must not be stacked when their axes are vertical. The minimum edge-edge spacing between such adjacent cylinders and their maximum \(^{235}\text{U}\) contents are given in Table IV for each type cylinder.
Such horizontal and vertical arrays are not limited in length and width.

- The average hydrogenous material content of these arrays shall be no more than 1% by volume; i.e., no 30-cm cube shall contain more than 270 cm$^3$ of hydrogenous material.

- No fissile material may be stored above or below these arrays.

- Within each array, construction features of the equipment must be such as to positively maintain the specified minimum spacings for the largest cylinders intended to be placed therein, and to positively exclude any larger cylinders that require greater spacings if such cylinders could inadvertently be placed therein.

- Between two adjacent arrays, minimum safe spacing must be maintained by physical barriers 1) on all sides of arrays of vertical cylinders, and 2) on two sides of arrays of horizontal cylinders, in the directions perpendicular to the cylinder axes. For an array of vertical cylinders, the width of the perimeter barrier must be at least half of the specified intra-array edge-edge spacing, as measured from the outer edge of the outermost storage positions. For an array of horizontal cylinders, the barrier must extend for at least half of the specified intra-array center-center spacing, as measured from the centerline of the outermost storage positions. However, the requirement for these perimeter barriers may be waived for any array for which the minimum spacings are positively maintained by other means, as by stanchions, permanently installed equipment, or the building structure.

b. Uncontained Massive Pieces$^6,7,8,35$

The maximum mass of $^{235}\text{U}$ present in massive pieces that may be handled in a group in air without regard to spacing within the group is given in Figure 4. Restrictions on the number and spacing of groups are in Section C.9.

c. Massive Pieces in Liquids$^34$

Up to two pre-extrusion logs containing up to 14.8 kg $^{235}\text{U}$/meter of length may be submerged in any liquid (except D$_2$O) that contains less than 1 gram of fissile isotope per liter of liquid.

Only one massive piece of any other type may be submerged in such a liquid.
4. **Storage and Handling of Tubes**

Fuel tubes may contain up to 720 g $^{235}$U/meter of length, their outer diameters may be up to 9.9 centimeters. Tubes greater than 30 centimeters in length shall be stored and handled as specified in this section. Shorter tubes shall be stored and handled under the rules for scrap (Section C,6). However, tubes may be cut into any number of cylindrical sections and then supported either 1) on a mandrel or 2) in an encapsulation tube so designed that the normal orientation of successive sections of the tube is maintained. Cut tubes thus supported shall be stored as single tubes, under Sections C,4,a and C,4,b. Mandrels or encapsulation tubes containing tube sections shall not be immersed in any liquid.

a. **Tubes in Regular Arrays**

Fuel tubes may be stored horizontally in a layer no more than nine tubes high and unlimited in length and width. Within this layer:

- The tube shall be in a regular rectangular lattice,*
- The center-to-center spacing of tubes shall be at least 15 x 19 centimeters, and
- The average hydrogenous material content shall be no more than 1% of the volume of the layer; i.e., no 30-cm cube shall contain more than 270 cm$^3$ of hydrogenous material. (For specific exceptions to this general limit, see Supplement No. 9.)

Up to 6 tubes may be stored at a center-to-center spacing of at least 15 x 15 cm, provided that the hydrogenous material limits above are applied.

Fuel tubes may be stored on >15 cm centers in a one tube high layer unlimited in length and width with no limit on the amount of hydrogenous material in and around this layer.

---

* Two or more groups of tubes each in such a regular lattice need not be aligned to maintain the same regular lattice as long as a spacing >19 centimeters is maintained between the vertical center-lines of the closest tubes in each group.
No other fissile material shall be stored above or below any layer of tubes. However, up to 8 tubes or assemblies on >15 x 19 centimeter centers in a container may be moved into, out of, or over this layer at any time.

b. Tubes in Borated Concrete - See Supplement 2
c. Uncontained Tubes

The maximum number of assemblies which may be handled in an isolated group without regard to spacing is given by

\[
\text{safe number} = 4017 \text{ (g U-235/m)}^{-1.1255} + 2.6
\]

rounded down to the nearest integer.

These tubes may be in air or in any liquid that is not a better moderator than H₂O; i.e., the minimum critical number of tubes in the liquid is no less than it is in H₂O. The liquid shall contain no more than one gram of fissile isotopes per liter of liquid. Restrictions on the number and spacing of groups are in Section C,9.

d. Tubes on Racks in Solutions

The limits in Section C,4,c apply to tubes on racks in solutions.

5. Storage and Handling of Assemblies

Assemblies of two or three concentric fuel tubes shall contain a maximum of 1310 g ²³⁵U/m of length.

a. Assemblies in Regular Arrays

Assemblies may be stored in arrays as tubes are stored (Section C,4,a).

b. Borated Concrete Rack - See Supplement 2
c. Uncontained Assemblies

The maximum number of assemblies which may be handled in an isolated group without regard to spacing is given by

\[
\text{safe number} = 4524 \text{ (g U-235/m)}^{-1.1647} + 2.4
\]

rounded down to the nearest integer.
These assemblies may be in air or in any liquid that is not a better moderator than $H_2O$; i.e., the minimum critical number of assemblies in the liquid is no less than it is in $H_2O$. The liquid shall contain no more than one gram of fissile isotopes per liter of liquid. Restrictions on the number and spacing of groups are in Section C,9.

6. Storage and Handling of U-Al Scrap

U-Al scrap is broken sections of massive pieces, tube sections <30 cm long, and any other U-Al alloy not described in Sections C,3 and C,4.

a. Containers with Unlimited U-Al

1. Metal Cans$^{9,8,12}$

Short cans (up to 17.8 cm ID x 30.5 cm tall) and tall cans (up to 15 cm ID x 48 cm tall) may be filled with U-Al scrap and massive pieces. Restrictions on handling individual cans are in Section C,9. Short cans may be stored in all arrays described below; tall cans may be stored only in arrays described in 1) and 2).

1) One-High Arrays$^{32,33}$

Unlimited content cans may be stored vertically in a one-high horizontal rectangular lattice with an average center-center spacing of at least 34 cm and an edge-edge spacing of at least 8 cm. The bottom of the cans must be at least 20 cm from the floor.

2) Two-High Arrays$^{32,33}$

Unlimited-content cans may be stored vertically in two-high arrays. Within these arrays

- the cans in each layer shall be in a rectangular horizontal array with an average center-center spacing of at least 48 cm and an edge-edge spacing of at least 18 cm, and

- the vertical center-center spacing between cans shall be at least 57 cm. The bottoms of cans must be at least 20 cm from the floor.

3) Other Arrays$^{9,8,10,14}$

Unlimited-content cans in arrays that are more than two cans high must meet the limits for vertical and horizontal spacings given in Figure 5 and Table II.
2. Graphite Molds

An unlimited amount of U-Al may be placed inside graphite molds that may be up to 17.8 cm ID and 30.5 cm tall. These molds must be stored in arrays described in 6,a,1,1) and 2).

b. Containers with Limited U-Al

U-Al scrap and massive pieces may be placed in metal cans with dimensions larger than those in 6, a, 1 but no larger than 22 cm ID x 33 cm tall; however, the following limits must not be exceeded:

- $^{235}$U: 500 g
- Hydrogenous Material:
  - with no graphite: 2900 g
  - with graphite: 1900 g

These limited-content cans may be stored vertically in a one-high horizontal rectangular-lattice array with an average center-center spacing of at least 32 cm and an edge-edge spacing of at least 10 cm.

c. Uncontained U-Al

No more than 600 g $^{235}$U in the form of U-Al scrap may be accumulated in air at any location without confining it to an approved U-Al container or a mandrel (for tube sections, as described in Section C,4). Restrictions on the number and spacing of such accumulations are in Section C,9.

d. U-Al in Liquids

The limits for enriched uranium metal in liquids, Section C,1 apply to $^{235}$U in U-Al scrap.

7. Scrap Graphite

Scrap graphite containing up to 10 wt % $^{235}$U shall be handled and stored within the limits of Figure 1 or 2. Figure 1 gives the maximum safe areal density (kg/m²) of $^{235}$U for a given areal density of scrap graphite. As an alternative to the limits in Figure 1, limited quantities may be handled and stored in isolated accumulations. The maximum safe mass of $^{235}$U in such an accumulation is given in Figure 2 as a function of the wt % of $^{235}$U in the scrap graphite. Restrictions on the number and spacing of such accumulations are given in Section C,9.
8. Spacing Between Dissimilar Forms of U-Al

When U-Al alloy in different forms, such as massive pieces, tubes, and scrap, are handled or stored, the minimum spacing between two contiguous arrays shall be the sum of one-half of each of the minimum spacings permitted within the two arrays.

9. Spacing Between Accumulations of $^{235}\text{U}$

A 1-meter separation shall be maintained between accumulations of materials containing $^{235}\text{U}$ as defined in Sections C,1,b; C,1,c; C,3,b; C,4,c; C,5,c; C,6,a,1; C,6,c; C,6,d; C,7; or C 11,b.

10. Processing Single Fissile Units

One, and only one, fissile unit* may be handled by each person and processed in equipment designed to process only one fissile unit. If such single unit equipment is fixed, it must be located so that fissile material on it would not be closer to fissile material on adjacent fixed equipment than permitted by this Supplement. If such equipment is mobile, it must be unique within each building.

11. MK2 and MK8 Cores and Slugs

MK2 and MK8 cores are 2.6 cm diameter by 15.2 cm or 30.5 cm long cylinders of uranium-aluminum alloy each containing up to 1.05 g $^{235}\text{U}$/cm. Slugs are made by sealing these cores in aluminum.

a. Cores and Slugs in Regular Arrays

MK2 and MK8 cores and slugs shall be stored with their axes vertical on a square pitch of at least 7.6 cm. They may be stacked in an array that is unlimited in length and width, but must be less than 2.87 m high. Arrays of cores and slugs must be separated from other approved arrays of fissile material as specified in Section C,8.

b. Uncontained Cores and Slugs

Cores and slugs may be stored and handled under the rules for U-Al scrap as specified in Section C,6. A maximum of 2 cores or slugs may be handled without spacing restrictions. Up to 48, 30.5-cm cores or 92, 15.2-cm cores are allowed in an unconfined group. Restrictions on the number and spacing of such accumulations are in Section C,9.

* Fissile units include: storage cans of enriched uranium metal, tare pans, charge cans, cans of U-Al, packages of used air filters, used crucibles, massive pieces of U-Al, fuel tubes, and fuel tube assemblies.
D. REFERENCES


10 of 18


19. Deleted.

20. Deleted.


22. Deleted.

23. Deleted.


27. Deleted.


30. Deleted.


39. Deleted
TABLE II

Storage of Scrap Cans in Planar Arrays*

A. Cans Without Lids

The table below applies when the scrap cans do not have lids to preclude water accumulation.

<table>
<thead>
<tr>
<th>Maximum Height** of Each Planar Array, ft</th>
<th>Minimum Separation Between Planar Arrays (center-to-center), ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>28</td>
</tr>
<tr>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>25</td>
<td>16.5</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>40</td>
<td>16</td>
</tr>
<tr>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td>4</td>
<td>10.5</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>6.5</td>
</tr>
<tr>
<td>4</td>
<td>4.5</td>
</tr>
</tbody>
</table>

B. Cans With Lids

If all scrap cans in each plane have lids to preclude water accumulation, the planes may be up to 30 feet long, 9 feet high, and as little as 3 feet apart.

* As described in Fig. 5.
** From a common base plane.
# TABLE III. MINIMUM SPACINGS FOR HORIZONTAL CYLINDERS

<table>
<thead>
<tr>
<th>Cylinder Type</th>
<th>Maximum OD, cm</th>
<th>Maximum 235U Content, kA/m</th>
<th>Minimum Axis-Axis Spacing, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-extrusion Billets</td>
<td>32.7</td>
<td>63.6</td>
<td>41.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 Layer</td>
</tr>
<tr>
<td>Other Hollow Cylinders</td>
<td></td>
<td></td>
<td>32.3</td>
</tr>
<tr>
<td></td>
<td>32.3</td>
<td>18.2</td>
<td>36.4</td>
</tr>
<tr>
<td></td>
<td>28.2</td>
<td>18.2</td>
<td>37.2</td>
</tr>
<tr>
<td></td>
<td>23.4</td>
<td>18.2</td>
<td>37.2</td>
</tr>
<tr>
<td></td>
<td>27.1</td>
<td>18.2</td>
<td>37.2</td>
</tr>
<tr>
<td></td>
<td>18.8</td>
<td>14.8</td>
<td>37.2</td>
</tr>
<tr>
<td></td>
<td>24.0</td>
<td>14.8</td>
<td>37.2</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td>14.8</td>
<td>37.2</td>
</tr>
<tr>
<td></td>
<td>15.6</td>
<td>9.9</td>
<td>37.2</td>
</tr>
<tr>
<td>Solid Cylinders</td>
<td>15.9</td>
<td>16.9</td>
<td>37.2</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td>16.9</td>
<td>37.2</td>
</tr>
<tr>
<td></td>
<td>11.8</td>
<td>9.3</td>
<td>37.2</td>
</tr>
</tbody>
</table>

*No end-end spacing of cylinders is required.

**Not Permitted
### TABLE IV. MAXIMUM $^{235}$U CONTENT AND MINIMUM SPACING OF VERTICAL U-AL CYLINDERS*

<table>
<thead>
<tr>
<th>Cylinder Description</th>
<th>Max. U-Al OD, cm</th>
<th>Max. U-Al Length, cm</th>
<th>Maximum $^{235}$U Content, kg/m</th>
<th>Minimum Edge-Edge Spacing, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Extrusion Billets*</td>
<td>28.0 to 32.5</td>
<td>52</td>
<td>63.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Other Hollow Cylinders</td>
<td>28.1 to 32.5</td>
<td>52</td>
<td>19.5</td>
<td>7.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>17.5 to 28.0</td>
<td>52</td>
<td>16.5</td>
<td>7.5</td>
</tr>
<tr>
<td>&quot;</td>
<td>12.0 to 17.4</td>
<td>40</td>
<td>11.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Solid Cylinders</td>
<td>13.0 to 15.9</td>
<td>40</td>
<td>16.9</td>
<td>7.5</td>
</tr>
</tbody>
</table>

* With or without graphite molds and/or cores except for pre-extrusion billets which have no graphite molds or cores.

** This spacing must be measured from the outside surface of the piece not from the outside surface of the U-Al; i.e., for billets, measure from the outside surface of the outer aluminum sheath; for ingots in molds, measure from the outside of the graphite mold.

---

TABLE V — Deleted
FIG. 1 MAXIMUM SAFE AREAL DENSITY OF $^{235}$U IN SCRAP GRAPHITE

FIG. 2 MAXIMUM SAFE MASS OF $^{235}$U IN AN ISOLATED ACCUMULATION OF SCRAP GRAPHITE
FIGURE 3 - DELETED

FIGURE 3A - DELETED

NOTE: When material of different concentrations (kg $^{235}$U per meter of U-AI) is in an isolated group, the maximum mass permitted is that corresponding to the lowest concentration.

FIG. 4 MAXIMUM MASS OF $^{235}$U IN THE FORM OF U-AI MASSIVE PIECES IN ISOLATED GROUPS
The minimum separation between racks is given in Table II as a function of their height and length.

FIG. 5 PLANAR ARRAYS OF U-A1 SCRAP CANS
BORATED CONCRETE STORAGE RACK
BUILDING 321-M

Description

- Southwest Rack - a 13 high x 7 wide stack of concrete slabs with an average boron content of 0.58 wt % (Reference 1). Each slab measures 15 cm x 167 cm x 412 cm, and has 10 holes 10.3 cm in diameter.

- Southeast Rack - a 10 high x 10 wide stack of concrete slabs with an average boron content of 0.58 wt %. Each slab measures 20 cm x 167 cm x 412 cm and has 9 holes 13 cm in diameter (Reference 2).

Process Analysis

The calculated reactivities of each borated concrete loaded with 1310 g 235U/meter Mark 16 assemblies under normal conditions (i.e., no flooding) and with accidental flooding are:

<table>
<thead>
<tr>
<th>Storage Location</th>
<th>Boron in Concrete</th>
<th>Wt %</th>
<th>keff + 2σ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No Flooding</td>
</tr>
<tr>
<td>Southeast Rack</td>
<td>0.58</td>
<td>0.15</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.534</td>
</tr>
<tr>
<td>Southwest Rack</td>
<td>0.58</td>
<td>0.25</td>
<td>&lt;0.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.478</td>
</tr>
</tbody>
</table>

Limits

1. An individual tube or an assembly of tubes containing no more than 1310 g 235U/meter of length may be stored in each storage position in the Southwest rack if the concrete contains at least 0.25 weight percent boron and in the Southeast rack if the concrete contains at least 0.15 weight percent boron.

2. The boron content shall be reconfirmed by neutron absorption measurements at 60-month intervals.
REFERENCES

1. Drawing S5-3-504.

2. Drawing S5-3-2665 and 2666.


CASTING FURNACES
BUILDING 321-M

Description:

Three induction furnaces, each containing a graphite crucible (21.0 cm ID x 40.6 cm deep) that is supported by a "Kaocrete" D liner, surrounded by a water-cooled copper induction heating coil and various ceramic insulators, and enclosed in a cuboidal "Transite" housing (Reference 1). The furnaces are in a single row on 4.3 m centers.

Process Analysis (Reference 1):

The calculated maximum reactivities of furnace crucibles containing U-Al alloy scrap with a surface/volume ratio of 4.0 cm$^{-1}$ (equivalent to that of 1.5-cm spheres or cubes) are given below for three conditions of moderation and reflection:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>$k_{eff}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No water inside or outside of the crucible (normal operation)</td>
<td>$&lt;&lt; 0.932$</td>
</tr>
<tr>
<td>Water inside, none outside of the crucible (the worst foreseeable deviation, see Reference 1)</td>
<td>0.932</td>
</tr>
<tr>
<td>Full water flooding inside and outside of the crucible (judged incredible, see Reference 2)</td>
<td>1.016</td>
</tr>
</tbody>
</table>

Limits:

1) A maximum of 8000 g $^{235}$U in any form may be in each furnace crucible.

2) Any number of pieces of U-Al alloy with a surface/volume ratio of 4.0 cm$^{-1}$ or less, i.e. with each dimension 1.5 cm or more, may be added to a cold crucible (before the initial charge has begun to melt), up to the total limit of 8000 g $^{235}$U.
3) Pieces of U-Al alloy with a surface/volume ratio more than 4.0 cm$^{-1}$, i.e. with any dimension less than 1.5 cm, shall not be permitted in a cold crucible in combination with any hydrogenous material. To avoid such a condition small pieces of U-Al alloy, and all uranium metal for the charge, should not be added until the initial charge has begun to melt.

REFERENCES


DROSS MOLD AND LEACHED FLUX TURNTABLES

Descriptions:

• The Dross Mold turntables have a 50 cm radius steel plate with spaces for six dross molds spaced equidistant on a 27 cm radius circle. (Reference 3)

• The Leached Flux turntables have a 50 cm radius steel plate with spaces for two leached flux molds and two dross molds in a square array with a minimum pitch of 36 cm. (Reference 3)

Process Analysis:

• KENO calculations show that $k_{eff}$ would not exceed 0.87 for any single foreseeable deviation in the storage of any authorized U-Al fissile units on the Dross Mold turntables. (Reference 3)

• The spacers on the Leached Flux turntable will limit the center-to-center spacings of any U-Al fissile units that will fit in the spacers to more than the minimum spacings required by DPSTS-300 SUP-1. (Reference 3)

Limit:

Any U-Al fissile unit authorized by DPSTS-300 SUP-1 with or without a graphite mold that will fit in the spacers of these turntables may be placed in each spacer.

References:


URANIUM-ALUMINUM SCRAP CRUSHER
BUILDING 321-M

**Description:**

A vertical 50-ton Dake "Elec-draulic II" model 8-005 press is used to break large pieces of uranium-aluminum alloy scrap, such as ingot risers, into smaller pieces that can be charged to the furnace crucibles. A 51 x 31 x 46-cm high enclosure is fitted to the ram and anvil of the press, to confine the fragments produced. The bottom of this enclosure is 91 cm from the building floor.

**Process Analysis (Reference):**

An evaluation of all possible sources of water that could flood the area surrounding the hydraulic press, and the routes for loss of water from this area and from the building, shows that flooding the crushing enclosure is not credible. Thus, the only credible source of moderator within the enclosure is the 7.57 liters of oil that could leak from the hydraulic cylinder at the top of the press. With this limit on the amount of moderator that could be present, and conservatively assuming that the uranium-aluminum alloy is finely crushed, 50 kg $^{235}\text{U}$ at the maximum authorized alloy concentration of 1.23 g/cc would be required to form a homogeneous slab in the enclosure with a $k_{\text{eff}}$ of 0.95. This amount of $^{235}\text{U}$ is more than six times the maximum amount (7.55 kg) in any single ingot currently produced.

**Limit:**

Uranium-aluminum alloy containing a maximum of 25 kg $^{235}\text{U}$ may be within the enclosure of the scrap crushing press.

**Reference:**

ENRICHED URANIUM STORAGE VAULT BUILDING 321-M

DESCRIPTION

The existing fixed racks for uranium storage in the 321-M vault include:

1. 116 covered pressure cookers in a three tier array with center-to-center spacings of at least 61 cm (two aisles divide this array to form three subarrays of 26, 45, and 45 units).

2. Positions for 26 open charge cans in a 2 x 13 vertical planar array.

In addition, up to eight DT-14 shipping containers may be placed in each of the two aisles within the array of pressure cookers.

PROCESS ANALYSIS

1. Calculations for the fully loaded vault with charge cans replaced by an extra wall rack accommodating more than twice as much 235U, with eight DT-14 drums (or eight extra pressure cookers) in each of the two aisles within the array of pressure cookers, and with the 19 kg of 235U in each position (including the drums) assumed to be in the form of a solid, full density metal sphere gave a $k_{eff}$ about 0.05 less than the maximum calculated value (uncorrected for bias) judged sufficiently small to ensure subcriticality. Without the drums $k_{eff}$ was calculated to be about 0.02 smaller.

2. Double batching a unit caused the calculated $k_{eff}$ slightly to exceed the maximum acceptable value with the DT-14 drums absent. However, although double-batching a unit is perhaps credible, compact assemblage of uranium pieces (as represented by spheres) in all units including the one double-batched is not credible. Under normal conditions, with the uranium distributed in tare pans at approximately half density, $k_{eff}$ was calculated, with DT-14 drums absent, to be about 0.27 less than the maximum acceptable value. Double-batching a unit under these conditions increased the calculated $k_{eff}$ only slightly.
3. The isotopic composition of the uranium was found to have little effect.\(^1\)

4. Personnel within the vault, represented by 180 lb cylinders of water had little effect.\(^1\)

5. Filling each container with 1% density water (67 g per container) had no significant effect whether units were spherical or distributed in tare pans.\(^1\)

6.Flooding a unit (with uranium distributed in tare pans) increased \(k_{\text{eff}}\) by only about 0.02.\(^1\)

7. Flooding the entire vault has been judged incredible,\(^2\) but would isolate units because of their spacing.

8. Calculations of reactivity of the entire storage vault for the previous configuration of 45 pressure cookers in a 5 x 9 horizontal planar array with all pressure cookers containing samples in a homogenous mixture with water showed that a mass limit of 800 g \(^{235}\text{U}\) was subcritical even if the vault were fully flooded. The filling of all pressure cookers with samples (with no flooding) resulted in a calculated \(k_{\text{eff}}\) 0.05 smaller than if the cookers contained uranium metal spheres.\(^2\) It was therefore considered unnecessary to calculate the reactivity of samples for the present configuration.

9. No calculations were made for charge cans in conjunction with the present configuration of pressure cookers. The previous calculations,\(^3\) and the substitution of an additional rack of pressure cookers for charge cans were considered sufficient.

**LIMITS**

1. The enriched uranium storage vault may contain a maximum of 2700 kg \(^{235}\text{U}\) as follows:

   a. A maximum of 19 kg \(^{235}\text{U}\) in each of 116 pressure cookers on fixed racks.

   b. A maximum of 16 DT-14 shipping containers with up to 18 kg \(^{235}\text{U}\) in each container.\(^4\)

   c. A maximum of 8 kg \(^{235}\text{U}\) in each of 26 charge cans on the fixed rack.
2. There is no restriction on the isotopic composition of uranium.

3. The following amounts of hydrogenous material may be in the containers mentioned above.
   
a. Pressure cookers -
      
      < 800 g $^{235}$U in cookers - no restrictions on hydrogenous material

      > 800 g $^{235}$U - no hydrogenous material

b. DT-14 containers - up to 120 g of hydrogenous materials

c. Charge cans - no hydrogenous materials
REFERENCES


CASTING AREA GLOVE BOX

Description

The casting area glove box (Reference 1) has two pairs of glove ports for processing U-Al waste that could produce airborne contamination, e.g. removing U-Al from air filters or used graphite crucibles. The U-Al accumulates in a 215 cm x 90 cm stainless steel pan and is subsequently swept through one of two trap doors into a can whose maximum dimensions are 17.8 cm ID x 30.5 cm tall. A steel railing in front of the glove box, a hood behind the glove box, and the closely spaced legs of the glove box prevent carts or dollies of fissile materials from being placed under the stainless steel pan.

Process Analysis

Reactivity calculations using the MGEX code show that k_eff ≤ 0.95 for the most reactive foreseeable deviation: doubling the mass limits for 235U, hydrogenous material, or graphite (Reference 2).

Limits

The contents of the glove box shall not exceed the following limits:

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Limit, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>235U (as U-Al)</td>
<td>25</td>
</tr>
<tr>
<td>Hydrogenous Material*</td>
<td>3</td>
</tr>
<tr>
<td>Graphite</td>
<td>40</td>
</tr>
</tbody>
</table>

No unalloyed uranium is permitted in the glove box.

References

1. Drawing S5-3-4496 through 4503.

* Excluding the wooden HEPA filter frames.
POLYVINYL CHLORIDE ON SHIPPING CONTAINER SPACERS
BUILDING 321-M

Description:
Intra-area movements of fuel tubes are made with canvas-sided trailers that have positions for 16 tubes in a $4 \times 4$ rectangular array, on 6-inch by 7-1/2-inch centers. Interarea movements of reactor fuel and target assemblies are made with aluminum caskets that have positions for up to 8 assemblies in a $2 \times 4$ rectangular array, on 6-inch by 7-1/2-inch centers. Padding or a coating of polyvinyl chloride (PVC) on the aluminum spacers in these shipping containers is necessary to avoid damage to the outer surface of the tubes.

Process Analysis: (See Reference)
Reactivities were calculated for the most reactive credible arrays of fuel assemblies in trailers and caskets, and with the addition of a PVC coating on the spacers; this coating was assumed to be twice the normal thickness. The effect of the PVC on the calculated reactivity was not statistically significant for any of the assumed conditions of moderation and reflection. Representative calculated values of $k_{\text{eff}}$ for $4 \times 24$ arrays of caskets are given below.

<table>
<thead>
<tr>
<th>Moderator &amp; Reflector</th>
<th>$k_{\text{eff}}$</th>
<th>Without PVC</th>
<th>With PVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% H$_2$O in Voids, Concrete on 1 Side</td>
<td>0.41</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>1% H$_2$O in Voids, 100% H$_2$O on 6 Sides</td>
<td>0.77</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>100% H$_2$O in Voids, 100% H$_2$O on 6 Sides</td>
<td>0.90</td>
<td>0.92</td>
<td></td>
</tr>
</tbody>
</table>

Limits
1) The following maximum amounts of PVC coating may be on each of the standard aluminum spacers in the trailers and caskets used for shipping fuel tubes and assemblies:

- Trailer full spacers - 800 g
- Trailer half spacers - 550 g
- Casket spacers - 800 g
Limits: (Continued)

2) Spacers coated as described above may be used at three positions along the length of trailers and caskets.

Reference:

OUTGASSING OVEN RACKS FOR PRE-EXTRUSION BILLETS

Description:

A rack that can accommodate three 33 cm O.D. pre-extrusion billets in a triangular array (Reference 1) is used during the outgassing of the billets. Two of these racks are placed end-to-end on one of the two outgassing oven rack transfer carts (Reference 2) and then loaded with billets. The two loaded racks are moved to one of four outgassing ovens and both racks are rolled into the oven.

Process Analysis:

The KENO code calculated a maximum $k_{\text{eff}} = 0.944 \pm 0.007$ for these racks loaded with pre-extrusion billets with the most reactive foreseeable deviation: flooding two adjacent carts each containing two loaded racks, a total of 12 pre-extrusion billets. (References 3 and 4)

Limit:

Each of the 3 billets on a rack shall not exceed 33 cm O.D. and shall contain no more than 21.7 kg of $^{235}$U.

References:

1. Drawing S5-3-3681.
2. Drawing S5-3-1329.
BORATED CONCRETE STORAGE RACK
BUILDING 321-M

Description

- Southwest Rack - a 13 high x 7 wide stack of concrete slabs with an average boron content of 0.58 wt % (Reference 1). Each slab measures 15 cm x 167 cm x 412 cm, and has 10 holes 10.3 cm in diameter.

- Southeast Rack - a 10 high x 10 wide stack of concrete slabs with an average boron content of 0.58 wt %. Each slab measures 20 cm x 167 cm x 412 cm and has 9 holes 13 cm in diameter (Reference 2).

Process Analysis

The calculated reactivities of each borated concrete loaded with 1310 g 235U/meter Mark 16 assemblies under normal conditions (i.e., no flooding) and with accidental flooding are:

<table>
<thead>
<tr>
<th>Storage Location</th>
<th>Boron in Concrete</th>
<th>( k_{\text{eff}} + 2\sigma ) No Flooding</th>
<th>( k_{\text{eff}} + 2\sigma ) Flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southwest Rack</td>
<td>0.58</td>
<td>0.27</td>
<td>0.76</td>
</tr>
<tr>
<td>Rack</td>
<td>0.15</td>
<td>0.534</td>
<td>0.859</td>
</tr>
<tr>
<td>Southwest Rack</td>
<td>0.58</td>
<td>&lt;0.41</td>
<td>&lt;0.83</td>
</tr>
<tr>
<td>Rack</td>
<td>0.25</td>
<td>0.478</td>
<td>0.950</td>
</tr>
</tbody>
</table>

Limits

1. An individual tube or an assembly of tubes containing no more than 1310 g 235U/meter of length may be stored in each storage position in the Southwest rack if the concrete contains at least 0.25 weight percent boron and in the Southeast rack if the concrete contains at least 0.15 weight percent boron.

2. The boron content shall be reconfirmed by neutron absorption measurements at 60-month intervals.
REFERENCES

1. Drawing S5-3-504.

2. Drawing S5-3-2665 and 2666.


CASTING FURNACES
BUILDING 321-M

Description:

Three induction furnaces, each containing a graphite crucible (21.0 cm ID x 40.6 cm deep) that is supported by a "Kaocrete" D liner, surrounded by a water-cooled copper induction heating coil and various ceramic insulators, and enclosed in a cuboidal "Transite" housing (Reference 1). The furnaces are in a single row on 4.3 m centers.

Process Analysis (Reference 1):

The calculated maximum reactivities of furnace crucibles containing U-Al alloy scrap with a surface/volume ratio of 4.0 cm⁻¹ (equivalent to that of 1.5-cm spheres or cubes) are given below for three conditions of moderation and reflection:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>$k_{eff}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No water inside or outside of the crucible</td>
<td>&lt;&lt; 0.932</td>
</tr>
<tr>
<td>(normal operation)</td>
<td></td>
</tr>
<tr>
<td>Water inside, none outside of the crucible</td>
<td>0.932</td>
</tr>
<tr>
<td>(the worst foreseeable deviation, see Reference 1)</td>
<td></td>
</tr>
<tr>
<td>Full water flooding inside and outside of the crucible</td>
<td>1.016</td>
</tr>
<tr>
<td>(judged incredible, see Reference 2)</td>
<td></td>
</tr>
</tbody>
</table>

Limits:

1) A maximum of 8000 g $^{233}$U in any form may be in each furnace crucible.

2) Any number of pieces of U-Al alloy with a surface/volume ratio of 4.0 cm⁻¹ or less, i.e. with each dimension 1.5 cm or more, may be added to a cold crucible (before the initial charge has begun to melt), up to the total limit of 8000 g $^{233}$U.
3) Pieces of U-A1 alloy with a surface/volume ratio more than 4.0 cm$^{-1}$, i.e. with any dimension less than 1.5 cm, shall not be permitted in a cold crucible in combination with any hydrogenous material. To avoid such a condition small pieces of U-A1 alloy, and all uranium metal for the charge, should not be added until the initial charge has begun to melt.

REFERENCES


DROSS MOLD AND LEACHED FLUX TURNTABLES

Descriptions:

- The Dross Mold turntables have a 50 cm radius steel plate with spaces for six dross molds spaced equidistant on a 27 cm radius circle. (Reference 3)

- The Leached Flux turntables have a 50 cm radius steel plate with spaces for two leached flux molds and two dross molds in a square array with a minimum pitch of 36 cm. (Reference 3)

Process Analysis:

- KENO calculations show that $k_{eff}$ would not exceed 0.87 for any single foreseeable deviation in the storage of any authorized U-Al fissile units on the Dross Mold turntables. (Reference 3)

- The spacers on the Leached Flux turntable will limit the center-to-center spacings of any U-Al fissile units that will fit in the spacers to more than the minimum spacings required by DPSTS-300 SUP-1. (Reference 3)

Limit:

Any U-Al fissile unit authorized by DPSTS-300 SUP-1 with or without a graphite mold that will fit in the spacers of these turntables may be placed in each spacer.

References:


URANIUM-ALUMINUM SCRAP CRUSHER
BUILDING 321-M

Description:

A vertical 50-ton Dake "Elec-draulic II" model 8-005 press is used to break large pieces of uranium-aluminum alloy scrap, such as ingot risers, into smaller pieces that can be charged to the furnace crucibles. A 51 x 51 x 46-cm high enclosure is fitted to the ram and anvil of the press, to confine the fragments produced. The bottom of this enclosure is 91 cm from the building floor.

Process Analysis (Reference):

An evaluation of all possible sources of water that could flood the area surrounding the hydraulic press, and the routes for loss of water from this area and from the building, shows that flooding the crushing enclosure is not credible. Thus, the only credible source of moderator within the enclosure is the 7.57 liters of oil that could leak from the hydraulic cylinder at the top of the press. With this limit on the amount of moderator that could be present, and conservatively assuming that the uranium-aluminum alloy is finely crushed, 50 kg $^{235}$U at the maximum authorized alloy concentration of 1.23 g/cc would be required to form a homogeneous slab in the enclosure with a $k_{eff}$ of 0.95. This amount of $^{235}$U is more than six times the maximum amount (7.55 kg) in any single ingot currently produced.

Limit:

Uranium-aluminum alloy containing a maximum of 25 kg $^{235}$U may be within the enclosure of the scrap crushing press.

Reference:

ENRICHED URANIUM STORAGE VAULT BUILDING 321-M

DESCRIPTION

The existing fixed racks for uranium storage in the 321-M vault include:

1. 116 covered pressure cookers in a three tier array with center-to-center spacings of at least 61 cm (two aisles divide this array to form three subarrays of 26, 45, and 45 units).

2. Positions for 26 open charge cans in a 2 x 13 vertical planar array.

In addition, up to eight DT-14 shipping containers may be placed in each of the two aisles within the array of pressure cookers.

PROCESS ANALYSIS

1. Calculations for the fully loaded vault with charge cans replaced by an extra wall rack accommodating more than twice as much $^{235}$U, with eight DT-14 drums (or eight extra pressure cookers) in each of the two aisles within the array of pressure cookers, and with the 19 kg of $^{235}$U in each position (including the drums) assumed to be in the form of a solid, full density metal sphere gave a $\kappa_{\text{eff}}$ about 0.05 less than the maximum calculated value (uncorrected for bias) judged sufficiently small to ensure subcriticality. Without the drums $\kappa_{\text{eff}}$ was calculated to be about 0.02 smaller.

2. Double batching a unit caused the calculated $\kappa_{\text{eff}}$ slightly to exceed the maximum acceptable value with the DT-14 drums absent. However, although double-batching a unit is perhaps credible, compact assemblage of uranium pieces (as represented by spheres) in all units including the one double-batched is not credible. Under normal conditions, with the uranium distributed in tare pans at approximately half density, $\kappa_{\text{eff}}$ was calculated, with DT-14 drums absent, to be about 0.27 less than the maximum acceptable value. Double-batching a unit under these conditions increased the calculated $\kappa_{\text{eff}}$ only slightly.\(^1\)
3. The isotopic composition of the uranium was found to have little effect.\(^1\)

4. Personnel within the vault, represented by 180 lb cylinders of water had little effect.\(^1\)

5. Filling each container with 1\% density water (67 g per container) had no significant effect whether units were spherical or distributed in tare pans.\(^1\)

6. Flooding a unit (with uranium distributed in tare pans) increased \(k_{\text{eff}}\) by only about 0.02.\(^1\)

7. Flooding the entire vault has been judged incredible,\(^2\) but would isolate units because of their spacing.

8. Calculations of reactivity of the entire storage vault for the previous configuration of 45 pressure cookers in a 5 x 9 horizontal planar array with all pressure cookers containing samples in a homogenous mixture with water showed that a mass limit of 800 g \(^{235}\text{U}\) was subcritical even if the vault were fully flooded. The filling of all pressure cookers with samples (with no flooding) resulted in a calculated \(k_{\text{eff}}\) 0.05 smaller than if the cookers contained uranium metal spheres.\(^2\) It was therefore considered unnecessary to calculate the reactivity of samples for the present configuration.

9. No calculations were made for charge cans in conjunction with the present configuration of pressure cookers. The previous calculations,\(^3\) and the substitution of an additional rack of pressure cookers for charge cans were considered sufficient.

**LIMITS**

1. The enriched uranium storage vault may contain a maximum of 2700 kg \(^{235}\text{U}\) as follows:
   a. A maximum of 19 kg \(^{235}\text{U}\) in each of 10 pressure cookers on fixed racks.
   b. A maximum of 16 DT-14 shipping containers with up to 18 kg \(^{235}\text{U}\) in each container.\(^4\)
   c. A maximum of 8 kg \(^{235}\text{U}\) in each of 26 charge cans on the fixed rack.
2. There is no restriction on the isotopic composition of uranium.

3. The following amounts of hydrogenous material may be in the containers mentioned above.

   a. Pressure cookers -
      
      \[ 800 \text{ g } \^{235}\text{U} \text{ in cookers} \quad \text{no restrictions on hydrogenous material} \]
      
      \[ > 800 \text{ g } \^{235}\text{U} \quad \text{no hydrogenous material} \]

   b. DT-14 containers - up to 120 \text{ g of hydrogenous materials}\]

   c. Charge cans - no hydrogenous materials
REFERENCES


CASTING AREA GLOVE BOX

Description

The casting area glove box (Reference 1) has two pairs of glove ports for processing U-AI waste that could produce airborne contamination, e.g. removing U-AI from air filters or used graphite crucibles. The U-AI accumulates in a 215 cm x 90 cm stainless steel pan and is subsequently swept through one of two trap doors into a can whose maximum dimensions are 17.8 cm ID x 30.5 cm tall. A steel railing in front of the glove box, a hood behind the glove box, and the closely spaced legs of the glove box prevent carts or dollies of fissile materials from being placed under the stainless steel pan.

Process Analysis

Reactivity calculations using the MGEX code show that $k_{\text{eff}} \leq 0.95$ for the most reactive foreseeable deviation: doubling the mass limits for $^{235}\text{U}$, hydrogenous material, or graphite (Reference 2).

Limits

The contents of the glove box shall not exceed the following limits:

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Limit, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{235}\text{U}$ (as U-AI)</td>
<td>25</td>
</tr>
<tr>
<td>Hydrogenous Material*</td>
<td>3</td>
</tr>
<tr>
<td>Graphite</td>
<td>40</td>
</tr>
</tbody>
</table>

No unalloyed uranium is permitted in the glove box.

References

1. Drawing S5-3-4496 through 4503.

* Excluding the wooden HEPA filter frames.
POLYVINYL CHLORIDE ON SHIPPING CONTAINER SPACERS
BUILDING 321-M

Description:

Intra-area movements of fuel tubes are made with canvas-sided trailers that have positions for 16 tubes in a 4 × 4 rectangular array, on 6-inch by 7-1/2-inch centers. Interarea movements of reactor fuel and target assemblies are made with aluminum caskets that have positions for up to 8 assemblies in a 2 × 4 rectangular array, on 6-inch by 7-1/2-inch centers. Padding or a coating of polyvinyl chloride (PVC) on the aluminum spacers in these shipping containers is necessary to avoid damage to the outer surface of the tubes.

Process Analysis: (See Reference)

Reactivities were calculated for the most reactive credible arrays of fuel assemblies in trailers and caskets, and with the addition of a PVC coating on the spacers; this coating was assumed to be twice the normal thickness. The effect of the PVC on the calculated reactivity was not statistically significant for any of the assumed conditions of moderation and reflection. Representative calculated values of $k_{eff}$ for 4 × 24 arrays of caskets are given below.

<table>
<thead>
<tr>
<th>Moderator &amp; Reflector</th>
<th>Without PVC</th>
<th>With PVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1% H$_2$O in Voids, Concrete on 1 Side</td>
<td>0.41</td>
<td>0.43</td>
</tr>
<tr>
<td>1% H$_2$O in Voids, 100% H$_2$O on 6 Sides</td>
<td>0.77</td>
<td>0.76</td>
</tr>
<tr>
<td>100% H$_2$O in Voids, 100% H$_2$O on 6 Sides</td>
<td>0.90</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Limits

1) The following maximum amounts of PVC coating may be on each of the standard aluminum spacers in the trailers and caskets used for shipping fuel tubes and assemblies:

- Trailer full spacers - 800 g
- Trailer half spacers - 550 g
- Casket spacers - 800 g
Limits: (Continued)

2) Spacers coated as described above may be used at three positions along the length of trailers and caskets.

Reference:

OUTGASSING OVEN RACKS FOR PRE-EXTRUSION BILLETS

Description:

A rack that can accommodate three 33 cm O.D. pre-extrusion billets in a triangular array (Reference 1) is used during the outgassing of the billets. Two of these racks are placed end-to-end on one of the two outgassing oven rack transfer carts (Reference 2) and then loaded with billets. The two loaded racks are moved to one of four outgassing ovens and both racks are rolled into the oven.

Process Analysis:

The KENO code calculated a maximum $k_{eff} = 0.944 \pm 0.007$ for these racks loaded with pre-extrusion billets with the most reactive foreseeable deviation: flooding two adjacent carts each containing two loaded racks, a total of 12 pre-extrusion billets. (References 3 and 4)

Limit:

Each of the 3 billets on a rack shall not exceed 33 cm O.D. and shall contain no more than 21.7 kg of $^{235}\text{U}$.

References:

1. Drawing S5-3-3681.
2. Drawing S5-3-1329.
PRE-EXTRUSION BILLET OUTGASSING OVEN

DESCRIPTION

The "Despatch" outgassing oven (Reference 1) has positions for 20 pre-extrusion billets, placed with their axes horizontal in a 2-high by 10-long vertical planar array. Within this array, the axis-axis vertical spacing between billets is 88.9 cm and the horizontal spacings are 48.2 cm and 75.6 cm, alternately. The distance from the building floor to the center of the bottom row of billets is 80.6 cm. Besides these positions there are positions for 10 coextrusion billets in two rows. The latter positions are above and midway between each pair of positions for pre-extrusion billets at the 48.2 cm spacing.

Process Analysis

A KENO calculation\(^2\) for an array of 30 pre-extrusion billets more compactly arranged than in the oven and closely reflected on six sides by a thick water reflector gave a \(k_{\text{eff}}\) of 0.869, which is well below the maximum value of 0.94 for which subcriticality is assured. The 10 positions for coextrusion billets actually will physically not accommodate pre-extrusion billets. Potential reflectors are actually much farther from the array than was assumed. The uranium content of the billets in this calculation was 1.23 g \(^{235}\text{U}\)/cc, the Technical Standard limit. At nominal \(^{235}\text{U}\) content and planned loadings of the oven, \(k_{\text{eff}}\) is substantially smaller (0.72), still with close reflection by water. Moderation by 1% \(\text{H}_2\text{O}\) within all voids of the lattice of 30 billets has no significant effect.

Limit

Each billet in this oven may be a maximum of 32.7 cm o.d. and may contain a maximum of 49.2 kg \(^{235}\text{U}\).

REFERENCES

1. Drawing S5-3-5002.

FISSILE MATERIAL SHIPPING CONTAINERS

Description

The 6M and DT-14A drum designs are shown in Figures 1 and 2, respectively. Material to be shipped in these drums is sealed in a steel can. The DT-7 drum design is shown in Figure 3. Material to be shipped in the DT-7 drums is packaged in plastic bags which then are placed in a 3-gallon can with a friction lid.

Other shipping containers are described in their Certificate of Compliance.

Process Analysis

KENO calculations (References 1, 2, 3) show that 6M, DT-7, and DT-14A drums in large planar or stacked arrays, either mixed or segregated, would be subcritical with any single foreseeable deviation from the limits specified below. The results of these calculations are summarized in the following table.

<table>
<thead>
<tr>
<th>Material in Drums</th>
<th>20 x 20 Planar Array</th>
<th>Stacked Array**</th>
</tr>
</thead>
<tbody>
<tr>
<td>6M Drums</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U-A1-H₂O</td>
<td>0.71</td>
<td>0.77</td>
</tr>
<tr>
<td>U</td>
<td>-</td>
<td>0.96</td>
</tr>
<tr>
<td>DT-7 Drums</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U-A1-H₂O</td>
<td>0.69</td>
<td>0.88</td>
</tr>
<tr>
<td>U-A1-H₂O-C</td>
<td>-</td>
<td>0.93</td>
</tr>
<tr>
<td>DT-14A Drums</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U-A1-H₂O</td>
<td>≤ 0.74</td>
<td>≤ 0.90</td>
</tr>
<tr>
<td>U</td>
<td>-</td>
<td>≤ 0.96</td>
</tr>
</tbody>
</table>

* The bias is 0.04 for all cases except the 6M drums containing U metal for which the bias is 0.06.

** The calculated array size was 6 x 6 x 6 for 6M drums, 5 x 5 x 5 for DT-7 drums, and 6 x 6 x 5 for DT-14A drums.
Limits

1. 6M, DT-7, and DT-14A Shipping Containers.

   a. The contents of each container shall comply with the following limits:

<table>
<thead>
<tr>
<th>Type Drum</th>
<th>Authorized Contents</th>
<th>H/235U Atom Max. 235U Content, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>6M</td>
<td>U-Al Scrap*</td>
<td>3 (Max)</td>
</tr>
<tr>
<td></td>
<td>U-Metal**</td>
<td>0.00++</td>
</tr>
<tr>
<td>DT-7</td>
<td>U-Metal** or U-Al Scrap*</td>
<td>See footnote &quot;+&quot;</td>
</tr>
<tr>
<td>DT-14A</td>
<td>U-Al Scrap (≤1.15 g 235U/cc of U-Al)</td>
<td>≤ 3.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 3.22 but ≤10.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;10.7 but ≤21.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;21.4</td>
</tr>
<tr>
<td></td>
<td>U-Metal**</td>
<td>0.00++</td>
</tr>
<tr>
<td></td>
<td>U-Compounds***</td>
<td>≤ 0.43</td>
</tr>
</tbody>
</table>

   b. The maximum numbers of these drums that may be included in a stacked array (in any arrangement) shall be such that the value of the following expression shall not exceed 100:

   \[ 1.0 \times (6M) + 0.9 \times (DT-7) + 0.6 \times (DT-14A) \]

   In this equation, the parenthetic values are the numbers of each type of drum in the array.

   c. A stacked array of drums as described above shall be separated from other fissile material by a space of at least 2 meters. However, a planar array of drums is unlimited as to number of drums or spacing from other fissile material.

   d. Individual steel cans in which U-Metal and U-Al scrap is packaged for 6M and DT-14A containers shall have a maximum capacity of 5.0 liters. More than one can may be in each 6M or DT-14A container; however, the total capacity of all cans in a DT-14A container shall not exceed 6.8 liters.

   * The U-Al alloy in the scrap shall contain no more than 1.23 g 235U per cubic centimeter.

   ** Unalloyed uranium metal of any enrichment in the 235U isotope.

   *** Uranium compounds shall have a 235U density ≤8.33 g 235U/cc and shall be packaged in water-tight metal cans or water-tight polyethylene bottles, ≥1 mm wall thickness.

   † Each DT-7 drum may contain up to 1.9 kg of hydrogenous material if graphite is present or up to 2.9 kg if no graphite is present.

   ++ Less than or equal to 120 grams of packaging may be used.
2. Other Shipping containers.

Shipping containers not authorized by Section 1 above may be handled and stored in the 300 Area under the following restrictions.

a. The design and contents of the containers shall comply with a valid Certificate of Compliance (Reference 4).

b. The containers shall remain sealed while they are in the 300 Area.

c. The number of such containers permitted in an isolated grouping and the spacing from other fissile material required to provide this isolation are given below.

<table>
<thead>
<tr>
<th>Fissile Class (Reference 5)</th>
<th>Total Number of Containers Permitted</th>
<th>Minimum Separation From Other Fissile Material, meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Unlimited Number</td>
<td>2</td>
</tr>
<tr>
<td>II</td>
<td>(Correspondence to a Total Transport Index* of 100)</td>
<td>2</td>
</tr>
<tr>
<td>III</td>
<td>As Specified in the Certificate of Compliance</td>
<td>6</td>
</tr>
</tbody>
</table>

* Where the Total Transport Index equals the sum of the individual transport indices for all containers in the isolated group.
References


5. 49 CFR 6 173.389.


Bolt Ring (12 gauge)

Head and Gasket

Solid industrial cane fiberboard ("Celotex")
Minimum density 0.208 g/cc

Bolt (5/8 in.)

Vent Holes
(minimum of 4 required 1.2 cm diameter)

Spec. 2R
13.3 cm I.D.
60 cm inside height

Spec. 6C or 17C
Capacity: 210 liters
(55 gallons)

FIGURE 1. 6M Shipping Drum (CFR 49 S 178.104)
NOTE: The inner surface of the 2R container is coated with a cadmium layer 0.03 cm thick. The cadmium layer is coated with Monothane™ (Synair Corp.) polyurethane rubber to give an ID of 15.8 cm at the top and 15.3 cm at the bottom.

FIGURE 2. DT-14A Shipping Drum (USA/9860/B(U)F)
FIGURE 3. DT-7 Shipping Drum (USA/6227-C/B7)
Pu-Be Sources

Description

Sources covered under this supplement contain up to 160 g plutonium mixed with beryllium at a Be to Pu atom ratio of ~13 sealed in two concentric metal cylinders.

Process Analysis

KENO calculations (Reference) show that up to 100 sources would be subcritical in air, in water, or if inadvertently placed adjacent to other approved arrays of fissile material. Therefore, the limits specified herein provide double contingency protection from a nuclear accident.

Limits

- Each Pu-Be source shall contain no more than 160 g $^{239}$Pu.
- Up to 50 such sources may be in each 300 Area building.
- Pu-Be sources shall be kept at least 1 meter away from other fissile material.

Reference

USED FILTER STORAGE CABINET

Description

A metal cabinet for the storage of twelve HEPA filters or bags containing up to six pre-filters in a 3-high x 4-wide x 1-deep rectangular array (Reference 1). The minimum edge-to-edge spacing between filters is 15 cm horizontally and 53 cm vertically. Although not a requirement, the cabinet shelves keep the filters four cm above the floor.

Process Analysis

KENO calculations show that with the worst foreseeable deviation the reactivity of the cabinet, $K_{\text{eff}} + 2\sigma$, is 0.85 (Reference 2).

Limits

- A single HEPA filter or package containing up to six pre-filters may be placed on each shelf of the cabinet.
- Each HEPA filter or package of pre-filters shall contain no more than 500 $\mu$Ci $^{235}$U.
- All other fissile material shall be kept 1 meter away from this cabinet.

References

COMBINATION FILE SAFES

Description
Two steel cans, 15-cm ID x 25-cm tall, are positioned at opposite ends in each of four drawers in two adjacent combination lock safes (References 1 and 2).

Process Analysis
Reactivity calculations show that, with the worst foreseeable deviations, the normalized $k_{eff} + 2\sigma$ is less than 0.94 with the safes either in the expanded metal cage (Reference 1) or in the concrete vault (Reference 2).

Limitations
- Each can in the safes may be filled with U-Al alloy and any amount of hydrogenous materials.
- All other arrays of fissile material except the Scrap Can Transfer Cart (Reference 3), which may be adjacent to the safe, must be kept at least 1 meter from the cans in the safes.
- The safes in the concrete vault must be at least 25 cm apart and at least 2.5 cm from the concrete walls.
- The safes must be secured to prevent their disarrangement during design basis earthquake or tornado.

References


LOW-K NTGs

Description

The Building 321-M Low-K NTG and the Building 320-M Low-K NTG are instruments that measure the nuclear reactivity of fuel tubes, target tubes, and miscellaneous materials. These two NTGs are shown in drawings 55-3-4966, 4970, 4971, 4972, 4976, and 4977.

Process Analysis

KENO calculations that have been correlated with experimental data show that criticality would not occur with the worst foreseeable sequence of errors (Reference 1). Accidental criticality is judged to be incredible because this would require fabrication of fuel tubes with extremely high $^{235}$U contents and full flooding of the test hole. The $^{235}$U content required to cause criticality exceeds the fuel fabrication process capacity and there is no known mechanism for flooding the test hole. Design of charge tables and lattice shielding effectively isolates the NTG core and fuel tubes being tested from the arrays of fissile materials that may be placed adjacent to the NTG. Therefore, any fuel tube authorized by DPSTS-300-SUP-1 may be safely processed through the NTGs.

Limits and Requirements

1. No more than two NTG cores or slugs shall be placed in each NTG lattice fuel position.

2. Neutron multiplication measurements shall be made during the initial NTG lattice fuel loadings to ensure that the NTGs remain conservatively subcritical and to confirm the design $\kappa_{eff}$.

References

U-AL CHIP COMPACTOR

Description

The U-AL chip compactor consists of a 200-ton hydraulic press, a 15.3-cm-ID x 34-cm-tall die containing a 3.8-cm-thick ejector, and a 90-cm x 180-cm x 110-cm-tall glove box enclosure around it (Reference 1).

Process Analysis

HRXN-KENO calculations show that with the worst foreseeable deviation, the reactivity, $k_{eff} + 2\sigma$, of the enclosure is 0.912 (References 3 and 4).

Limits

1. A maximum of 4800 g $^{235}$U may be in the enclosure at any time.

2. The press reservoir must contain no more than 160 liters of oil.

3. The prefilter-HEPA filter combination must contain less than 500 g $^{235}$U.

4. A scrap can may not be at the exit port while more than 200 g of uncompacted U-AL chips are in the enclosure.

References

1. Drawing No. 55-3-4794, 4795, and 4797.


MARK 15

A. APPLICABILITY

This supplement provides the nuclear criticality safety limits for processing, storing, and shipping the following forms of Mark 15 uranium.

- Bare cores
- Canned slugs
- Scrap
- Aqueous uranyl nitrate solution
- Uranium metal slurries
- Uranium oxide slurries

These limits apply everywhere in the 300-Area and in any other facilities under the control of the Raw Materials Department.

B. DESCRIPTION

Mark 15 cores are hollow cylinders of uranium as described below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Core</th>
<th>ID, cm</th>
<th>OD, cm</th>
<th>Length, cm</th>
<th>Wgt, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner</td>
<td></td>
<td>5.13</td>
<td>6.62</td>
<td>21.2</td>
<td>5.50</td>
</tr>
<tr>
<td>Outer</td>
<td></td>
<td>8.04</td>
<td>9.25</td>
<td>21.2</td>
<td>6.56</td>
</tr>
</tbody>
</table>

Mark 15 slugs are produced by plating a thin layer of nickel (~.002 cm) on these cores and then encasing them in aluminum intimately bonded to the nickel and uranium.
C. Process Analysis

1. Uranium containing 1.106 wt% $^{235}$U can not be critical unless it is moderated.\(^3\)

2. Calculations in Reference 1 show:
   - that an infinite number of NLO steel lined wood boxes full of Mark 15 without skids and with optimum moderation would have $K_{eff} = 0.910$ and
   - that 252 of these containers full of Mark 15 damaged in a "hypothetical accident" and subsequently moderated to produce the highest reactivity would have $K_{eff} = 0.976$.

Accordingly, federal regulation 10 CFR 71 permits shipping an unlimited number of these containers.

3. Calculations in Reference 3 show that for the most reactive array of Mark 15 inner cores in water $K_{eff} = 0.98$ for a spherical array of 270 cores or for a 33.5 cm thick infinite slab.

4. Calculations in Reference 3 show that any of the tanks in Table 1 would be subcritical with the worst foreseeable deviation, i.e. filling with Mark 15 inner cores.

5. Calculations in Reference 2 show that for the most reactive sized pieces of uranium in water $K_{eff} = 0.98$ for a 26 cm thick infinite slab or for 800 kg of uranium in a sphere.

6. Calculations in Reference 3 show that $K_{eff} = 0.98$ for the most reactive concentration of $UO_2$ in water in a sphere with a uranium content of 5181 kg or with a volume of 1538 liters. Any other compound encountered in the 300-Area would be less reactive.

7. The calculated reactivity, $K_{eff}$, for an unlimited number of adjacent four-high stacks of aluminum boxes\(^5\) full of Mark 15 inner slugs with the most reactive flooding is 0.88 and 0.96 for a similar array of pallets of cardboard boxes full of Mark 15 outer slugs.\(^2\)

8. The probability of accidental criticality during the shipment of Mark 15 slugs between the 300 and 100-Areas was conservatively estimated as $8 \times 10^{-9}$/hr.\(^2\) This probability is acceptably low and thus an unlimited number of these boxes may be in a shipment.
D. Limits

1. Enrichment

The uranium shall contain no more than 1.106 weight percent $^{235}\text{U}$.

2. Uranium in Air

An unlimited amount of this uranium ($<1.106$ wt% $^{235}\text{U}$) in any form may be handled in air provided accidental moderation is judged incredible.

3. Core Shipping Containers$^{1,2}$

a. Mark 15 inner or outer cores may be shipped in NLO steel lined wood boxes; only one type core in each box. There are no nuclear criticality safety limits on the number of these boxes in a shipment.

b. In storage, the boxes of cores may be stacked up to six high and must be sealed sufficiently to retain the cores if the stacks of boxes accidentally overturned. There is no limit on the number of such stacks or their spacing from other approved arrays of fissile material. Core storage areas must have a fire suppression system to ensure that the boxes will not burn in the event of a fire.

4. Cores and Slugs in Water

a. Up to 270 cores or slugs may be in water with no restrictions except that all other fissile material must be $>1$ meter away.

b. An unlimited number of cores and slugs may be in a single horizontal layer $<33.5$ cm thick. There must be no other fissile material above or below this layer.

5. Cores and Slugs in Tanks of Aqueous Solutions

Mark 15 cores or slugs may be processed in the tanks listed in Tables 1 and 2. Table 1 lists the tanks which may contain water or any aqueous solution; they have no solute limits. Table 2 lists the tanks which must contain the listed minimum solute concentrations. Cores or slugs must be processed only on the racks and the conveyors or in the baskets provided.
6. **Scrap**
   a. Mark 15 scrap is any piece of Mark 15 uranium weighing less than 3.25 kg.
   
b. Up to 800 kg of uranium scrap may be amassed in any amount of water with no restrictions except that all other fissile material must be >1 meter away.
   
c. An unlimited amount of uranium scrap in water may be in a single horizontal layer <26 cm thick. There must be no other fissile material above or below this layer.
   
d. Up to 800 kg of Mark 15 scrap may be in each offplant shipment. No other fissile material may be in this shipment.

7. **Aqueous Uranium Compound Slurries**
   a. Up to 5000 kg of uranium as a compound may be amassed in any amount of water with no restrictions except that all other fissile material must be <1 meter away.
   
b. Up to 1500 liters of an aqueous uranium compound slurry may be amassed with no restrictions except that all other fissile material must be >1 meter away.
   
c. Up to 430 kg of this slurry may be sealed in a 55 gallon drum. An unlimited number of these drums may be in a one-high planar array.

8. **Slug Shipments Between 300 and 100 Areas**
   a. Up to 144 inner slugs may be packaged in an aluminum box. Outer slugs may be packaged in cardboard or aluminum boxes, up to 20 or 64 to a box, respectively.
   
b. In storage, cardboard boxes of slugs must be on 15-cm thick pallets; up to 4 boxes per pallet. These loaded pallets and aluminum boxes may be stacked up to 4 high.
   
c. An unlimited number of cardboard or aluminum boxes, stacked up to 2 high may be in each shipment between the 300 and 100 Areas.
References


### TABLE 1

**BUILDING 313-M TANKS FOR PROCESSING MARK 15 -**

**Tanks With No Solute Limits**

<table>
<thead>
<tr>
<th>Tank Designation</th>
<th>E.P. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>212</td>
</tr>
<tr>
<td>Nitric Acid</td>
<td>211</td>
</tr>
<tr>
<td>Water</td>
<td>279A</td>
</tr>
<tr>
<td>Nitric Acid</td>
<td>280</td>
</tr>
<tr>
<td>Water</td>
<td>279B</td>
</tr>
<tr>
<td>Water</td>
<td>4031.1</td>
</tr>
<tr>
<td>Nitric Acid</td>
<td>4043-A</td>
</tr>
<tr>
<td>Nitric Acid</td>
<td>4033.7</td>
</tr>
<tr>
<td>Nitric Acid</td>
<td>4043.3</td>
</tr>
<tr>
<td>Nitric Acid</td>
<td>4044</td>
</tr>
<tr>
<td>Water</td>
<td>4033.8</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>4045</td>
</tr>
<tr>
<td>Water</td>
<td>4033.9</td>
</tr>
<tr>
<td>Rinse Tank</td>
<td>20127</td>
</tr>
<tr>
<td>Bond Tester</td>
<td>20379</td>
</tr>
<tr>
<td>Quench</td>
<td>20329</td>
</tr>
<tr>
<td>Accumulator-Lubricator</td>
<td>20324</td>
</tr>
</tbody>
</table>

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TABLE 2

BUILDING 313-M TANKS FOR PROCESSING MARK 15 - Tanks With Required Solutes

<table>
<thead>
<tr>
<th>Tank</th>
<th>E.P. No.</th>
<th>Solute</th>
<th>Minimum Concentrations, g/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caustic</td>
<td>278</td>
<td>NaOH</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NaNO₃</td>
<td>180</td>
</tr>
<tr>
<td>Caustic</td>
<td>276</td>
<td>NaOH</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NaNO₃</td>
<td>180</td>
</tr>
<tr>
<td>Nitric Acid</td>
<td>4031.2</td>
<td>HNO₃</td>
<td>520</td>
</tr>
<tr>
<td>Anodic Etch</td>
<td>4042.1</td>
<td>HCl</td>
<td>9.8</td>
</tr>
<tr>
<td>Anodic Etch</td>
<td>4042.2</td>
<td>HCl</td>
<td>9.8</td>
</tr>
<tr>
<td>Plating Tank</td>
<td>4048.1</td>
<td>H₃BO₃</td>
<td>29</td>
</tr>
<tr>
<td>Plating Tank</td>
<td>4048.2</td>
<td>H₃BO₃</td>
<td>29</td>
</tr>
<tr>
<td>Plating Tank</td>
<td>4048.3</td>
<td>H₃BO₃</td>
<td>29</td>
</tr>
</tbody>
</table>
SPECIAL MARK 15

A. Applicability

This supplement provides the nuclear criticality safety limits for processing, storing, and shipping special (1.106 to 1.400 wt % $^{235}\text{U}$) Mark 15 cores, slugs, and scrap.

These limits apply in Building 723-A, everywhere in the 300-Area, and in any other facilities under the control of the Raw Materials Department.

B. Description

Mark 15 cores are hollow cylinders of uranium as described below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Core ID, cm</th>
<th>OD, cm</th>
<th>Length, cm</th>
<th>Wgt, kg</th>
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<td>21.2</td>
<td>5.50</td>
</tr>
<tr>
<td>Outer</td>
<td>8.04</td>
<td>9.25</td>
<td>21.2</td>
<td>6.56</td>
</tr>
</tbody>
</table>

Mark 15 slugs are cores that are encased in aluminum.

C. Process Analysis

1. Uranium containing 1.400 wt% $^{235}\text{U}$ can not be critical unless it is moderated.

2. Calculations in Reference 1 show that for the most reactive array of special Mark 15 inner cores in water, $K_{eff} = 0.98$ for a spherical array of 110 cores or for a 24 cm-thick infinite slab.

3. Calculations in Reference 2 show that, for the most reactive sized pieces of uranium in water, $K_{eff} = 0.98$ for a 20 cm thick infinite slab or for 360 kg of uranium in a sphere.

D. Limits

1. Enrichment

The uranium shall contain no more than 1.400 weight percent $^{235}\text{U}$.
2. **Uranium in Air**

An unlimited amount of this uranium (1.10b to 1.400 wt% 235U) in any form may be handled in air, provided moderation is judged incredible. Where moderation is judged credible, the limits in Sections D.3 and D.4 apply.

3. **Special Mark 15 Cores and Slugs in Water**

   a. Up to 110 cores or slugs may be in water with no restrictions except that all other fissile material must be >1 meter away.

   b. An unlimited number of cores and slugs may be in a single horizontal layer <24 cm thick. There must be no other fissile material above or below this layer.

4. **Special Mark 15 Scrap**

   a. Special mark 15 scrap is any piece of special Mark 15 uranium weighing less than 3.25 kg.

   b. Up to 360 kg of this uranium scrap may be amassed in any amount of water with no restrictions except that all other fissile material must be >1 meter away.

   c. An unlimited amount of this uranium scrap in water may be in a single horizontal layer <20 cm thick. There must be no other fissile material above or below this layer.

5. **Off-Plant Shipments**

Up to 110 cores or slugs, or 360 kg of scrap may be in each off-plant shipment. These materials may be packaged in any container that has an applicable certificate of compliance. No other fissile material may be in this shipment.

References


INGOT AND CORE RACKS

Description

These racks each consist of 6 storage troughs in a 3 high by 2 wide array on 35.5 cm centers, both horizontally and vertically (Reference 1). The construction of the racks prevents inserting ingots or cores with OD's greater than 27.3 cm in the bottom four troughs. Each rack is bolted to the floor to provide an access aisle of at least 30 cm between racks.

Process Analysis

HRXN-KENO calculations were made for the following worst case:

- a 3-high by 20-wide array of horizontal U-Al ingots 500 cm long on 35.5 cm centers, both horizontally and vertically.
- the hollow ingots in the top layer were 32 cm OD and contained 18.2 kg $^{235}$U/meter, those in the bottom two layers were 27.6 cm OD and contained 18.2 kg $^{235}$U/meter, and
- the entire array was flooded.

The resulting $k_{eff} + 2\sigma$ was 0.88 (Reference 2). The actual value would be less because the 27.6 cm OD ingots will not fit in the bottom two layers.

The racks are constructed to ensure that U-Al cylinders up to 33 cm OD will remain in the racks during a design basis tornado and earthquake (References 3 and 4).

Limits

U-Al cylinders stored in the ingot and core racks must not exceed 32.3 cm OD nor 18.2 kg $^{235}$U/meter of length.
References

1. Drawing Number D-117222.


NO. 10 CAN STORAGE RACKS

Description

The No. 10 can storage rack has two levels. On the lower level the can bottoms are at least 20 cm above the floor and the vertical center-to-center spacing between cans on the two levels is at least 60 cm. The cans stand upright on both layers in a regular square array on at least 29 cm centers. This array is unlimited in length and width. Each rack extends 14.5 cm beyond the center of the outermost storage position so that the 29 cm center-to-center spacing is maintained if two racks are adjacent.

Process Analysis

HRXN-KENO calculations normalized to experiments show that $k_{eff} + 2\sigma$ is $< 0.76$ for the maximum normal conditions and 0.962 for the worst foreseeable deviation (Reference).

Limits

1. The maximum inside dimensions of cans stored in these racks shall be 15.6 cm ID x 17.8 cm tall.

2. The cans may be filled with U-Al containing up to 1.15g $^{235}$U/cc of U-Al at a $\text{H}/^{235}$U atom ratio of no more than 10.7.

Reference

APPLICABILITY

This supplement provides nuclear criticality safety limits for processing and storing the following:

- Dross Rods
- Dross Rod Molds
- Muffins
- Muffin Pans

DESCRIPTION (Reference 1)

Dross rods are cylinders of U-Al alloy dross 6.35 cm OD x 16.5 cm long.

Dross rod molds are graphite cylinders 20.3 cm OD x 20.3 cm long with four cylindrical holes 6.35 cm OD x 16.5 cm deep arranged in a square lattice on 7.6 cm centers. Molten U-Al alloy dross is poured into these holes to produce dross rods.

Muffins are cylinders of U-Al alloy dross 6.35 cm OD x 2.5 cm high.

Muffin pans are graphite cuboids 26.7 cm x 26.7 cm x 5.1 cm with nine cylindrical holes into which molten U-Al alloy dross is placed to produce muffins. The holes are 6.35 cm ID x 2.5 cm deep arranged in a 3 x 3 square lattice on 7.6 cm centers.

PROCESS ANALYSIS (Reference 1)

(1) A "spherical" array of 18 dross rods at their most reactive spacing in water would have a $k_{eff}$ (normalized to experiments) of 0.92.

(2) An unlimited number of dross rods are subcritical in water at a center-to-center spacing of 14 cm or more in a square lattice. With 1% water moderation in this array, an array height of 95 cm or six rods ensures subcriticality. All intermediate amounts of moderation are judged incredible (Reference 2).

(3) A two-high array of dross rod molds with a square lattice pitch of 34 cm and a top-to-bottom spacing of 30 cm has a calculated $k_{eff} = 0.75$ with 1% $H_2O$ moderation and 0.70 with 100% $H_2O$ moderation.
A six-high array of muffin pans filled with U-Al unlimited in length and width and with a top-to-bottom spacing of 10.16 cm has a calculated $k_{eff} + 2\sigma$ of 0.78 and 0.83 when flooded; a calculated $k_{eff} + 2\sigma < 0.95$ is judged safe.

LIMITS

1. The U-Al alloy dross shall contain no more than 1.23 g $^{235}$U/cc.

2. The average hydrogenous material content of all arrays below shall be no more than 1% of the array volume.

3. Up to 18 dross rods may be in an unconfined group separated from all other fissile material by one meter.

4. Store dross rods in a square array with a center-to-center spacing of 14 cm or more. When the rod axes are horizontal, the array may be up to six rods high; when the rod axes are vertical, the array may be up to 95 cm thick. Both arrays may be unlimited in length and width and must be spaced from other approved arrays as specified in DPSTS-300-SUP-1,C,8.

5. Dross rod molds filled with U-Al may be stored in a square array on >34 cm centers. This array may be up to two high with a top-to-bottom spacing of at least 30 cm. These arrays are unlimited in length and width.

6. Muffin pans filled with U-Al may be stored in up to six horizontal layers with a top-to-bottom spacing of at least 10.16 cm. Within each layer the muffin pans must rest on their 26.7 x 26.7 cm face, one pan high. An unlimited number of pans may be adjacent to each other.

REFERENCES


LIQUID REMOVAL RACK

APPLICABILITY

This supplement provides nuclear criticality safety limits for processing and storing U-Al alloy in the Liquid Removal Rack.

DESCRIPTION

The Liquid Removal Rack consists of the Used Crucible Cooling Rack (Reference 1) on which a Dump Pan, Liquid Tray, and a holder for a Ladle Can will be installed on the front left two storage positions. Maximum inside dimensions will be 48.3 cm x 22.9 cm x 7.7 cm deep for the Dump Pan and 10.2 cm x 22.9 cm x 2.5 cm deep for the Liquid Tray. In its horizontal position the Dump Pan will be at least 15.8 cm above a Ladle Can stored in the holder beneath it and at least 2.5 cm above the Liquid Tray on the opposite end of the Dump Pan.

PROCESS ANALYSIS (Reference 2)

1) With alloy containing 1.23g $^{235}$U/cc of alloy filling the Dump Pan, Liquid Tray, and a Ladle Can and ingots containing 16.5 kg $^{235}$U/meter in each of the six storage positions, the calculated $k_{eff} + 2\sigma$ is 0.38.

2) With the worst foreseeable deviation, a U-Al-H$_2$O mixture in the Pan, Tray, Ladle Can, and in Scrap Cans in the six storage positions, the calculated $k_{eff} + 2\sigma$ is 0.76.

LIMITS

1) U-Al scrap processed and stored in the Liquid Removal Rack must contain no more than 1.23g $^{235}$U/cc.

2) A fissile unit may be stored in each rack storage position provided that it will physically fit and its $^{235}$U content does not exceed limits in DPSTS-300-SUP-1 and 24.

REFERENCES

1) Drawing S4-3-528.
