6.0 NUCLEAR CRITICALITY SAFETY (NCS)

6.1 PURPOSE OF REVIEW

The purpose of this review is to determine whether the applicant, in the license application and supported by materials on the docket, has (1) established an adequate organization with which to implement the NCS program; (2) established an adequate NCS program to ensure safe operation of the facility; (3) implemented adequate controls and limits on parameters relied on to prevent nuclear criticality; and (4) assessed accident sequences identified in the Criticality Safety Evaluations (CSEs) and documented in the Integrated Safety Analysis (ISA) leading to a nuclear criticality, as required by the proposed 10 CFR Part 70.

6.2 RESPONSIBILITY FOR REVIEW

Primary: Nuclear Process Engineer (NCS Reviewer)

Secondary: Chemical Safety Reviewer

Supporting: Project Manager and Fuel Cycle Inspector (as needed)

6.3 AREAS OF REVIEW

The staff should review the application to determine whether the applicant has (1) described an adequate NCS program; (2) implemented the facility management measures; (3) identified and committed to the responsibilities and authorities for individuals implementing the NCS program; and (4) established an adequate criticality accident alarm system (CAAS).

6.3.1 Organization and Administration

The primary reviewer should review the applicant's organization and administration to determine whether the applicant has identified the responsibilities and authorities for organizations and individuals implementing the NCS program. This review should include:

A. For familiarity, the general administrative organization methods used by the applicant.

B. The administrative organization of the NCS program, including authority and responsibilities of each position identified, including organizations and individuals with responsibility for NCS.

C. Experience and education requirements of management and staff positions with NCS responsibility.

6.3.2 Management Measures

The primary reviewer should review the applicant's management measures in support of the applicant's ability to implement and maintain the NCS program, and to ensure the continued availability and reliability of items relied on for safety. The following areas of the application related to the applicant's management measures should be reviewed:

A. Management functions discussed in SRP Sections 15.1 through 15.8, specifically as they relate to NCS.

B. The commitment to measures implementing the requirements of proposed 10 CFR 70.64 (Baseline Design Criteria) to ensure that the initial facility design meets these baseline design criteria (BDC) for NCS.

C. The implementation of the requirements of proposed 10 CFR 70.72 (Facility Change and Change Process) to ensure that: (1) facility changes are managed to maintain the integrity of the facility's safety basis and to ensure they receive the appropriate level of NCS review in accordance with proposed 70.72(a) and proposed 70.72(b) and (2) facility changes requiring NRC approval in accordance with proposed 70.72(c) are appropriately identified and treated.

6.3.3 Technical Practices

The primary reviewer should review the applicant's implementation of NCS technical practices to ensure the safe operation of the facility. This review should include:

A. The commitment to derive and implement NCS controls and limits in accordance with technical practices as described in the application, by incorporating them into the applicant's NCS program.

B. Technical practices, including a description of the management measures which ensure operability of the CAAS and emergency response procedures.

C. The technical practices to ensure that limits on controlled parameters have an adequate safety margin. These practices should include those to ensure that the methods used to develop NCS limits are properly validated.

D. The technical practices to ensure that sufficient NCS controls, developed in the CSEs and flowed into the ISA, are identified for each process.

E. The areas of review listed in Section 5.3 (ISA Summary) as they relate to NCS, specifically: (1) potential accident sequences that could result in nuclear criticality; (2) specific controls relied on to provide reasonable assurance that an inadvertent criticality will not occur; and (3) a demonstration that the likelihood of failure is sufficiently low so as to demonstrate compliance with the double contingency principle.

F. The commitment to prepare and maintain applicable safety basis documentation in enough detail so that criticality controls and double contingency analysis can be reviewed and inspected by NRC and licensee staff.

6.4 ACCEPTANCE CRITERIA

To provide for NCS, the applicant's use of standards should be considered acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

If an applicant intends to conduct activities where a standard applies and the standard has been endorsed by an NRC Regulatory Guide, then a commitment to comply with all of the requirements (i.e., "shalls") and the appropriate recommendations (i.e., "shoulds") of the standard should constitute an acceptable program under the NRC regulations with respect to the safety aspects addressed by the standard. If the applicant does not intend to comply with all recommendations in the standard, alternative methods of meeting the intent of the standard should be proposed. Notwithstanding such a general commitment to a standard, the applicant should clarify broad requirements in the standard by more specific commitments in the application. Any variations from the requirements of the standard should be identified and justified in the application.

Throughout this chapter, reference is made to specific portions of the standards. This is not meant to imply that they are more important than other portions of the standards, but only that further elaboration is needed.

Individual commitments to the acceptance criteria are expected only when the acceptance criteria are relevant to the operations and materials to be licensed.

6.4.1 Regulatory Requirements

The regulatory basis for the review should be the general and additional contents of an application for construction approval or the license application as required by 10 CFR 70.22 and proposed 70.65, respectively. In addition, the NCS review should be conducted to ensure compliance with 10 CFR 70.24 and proposed 10 CFR 70.61, 70.62, 70.64, 70.72, and Appendix A of 10 CFR Part 70.

6.4.2 Regulatory Guidance

The NRC Regulatory Guide (RG) 3.71,*"Nuclear Criticality Safety Standards for Fuels and Materials Facilities,"* August 1998, endorses the ANSI/ANS-8 national standards listed below in part or in full.

A. ANSI/ANS-8.1-1983 (Reaffirmed in 1988), *"Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors."*

B. ANSI/ANS-8.3-1997, *"Criticality Accident Alarm System."*

C. ANSI/ANS-8.5-1996, *"Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material."*

D. ANSI/ANS-8.6-1983 (Reaffirmed in 1995), *"Safety in Conducting Subcritical Neutron-Multiplication Measurements In Situ."*

E. ANSI/ANS-8.7-1975 (Reaffirmed in 1987), *"Guide for Nuclear Criticality Safety in the Storage of Fissile Materials."*

F. ANSI/ANS-8.9-1987 (Reaffirmed in 1995), *"Nuclear Criticality Safety Criteria for Steel-Pipe Intersections Containing Aqueous Solutions of Fissile Materials."*

G. ANSI/ANS-8.10-1983 (Reaffirmed in 1988), *"Criteria for Nuclear Criticality Safety Controls in Operations With Shielding and Confinement."*

H. ANSI/ANS-8.12-1987 (Reaffirmed in 1993), *"Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors."*

I. ANSI/ANS-8.15-1981 (Reaffirmed in 1995), *"Nuclear Criticality Control of Special Actinide Elements."*

J. ANSI/ANS-8.17-1984 (Reaffirmed in 1997), *"Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors."*

K. ANSI/ANS-8.19-1996, *"Administrative Practices for Nuclear Criticality Safety."*

L. ANSI/ANS-8.20-1991, *"Nuclear Criticality Safety Training."*

M. ANSI/ANS-8.21-1995, *"Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors."*

N. ANSI/ANS-8.22-1997, *"Nuclear Criticality Safety Based on Limiting and Controlling Moderators."*

O. ANSI/ANS-8.23-1997, *"Nuclear Criticality Accident Emergency Planning and Response."*

These ANSI standards are not requirements, but represent practices that have been found generally acceptable to NRC staff. The reviewer should check the current version of RG 3.71 to determine the currently endorsed versions of these standards. Reference in this chapter to a specific version should not be construed as discouraging the applicant from using the most recent version of a standard. However, if the applicant commits to an unendorsed standard, responsibility for demonstrating that this constitutes an acceptable methodology rests with the applicant.

6.4.3 Regulatory Acceptance Criteria

Throughout Section 6.4.3, are several examples of how the regulatory acceptance criteria may be met in practice. The examples are presented in italicized text.

6.4.3.1 Organization and Administration

The importance of management measures and the corporate safety culture in preventing accidental criticality cannot be overstated. Programmatic failure has been a major contributor to most of the historic accidents, much more than failures of a technical or analytical nature. The most theoretically robust control systems will not work if the facility management does not make safety a top priority and creates an atmosphere of safety consciousness and accountability. Although the majority of this chapter is devoted to the technical aspects of the NCS program, the primacy of administration, organization, and management measures is stressed by placing it first in this chapter.

To provide for NCS, the applicant's organization and administration implementing the safety program in proposed 10 CFR 70.62(a) should be considered acceptable if the applicant has met the following acceptance criteria. (Information related to these acceptance criteria may be consolidated with other organization and administration descriptions elsewhere in the application in response to Chapter 4.0.):

A. The applicant meets the acceptance criteria related to NCS in SRP Section 4.4.3 (Organization and Administration). Further, the applicant has described organizational positions, functional responsibilities, experience, and adequate qualifications of persons responsible for NCS.

B. The applicant commits to the endorsed requirements related to organization and administration in ANSI/ANS-8.1-1983, "*Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*" (applicable section is Section 4.1). Where similar requirements also exist in ANSI/ANS-8.19-1996, "*Administrative Practices for Nuclear Criticality Safety*," the applicant commits to follow the more detailed requirements of ANSI/ANS-8.19-1996 (Sections 4 through 10).

As an example of how an applicant may meet the requirements of Item B, the reviewer may observe that: The criticality safety staff would typically be trained under a documented qualification program, which includes facility and process familiarization; criticality safety practices, procedures, and guides; use of criticality codes; and all other information needed to permit them to function as safety specialists. The NCS staff is involved in responding to emergency and accident conditions as part of the emergency response organization. Independent of operations means they would be enabled to review and concur on procedures and facility operations and have shut-down authority over any operations the staff considers unsafe; they would report to the safety manager and would be independent of operations at the highest practical level, preferably to an official at a sufficiently high level to have the authority to make commitments to the NRC and have accountability for the overall safety of the facility.

C. The applicant commits to provide NCS postings for administrative controls in areas, operations, work stations, and storage locations that provide operators a reference for ensuring conformance and safe operation.

D. The applicant commits to the policy that: "All personnel shall report defective NCS conditions to the NCS function, directly or through a designated supervisor, and take no further action not specified by approved written procedures until NCS has analyzed the situation."

E. The applicant's administration of the facility should include commitments that foster ownership of safety by organizations at all levels, including operations, maintenance, engineering, and management (not just the NCS Organization). The applicant commits to a corporate policy of instilling a safety ethic in the workforce and making safety a top priority.

6.4.3.2 Management Measures

To provide for NCS, the applicant's management measures required by proposed 10 CFR 70.62(d) should be considered acceptable if the applicant has met the following acceptance criteria. Management measures may be graded in accordance with proposed 10 CFR 70.62(d), with appropriate justification provided if the highest level of assurances is not used.

A. Training (These acceptance criteria are in addition to those specified in SRP Section 15.4.):

   i. The applicant commits to the endorsed training requirements in both ANSI/ANS-8.19-1996, *"Administrative Practices for Nuclear Criticality Safety"* (applicable sections are Sections 4.2, 4.4, 5.2 and 5.3, 6.2 through 6.5, 10.2, and 10.5) and ANSI/ANS-8.20-1991, *"Nuclear Criticality Safety Training"* (Sections 5 through 8).

   ii. The applicant commits to provide instruction in the training program regarding the use of process variables as NCS controls, if such controls are credited for NCS.

   iii. The applicant commits to provide instruction in the training program regarding the policy discussed in Item D of Section 6.4.3.1.

B. Procedures (These acceptance criteria are in addition to those specified in Section 15.5.):

   i. The applicant commits to the endorsed procedural requirements in ANSI/ANS-8.19-1996, *"Administrative Practices for Nuclear Criticality Safety"* (applicable section is Section 7).

   ii. Administrative controls that are incorporated into procedures are reiterated in distinctive and readable criticality safety postings. Postings and procedures should be controlled to ensure that they reflect the current administrative controls and limits.

C. Audits and Assessments (These acceptance criteria are in addition to those specified in Section 15.6.):

   i. The applicant commits to the endorsed audit and assessment requirements in ANSI/ANS-8.19-1996, *"Administrative Practices for Nuclear Criticality Safety"* (applicable sections are Sections 4.6, 6.6, 7.8, and 8.4).

   ii. Operations are reviewed at least annually to ascertain that procedures are being followed and that process conditions have not been altered to adversely affect NCS. These reviews are conducted, in consultation with operating personnel, by applicant staff who are knowledgeable in NCS and who (to the extent practicable) are not immediately responsible for the operations.

   iii. The applicant commits to conducting and documenting weekly NCS walkthroughs (e.g., checklists) of all operating SNM process areas such that all operating SNM process areas should be reviewed at least every two weeks. Identified weaknesses should be incorporated into the facility corrective actions program and should be promptly and effectively resolved. An alternate plan for reduced frequency may be justified on the basis of risk.

   iv. The applicant commits to conducting and documenting quarterly NCS audits such that all NCS aspects of management measures (see Sections 15.1 through 15.8) should be audited at least every 2 years. An alternate plan for reduced frequency may be justified on the basis of risk.

6.4.3.3 Technical Practices

6.4.3.3.1 Analytical Methodology

To provide for NCS, the applicant's NCS methodologies should be considered acceptable if the applicant has met the following acceptance criteria:

A. The applicant commits to the endorsed technical requirements in ANSI/ANS-8.1-1983, *"Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors"* (Sections 4.2 and 4.3; Sections 5 and 6 contain single-parameter and multi-parameter limits that may be referenced).

B. The applicant commits to the intent of the requirement in Regulatory Guide 3.71, *"Nuclear Criticality Safety Standards for Fuels and Materials Facilities,"* related to validation reports, that is, the applicant should demonstrate: (1) the adequacy of the margin of subcriticality for safety by assuring that the margin is large compared to the uncertainty in the calculated value of k-eff and (2) determination of the area(s) of applicability (AOA) and use of the code within the AOA, including justification for extending the AOA by making use of trends in the bias.

C. As part of providing reasonable assurance that an adequate margin of subcriticality has been provided, in accordance with proposed 10 CFR 70.61(d), the applicant has, at the facility, a documented, reviewed, and approved validation report (by NCS and management) for each methodology which will be used to make an NCS determination (e.g., experimental data, reference books, hand calculations, deterministic computer codes, probabilistic computer codes). These methodologies may include Monte Carlo or deterministic computer codes, hand calculations, handbooks, experiments, or other applicable methods. The validation report should contain the following, in sufficient detail to permit an independent reconstruction of results by the NCS reviewer:

  i. A description of the theory of the methodology in sufficient detail, clarity, and lack of ambiguity that allows understanding of the methodology, including validity of assumptions and independent duplication of results.

  ii. A description of the AOA that identifies the range of values for which valid results have been obtained for the parameters used in the methodology. The AOA is the range of material compositions and geometric arrangements within which the bias of a calculational method is established. Particular attention should be given to validating the code for calculations involving mixed oxides of differing isotopics and defining the isotopic ranges covered by the available benchmark experiments. In accordance with the provisions in ANSI/ANS-8.1-1983, *"Nuclear Criticality Safety in Operations With Fissionable Material Outside Reactors"* (applicable section is Section 4.3.2), any extrapolation of the AOA beyond the physical range of the data should be supported by an established mathematical methodology.

  iii. A description of the use of pertinent computer codes, assumptions, and techniques in the methodology.

  iv. A description of the verification of the proper functioning of the mathematical operations in the methodology (e.g., mathematical testing).

  v. A description of the benchmark experiments and data derived therefrom that were used for validating the methodology.

  vi. A description of the bias, uncertainty in the bias, uncertainty in the methodology (e.g., from statistics, computational convergence, and nuclear cross section data), uncertainty in the data, uncertainty in the benchmark experiments, and Margin of Subcriticality for

Safety, as well as the basis for these items, as used in the methodology. If the bias is determined to be advantageous to the applicant, the applicant shall use a bias of 0.0 (e.g., in a critical experiment where the k-eff is known to be 1.0 and the code calculates 1.02, the applicant cannot use a bias of 0.02 to allow calculations to be made above the value of 1.0).

vii. A description of the software and hardware that will use the methodology.

viii. A description of the verification process and results.

D. The applicant commits to incorporate each documented, reviewed, and approved validation report (by NCS and management) into the configuration management program.

E. The applicant commits to performing NCS evaluations using specific standardized methods, including the use of only validated calculational methods. The applicant should commit to incorporating these methods into the facility safety program.

F. The applicant commits to assuming credible optimum conditions (i.e., most reactive conditions physically possible) for each controlled parameter unless specified controls are implemented to limit the controlled parameter to a certain range of values.

As an example of how Items E and F may be met, the reviewer would observe that: The applicant establishes standard criteria for modeling arrays of fissile units under certain conditions. Sample criteria for certain criticality parameters follow. If reflection is not controlled, the array is assumed to be fully flooded, unless a more reactive water density or reflector material exists. If moderation is not controlled, the optimal weight percent of water (or more reactive credible moderator) is assumed. If mass is not controlled, the units are assumed to be completely filled. If neutron poison is not controlled, no credit is taken for the material of construction of the containers and fissile material is modeled to the outer diameter. If interaction is not controlled, the units are stacked together in the most reactive configuration in the corner of the room (reflected by concrete walls and the floor). Optimal values of these parameters may be determined using sensitivity studies. Less reactive values may be used if appropriate items relied on for safety are used to limit the parameters.

G. The applicant commits to consider the variability and uncertainty in a process and the NCS subcritical limit when setting NCS safety limits.

As an example of Item G, the reviewer should ensure that: If mass is controlled to a certain value on the basis of measuring concentration of material transferred to a waste tank, then the uncertainty in the volume of the tank, the identity of the solutions transferred, and the precision of any in-line monitors or sampling methods should be taken into consideration in setting the mass limit.

6.4.3.3.2 Additional Technical Practices

CSEs should be considered the main source of information regarding the adequacy of criticality controls. The CSEs are the documents used to develop the safety basis of facility operations. The reviewer should confirm that the CSEs establish an adequate safety basis and then verify that all controls needed by sampling selected CSEs are as flowed into the ISA Summary as items relied on for safety (IROFS).

To provide for NCS, the applicant's commitment to NCS technical practices, in meeting the performance requirements of proposed 10 CFR 70.61(d) and Baseline Design Criteria of proposed 70.64(a)(9), should be considered acceptable if the applicant has met the following acceptance criteria:

A. Although the applicant may use a single NCS control to maintain the values of two or more controlled parameters, this use constitutes only one component necessary for double contingency protection.

B. Based on the performance requirements in proposed 10 CFR 70.61, the applicant commits to the policy that: "No single credible event or failure could result in a criticality accident."

As an example of how the applicant may satisfy Item B, the applicant may observe that: A metering pump to a uranyl nitrate-plutonium nitrate blending tank may control both the concentration in the tank and the "enrichment" (plutonium isotopics) in the tank, but its failure would be considered a single event that defeats both parameters. Therefore, an additional control is needed to meet double contingency.

C. The applicant commits to the preferred use of passive-engineered controls to ensure NCS. The applicant should commit to the following preference, in general, for controls to ensure NCS: (1) passive-engineered, (2) active-engineered, (3) augmented-administrative, and (4) simple-administrative. When choosing not to use a passive-engineered control, the applicant commits to provide justification in the CSE. This should also be documented in the ISA.

D. The applicant commits to incorporate controlled parameters into the facility management measures of proposed 10 CFR 70.62(d).

E. The applicant commits to perform an evaluation, for all controlled parameters, that shows that during both normal and credible abnormal conditions, the controlled parameter will be maintained.

F. The applicant commits to describe controlled parameters for each process used as NCS control. Examples of controlled parameters available for NCS control are: mass, geometry, density, enrichment, reflection, moderation, concentration, interaction, neutron absorber, and volume.

G. When controlled parameters are controlled for safety reasons by measurement, reliable methods and instruments should be used. It is acceptable if the applicant commits to representative sampling, reliable measurement instruments and methods, and dual independent measurements where there is significant susceptibility to human error.

As an example of Item G, the reviewer should ensure that: If dual independent sampling is the only control maintaining subcriticality upon transfer of dilute solution to an unfavorable geometry tank, the following conditions would be met: to qualify as independent, the two samples would be withdrawn by different individuals and at different points in the process or at different times with mixing to ensure a representative sample in between the measurements. They would be analyzed by different analysts using different methods in the lab, and a supervisor would be required to check results before authorizing the transfer. In addition, attention should be paid to common-mode failures that can defeat both samples such as circumventing this robust system by having a single isolation valve leak through or by not having the transfer valve locked or tagged so that an operator can effect the transfer by himself.

6.4.3.3.2.0 Methods of NCS Control

Several methods of NCS control (i.e., controlled parameters) are available. These are summarized below. Justification for not using geometry control as the preferred method should be fully documented in the NCS evaluations and ISA.

The controls used to establish limits on the following criticality parameters should be identified as IROFS in the CSEs and ISA. Tolerances on the controlled parameters should be conservatively taken into account in setting operating limits and controls established to prevent exceeding subcritical values of parameters.

The use of single parameter limits (favorable geometry, safe volume or mass, etc.) may be invalid when interactions with other units are taken into account. Interaction should be fully evaluated, and spacing controls should be used in conjunction with those other controls as needed to ensure subcriticality.

6.4.3.3.2.1 Mass Control

The use of mass as a controlled parameter should be considered acceptable if:

A. When mass limits are derived for a material which is assumed to have a given weight percent of SNM, determinations of mass are based on either: (1) weighing the material and assuming the entire mass is SNM or (2) physical measurements to establish the actual weight percent of SNM in the material. When process variables can affect the bounding weight percent of SNM in the mixture, the process variables are identified as IROFS in the CSEs and ISA Summary. The acceptance criteria in Section 6.4.3.3.2.12 are met.

B. Theoretical densities for fissile mixtures shall be used unless lower densities are ensured by the establishment of NCS controls.

C. When physical measurement of the mass is needed, the measurement is obtained by using instrumentation subject to facility quality assurance measures as specified in 10 CFR 70.22(f).

D. When overbatching of SNM is possible, the mass of SNM in a single batch is limited so that the mass of the largest credible overbatch resulting from a single failure is safely subcritical, taking system sensitivities into account. Overbatching beyond double batching should be considered in establishing the margin of safety.

E. When overbatching of SNM is not possible, the mass of SNM in the batch is limited to be safely subcritical, taking system sensitivities into account.

F. In setting mass limits, tolerances in determining the mass should be taken into account. The determination of the minimum critical mass should be based on spherical geometry or the actual fixed geometry of the system if it is controlled.

As an example of implementing mass control (especially Items A and C), the reviewer may observe that: If meeting the subcritical limits on mass for handling of filtercake depends on the relative percentage of plutonium in the filtercake, then reliable means are proposed to require sampling, NDA (non-destructive assay) scanning, or other direct measurement of the mass content. These controls are unnecessary if the filtercake is assumed to be 100% plutonium in the normal case calculations. The measurement equipment employed would be tested and calibrated regularly. Great caution is needed for NCS evaluation of mixtures of fissile isotopes of different elements.

6.4.3.3.2.2 Geometry Control

The use of geometry as a controlled parameter should be considered acceptable if:

A. Before beginning operations, all dimensions and nuclear properties which rely on geometry control are verified. The facility configuration management program should be used to maintain these dimensions and nuclear properties.

B. All credible means of transferring fissile materials to unfavorable geometry are evaluated and controls (IROFS) established against this contingency.

C. When using large single units, conservative margins of safety (such as 90% of the minimum critical cylinder diameter, 85% of the minimum critical slab thickness, and 75% of the minimum critical sphere volume) are used. Justification should be provided for proposed alternatives to these limits, taking system sensitivities into account.

D. Possible mechanisms for changes to the fixed geometry should be evaluated and controls established as needed. Where such credible mechanisms exist (such as deformation by static loads or pressure, corrosion, etc.), the applicant should describe the design and surveillance program for these units.

As an example of implementing geometry control (especially Items A, C, and D), the reviewer would observe that: When taking credit for the slab thickness of a set of fuel rods, the diameter of the rods and the depth of the restraining device would be conservatively taken into account, by performing field measurements and adding the geometrical tolerance to the nominal dimensions. The safety limit would be no more than some specified percentage (say, 85%) of the minimum critical slab thickness based on calculations or handbook data. A higher subcritical limit may be proposed if the applicant can demonstrate that conservative assumptions--such as neglecting the neutron absorption effect of the cladding and assuming that all the space is taken up by fuel--would be sufficient to make up the difference in margin. This would also take into consideration mounding of fuel rods and variations in the ability of the operators to meet the depth requirement.

6.4.3.3.2.3 Density Control

The use of density as a controlled parameter should be considered acceptable if:

A. When process variables can affect the density, the process variables are identified as IROFS in the CSEs and ISA Summary. The acceptance criteria in Section 6.4.3.3.2.12 are met.

B. When physical measurement of the density is needed, the measurement is obtained by using instrumentation subject to facility quality assurance measures as specified in 10 CFR 70.22(f).

As an example of implementing density control (especially Item A), the reviewer may observe that: Process variables that could be controlled, that may affect the density of pellets in trays removed from a sintering furnace, including: the length of residence time in the furnace, the temperature of the furnace, the additives added to the fuel, the force applied by the pellet press, the reduction in effective density due to geometrical packing, and so forth. These would only be significant if a lower density than theoretical was assumed.

6.4.3.3.2.4 Isotopics Control

Isotopic abundance (isotopics) is taken to include both the $^{235}U/U$ concentration (enrichment) and the concentration of fissile and non-fissile plutonium isotopes (such as ^{239}Pu, ^{240}Pu, ^{241}Pu) as well as the relative abundance of plutonium to uranium.

The use of isotopics as a controlled parameter should be considered acceptable if:

A. When taking credit for isotopic mixtures, where different isotopic mixtures could co-exist, controls are established to clearly label and segregate the SNM of different isotopic mixtures. Moreover, determinations of isotopic content shall be based on dual independent sampling and analysis of each lot of fissile material.

B. When physical measurement of the isotopics is needed, the measurement is obtained by using instrumentation subject to facility quality assurance measures as specified in 10 CFR 70.22(f).

As an example of implementing isotopics control (Items A and B), the reviewer may observe that: Plutonium and uranium oxides are stored in readily identifiable containers with distinctive colors, with storage arrays conspicuously posted in different areas of the facility. Training would be conducted and standards for handling uranium and plutonium oxides should be consistent throughout the facility to ensure uniform handling. Upon receipt, containers could be scanned and/or sampled and the results compared to shipping documents.

6.4.3.3.2.5 Reflection Control

The use of reflection as a controlled parameter should be considered acceptable if:

A. When determining subcritical limits for an individual unit, the wall thickness of the unit and all reflecting adjacent materials of the unit are conservatively bounded by the assumed reflection conditions, leaving allowances for transient reflectors as discussed in the next item. (This effect may be significant for a MOX facility, where thick hydrogenous reflectors may provide shielding in several areas.)

B. At a minimum, reflection conditions equivalent to a one-inch tight-fitting water jacket are assumed to account for personnel and other transient incidental reflectors not evaluated in the unreflected unit models. This will be considered bounding for all hydrogenous reflectors further than one foot away from the surface of the unit. Justification for less conservative reflection conditions should be included in the application.

C. When loss of reflection control can lead to criticality, by itself or in conjunction with any other single failure, rigid and testable personnel barriers are established and maintained through the configuration management and maintenance programs.

D. Full water reflection of units may be assumed to be represented by twelve inches of close-fitting water. Under certain conditions, however, materials such as concrete, beryllium, carbon, and polyethylene may be more effective than water.

E. Conservative reflection conditions are established when evaluating the criticality safety of arrays.

As an example of implementing reflection control (especially Items A, B, and C), the reviewer would observe that: Conservative assumptions about the thickness and composition of tangent concrete walls and floors for storage vaults, and firebrick around oxidation furnaces, are taken into account in the calculations. Beyond this, one inch nominal reflection is considered conservative to model water pipes, personnel, and other reflecting materials that may be nearby. If full water reflection is not adequately subcritical, postings and barriers could be erected to ensure that nominal reflection conditions are not exceeded.

6.4.3.3.2.6 Moderation Control

The use of moderation as a controlled parameter should be considered acceptable if:

A. When using moderation, the applicant commits to the requirements in ANSI/ANS-8.22-1997, *"Nuclear Criticality Safety Based on Limiting and Controlling Moderators."*

B. When process variables can affect the moderation, the process variables are identified as IROFS in the CSEs and ISA Summary. The acceptance criteria in Section 6.4.3.3.2.12 are met.

C. When physical measurement of the moderator is needed, the measurement is obtained by using instrumentation subject to facility quality assurance measures as specified in 10 CFR 70.22(f).

D. When designing physical structures, the design precludes the ingress of moderation.

E. When sampling of the moderator is needed, the sampling program uses dual independent sampling and analysis methods. The process should be designed such that a single operator acting alone cannot physically circumvent the sampling and analysis program.

F. When developing firefighting procedures for use in a moderation controlled area, restrictions are placed on the use of moderator material. Moderation controlled areas should be physically segregated from potential ignition sources. The effects of the fire and the moderating material on fissile material should be evaluated as applicable.

G. Limits on moderators as firefighting agents are established in the CSE and flow into the ISA. The ISA may weigh the competing risks from criticality accidents and fires and determine that the overall risk to the worker and public is minimized by allowing the use of water. The CSE is the primary document used to develop the safety basis, and thus should govern the safety of operations; the CSE should be revised so that the safety conclusions harmonize between the two documents.

H. After evaluating all credible sources of moderator for the potential for intrusion into a moderation controlled area, the ingress of moderator is precluded or controlled.

I. The effects of varying levels of interstitial moderation are evaluated when the calculational methods consider interacting arrays of fissile units.

As an example of implementing moderation control (especially Items G, H, and I), the reviewer would observe that: If a fissile material system is not adequately subcritical with a few percent water density between array elements, water pipes and sprinklers would be excluded from that area. Also, the effects of fire suppression systems and activities would be evaluated. For areas under moderation control, overhead water pipes could be excluded or sleeved within secondary piping and a means provided to detect leakage from the inner pipe; drains could be provided to prevent water accumulation; and/or watertight cans and gloveboxes could be credited as a moderation barrier.

6.4.3.3.2.7 Concentration Control

The use of concentration as a controlled parameter should be considered acceptable if:

A. When process variables can affect the concentration, the process variables are identified as IROFS in the CSEs and ISA Summary, including assumptions relied on to determine solubility limits. The acceptance criteria in Section 6.4.3.3.2.12 are met.

B. High concentrations of SNM in a process are precluded.

C. When using a tank containing concentration-controlled solution, the tank is normally closed and locked.

D. When sampling of the concentration is needed, the sampling program uses dual independent sampling methods. The process should be designed such that a single operator acting alone cannot physically circumvent the sampling program.

E. After identifying possible precipitating agents, precautions are taken to ensure that such agents will not be inadvertently introduced.

F. All other concentrating mechanisms are identified and controls established to prevent overconcentration. Surveillance is provided to ensure the effectiveness of these controls.

G. When physical measurement of the concentration is needed, the measurement is obtained by using instrumentation subject to facility quality assurance measures as specified in 10 CFR 70.22(f).

As an example of implementing concentration control (especially Items A, B, C, D, and F), the reviewer may observe that: Plutonium nitrate tanks under concentration control should be locked and tagged, and dual independent sampling as well as an in-line monitor provided on the input line to prevent transfer of concentration solutions to the tank. (It may be difficult to determine that a single sampling and analysis constitutes a robust control, due to the number and complexity of steps involved. Specifying dual controls provides added reliability.) Process variables which maintain the plutonium nitrate in a solution form could be controlled--acid molarity, and possible precipitating agents should be excluded by removing hard-piped connections to the tanks and should be monitored by the sampling program.

6.4.3.3.2.8 Interaction Control

The use of interaction as a controlled parameter should be considered acceptable if:

A. When maintaining a physical separation between units, engineered devices (i.e., spacers) with a minimum spacing are used. The structural integrity of the spacers should be sufficient for normal and credible abnormal conditions; or:

B. Unit spacing is controlled by rigorous procedures (if the spacing is identified in workstation procedures with visual indicators and postings). Justification for this method should be provided in the application and should demonstrate that multiple procedural violations will not by themselves lead to criticality.

As an example of implementing interaction control (Items A and B), the reviewer may observe that: 11-liter (2.906 gallons nominal) cylinders containing plutonium or uranyl nitrate are stored within birdcage drums, which are examined periodically for denting or other deformation. If it is important that they not be stored in a triangular pitch array, painted lines or circles on the floor and postings could be used to enforce administrative controls. In the absence of birdcage drums or other passive devices, calculations may explicitly demonstrate that placing together several cylinders in a tight configuration in the corner of the room will not result in a criticality.

C. When evaluating the criticality safety of units in an array or pairs of arrays, the spacing limits in ANSI/ANS-8.7-1975, "*Nuclear Criticality Safety in the Storage of Fissile Materials*," are followed (Sections 5 and 6), or spacing is based on validated calculational methods.

6.4.3.3.2.9 Neutron Absorber Control

The use of neutron absorber as a controlled parameter should be considered acceptable if:

A. When using borosilicate-glass Raschig rings, the applicant commits to the endorsed requirements in ANSI/ANS-8.5-1996, *"Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material."*

B. When using fixed neutron absorbers, the applicant commits to the endorsed requirements in ANSI/ANS-8.21-1995, *"Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors."*

As an example of implementing neutron absorber control (especially Item B), the reviewer would observe that: If credit is to be taken for the gadolinium percentage in MOX fuel, the concentration of this isotope is measured, and all items affecting it should be classified as IROFS. If fixed poison rods are credited, then the poison loading and dimensions would be declared as IROFS and monitored (as in pickling operations where it could be leached away).

6.4.3.3.2.10 Volume Control

The use of volume as a controlled parameter should be considered acceptable if:

A. When using volume control, geometrical devices are used to restrict the volume of SNM and engineered devices limit the accumulation of SNM.

B. When physical measurement of the volume is needed, the measurement is obtained by using instrumentation that is subjected to quality assurance.

As an example of implementing volume control (especially Item A, the reviewer would observe that: The volume of a container of plutonium nitrate is controlled to some fixed percentage (say, 75%) of the minimum critical volume, assuming spherical geometry, 0.3 m (12 inches) of water reflection, and optimal concentration.

6.4.3.3.2.11 Heterogeneity Control

The use of heterogeneity as a controlled parameter should be considered acceptable if:

A. When process variables can affect the heterogeneity, the process variables are identified as IROFS in the CSEs and ISA summary. Methods of causing the material to become inhomogeneous are evaluated. The acceptance criteria in Section 6.4.3.3.2.12 are met.

B. Computer calculations that take heterogeneity into account are appropriately validated with benchmark experiments that display effects of heterogeneity. Computer calculations use the appropriate cell-weighting to ensure that resonance self-shielding is taken into account.

C. A physical measurement of the scale of heterogeneity is obtained based on the observed physical characteristics of the material, and the calculations shown to be conservative with respect to these measurements.

Heterogeneous effects are particularly relevant to deriving NCS limits for low-enriched uranium processes, where heterogeneous systems are typically more reactive than homogeneous systems for all other parameters being equal.

As an example of implementing herogeneity control (Items A, B, and C), the reviewer would observe that: A motorized stirrer and acid molarity are credited in maintaining a highly concentrated solution homogeneous. These could be identified as IROFS and the system evaluated over the entire range of heterogeneity if it is determined that heterogeneity is a significant effect, and if it is desirable to credit. If the solution is completely homogeneous, the system may be safe because of homogeneity, and if the material has precipitated out, it may be safe because it is a safe slab. The intermediate configuration may not be bounded and would typically be evaluated separately. The validation report contains benchmarks that contain heterogeneous effects, to ensure that the bias is known when using resonance self-shielding.

6.4.3.3.2.12 Process Variables

The use of process variables as a controlled parameter should be considered acceptable if:

A. Process variables relied on for criticality safety are identified as IROFS in the CSEs and ISA summary and are subject to quality assurance sufficient to ensure that the associated controlled parameter safety limit is not exceeded.

As an example of implementing process variables, the reviewer may observe that: Process variables identified as IROFS, including temperature in an oxidation furnace that is credited in excluding moderator, force of a pellet press credited in controlling density, and the presence of radionuclides that do not affect the reactivity but which can bias the measurement of monitoring equipment.

6.4.3.3.3 Requirements of 10 CFR 70.24 (Criticality Accident Requirements)

To provide for NCS, the applicant’s description of measures to meet the requirements in 10 CFR 70.24 should be considered acceptable if the applicant has met the following acceptance criteria:

A. The applicant has fully demonstrated that the facility CAAS meets the requirements of 10 CFR 70.24.

B. The applicant has fully demonstrated that the facility meets the remaining criticality accident requirements of 10 CFR 70.24.

C. The applicant commits to the endorsed requirements in ANSI/ANS-8.3-1997, *"Criticality Accident Alarm System."*

D. Beyond these requirements, the applicant commits to any additional requirements in Regulatory Guide 3.71, *"Nuclear Criticality Safety Standards for Fuels and Materials Facilities,"* (Section C) which modify requirements in the ANSI/ANS-8.3 standard.

E. In accordance with the performance requirements of proposed 10 CFR 70.61(a) to limit the risk of high-consequence events including externally initiated events:

   i. The applicant commits to having a CAAS that is designed to remain operational during credible events such as a seismic shock equivalent to the site-specific design-basis earthquake or the equivalent value specified by the Uniform Building Code.

   ii. The applicant commits to having a CAAS that is designed to remain operational during normal operating conditions and should be resistant to damage during other credible events, to the extent practical (up to design basis events). These events would include fires, explosions, corrosive atmospheres, etc.

G. The applicant commits to having a CAAS alarm that is clearly audible in areas that must be evacuated or provides alternate notification methods that are documented to be effective in notifying personnel that evacuation is necessary.

H. The applicant commits to rendering operations safe, by shutdown and quarantine if necessary, in any area where CAAS coverage has been lost and not restored within a specified number of hours. The number of hours should be determined on a process by process basis because shutting down certain processes, even to make them safe, may carry a larger risk, than being without a CAAS for a short time. The applicant should commit to compensatory measures (e.g., limit access, halt SNM movement) when the CAAS system is not functioning due to maintenance.

I. The applicant evaluates the effect of credible shielding in demonstrating the adequacy of the dual alarms to detect a nuclear criticality.

J. In accordance with the provisions of 10 CFR 70.24(b)(1) and (b)(2):

   i. The applicant commits to the requirements in ANSI/ANS-8.23-1997, *"Nuclear Criticality Accident Emergency Planning and Response."*

   ii. The applicant either has an emergency plan or satisfies the alternate requirements found in 70.22(h)(1)(i). (See SRP Chapter 14.0)

   iii. The applicant commits to provide emergency power for the CAAS.

As an example of adequate CAAS coverage (Items A through I), the reviewer may observe a commitment to place alarms such that two detectors cover all fissile material processing and transfer areas, with two detectors required to actuate the evacuation signal to minimize accidental actuation. In addition the applicant would perform shielding calculations (using, for *instance, the Monte Carlo Neutron Proton (MCNP) Code) to demonstrate the alarm coverage radius, taking conservative estimates of the intervening shielding and using housekeeping practices that minimize the presence of this shielding material. If the CAAS alarm is in an area where process noise would render the alarm inaudible, alternate measures such as flashing strobe lights may be proposed.*

K. Exceptions to the CAAS requirements of 10 CFR 70.24 will be considered when the risk of nuclear criticality is sufficiently low that the exposure of facility personnel is not a regulatory or safety concern. The applicant should provide justification by demonstrating that the risk to facility personnel is significantly less than that afforded under the double contingency principle. To support this justification, the applicant may take credit for shielding or other dose mitigation or demonstrate that a criticality is incredible due to amounts and forms of SNM that are or may be present.

As an example of possible justifications for the exclusion of CAAS coverage (Item K), the reviewer may observe: (1) the applicant has materials whose physical form and isotopic characterization would require masses vastly in excess of what the applicant is authorized to possess to cause criticality; (2) the facility has been demonstrated to have adequate shielding to prevent any operator from receiving a dose in excess of 20 rad. In this case, measures would still be provided to alert operations to the fact of a criticality; (3) operators are excluded from processing areas by hostile conditions to a distance adequate to ensure safety; or (4) other process conditions exist such that there are no identifiable accident sequences that could credibly lead to a criticality.

6.4.3.3.4 Requirements of Proposed 10 CFR 70.61 (Subcriticality of Operations and Margin of Subcriticality for Safety)

To provide for NCS, the applicant’s description of measures to implement the subcriticality of operations and margin of safety for subcriticality requirements in proposed 10 CFR 70.61 should be considered acceptable if the applicant has met the following acceptance criteria:

A. The applicant commits to technical practices as applicable in the endorsed versions of ANSI/ANS-8.1, 8.5, 8.7, 8.9, 8.10, 8.12, 8.15, 8.21, and 8.22.

B. The applicant submits justification for the minimum subcritical margin (frequently referred to as the administrative or arbitrary margin) for normal and credible abnormal conditions. Abnormal conditions should meet the following criterion to provide reasonable assurance of adequate protection:

   i. If the fact that a condition is abnormal is credited for double contingency (that is, the abnormality is taken as justification for having a lower margin of subcriticality than would be permissible for normal conditions), then the abnormal conditions should meet the standard of being at least "unlikely" from the standpoint of the double contingency principle. A condition that occurs on a regular basis during facility operations would not be considered abnormal. In addition, the increased risk associated with the less conservative margin should be commensurate with and offset by the unlikelihood of achieving the condition to begin with.

As an example of Item B(i), the reviewer would review the justification for the use of a minimum subcritical (administrative) margin. For example, justification for a margin of 0.02 for abnormal conditions may reference, among other things, the unlikelihood of achieving the abnormal condition. The applicant would then rigorously define what is meant by an abnormal condition. A spill of SNM when open containers of powder are manually handled would not be considered an abnormal occurrence; spills outside the tube of a favorable geometry sintering furnace would probably be an abnormal occurrence, unless operating history showed otherwise. An applicant wishing to use a minimum subcritical margin of 0.02 instead of a more conservative value (such as 0.05, which is typically considered acceptable for most cases where there are a statistically significant number of benchmarks) for instance, for abnormal events may demonstrate that the increase in risk by reducing the conservatism in k_{eff} *by the proposed amount is offset by the low likelihood of occurrence of the abnormal condition. This should take into consideration the estimated uncertainty in the bias.*

C. The applicant commits to determining subcritical limits for k-eff calculations such that:

$$\text{k-subcritical} = 1.0 - \text{bias} - \text{margin}$$

where margin includes adequate allowance for uncertainty in the methodology, data, and bias to assure subcriticality.

D. The applicant commits to determining operation limits for controlled parameters, such that there is an adequate margin of safety to ensure the subcritical limit will not be exceeded. The applicant should commit to perform studies of the sensitivity of k_{eff} to variations in the parameters. The margin of safety should be based on these sensitivity studies and the ability of the control to maintain the operating limits.

E. The applicant commits to determining whether each calculation to establish subcritical limits for facility processes lies within the AOA of the calculational method employed, and documenting the determination that it is within the AOA. (The AOA for the method should be defined in the validation report; see Section 6.4.3.3.1).

As an example of Item E, the reviewer should ensure that: The applicant's validation report states the range of material chemical and physical forms, isotopic concentrations, moderation range, other materials assumed validated, neutron energy ranges, any code options and/or statistics used, and any other pertinent information that defines the AOA. The applicant would then commit to evaluating each application to determine whether it falls into the code's AOA and documenting this in the evaluation. If this information is not unambiguously spelled out in the validation report, then an equivalent analysis may be conducted in each evaluation. In addition, those cases which are most relevant would be evaluated when determining the bias and AOA. For instance, plutonium oxide lattice cases would not be in the same AOA as high-enriched uranium fast metal cases and the bias should be determined for each AOA.

F. The applicant meets the acceptance criteria in Section 5.4 (ISA Summary) as they relate to subcriticality of operations and margin of subcriticality for safety.

6.4.3.3.5 Requirements of Proposed 10 CFR 70.64 (BDC) [for new facilities and processes only]

To provide for NCS, the applicant's description of measures to implement the BDC requirements in proposed 10 CFR 70.64 should be considered acceptable if the applicant has met the following acceptance criteria:

A. The applicant commits to the double contingency principle in determining NCS controls in the design of new facilities or new processes at existing facilities. When evaluating double contingency protection, the term "unlikely" should be used in a manner consistent with Section 4.2.2 of ANSI/ANS-8.1-1983.

B. Protection should be provided by either the control of two (or more, as needed) independent process parameters, or a system of multiple independent controls on a single process parameter.

The former method, two-parameter control, is the preferred approach due to the difficulty of preventing common-mode failure when controlling only one parameter. In all cases, no single credible event or failure shall result in a criticality accident.

The term "concurrent" as used in double contingency means, for the purpose of this review, that the effect of the first process change persists until the second change occurs, at which point the system is potentially at or above critical. It does not mean that the two events initiating the change must occur simultaneously.

As an example of meeting the double contingency principle (Items A and B), the reviewer should ensure that: If dual geometry control for a highly concentrated plutonium nitrate system is ensured by having an inner and an outer containment, means are provided for detecting whether the solution has intruded into the outer containment. Otherwise, the inner containment could have been breached and remained breached for an extended period of time. In this case, double contingency is not met even though two non-simultaneous failures are required. The time interval needed to detect and correct the failure should be considered and may be credited in the determination that the two failures in combination are highly unlikely.

Dependence between the two or more events in the accident sequence should be taken into account in assessing the likelihood, so that the occurrence of both events taken together is highly unlikely. This dependence can occur because one event causes the other to become more likely, or because occurrence of some other event increases the likelihood of both events. This latter type can be the occurrence of a fire or other environmental degradation, the use of non-diverse equipment, or the same operator performing two actions. Another type of dependence that must be considered is common cause failure, that is, a single event failure. If any such single event exists that could cause criticality, it by itself must qualify as highly unlikely.

As an example of common cause effects, as discussed in the preceding paragraph, a process may depend on geometry and moderation control, or on dual moderation controls, but a major fire in the facility may defeat both by causing sprinkler activation and by bringing material together into a more reactive configuration. Such externally-initiated common mode failure scenarios would be evaluated in the CSE and flowed into the ISA.

C. Adequate justification for allowing an exception to the double contingency principle includes:

i. The impracticality of implementing the double contingency principle is thoroughly documented by showing excessive costs and severe operational burdens that would be imposed on the facility compared to the risk reduction gained by implementing the principle; and

ii. Enough redundancy and diversity exists to ensure that the probability of criticality remains highly unlikely. Even if the consequences of criticality are mitigated such that they do not rise to the threshold of proposed 10 CFR 70.61(b)(1), criticality shall still be highly unlikely. However, the mitigation may constitute grounds, along with other considerations, for granting exemption from the requirements to establish double contingency.

Care should be taken to use a definition of “unlikely” that is consistent with the definition in SRP Section 6.8, rather than the definition in Chapter 5 (Integrated Safety Analysis) for intermediate consequence events. Although the terminology used is the same, the context differs. As Section 6.8 states, the scope of the definitions there are confined to this chapter.

As an example of possible exceptions to the double contingency principle (Item C), the reviewer may evaluate a process that requires the processing of large quantities of plutonium or uranium oxide to achieve an acceptable throughput. In the case of low-plutonium mixed oxide powder, the only practicable method of ensuring subcriticality may be moderation control. Multiple controls on moderation in a large geometry hopper or fluidized bed reactor may be sufficient to ensure double contingency. Such a case may or may not constitute single-parameter double contingency; single contingency may be authorized based on a demonstration that it would require a single almost incredible event--like a catastrophic breach in containment due to an explosion--before criticality is possible. Another example may be a system that relies only on an unusually rigorous passive geometry control.

In a shielded facility, single contingency may be authorized based on reduced risk to personnel. Controls would still be in place, however, to ensure against criticality, and will be evaluated on a case-by-case basis, taking mitigation into account as one of the factors.

6.4.3.3.6 Requirements of Proposed 10 CFR 70.65 (ISA Summary)

The applicant is required to meet the performance criteria in proposed 10 CFR 70.61(b) and (c) as well as the performance requirements in proposed 70.61(d), which include the requirement to limit the risk of an inadvertent nuclear criticality by assuring that all nuclear processes remain subcritical. The applicant’s evaluation of NCS Accident Sequences should be performed in a manner consistent with the applicant’s evaluation of non-NCS Accident Sequences used to meet proposed 10 CFR 70.61(b) and (c); however proposed 10 CFR 70.61(d) requires the applicant to use prevention methods as the primary means to meet the performance requirements of proposed 10 CFR 70.61(b) and (c).

To provide for NCS, the applicant's implementation of the ISA requirements in proposed 10 CFR 70.65 should be considered acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

A. Accident Sequences:

   i. The applicant meets the acceptance criteria in Section 5.4 (ISA Summary) related to accident sequences for NCS.

   ii. The applicant commits to evaluate the loss of each criticality control as a separate accident sequence. (Appendix A of ANSI/ANS-8.1-1983 provides guidance on the types of accident sequences that should be considered.)

B. Consequences:

   i. The applicant meets the acceptance criteria in Section 5.4 (ISA Summary) related to consequences for NCS.

   ii. In determining the consequences of a criticality, the applicant may commit to the requirements in ANSI/ANS-8.10-1983, *"Criteria for Nuclear Criticality Safety Controls in Operations With Shielding and Confinement."* The justification for considering a criticality accident as other than a high-consequence event should be fully documented and provided as part of the application.

As an example of Item B(ii): A criticality in a shielded facility may not be a high consequence event, but still requires an explicit exemption from the double contingency requirement. Further justification may include areas where personnel are excluded because of hostile operating conditions.

C. Likelihoods:

   i. The applicant meets the acceptance criteria in Section 5.4 (ISA Summary) related to likelihoods for NCS.

   ii. In demonstrating compliance with the double contingency principle, the term "unlikely" is taken to mean that an event--or a set of events credited as one leg of double contingency--is not anticipated to occur during the lifetime of the facility at any particular point in the process or in any particular accident sequence. In demonstrating unlikelihood the applicant may credit credible process conditions, previous facility history (for existing facilities), and management measures which ensure the availability and reliability of controls when needed. The applicant may choose to define the terms "unlikely" and "highly unlikely" differently, but must still demonstrate compliance with the performance requirements of proposed 10 CFR 70.61(b) and 70.64(a)(9).

As an example of what is meant in Item C(ii), for passive and active engineered controls, management measures such as maintenance, configuration management, surveillance, and so on may be considered adequate to ensure that failure of the control is unlikely. For instance, a fissile material pump that functions as an IROFS would be considered to be sufficiently reliable if it was periodically functionally tested, if the oil were changed and the proper lubrication used in accordance with the manufacturer's specifications, if the environment in which it were used was within the pump's operating parameters (such as temperature), if gaskets and bearings were replaced on a frequency dictated by the manufacturer's wear data, and if its criticality significant characteristics were verified upon installation and configuration controlled.

For a simple administrative control such as spacing in an array, failure would not be considered unlikely if the operator were required to place units within half an inch center-to-center, if there were no passive spacing devices and no painted guides on the floor. A simple administrative control on spacing would be acceptable as a reliable control with the proper training, postings, floor markings, and supervisor attention, but its failure may still not be sufficiently unlikely to be credited as a single leg of double contingency. If two such spacing violations could lead to criticality, then a more rigorous interaction control would probably be required. Multiple failures of the same control may not be considered distinct contingencies, if they can result from the same operator's error. More than two controls may be needed as one leg of double contingency, if they are not individually unlikely to fail.

D. Risk:

i. The applicant meets the acceptance criteria in Section 5.4 (ISA Summary) related to risks for NCS.

E. IROFS:

   i. The applicant meets the acceptance criteria in Section 5.4 (ISA Summary) related to IROFS for NCS.

6.4.3.3.7 Requirements of Proposed 10 CFR 70.72 (Facility Change Process)

To provide for NCS, the applicant's description of measures to implement the facility change process requirements in proposed 10 CFR 70.72 should be considered acceptable if the applicant has met the following acceptance criteria:

A. The applicant commits to a change control process that is sufficient to ensure that the safety basis of the facility will be maintained during the lifetime of the facility. This change process must be documented in written procedures and must ensure that:

   i. All potentially affected SNM processes are evaluated to determine the effect of the change on the safety basis of the process, including the effect on bounding process assumptions, on the reliability and availability of nuclear criticality controls, and on the criticality safety of connected processes. The change control process must have procedures for the review and approval of facility changes by the criticality safety organization to determine the potential effects on nuclear criticality safety.

B. The change control process must be connected to the facility's configuration management system to ensure that changes to the criticality safety basis are incorporated into procedures, evaluations, criticality postings, drawings, any other safety basis documentation, and the ISA.

C. The applicant commits to a program to determine whether facility changes require prior NRC approval in accordance with the criteria of proposed 10 CFR 70.72(c). This program must be documented in written procedures and must involve individuals qualified to determine the incremental effect of changes to the safety basis as documented in the ISA and established in the CSEs; the change shall be compared to the baseline (latest NRC approved) version of the ISA.

An example of changes that could be made without prior NRC approval would include certain changes to a uranium solution pump. The attributes important to this pump are the plenum volume (pump is safe volume) and diameter, volume of the oil reservoir (safe volume and limited moderator into process), and pump capacity (required to prevent overflowing downstream equipment). A change that would not require prior NRC approval would be changing the manufacturer or model number of the pump, provided that this did not affect any of the above attributes. Changing from a centrifugal to a positive displacement pump may not require additional changes, unless this introduced additional accident sequences or reduced the reliability of the pump or any of the pump's characteristics important to NCS. Replacement of a backflow preventer with a check valve would require prior approval because although it did not change any controlled parameters or introduce any new accident sequences, it reduced the margin of safety by replacing a robust control with one which was more likely to fail.

6.4.3.3.8 Requirements of Proposed 10 CFR 70 Appendix A (Reportable Safety Events)

The applicant's description of measures to implement the reporting requirements in proposed 10 CFR 70 Appendix A should be considered acceptable if the applicant has met the following acceptance criteria:

A. The applicant has a program for evaluating the criticality significance of criticality safety events and an apparatus in place for making the required notification to the NRC Operations Center. The determination of significance should be made by qualified individuals (such as facility NCS staff). The determination of loss or degradation of double contingency protection should be made against the current version of the facility safety basis documents.

B. The applicant incorporates the reporting criteria of Appendix A and the report content requirements of 10 CFR 70.50 into the facility emergency procedures.

C. The applicant commits to issue the necessary report based on whether the IROFS credited for double contingency were lost, irrespective of whether the safety limits of the associated criticality parameters were actually exceeded.

D. The applicant makes the following commitment: If it cannot be determined within one hour of whether the criteria of 10 CFR Appendix A Paragraph (a) or (b) apply, the event shall be treated as a one-hour report.

As an example of the foregoing criteria (Items A through D), the reviewer should consider the hypothetical case of an upset in an unfavorable geometry waste water tank, which typically relies solely on mass control for criticality safety. An unauthorized transfer to this tank would be reportable as a one-hour report, even if it were unknown whether an unsafe mass had been transferred (since mass is what is maintaining subcriticality). Even if it were later determined that an unsafe mass did not accumulate in the tank, this report should not be retracted. In this case, the mass control was lost even if the mass did not physically exceed a safe value, because the multiplicity of positive controls needed for double contingency was not maintained - thus, it would be reportable under Items C and D above.

As a second example, consider the case of a slab of molybdenum boats containing green MOX pellets, which are heat-treated in a sintering furnace. Typical criticality controls for this example would include the mass in each boat, the depth of pellets in the boat, and moderation. The depth of pellets is controlled (in this hypothetical example) by the boat's dimensions, although the boats are demonstrated to be adequately subcritical when filled up to the top with pellets at theoretical density. An applicant controlling mass in these boats may establish an operating limit lower than the actual capacity of the boats in order to ensure that the material is processed uniformly and to give the operators a certain amount of margin in filling the boats. The formal subcritical limit established in criticality safety evaluations typically exceeds this operating limit by a substantial amount. When controls are established with such conservatism, it may take several events before criticality is possible, including exceeding the analyzed safe slab depth of the boat and adding moderator. Because several events are needed for criticality even after an *upset occurs, merely exceeding the operating limit would not be reportable as an immediate report under Appendix A Paragraph (a)(5). Double contingency would not be lost in this hypothetical case. The filling of a boat to two grams more than that allowed in the operating limit would not be considered significant (since the boats had been shown adequately subcritical even when overfilled well beyond this) and would not require reporting. This of course requires a significance determination as to what constitutes a significant loss of mass control in the CSE.*

However, the filling of a boat until the material mounded over the top would violate both geometry and mass control and would be a significant loss of the control, since the mass would exceed the pre-analyzed condition. The resultant condition, and that of exceeding the subcritical limit, would constitute a twenty-four hour reportable event~~s~~ since the IROFS failed to meet the performance requirements of 10 CFR 70.61(e). Overflowing the material out of the boat and onto the floor, however, if it were not analyzed and shown to be subcritical as an upset condition in the criticality safety evaluation, would be reportable as an unanalyzed condition.

The information to be submitted in these reports should include, to the extent known at the time of the event, the quantities and isotopics of the materials involved, their moderation levels, and any other pertinent information needed to assess their k_{eff} *, the particular procedural failure that led to the event, and the condition of the remaining geometry and moderation controls to allow NRC to determine the actual and potential significance of the event.*

6.5 REVIEW PROCEDURES

6.5.1 Acceptance Review

The primary reviewer should perform an acceptance review to determine if the application for construction approval or license application adequately addresses the items in Section 6.3, "Areas of Review."

Guidance specific to the application for construction approval and the license application is provided below.

A. Application for Construction Approval

   Specifically, the safety assessment of the design basis should address Sections 6.3.1 to 6.3.3 consistent with the level of design. Where information is under development or not yet available, the applicant may use a commitment to provide the material with the license application in lieu of the actual material.

The specific areas of interest during the design phase are described below:

i. The commitment to establish an NCS organization and administration in accordance with the acceptance criteria of Section 6.4.3.1.

ii. The commitment to establish management measures for NCS in accordance with the acceptance criteria of Section 6.4.3.2.

iii. The commitment to design and operate the facility using technical practices that are in accordance with the acceptance criteria of Section 6.4.3.3. In particular:

   a. The applicant commits to design and operate the facility in accordance with the BDC (that is, commits to the double contingency principle).

   b. The applicant commits to install and maintain a CAAS for applicable areas of the facility, or includes an exemption request with the construction application.

   c. The applicant commits to the following design criteria: Geometry control shall be the preferred mode of control for criticality safety and shall be designed into the facility to the greatest extent practical. Where geometry control is not practical, reliance shall be based on other passive engineered controls to the greatest practical extent.

   d. The applicant provides a description of the overall process and, for each major process step, identifies which criticality safety parameters will be relied on to satisfy the BDC.

   e. The applicant demonstrates an ability to design the facility in accordance with the Baseline Design Criteria by providing validation reports to support calculations of subcritical limits, and proposed margins of subcriticality.

B. License Application

Specifically, the safety assessment of the license application should address Section 6.3 in full.

If the primary reviewer verifies that NCS is adequately addressed (application for construction approval or license application), the primary reviewer should accept the application for the safety evaluation in Section 6.5.2. If the primary reviewer identifies significant deficiencies in the material provided, the primary reviewer should request that the applicant submit additional information prior to the start of the safety evaluation.

6.5.2 Safety Evaluation

After determining that the application is acceptable for review in accordance with either Section 6.5.1(A) (application for construction approval) or 6.5.1(B) (license application), the primary reviewer should perform a safety evaluation against the acceptance criteria described in Section 6.4. On the basis of its review, the staff may request that the applicant provide additional information or modify the application to meet the acceptance criteria in SRP Section 6.4.

The primary reviewer should consult with the supporting reviewers to identify and resolve any issues of concern related to the application for construction approval or the licensing application. For the license application, the primary reviewer (acting as a secondary or supporting reviewer) should also coordinate with other reviewers concerning NCS regarding the following:

i. In support of the primary reviewer for Chapter 9.0, the NCS reviewer should determine whether the acceptance criteria in Chapter 9.0 have been met as they relate to NCS.

ii. In support of the primary reviewer for Sections 15.1 through 15.8, the NCS reviewer should determine whether the acceptance criteria in Sections 15.1 through 15.8 have been met as they relate to NCS.

iii. In support of the primary reviewer for Chapter 5.0, the NCS reviewer should determine whether the acceptance criteria in Chapter 5.0 have been met as they relate to NCS.

iv. In support of the primary reviewer for Chapter 14.0, the NCS reviewer should determine whether the acceptance criteria in Chapter 14.0 have been met as they relate to NCS.

v. In determining whether the acceptance criteria have been met, the reviewer should become familiarized with the proposed operation and the dominant criticality safety risks. The reviewer should select a risk-informed sample of accident scenarios from the applicant's ISA Summary to review in evaluating the applicant's technical practices, in conjunction with the applicant's CSEs.

6.6 EVALUATION FINDINGS

The primary reviewer should document the safety evaluation by preparing material suitable for inclusion in the Safety Evaluation Report (SER). The primary reviewer should describe the review, explain the basis for the findings, and state the conclusions.

The staff could document the safety evaluation (for the application for construction approval) as follows:

The staff reviewed the Nuclear Criticality Safety (NCS) measures described in the application for construction approval according to Chapter 5.0 of the NUREG-1718. The staff is satisfied that: (1) The applicant's commitments to establish an NCS organization and administration, management measures, and technical practices for NCS are in broad agreement with regulatory acceptance criteria; (2) the adequate implementation of these commitments is likely to generate an acceptable license application; and (3) the applicant has established design criteria that in broad agreement with the Baseline Design Criteria of 10 CFR 70.64. Based on these findings, staff concludes that there is reasonable assurance that a facility designed in compliance with the aforementioned application for construction approval will be found acceptable without major re-engineering or re-design. Therefore, the applicant's NCS design basis meets the requirements to approve construction of the facility under 10 CFR Part 70.

The staff could document the safety evaluation for the license application as follows:

The staff reviewed the Nuclear Criticality Safety (NCS) program of the license application for the [insert name of facility] according to Chapter 6.0 of the NUREG-1718. The staff evaluated [state what was evaluated] and found that [state the findings]. The staff has reasonable assurance that: (1) The applicant will have in place a staff of managers, supervisors, engineers, process operators, and other support personnel who are qualified to develop, implement, and maintain the NCS program in accordance with the facility organization, administration, and management measures; (2) the applicant's conduct of operations will be based on NCS technical practices which will ensure that the fissile material will be possessed, stored, and used safely according to the requirements in 10 CFR Part 70; (3) the applicant will develop, implement, and maintain a criticality accident alarm system in accordance with the requirements in 10 CFR 70.24 and in accordance with its emergency management program; and (4) the applicant will have in place an NCS program in accordance with the subcriticality of operations and margin of subcriticality for safety requirements in 10 CFR 70.61 and Baseline Design Criteria in 10 CFR 70.64.

Based on this review, the staff concludes that the applicant's NCS program meets the requirements of for a license to possess and use SNM under 10 CFR Part 70 and provides reasonable assurance for the protection of public health and safety, including workers and the environment.

Note: The NCS safety evaluation for the ISA Summary requirements for proposed 10 CFR 70.65 should be included in the safety evaluation that supports Chapter 5.0 of this SRP.

6.7 REFERENCES

A. Code of Federal Regulations, Title 10, Part 70, Domestic Licensing of Special Nuclear Material, U.S. Government Printing Office, Washington, D.C., 1999.

B. Proposed 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material; Possession of a Critical Mass of Special Nuclear Material." 64 FRN 41338, July 30, 1999.

C. LA-10860-MS, *Critical Dimensions of Systems Containing ^{235}U, ^{239}Pu, and ^{233}U*, H. C. Paxton and N. L. Pruvost, Los Alamos National Laboratory, Los Alamos, NM, 1987.

D. LA-12808/UC-714, *Nuclear Criticality Safety Guide*, N. L. Pruvost and H. C. Paxton, Los Alamos National Laboratory, Los Alamos, NM, 1996.

E. DP-1014, *Maximum Safe Limits for Slightly Enriched Uranium and Uranium Oxide*, H. K. Clark, Du Pont de Nemours and Co., Aiken, SC, 1966.

F. DOE/NCT-04, A Review of Criticality Accidents, W. R. Stratton, Revised by D. R. Smith, U.S. Dept. of Energy, March 1989.

G. *Nuclear Criticality Safety--Theory and Practice*, R. A. Knief, American Nuclear Society, La Grange Park, IL, 1985.

H. DOE Order 420.1 (Change 2), *Facility Safety*, October 24, 1996.

6.8 NCS DEFINITIONS

The terms defined below are in addition to the definitions that apply to the entire SRP. Where the definition below disagrees with the global usage, the term below governs. These are terms with a specific meaning to nuclear criticality safety, and the scope of these definitions is confined to SRP Chapter 6.

abnormal condition: Any event that is not planned for as a regular occurrence in the facility or operation design. Any event whose occurrence would result in suspension of fissile material operations and movement and require specific recovery actions to restore adequate protection. A condition that can only be reached by exceeding the safety limits of a controlled parameter but which is planned for in CSEs.

adequate protection: A condition that exists when the risk of criticality is sufficiently low. Adequate protection is presumed to exist when double contingency is maintained, for example.

administrative margin: Margin in k_{eff} in addition to the bias and uncertainties in the bias, to allow for unquantified uncertainties in calculating k_{eff}.

area(s) of applicability: The range of physical parameters (e.g., isotopic abundance, moderation, neutron energy, etc.) characterizing a fissile material system over which the code is validated. That is, the range of parameters covered by the benchmark experiments and for which the bias has been determined. The AOA may be extended by extrapolating the bias using conservative assumptions and methods.

bias: The numerical difference between the calculated and experimental values of k_{eff}. For a group of experiments over a particular AOA, the bias is established as a function of the trending parameter(s).

concurrent: In the context of double contingency, the effect of the first process change persists until the second change occurs. It does not mean simultaneous, but rather that both controls are in a failed state at the same time.

contingency: A loss of criticality control that results in one or more controlled parameters exceeding their safety limits.

control: A system, device, or personnel action intended to regulate a device or process. For criticality safety, any item relied on to prevent or mitigate a criticality accident; synonymous with item relied on for safety or barrier.

degradation: Degradation of a control or controlled parameter occurs when an IROFS identified in the ISA, which maintains the controlled parameter within its safety limits, continues to perform its function but with reduced reliability and availability such that the likelihood of its failure is no longer unlikely.

equivalent replacement: In the context of 10 CFR 70.72(c)(2), any item substituted for an IROFS which does not differ in any attribute(s) identified as important for NCS in the ISA or otherwise relied on for NCS. Substitution of an IROFS should not cause the bounding values of any controlled parameters to be exceeded, should not introduce new accident sequences or failure modes, and should not decrease the reliability and availability of the IROFS for which it is being substituted. If substitution causes at least one of the above, NRC prior approval is required.

highly unlikely[1]: Having a probability of occurrence < 10^{-5} /year/event. Such events should not be expected to occur during the lifetime of the facility. As facility- and process-specific failure data are generated, the definition of highly unlikely should be refined; that is, if a particular control failure is observed, it should no longer be credited as highly unlikely for double contingency.

incredible: Having a probability of occurrence < 10^{-6}/year/event. Demonstration of incredibility will be considered adequate if the resulting conditions are: (1) prohibited by physical laws or not achievable with quantities and materials allowed at the facility, (2) having no identifiable accident sequence that could lead to upset conditions, or (3) requiring a combination of several events such that the probability of occurrence is significantly less than that required to meet the double contingency principle.

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[1]These definitions are predicated on the assumption that there are approximately 1000 high consequence accident sequences in the industry (see SRP Section 5.4.3.2). These numbers would need to be adjusted if this assumption is invalid.

independent: In the context of double contingency, two control failures are independent if the occurrence of one does not cause or increase the probability of occurrence of the other; if the probability of both occurring is independent of the order in which they occur; and if there are no identifiable common mode failures. In the context of dual independent sampling, this implies that no single procedural error by an operator or laboratory analyst can lead to incorrect sample results. In the context of independent reviews, this means that a qualified criticality analyst, employed by the applicant or NRC, should be capable of verifying the criticality safety basis of the covered operation without resorting to additional sources of information beyond those included with the criticality safety evaluation.

loss of control: Loss of a control or a controlled parameter occurs when an IROFS identified in the ISA, which maintains the controlled parameter within its safety limits, ceases to function as designed, or cannot be verified to function as designed, whether or not the controlled parameter actually exceeds its safety limits.

margin of subcriticality: The difference between the bias (or calculated value at which k_{eff} is expected to be critical) and the calculated value of k_{eff}, including allowances for uncertainty in the bias.

normal condition: A condition specifically allowed for as part of one of the normal modes of operation in the facility design, in which all controlled parameters are within their safety limits.

operating limit: A value of a controlled parameter to which actual operations are restricted with sufficient margin to ensure that exceeding the safety limit is an unlikely event.

process variable: Any physical characteristic of a fissile material operation that is controlled within certain limits to maintain subcriticality (e.g., temperature or pressure) by indirectly limiting the value of a controlled parameter (mass, geometry, concentration, etc.).

redundancy and diversity: Having multiple controls sufficient to ensure that criticality is highly unlikely, but not meeting the full requirements of the double contingency principle.

safety limit: A value of a controlled parameter established by criticality safety evaluation. This typically would be equal to the subcritical limit, but could conceivably be less.

safety margin: The difference between the value of a controlled parameter at which a system is critical and the subcritical limit of that parameter.

subcritical: Demonstrated to not be critical. Having a value of k_{eff} less than the bias minus the uncertainty in the bias and minus the administrative margin.

subcritical limit: The bounding value of a controlled parameter in the normal case conditions. The actual operating limit is the value at which the parameter is controlled to ensure that the subcritical limit is not exceeded.

type of accident: In the context of 10 CFR Part 70, two accident sequences constitute different types of accidents if they differ in regard to the initiating event, the consequences (k_{eff} or the values of the criticality parameters of the resulting condition), or the physical mechanism by which the system reaches the ultimate state.

unlikely[2]: Having a probability of occurrence < 10^{-2}/year/event. Such events should only be expected rarely during the lifetime of the facility, if at all. Demonstration of unlikelihood will be considered adequate if appropriate assurance measures are applied. As facility- and process-specific failure data are generated, the definition of unlikely should be refined; that is, if it is found that a control fails on a regular basis, it should no longer be credited as unlikely for double contingency.

validation: The process of demonstrating with reasonable assurance that a calculational method can accurately compute the value of k_{eff} for a certain AOA, by comparing calculations to accepted benchmark experiments similar in composition to the desired applications.

verification: The process of demonstrating with reasonable assurance that a calculational method performs mathematical functions correctly and consistently over a period of time.

[2]See footnote on previous page.