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December 15, 2009

Director
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

References: 1) Docket No. 70-143; SNM License 124
2) NRC Inspection Report No. 70-143/2009-202, dated May 1, 2009

Subject: Request for License Amendment to Chapter 4 Regarding Nuclear Criticality Safety

Nuclear Fuel Services, Inc. (NFS) hereby submits a request for an amendment to Chapter 4, "Nuclear Criticality Safety," of SNM-124 per the requirements set forth in 10 CFR 70.34. Included in the Attachment is a revised Chapter 4 in its entirety. Changes are denoted by vertical lines in the margin of the affected pages and are summarized below.

Section 4.2.1.2 Reflection: The section describing the reflection requirements was amended to improve clarity, and reformatted.

Section 4.2.2.4 Array Reflection: The section was deleted due to the requirements being moved to Section 4.2.1.2 above.

If you or your staff have any questions, require additional information, or wish to discuss this, please contact me, or Mr. Randy Shackelford, Nuclear Criticality Safety Manager, at (423) 743-2504. Please reference our unique document identification number (21G-09-0200) in any correspondence concerning this letter.

Sincerely,

NUCLEAR FUEL SERVICES, INC.

David L. Kudsin

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DMG/pdj
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Attachment

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NUCLEAR CRITICALITY SAFETY

Subject matter in this chapter that is enclosed by parentheses is presented only for information purposes and is not to be considered as a license condition.

4.1 Administrative Conditions

4.1.1 Nuclear Criticality Safety Philosophy

All process equipment and systems shall be designed to incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible.

In those processes where it has been determined that double contingency is not practicable to implement, NFS shall implement sufficient redundance and diversity on changes in one process condition such that at least two unlikely, independent, and concurrent errors, accidents, or equipment malfunctions, are present before a criticality accident is possible.

Where practicable, reliance will be placed on equipment design in which "favorable" geometry is used rather than on administrative controls. The limiting dimensions for favorable geometry are a function of the most reactive credible values for the other nine parameters listed below. Fixed neutron absorbers may be used as part of a favorable geometry.

Criticality safety analyses used to demonstrate the safety of process equipment and systems shall show the following:

- Normal conditions – the most reactive values, as limited by identified controls on system parameters, are assumed for variables including the following:

  (a) Moderation,
  (b) Reflection,
  (c) Mass,
  (d) Concentration,
  (e) Density,
  (f) Enrichment,
  (g) Heterogeneity,
  (h) Geometry,
  (i) Spacing (Interaction), and
  (j) Neutron Absorbers.

- Accident conditions – all credible abnormal conditions, including the failure of any one designated safety control, are assumed to occur. An evaluation shall be

performed showing that the system is subcritical by either the subcritical limit criteria of this chapter or by validated analytical methods described in Section 4.2.3. In particular, subcriticality shall be evaluated, for each designated safety control, one at a time, assuming that just one control is failed, and all others functional. It shall be assumed that the parameter for the failed control and all uncontrolled nuclear criticality parameters are at their most reactive combination of credible values. Each parameter controlled by a safety control other than the one being evaluated shall be assumed at the most reactive value within its controlled range.

- Structural integrity – the integrity of any structure on which nuclear safety is directly dependent is considered.

A single criticality safety control may be composed of limits applied to two or more system parameters. For example, the volume of a system may be used in combination with the concentration parameter to establish mass as a control for the system.

4.1.1.1 Engineered Controls

Engineered controls detect an undesired situation and implement corrective action without requiring human intervention. Engineered controls must be:

1. capable of performing the criticality safety purpose for which they are specified;

2. maintained and/or calibrated on a schedule suitable for the specific device and the specific application;

3. verified as being properly installed prior to first use with fissile material;

4. modified only with documented prior approval of the criticality safety function;

5. replaced by approved procedures and/or devices in the event the controls fail—these controls must be:

   (a) approved by the same function that approved the failed controls, and

   (b) restricted in duration if the risks are increased, or a revised safety analysis must demonstrate that the increased risk is acceptable for extended use; and

6. so designed that when sampling is part of a control, the sampling is performed at a frequency consistent with the rate of variation of the parameter and with the implementation of control action.

Programs must be in place to assure that engineered controls meet criterion 2, 3, and 4.

4.1.1.2 Procedural/Administrative Controls

A procedural control requires human intervention in detecting an undesired condition and/or implementing corrective actions. Procedural controls must be:

- capable of performing the criticality safety purpose for which they are specified;
- implemented by operating procedures and/or postings;
- shown to be complied with by records;
- modified only with documented prior approval of the criticality safety function;
- supported by procedures and/or devices which provide continued control if operation is to be allowed to continue after a control has failed; and,
- so designed that when sampling is part of a control, the sampling is performed at a frequency consistent with the rate of variation of the parameter and with the implementation of control action.

4.1.2 Responsibilities for Nuclear Safety

Each proposed change to existing equipment or addition of new equipment used in the processing or storage of licensed material, and any procedure changes resulting therefrom, will receive a nuclear safety review.

The discipline managers shall assure that all such changes, modifications, or additions are reviewed by the safety discipline and the safety discipline manager shall assure that they are reviewed by the criticality safety function.

All changes, modifications, or additions will receive a detailed criticality safety analysis as outlined in Section 4.3, unless the following criteria are met:

- less than a safe mass, as defined in Section 4.2.1.3, exists and there is no possibility of double batching material, or
- the areal density is less than a safe areal density, as defined in Section 4.2.2.1, and there is no possibility of double batching material.

When either the criticality safety function review or the safety discipline manager review indicates that the change may significantly affect criticality safety, a detailed criticality safety analysis will be required. It shall include an analysis performed by a member of the criticality safety function having at least the qualifications of a junior member as described in Chapter 2, and an independent review performed by a member of the criticality safety function having at least the qualifications of a senior member as described in Chapter 2.

The criticality safety function determines the appropriate nuclear safety limits and controls to be applied to the proposed change. If concentration is chosen as the method of criticality control for an unfavorable geometry vessel, the president or his designated alternate must approve the proposed method. The discipline managers shall assure that the change and its proposed safety limits and controls are reviewed by the safety review committee and, as appropriate, approved by the president or his designated alternate.

The discipline managers shall assure that the change is not placed into operation until the criticality safety review and a detailed analysis, if required, are completed, and the concomitant nuclear criticality safety requirements and approval for operation are received from the criticality safety function.

4.1.3 Documentation and Records Retention

When a nuclear safety review requires a detailed criticality safety analysis, the initial analysis and the independent review will be documented and maintained, along with a copy of the proposed change, until the termination of the license. The analysis document shall clearly identify the criticality safety limits and controls established as a result of these reviews.

4.1.4 Procedures

Operations throughout the plant involving licensed material are covered by written procedures. Each procedure is reviewed and approved according to a formal management process as described in Chapter 2. The procedures incorporate nuclear safety limits and controls on operations involving licensed material.

The discipline managers shall assure that all operating procedures, which incorporate criticality limits and controls established by the criticality safety function, are developed and maintained and shall assure that foremen, operators, and other concerned personnel comply with these procedures.

4.1.5 Posting of Nuclear Criticality Safety Limits

Nuclear criticality safety requirements issued by the criticality safety function for each process system shall be available at each work area in the form of operating procedures. Clear, visible signs or notices will be posted at each work station, or area of like stations, to supplement the procedures by emphasizing specific limits and controls.

Posted nuclear criticality safety requirements shall be defined by the criticality safety function and shall, as appropriate, include:

- limits on material types and forms;

- allowable quantities by weight or number;

- allowable geometries;
- allowable enrichments;
- limits on reflecting materials;
- required spacing between units;
- control limits, on quantities such as moderation, concentration/density and the presence of additives.

4.1.6 Approval of New or Modified Equipment

Any new or modified equipment used in the processing or storage of SNM will be inspected and, if required, a preoperational test will be performed. The results from the inspection and test will be reviewed before the equipment is put into use. The presence of appropriate procedures, instructions, and/or posted criticality safety controls will be verified during the inspections. A junior member of the criticality safety function, as described in Chapter 2, will perform the inspections and reviews. A senior member will determine which preoperational tests are required.

New or modified equipment used for the processing or storage of SNM will not be allowed to be used until approval from the criticality safety function has been obtained.

4.1.7 Nuclear Safety Procedures

Activities conducted by the criticality safety function, that are required by the license to be conducted, will be in accordance with approved Safety procedures. Such activities shall include, but not be limited to, auditing and performing nuclear safety analyses.

4.2 Technical Criteria

4.2.1 Individual Units

The basic assumptions and design conditions used for nuclear criticality safety analyses of individual units (i.e., a process vessel or a container of SNM) are stated in this section.

Either the applicable design conditions and associated criteria will be utilized as specified or analytical methods, as described in Section 4.2.3.2, will be used to demonstrate the safety of each unit.

4.2.1.1 Internal Moderation

The design conditions for individual units will be based on the assumption that optimum moderation by water will be the normal condition unless a moderator more effective than water is credible or the degree of moderation is specifically limited.

When a moderator more effective than water is credible, nuclear safety parameters will be based on the optimum degree of moderation for the credible materials unless the degree of moderation is specifically limited.

When the degree of moderation is specifically limited to a value less than optimum, nuclear safety parameters will be based on that specific value.

This applies to water and moderators more effective than water.

Criticality safety of individual units based on control of moderation requires that sources of moderation internal and external to the unit be identified and controls be established for each source which are consistent with the requirements of Section 4.1.1. (Acceptable techniques for controlling and maintaining the proper degree of moderation are given in Chapter 14.)

4.2.1.2 Reflection

Reflection – Reflection control is a method of control which limits neutron return back into an SNM-bearing system. Refer to the following reflection requirements:

General Reflection Requirements

Conservative reflection conditions are established when evaluating the criticality safety of individual units or arrays. If reflection conditions are uncontrolled, the maximum credible amount of water reflection is considered when calculating system subcriticality. Under certain conditions, however, materials such as concrete, beryllium, carbon, and polyethylene may be more effective reflectors than water. The thickness and location of these types of reflectors (including water) are considered in the model. If it is credible for reflection conditions to exceed those used in the analysis of system subcriticality, then reflection controls are implemented to maintain conditions to within the bounds of the analysis. Where positive barriers are used to maintain reflection control, the barriers are maintained through the configuration management and maintenance programs.

Single or Individual Units

A single unit (e.g., vessel or container) is shown to be subcritical when reflected by at least 30 cm of close-fitting water unless:

1) reflector(s) more effective than water are within 30 cm of the unit, or

2) the 30 cm of close-fitting water reflection is not credible.

When reflectors more effective than water are within 30 cm of a single unit, the thickness and location of these reflectors are considered in the model. When a reflector is offset (by a physical device) from a single unit, subcriticality will be demonstrated for the thickness and material of the reflector at no more than the offset distance. The efficacy of the controls implemented to maintain the offset spacing is considered in the analysis of unit subcriticality. Subcriticality for single unit reflection may be demonstrated with calculations or by reference to documented subcritical values (e.g., maximum subcritical values provided in ANSI/ANS-8.1).

Multiple Portable Containers

When evaluating multiple portable containers, the containers are shown to be subcritical with at least a 10 cm thick close-fitting water reflector on one side of the containers and at least 2.5 cm of close-fitting water reflection on the remaining sides of the containers. These reflectors are modeled as slabs or a box that is tangential to the group of containers, or as a closefitting cylinder around the group of containers.

Enclosures/Gloveboxes

Subcriticality of enclosures is demonstrated with the accessible outer sides of the enclosures reflected by 10 cm of close-fitting water and the outer top and bottom of the enclosures reflected by at least 2.5 cm of close-fitting water. Evaluation of overall enclosure reactivity is calculated with portable containers inside the enclosure positioned as close as possible to the outer water reflectors, considering the design and construction of the enclosure, unless fixed spacing controls are implemented. At least 2.5 cm of water reflection is modeled on the remaining sides of the portable containers. This reflection is modeled as slabs or a box that is tangential to the group of containers, or as a closefitting cylinder around the container or group of containers. Note that a larger calculated effective neutron multiplication might result when the portable containers are spaced farther away from the outer reflectors, but nearer to other fixed fissile units that are inside the enclosure. The thickness and location of reflectors that may be more effective than water (e.g., concrete, beryllium, carbon, and polyethylene) are considered in the model.

Arrays

Ordered arrays (more than two units evenly spaced in one or more dimensions) of columns or storage racks are demonstrated to be subcritical using a conservatively representative number of blocks of close-fitting water 10 cm thick, 60 cm wide, and 180 cm tall reflecting the boundary of the array (e.g., boundary framework). The thickness and location of reflectors that may be more effective than water (e.g., concrete, beryllium, carbon, and polyethylene) are also considered. The density of water interspersed between units within the array is varied from 0.0 to 0.1 grams per cubic centimeter, to bound conditions that may exist during fire sprinkler activation. Where personnel may physically enter the array (e.g., storage vault), a conservatively representative number of

blocks of closefitting water 10 cm thick, 60 cm wide, and 180 cm tall is modeled adjacent to individual units within the array, unless the array remains subcritical for any amount of interspersed water.

4.2.1.3 Mass

The design conditions for individual units whose safety is based on fissile mass limits specified in Section 4.2.3.1 will meet the following criteria:

- If double batching is credible, the mass of any single accumulation shall not exceed a safe batch, which is defined to be no more than 45% of the minimum critical mass.

- Where volume controls prevent overbatching, a mass of 75% of the minimum critical mass shall not be exceeded.

The minimum critical mass values are assumed to be those for optimally-moderated, fully-reflected units unless otherwise limited by the controls specified in Sections 4.2.1.1 and 4.2.1.2.

Criticality safety of individual units based on control of mass requires that limits on the allowable mass of fissile material in each unit be established and controls be implemented to ensure that the limits are not exceeded. Mass limits may be specified in terms of fissile material weight or, if based upon known compositions, in terms of gross or net weights of materials. A system comprised of several individual units may be considered as a single unit if the total mass of fissile material in the system meets the criteria established in this section.

With the exception of an engineered volume control that physically prohibits the mass limit from being exceeded, the mass is controlled by determining and then limiting the quantity of fissile material available to, or present in, a unit. (Acceptable techniques for determining the mass values are given in Chapter 14.) The mass values are compared to, and controlled to be no more than, the specified criticality safety limits.

Engineered and/or procedural controls utilized to prevent the mass limits from being exceeded shall comply with the requirement of Section 4.1.1.

4.2.1.4 Concentration

(Solution concentration limits are normally expressed in terms of the maximum allowable mass of fissile material per unit volume; however, the corresponding minimum allowable moderator-to-fissile-material ratio may be utilized.)

The design conditions for individual units containing solutions will be based on the assumption that the most reactive fissile material concentration credible for the unit is

present, unless controls are established to limit the concentration to no more than a specific less reactive value.

When criticality safety is contingent only upon maintenance of a limited concentration of fissile material, the following criteria will be met:

- The concentration must be uniform throughout the unit and shall not exceed a safe value (i.e., no more than 45% of the minimum critical concentration for an infinite unit) when using data from Section 4.2.3.1 or analyses shall be performed that meet the criteria in Section 4.2.3.2.

- Controls shall be established to either prevent precipitation, settling, and/or selective layering into unsafe concentrations, or limit the total quantity of fissile material in the unit to no more than 75% of the minimum critical mass as specified in Section 4.2.3.1 or analyses shall be performed that meet the criteria in Section 4.2.3.2.

Concentration is controlled by determining and then limiting the quantity of fissile material per unit volume available to, or present in, a unit. (Acceptable techniques for determining concentration values are given in Chapter 14.) The concentration values are compared to, and controlled to be no more than, the specified criticality safety limits.

When prevention of precipitation, settling/and/or selective layering into unsafe concentrations is required the solubility is controlled, and, if necessary, the material is agitated and/or recirculated to prevent such conditions.

Engineered and/or procedural controls utilized to prevent the concentration limits from being exceeded shall comply with the requirements of Section 4.1.1.

4.2.1.5 Density

The design conditions for individual units containing non-solution compounds will be based on the assumption that the most reactive fissile material density credible for the unit is present, unless controls are established to limit the density to a specific maximum value.

Criticality safety of individual units based on control of density requires that limits on the allowable density be established and controls be implemented to ensure that the limits are not exceeded.

With the exception of a procedural control whereby the design and operation of a specific process prevents the density limit from being exceeded, the density is controlled by determining and then limiting the quantity of fissile material per unit volume available to, or present in, a unit. (Acceptable techniques for determining density values are given in Chapter 14.) The density values are compared to, and controlled to be no more than, the specified criticality safety limits.

The control of density for purposes of criticality safety shall comply with the requirements of Section 4.1.1.

4.2.1.6 Enrichment

The design conditions for individual units will be based on the assumption that fissile materials are fully enriched, unless the enrichment is based on measurements prior to the enrichment being used as a criticality control. Where materials having different enrichment values are mixed, and enrichment is used as the primary criticality control, the maximum enrichment measured is assumed throughout the system.

When enrichment is based upon supplier information, confirming measurements will be made by analyzing representative samples prior to processing of the material.

Low-enriched uranium materials are defined as those having less than 20 weight percent ^{235}U content. Materials containing greater than or equal to 20 weight percent ^{235}U are considered high-enriched. Fully enriched materials are assumed to be 100 weight percent ^{235}U.

The control of enrichment for purposes of criticality safety must comply with the requirements of Section 4.1.1.

4.2.1.7 Heterogeneity

The design conditions for individual units will be based on the assumption that optimum heterogeneity exists for low-enriched uranium unless the processes that produced the material can not result in heterogeneous conditions. Heterogeneity is also a concern for high-enriched metallic uranium (variable single unit density); however, this parameter is not required to be controlled for high-enriched non-metallic uranium.

Procedural controls are used to prevent heterogeneous materials from being input to any unit whose safety requires only homogeneous materials. All materials are characterized as either homogeneous or heterogeneous based on the processes that produced the materials.

The control of heterogeneity for purposes of criticality safety must comply with the requirements of Section 4.1.1.

4.2.1.8 Geometry

Geometric limits are established taking into account the reliability of the criticality data available and the structural integrity of the equipment for all credible conditions. The basic assumptions and design conditions for the variables already described in Section 4.2.1 are considered in the safety analysis of the geometry of an individual unit. Unless controls are established to limit the variables to specific values, they are all assumed to be

at their most reactive credible conditions; and the geometry of the unit is designed to account for those conditions. Standard buckling equations may be used to determine the geometric limits for finite units.

Equipment must be designed in accordance with standard industrial requirements to ensure the structural integrity of the components important to criticality safety. Engineered structures will be designed to prevent expansion, corrosion, and/or erosion of the unit to a critical configuration.

4.2.1.8.1 Diameter

When primary geometric nuclear safety control is provided by an engineered structure and technical data as described in Section 4.2.3.1 are used, the diameter will be limited to no more than 90% of the minimum critical diameter for an infinite unit.

4.2.1.8.2 Thickness

Limiting fissile material thickness/depth to provide primary nuclear safety control is subject to procedural controls, or engineered controls, or a combination thereof. In the cases where only procedural controls are used to maintain nuclear safety and technical data as described in Section 4.2.3.1 are used, the thickness will be limited to no more than 45% of the minimum critical thickness for an infinite unit.

When a combination of controls is used and technical data as described in Section 4.2.3.1 are used, the thickness of the fissile material will be procedurally limited to no more than 75% of the minimum critical thickness for an infinite unit, and the associated engineered structure will limit the thickness to no more than 90% of the critical thickness for an infinite unit in the event that the procedural control fails.

When only engineered structures are used to maintain nuclear safety and technical data as described in Section 4.2.3.1 are used, the limiting thickness may be no more than 85% of the minimum critical thickness for an infinite unit.

4.2.1.8.3 Volume

When volume is employed as the primary criticality control and technical data as described in Section 4.2.3.1 are used, that volume will be limited by an engineered structure to no more than 75% of the minimum critical volume.

4.2.1.8.4 Intersection of Pipes

The following design conditions will be met so that geometric nuclear safety control will be incorporated into pipe intersections:

- The solution must be a fissile salt having H/X $\geq$20.

- Individually, intersecting pipes must not exceed the diameter limit specified in Section 4.2.1.8.1.

- The allowable intersection diameter must extend at least 18 inches from the point of the intersection before an increase in the diameter is permitted.

- Nominally reflected conditions may be assumed only in accord with the conditions of Section 4.2.1.2.

Intersection of pipes is permitted if the effective diameter of intersection, d_e, does not exceed the maximum effective diameter determined by the appropriate relation in Table 4.1.

Table 4.1
INSIDE PIPE DIAMETER LIMITS FOR INTERSECTIONS

Intersection Configuration	Maximum Effective Diameter
Ell	0.818 D_c
Tee	0.750 D_c
Cross	0.692 D_c

Where D_c is the minimum critical cylinder diameter for the most reactive credible form of the material contained in the piping and reflection conditions around the piping. The effective diameter of an intersection, de, is computed from the relation

$$d_e = \left[\frac{\sum_{i=1}^{n} d_i^2}{n} \right]^{1/2}$$

where:

d_i = diameter of the "i"th branch of the intersection

n = number of branches

n = 2 for ells

n = 3 for tees and wyes

n = 4 for crosses

Pipe intersections separated by less than 18 inches (axis-to-axis) are permitted if, and only if, the effective intersection area per quadrant of all pipes within a sector is less than or equal to the appropriate limiting value in Table 4.2. The intersection area is defined as the area of intersection of an arm with the tangent plane of the column at the point where the axis of the arm intersects the column. A sector is defined as any 18-inch length of the central column. A quadrant is defined as one-fourth of a sector; the sector is divided into four quadrants by two perpendicular planes intersecting along the axis of the sector.

Table 4.2
CENTRAL COLUMN DIAMETER AND INTERSECTION AREA PER QUADRANT LIMITS

NUMBER OF QUADRANTS CONTAINING ARMS IN A SECTOR	NOMINAL REFLECTION		FULL REFLECTION	
	Maximum Central Column Diameter (inches)	Maximum Intersection Area Per Quadrant (square inches)	Maximum Central Column Diameter (inches)	Maximum Intersection Area Per Quadrant (square inches)
1	6.25	30.68	4.60	16.62
2	6.00	20.83	4.44	11.98
3 or 4	5.50	16.00	4.12	9.60

4.2.1.9 Fixed Neutron Absorbers

The use of a neutron absorber as a criticality controlled parameter is acceptable if the following criteria are met:

- The requirements for borosilicate-glass Raschig rings are described in Section 4.2.4.1.1.
- Procedures are established to ensure that the neutron absorber is effective in the system of its proposed use.
- Procedures are established to verify the presence and continuing effectiveness of fixed neutron absorbers before use and periodically thereafter.
- Controls are exercised to maintain the continued presence and the intended distribution and concentration of fixed neutron absorbers.
- Proper neutron spectra are used in the evaluation of the absorber worth (e.g., cadmium is an effective absorber for thermal neutrons, but ineffective for fast neutrons).

- The requirements of ANSI/ANS-8.21 are met, except that the evaluation of flux depression effects per ANSI/ANS-8.21 is not performed.

4.2.2 Multiple Units or Arrays

The basic assumptions and design conditions used for nuclear criticality safety analyses of multiple units within an array, and for analyses of multiple arrays, are stated in this section.

4.2.2.1 Areal Density

The design conditions for individual units, or an array of units whose criticality safety depends on the areal density of the fissile material, will be based on the assumption that the maximum credible mass is present and is distributed uniformly over the minimum credible area.

When criticality safety is contingent only upon maintenance of a limited areal density of fissile material, controls will be implemented to ensure that the limit is not exceeded. The controls will limit the areal density to a safe value, which is defined to be no more than 45% of the minimum critical areal density for an infinite unit.

Areal density is controlled by determining and then limiting the quantity of fissile material per unit area available to, or present in, a unit or an array of units. Controls utilized to prevent the areal density limits from being exceeded shall comply with the requirements of Section 4.1.1.

4.2.2.2 Interaction

The design conditions for interaction between multiple units or between arrays that experience neutron interaction will be based on values that can be demonstrated safe by one of the following methods:

- Unit Storage Criteria
- Solid Angle Method
- Surface Density
- Monte-Carlo Calculations
- American National Standard, ANSI N16.5-1975/ANS 8.7 "Guide for Nuclear Criticality Safety in the Storage of Fissile Materials."

Each application of Monte-Carlo calculations must comply with the requirements of Section 4.2.3.2.

Where control of the spacing between multiple units or between arrays is used to provide criticality safety, the spacing is controlled by one or more of the following techniques:

- The spacing is controlled by engineered devices that maintain the allowable locations of the units or arrays.

- The spacing between units within a work station is procedurally controlled through the use of visual indicators or postings that clearly identify the required spacing between the units and/or the permissible locations of the units.

- The spacing between a moveable unit and other units is controlled through the use of operating procedures.

- Sensitivity studies are conducted to ensure that controls in place can prevent unacceptable changes in assumed reflection conditions from leading to a criticality. These studies conservatively model credible reflection conditions in and around arrays to bound any possible accident conditions from exceeding facility safety limits.

Racks, spacers, and other equipment which help to maintain proper spacing between units or between arrays will be designed in accordance with standard industrial safety related requirements for structural integrity.

Units that meet the requirement of Section 4.2.4.8, "Neutron Isolation Controls," can be considered non-interacting and may be excluded from interaction analysis.

4.2.2.3 Interspersed Moderation

If the method used to determine safe spacing between multiple units or between arrays can account for the effects of interspersed moderation, the optimum interspersed water density will be assumed unless controls are established to limit the water density to a specific value.

Criticality safety of multiple units or arrays based on control of interspersed moderation requires that the sources of such moderation be identified and controls be established for each source.

4.2.3 Technical Data and Analytical Methods

The limiting values for single parameters for individual units may be determined either from the data presented in Section 4.2.3.1 or by analytical methods presented in Section 4.2.3.2.

4.2.3.1 Technical Data

(The data sources and references used to determine the limits specified in this section are listed in Chapter 14 if they are not otherwise identified herein.)

Tables 4.3 and 4.4 list the single-parameter limits for mass and geometry controls on individual units. The mass limits meet the requirements specified in Section 4.2.1.3 for safe values. Likewise, the geometry limits meet the fraction-of-critical-dimension requirements specified in Section 4.2.1.8. For enrichments less than 10 weight percent ^{235}U that are not specified in Tables 4.3A&B, either smooth-curve interpolation may be used or the values for any enrichment above the actual enrichment may be applied. Fully enriched limits shall be applied for all enrichments greater than 10 weight percent ^{235}U unless applicable safe values are determined using methods authorized in this chapter.

The limits in Table 4.4A apply to units containing aqueous solutions and mixtures no more reactive than fully enriched UO_2-water mixtures with uranium concentrations/ densities no greater than 8.0 g/cc. For maximum uranium densities less than 8.0 g/cc that are not specified in Table 4.4A, the values for any density above the actual density may be applied unless applicable safe values are determined using methods authorized in this chapter. The limits in Table 4.4B apply to units containing any uranium metal, up to fully enriched.

Adjustments to the geometry limits in Tables 4.3 and 4.4 may be made to account for conditions of less than optimum internal moderation, for conditions of less than full water reflection, or for lower uranium concentrations/densities. However, the resulting limits must comply with the fraction-of-critical-dimension requirements specified in Section 4.2.1.8, or the k_{eff} limits specified in Section 4.2.3.2, and the controls on the parameter(s) must comply with the applicable conditions in Section 4.2.1. Further, the basis of the safety evaluation for such an adjustment must be documented in accordance with Section 4.1.3.

Table 4.5 lists the single-parameter limits for concentration controls on individual units. The limits meet the requirements specified in Section 4.2.1.4 for safe values.

The safe concentration limit of fissile material diluted with moderator more effective than water shall be reviewed and approved by the NRC; Table 4.5 applies only to water moderated systems.

Table 4.3A

SINGLE PARAMETER LIMITS FOR FULLY REFLECTED UNITS OF HOMOGENEOUS LOW ENRICHED MATERIALS

ENR WT% U-235	MASS KG U-235		CYL DIA INCHES	SLAB THICKNESS INCHES				VOLUME LITERS
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
10.0	.570	.950	7.9	1.7	2.9	3.3	3.7	14.8
9.0	.600	1.000	8.2	1.8	3.0	3.4	3.8	15.8
8.0	.625	1.040	8.4	1.9	3.2	3.6	4.0	17.3
7.0	.660	1.100	8.7	2.0	3.4	3.8	4.2	19.3
6.0	.720	1.200	9.0	2.1	3.5	4.0	4.5	22.0
5.5	.755	1.255	9.5	2.2	3.7	4.2	4.7	23.4
5.0	.800	1.340	10.1	2.3	3.8	4.4	4.9	25.3
4.5	.855	1.425	10.3	2.4	4.1	4.6	5.1	28.8
4.0	.935	1.560	10.5	2.6	4.4	5.0	5.6	33.2
3.5	1.040	1.735	11.3	2.9	4.8	5.4	6.0	38.1
3.0	1.210	2.015	12.4	3.2	5.4	6.1	6.8	46.4
2.5	1.510	2.515	13.9	3.8	6.4	7.2	7.8	61.5
2.0	2.165	3.605	16.5	4.6	7.7	8.7	9.2	98.6
1.5	4.500	7.500	22.0	6.6	10.9	12.4	13.9	210.7
1.0	6.840	11.400	--	--	--	--	--	--

Table 4.3B

SINGLE PARAMETER LIMITS FOR FULLY REFLECTED UNITS OF HETEROGENEOUS LOW ENRICHED MATERIALS

ENR WT% U-235	MASS KG U-235		CYL DIA INCHES	SLAB THICKNESS INCHES				VOLUME LITERS
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
10.0	.530	.885	7.1	1.5	2.5	2.8	3.0	6.0
9.0	.550	.915	7.2	1.6	2.6	3.0	3.1	6.6
8.0	.565	.945	7.3	1.6	2.7	3.1	3.3	7.5
7.0	.595	.995	7.5	1.7	2.9	3.2	3.5	8.5
6.0	.635	1.055	7.8	1.8	3.0	3.4	3.6	10.4
5.5	.660	1.100	7.9	1.8	3.1	3.5	3.7	10.8
5.0	.700	1.165	8.1	1.9	3.2	3.6	3.9	11.7
4.5	.735	1.230	8.3	2.0	3.3	3.7	4.1	13.0
4.0	.785	1.310	8.5	2.1	3.4	3.9	4.3	14.9
3.5	.850	1.415	8.9	2.2	3.6	4.1	4.6	16.8
3.0	.960	1.600	9.3	2.3	3.9	4.4	5.0	20.3

ENR WT% U-235	MASS KG U-235		CYL DIA INCHES	SLAB THICKNESS INCHES				VOLUME LITERS
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
2.5	1.120	1.870	10.0	2.5	4.2	4.8	5.5	24.5
2.0	1.430	2.380	11.3	2.9	4.9	5.5	6.0	32.2
1.5	2.090	3.485	13.8	3.8	6.4	7.2	8.1	52.6
1.0	6.615	11.025	23.1	6.0	10.0	11.4	12.0	203.0

Table 4.4A

SINGLE PARAMETER LIMITS FOR FULLY REFLECTED UNITS OF HOMOGENEOUS 100.0 WT% ^{235}U COMPOUNDS AND WATER

MAX. DENSITY (gU/cc)	MASS KG U-235		CYL DIA INCHES	SLAB THICKNESS INCHES				VOLUME LITERS
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
4.0	0.365	0.610	4.7	0.7	1.2	1.3	1.4	4.2
5.8	0.365	0.610	4.5	0.6	1.1	1.2	1.3	3.7
8.0	0.365	0.610	4.3	0.6	1.0	1.1	1.2	3.3

Table 4.4B

SINGLE PARAMETER LIMITS FOR FULLY REFLECTED UNITS OF URANIUM METAL AT 100.0 WT% ^{235}U FOR ALL VALUES OF H/X

MASS KG U-235		CYL DIA INCHES	SLAB THICKNESS INCHES				VOLUME LITERS
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)
0.365	0.610	2.5	0.2	0.4	0.4	0.5	0.935

(A) Limit is ≤45% of minimum critical mass – double batching is credible
(B) Limit is ≤75% of minimum critical mass – double batching not credible
(C) Limit is ≤90% of minimum critical cylinder diameter
(D) Limit is ≤45% of minimum critical slab thickness
(E) Limit is ≤75% of minimum critical slab thickness
(F) Limit is ≤85% of minimum critical slab thickness
(G) Limit is ≤90% of minimum critical slab thickness
(H) Limit is ≤75% of minimum critical spherical volume

Table 4.5
CRITICAL AND SAFE CONCENTRATIONS IN AQUEOUS SOLUTIONS

ENRICHMENT	CRITICAL CONCENTRATION* (g ^{235}U/liter)	SAFE CONCENTRATION LIMIT (g ^{235}U/liter)
>5%	11.8	5.0
≤5%	14.1	6.1
≤4%	14.6	6.3
≤3%	15.6	6.7
≤2.5%	16.2	7.0
≤2%	17.6	7.6
* Reference: ARH 600, Volume II; Table III.B-2; Figures III.B.10(5)-2, III.B.10(4)-2, III.B.10(3)-2, III.B.10(2.5)-2, and III.B.10(2)-2 at K_∞=0.99.		

Dry ^{235}U Limit:

Safe dry mass = 10 kgs ^{235}U (hydrogen moderated only)
5.25 kgs ^{235}U (hydrogen and carbon moderated)

"Dry" mass limits must comply with the conditions of Section 4.2.1.3 and the degree of internal moderation shall meet the following criteria:

- H/^{235}U ≤ 4.0 for uranium compounds at greater than 10% to 100% enriched (hydrogen moderated only).

- H/^{235}U ≤ 10.0 for uranium compounds at 0.72% to 10% enriched (hydrogen moderated only).

- H/U ≤ 2.0 and C/U ≤ 900 for uranium compounds at 93.15% or less enrichment.

^{235}U Area Density Limits:

The areal density limits must comply with the conditions of Section 4.2.2.1 and must not exceed the following values:

- 0.19 grams ^{235}U/cm^2 for uranium compounds at greater than 5% to 100% enriched.

- 0.25 grams ^{235}U/cm^2 for uranium compounds at ≤ 5% enriched.

^{233}U Limit:

Because the form of the materials containing the isotope ^{233}U is restricted to residual contamination from past operations and small quantities for analysis and development studies, the nuclear safety limits are based primarily on the safe wet mass value of 250 grams ^{233}U. However, single-parameter limits for geometry controls on individual units containing ^{233}U may be established and implemented if approved by the NRC.

Transuranic Limits:

Plutonium is generally present in small quantities, such as residual radioactivity from prior operations, samples received for laboratory analysis, materials received for development studies, and processing of materials containing trace amounts of plutonium as a contaminant. The minimum subcritical mass limit, as stated in ANSI/ANS-8.1-1983, will be applied for these limited operations.

If, based on analytical results or an engineering evaluation, multiple fissile isotopes are determined to be present at greater than 15 ppm (uranium basis) in scrap material received for storage or processing, the effect of the multiple fissile isotopes on nuclear criticality safety will be evaluated. A U-235 fissile gram equivalent (FGE) for each fissile nuclide present in the material will be determined using the minimum subcritical mass limits as stated in ANSI/ANS-8.1-1993, and ANSI/ANS-8.15-1981. The nuclear criticality safety limit for the operation will be adjusted as determined by the nuclear safety function, if the total U-235 FGE for the other fissile nuclides is greater than 1% of the safety limit.

4.2.3.2 Analytical Methods

Nuclear criticality safety analyses shall utilize published experimental data, the results of NFS sponsored critical experiments, or analytical methods which have been validated by comparison with experimental data. An analytical method shall be considered validated when the following are established:

- the type of systems which can be modeled;
- the range of parameters which may be treated; and,
- the bias, if any, which exists in the results produced by the method.

Analytical methods used in nuclear criticality safety analyses shall include the reactivity formula, buckling equations, unit storage criteria, solid angle technique, surface density, and diffusion/transport computer codes. The guidelines for the preparation of the detailed validation report contained in ANSI/ANS-8.1-1983 will be followed for validation of all computer codes used on NFS computers. Each computer code validation study shall be performed by the organization using the codes for safety evaluations.

The preferred method for code validation is to use experiments that cover the operating enrichment range. Where enrichment ranges are not covered by experiments demonstrating a normal distribution, the following requirements shall be applied: 1) an independent code shall be required to demonstrate acceptance at the extended enrichment; and 2) the experiments within the enrichment range shall be used to demonstrate acceptance through a comparison of the attributes of the range to the extended range.

The analysis of k-eff values may be performed using validated versions of the SCALE modular code system or MCNP on an NFS validated computer. When nuclear safety is based on computer code calculations, the following criteria will be used:

- Each analysis shall be reviewed by an independent and qualified member of the criticality safety function having at least the qualifications of a senior member as described in Chapter 2.

- Failure limits for all k_{eff} calculations are established at a value such that the failure limit for k_{eff}, $k_{failure}$, = 1.0 – bias – margin. The bias, as defined in ANSI/ANS-8.1, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," is a measure of the systematic disagreement between the results calculated by a method and experimental data. The uncertainty in the bias (due to uncertainties in the precision of the calculation and the accuracy of the experimental data) is included when determining subcritical limits. The margin is equal to 0.015 to ensure that analytical or measurement errors do not produce non-conservative results.

- For nuclear criticality safety evaluations, the following methodology may be used:

a) Controlled Parameters:

1. When using results from validated analytical methods, the establishment of the safety limit for a controlled parameter relies on the ability to control the parameter at that safety limit so that the controlled parameter remains below the failure limit.

2. The failure limit for a controlled parameter is equal to the value of the parameter at which $k_{eff} = k_{failure}$.

3. For each controlled parameter, a determination of the correlation between k_{eff} and variations in the assessment of the measurement uncertainty for the controlled parameter and the ability to detect and control process variations that affect the controlled parameter is used to establish adequate safety margins.

4. If a controlled parameter can be demonstrated to be reliably controlled (i.e., to a 95% confidence level) to some maximum change in value that increases k_{eff}, then the controlled parameter safety limit is less than the failure limit by a factor of at

least three times this maximum change (e.g., if a parameter can be controlled to increase by no more than 5 percent of the failure limit, then the safety limit is below the failure limit by a factor of three times this controlled increase, or 85 percent of the failure limit).

5. A controlled parameter safety limit is not to exceed 95% of the failure limit for a controlled parameter.

6. Operating limits are established to ensure that safety limits are not exceeded.

7. A controlled parameter operating limit is not to exceed 85 percent of the safety limit unless it is not feasible for the parameter to exceed the safety limit.

8. A 95% confidence level is ensured by considering instrumentation tolerances and all credible process changes associated with the parameter.

b) Controls:

1. When using results from validated analytical methods where the safety basis relies on a control, establishment of the control safety limit requires the ability to operate the control at that safety limit so that the control remains below the failure limit.

2. The failure limit for a control is equal to the value of the control at which $k_{eff} = k_{failure}$.

3. For each control, a determination of the correlation between k_{eff} and variations in the control is made. This correlation along with an assessment of the measurement uncertainty for the control and the ability to detect and control process variations that affect the control is used to establish adequate safety margins.

4. If a control can be demonstrated to be reliably operated (i.e., to a 95% confidence level) to some maximum change in value that increases k_{eff}, then the control safety limit is less than the failure limit by a factor of three times this maximum change (e.g., if a control can be controlled to increase by no more than 5% of the failure limit, then the safety limit is below the failure limit by a factor of three times this controlled increase, or 85 percent of the failure limit).

5. A control safety limit is not to exceed 95% of the failure limit for a control.

6. Operating setpoints of controls are established to ensure that safety limits are not exceeded.

7. A control operating setpoint is not to exceed 85% of the value of the control safety limit unless it is not feasible for the control to exceed the safety limit.

8. A 95% confidence level is ensured by considering instrumentation tolerances and all credible process changes associated with the control.

For nuclear criticality safety evaluations, the following methodology may also be used unless a determination to use the previously stated methodology is chosen:

a) The neutron multiplication factor for normal operations shall be no greater than 0.90 and for all conditions required to be critically safe by the double-contingency principle shall be no grater than 0.95. This shall be applied as follows:

$K_a + 2\sigma$ - bias ≤ 0.90 for normal conditions,

$K_a + 2\sigma$ - bias ≤ 0.95 for failure of a single contingency,

Where

K_a = the average effective multiplication factor calculated for the desired application

σ = the statistical or convergence uncertainties in the calculation of K_a

bias = bias of analytical techniques which is the analytical result minus the experimental result (negative values only, positive values are assumed to be zero).

4.2.4 Special Controls

4.2.4.1 Criticality Control by Boron

4.2.4.1.1 Borosilicate-Glass Raschig Rings

Containers whose volume or dimensions exceed nuclearly safe parameters for solutions of fissile material intended as contents may be utilized by employing a fixed neutron absorber for criticality control.

Borosilicate-glass Raschig rings will constitute the fixed neutron absorber employed.

When such rings are used as the primary criticality control, they will be used in accordance with ANSI/ANS-8.5-1986, "Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material."

When such rings are used as a secondary criticality control (i.e., where concentrations are normally controlled to safe values without the rings), the standard shall apply except:

- Rough-cut rings may be used. Accumulation of glass fines in the bottom of such vessels is inconsequential, and determining the vessel volume and loss of glass volume due to breakage and settling is unnecessary. Precautionary inspections

are performed on an annual frequency to ensure that settling does not result in an accumulation of solution in a ring-free region near the top of the vessel.

- Vessels with open tops may be constructed so as to overflow at 100 percent of free volume, provided the vessel is filled with rings and inspected on an annual frequency.

- Analysis for boron content shall be performed once every 2 years (interval not to exceed 26 months).

- The glass volume fraction of a vessel need not be determined, since such a value is only used as a basis for limiting the maximum solution concentration of fissile material.

- The drop test need not be performed. Breakage of Raschig rings is accounted for by periodic inspections of the level in the tank.

- The limits of 5% enrichment are used for up to 6% enriched uranium.

4.2.4.1.2 Soluble Boron

Soluble boron may be used as a secondary criticality control in special processing equipment, provided other controls on the fissile material maintain safety under normal conditions. Measures to confirm the solubility and concentration of boron are required.

4.2.4.2 Heat Exchangers

Installation and use of heat exchangers will comply with the following considerations and limitations:

- An examination of the internal configuration of the heat exchanger and an assessment of the degree of geometrical nuclear control inherent will be performed.

- Internal dimensions and the structure must be such as to provide geometrical nuclear safety control, considering the fissile composition, degree of heterogeneity, reflection, etc.

- An assessment will be made of the possibility and consequence of leakage or diffusion from one side of the heat exchanger containing fissile material to the nonfissile-bearing side.

- By design, nonfissile liquids (cooling water, etc.) shall be piped to the heat exchanger so that under static or dynamic conditions, the positive pressure of the nonfissile fluid will exceed that of the fissile fluid side, or the nonfissile liquid will be contained in a safe-geometry or poisoned-recirculating system. Thus,

even in the event of a rupture, a tendency for fissile fluid to remain in that side of the heat exchanger will exist, or the nonfissile fluid remains safe even if fissile material leaks into it.

All equipment in service will be tested on an annual frequency for leaks and will be repaired or removed from service if leaks are found. Prior to being returned to service, a leak test will be performed on repaired equipment or on equipment that has been out of service more than 12 months since its last test.

4.2.4.3 Insulation or Jackets on Geometrically Favorable Equipment

The nuclear safety of equipment or piping will account for associated fluid jackets or porous insulation when geometry is the basis for safety.

System dimensions will be assumed to be the inside dimension of the fluid jacket or the outside dimension of the insulation, the maximum possible dimension containing fissile material. Exception to the above may be taken when it can be shown that double-contingency safety must be violated to generate that fissile configuration of maximum dimensions. The largest system dimensions consistent with the maximum credible occurrence will then be assumed.

4.2.4.4 Siphon Breaks

When geometrically favorable vessels are connected to geometrically unfavorable vessels, piping will be evaluated for the possibility of siphoning or overflowing fissile solution into the unfavorable vessels. If there is any possibility of siphoning due to failure of a single control, a siphon break or other positive means of preventing transference of solution to unfavorable vessels will be provided. Devices other than siphon breaks will be evaluated and tested to confirm acceptable reliability; in addition, redundancy of these devices is required.

All siphon breaks and other devices will be identified in operating procedures as being needed for criticality safety reasons, and will be visually inspected or tested for proper functioning on a frequency suitable for the specific device and the specific application. The frequency shall be established by a senior member of the criticality safety function, and reviewed and approved by the safety review committee. The frequency will be based on, as a minimum:

- the consequences of failure,
- the failure modes, and
- the failure history.

4.2.4.5 Presence of Vessels of Unfavorable Geometry and Volume

4.2.4.5.1 Solution-Bearing Vessels

Efficient storage of large quantities of solutions is made possible through the use of unfavorable geometry vessels. The presence or use of an unfavorable geometry vessel will be reviewed and approved by the safety review committee and the president. The following criteria will be used for approving unfavorable geometry vessels:

- There is no practical way to use favorable geometry vessels; and,
- The solution must be of a safe concentration as specified in Section 4.2.1, and controls to prevent precipitation, settling, and/or selective layering into unsafe concentrations must be established per Section 4.2.1.4; or,
- The solution must be of a safe concentration as specified in Section 4.2.1, and the total quantity of fissile material in the vessel will be controlled to no more than 75% of the minimum critical mass; or,
- The total quantity of fissile material in the vessel will not exceed one safe wet mass as required by Section 4.2.1.3; or,
- The vessel has a fixed neutron poison; or,
- The vessel is used solely for non-nuclear materials, and appropriate controls are used to prevent accidental introduction of nuclear materials into the vessel.
- The vessel is inspected for solids accumulations on a frequency suitable for the specific application. The frequency, as established by the safety review committee, will be no less than annual.

The use of unfavorable geometry vessels will be justified by:

- taking into consideration identified contributing causes of criticality accidents which have occurred in unfavorable geometries,
- demonstrating that such causes will be subject to administrative controls which are in the license conditions, and,
- demonstrating compliance with the double contingency principle.

4.2.4.5.2 Normally-Empty Vessels

For unfavorable geometry vessels not intended for storage of fissile materials or process chemicals, located in production areas, and containing no solutions under normal conditions, the following precautions shall be followed:

- The vessels shall be inspected for accumulation of solids or liquids at least every four months; and,

- A liquid detection and alarm system capable of detecting liquid levels prior to exceeding the specified slab thickness limit shall be installed and checked for operability at least every four months; and,

- The corrective actions, with response times, to be taken following an alarm shall be specified in an approved procedure; and,

- If more than 10 grams of uranium are found, such material shall be removed immediately and the NRC shall be notified within 24 hours.

4.2.4.6 Ventilation Systems

Due to the possible accumulation of fissile material in ventilation systems, a monitoring program shall be conducted to detect accumulations in the systems before quantities that are unsafe for unfavorable geometry vessels are reached. This monitoring program shall be conducted whenever processes connected to a ventilation system are being operated or when maintenance activities on the processing equipment or the ventilation equipment are being performed.

The monitoring frequencies and action levels are in the operating procedures for those ventilation systems whose safety is based on mass and/or concentration limits and controls. These monitoring frequencies and action levels are such that they will reliably prevent a safe mass or concentration from being exceeded. (See Section 10.3.3 for the safety analyses of these systems.) If any of the action levels are exceeded, corrective actions must be taken in accordance with approved procedures to reduce the uranium levels to acceptable values. The monitoring frequency shall be increased until the corrective actions are completed and compliance with the action levels is demonstrated.

In addition, if any of the action levels are exceeded, the following are performed:

- An investigation is made to determine the cause of the excessive fissile material in the system.

- A plan is implemented to correct identified problems.

- The criticality safety function is notified and allowed to participate in the establishment of corrective actions and in the subsequent investigation.

Measurements, sample analyses, corrective actions, and investigations are documented.

4.2.4.7 Release to Unfavorable Geometry and Volume

Solutions in which it is credible that critical masses or concentrations may accumulate and, thus, are confined to favorable geometry or fixed poisoned vessels, may be released to vessels of unfavorable geometry and volume only if:

- Safe mass or concentration is verified by analyzing each of two representative and independent samples (i.e., dual analysis); or,

- The favorable geometry vessel accumulating the solution is being used as a secondary criticality control and at least two separate stages function to remove fissile material between the potential source of fissile material and the unfavorable vessel.

The Discipline Manager is responsible for assuring that trained personnel verify that the mass or concentration is safe before authorizing release to the unfavorable geometry and volume vessel. Operating procedures provide the criteria for determining under what conditions materials may be transferred to an unfavorable geometry and volume vessel.

4.2.4.8 Neutron Isolation Controls

Equipment, facilities, and individually subcritical units may be considered to be neutronically isolated for the purpose of utilizing the unit storage criteria, or the solid angle technique of array evaluation, when their surfaces are separated by any of the following:

- A 12-inch-thick layer of water, or by the distance which is equivalent in isolational ability to a 12-inch-thick layer of water.

- The larger of the 12 feet or the greatest distance across an orthographic projection of the largest of the fissile accumulations on a plane perpendicular to the line joining their centers.

Arrays of birdcages and drums in vault/warehouse storage bins, (as described in Sections 15.1, 15.3, and 15.8), and the extraction area in Building 233 (Section 15.3) may be considered to be neutronically isolated for the purpose of utilizing the unit storage criteria, the solid angle method, or the shipping regulations for array evaluation when separated from adjacent arrays, or process areas, by the following:

- Twelve inches (12") of solid concrete (block or poured) of density equal to or greater than 140 pounds per cubic foot.

4.2.4.9 Packaging and Transportation Regulations

Criticality safety limits and controls on individual units and on arrays of units may be based on NRC and/or DOT packaging and transportation regulations if the units qualify

as approved shipping packages. Depending upon the type of packaging, any of the typical safety related parameters (e.g., mass, internal moderation, geometry, spacing, etc.) may be limited by the regulations to specific values for the fissile radioactive material being shipped. When the regulations are utilized in this manner, controls that are consistent with the applicable requirements of this chapter will be established to ensure that the limits are not exceeded. The safety evaluation for these units will be documented.

Upon receipt of notice that a particular unit has been decertified by the authorizing agency, the following actions will be implemented, depending on the cause for decertification. If the decertification was because of criticality safety concerns, authorization to add such units to existing arrays will cease immediately. If the units are to be used after one month, existing arrays will be reevaluated and a safety demonstration completed within one month. If the decertification was due to other reasons, storage of these units may continue under the certificate requirements for up to one year. The array storage criteria will be reevaluated and a safety demonstration completed if the units are to be used after one year.

4.3 Accident Analyses

The nuclear safety risks of each operation with more than a safe batch of fissile material, as defined in Section 4.2.1.3, will be evaluated to show that double contingency exists. The evaluation will consist of the following elements, as a minimum, for each such operation:

- The nuclear safety controls and/or devices (barriers),
- Credible accidents which could result in a failure of the barriers,
- The barrier(s) which prevents a criticality should any one of these accidents occur,
- The double contingency analysis for each accident, and
- An evaluation showing subcriticality for normal and credible abnormal conditions.

These evaluations will be performed for all new operations and modifications to existing systems prior to authorization for use.