5. NUCLEAR CRITICALITY SAFETY

5.1 Purpose of Review

The primary purpose of the review is to determine with reasonable assurance that the applicant has designed a facility that will provide adequate protection against criticality hazards related to the storage, handling, and processing of licensed materials as required by Title 10, Part 70, "Domestic Licensing of Special Nuclear Material," of the *Code of Federal Regulations* (10 CFR Part 70). The facility design must adequately protect the health and safety of workers and the public during normal operations and credible accident conditions from the accidental criticality risks in the facility. It must also protect against facility conditions that could affect the safety of licensed materials and thus present an increased criticality or radiation release risk.

Another purpose of this review is to determine, with reasonable assurance, whether the licensee's or applicant's nuclear criticality safety (NCS) program as described in the license application and integrated safety analysis (ISA) summary is adequate to meet the regulatory requirements in Title 10, Part 70, "Domestic Licensing of Special Nuclear Material," of the *Code of Federal Regulations* (10 CFR Part 70) and will support safe possession and use of nuclear material at the facility. The review should examine the parts of the license application and ISA summary that describe the NCS program. The review should ensure that either the license application for a new facility or license amendment to an existing facility meets the regulatory requirements of 10 CFR Part 70 as described in this chapter. The review should also ensure that, if applicable, the criteria specified in 10 CFR Part 70 for meeting 10 CFR 70.61, "Performance Requirements," are satisfied and that the contents of the ISA summary required by 10 CFR 70.65, "Additional Content of Applications," meet the regulatory requirements for the NCS-related areas of the ISA summary.

5.2 Responsibility for Review

Primary: Nuclear Process Engineer (NCS Reviewer)

Supporting: Licensing Project Manager
Fuel Cycle Inspection Staff
Primary Reviewers for Chapters 1, 3, 8, and 11 of this Standard Review Plan (SRP)

5.3 Areas of Review

5.3.1 License Application

The staff should review the license application and ISA summary, if applicable, to determine whether the application meets the 10 CFR Part 70 requirements for the NCS-related areas. The regulatory requirements for the license application review should comply with the general and additional content of an application, as required by 10 CFR 70.22, "Content of Applications," and 10 CFR 70.65, "Additional Content of Applications," respectively The NCS reviewer should review the application or amendment to determine whether the applicant has met the requirements of 10 CFR 70.23, "Requirements for the Approval of Applications," to ensure that the applicant has proposed equipment, facilities, and procedures to protect health and minimize danger to life or property, and 10 CFR 70.64, "Requirements for New Facilities or New

Processes at Existing Facilities," as applicable, to ensure that the design provides for criticality control including adherence to the double contingency principle.

The NCS reviewer should review the ISA related requirements in 10 CFR 70.62, "Safety Program and Integrated Safety Analysis," and 10 CFR 70.65, including the requirement for criticality monitoring and alarms. The regulation established in Title 10, Section 70.62(a), of the *Code of Federal Regulations* (10 CFR 70.62(a)) requires an applicant to develop, implement, and maintain a safety program that will reasonably protect the health and safety of the public and the environment from criticality hazards associated with processing, handling, and storing licensed materials during normal operations, anticipated operational occurrences, and credible accidents. For criticality safety the nuclear criticality safety program is the program used to address these process-specific risks, as well as other criticality related areas such as performing calculations, making criticality evaluations, or demonstration of subcritical margin. In addition, the NCS review should verify compliance with 10 CFR 70.61 for meeting the performance requirements and assuring that under normal and credible abnormal conditions that all nuclear processes are subcritical.

5.3.2 Nuclear Criticality Safety Program

The NCS reviewer should ensure that the applicant has committed to and implemented effective management of the NCS program in the license application and has provided enough qualified resources for an effective NCS program. The primary objective of an effective NCS program is to prevent an inadvertent nuclear criticality. Although 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material," does not require a nuclear safety program directly, an applicant should provide commitments pertaining to nuclear criticality safety in the following areas:

- establishing and maintaining NCS safety parameters and procedures
- establishing and maintaining NCS safety limits and NCS operating limits for controls
- conducting NCS evaluations to ensure that, under normal and credible abnormal conditions, all nuclear processes remain subcritical with an approved margin of subcriticality for safety
- providing training in procedures for criticality-related possession and use of nuclear material and for response to an inadvertent nuclear criticality
- complying with NCS baseline design criteria requirements in 10 CFR 70.64(a) if the application is for a new facility or for a new process at an existing facility
- complying with the NCS ISA summary change process requirements of 10 CFR 70.72, "Facility Changes and Change Process"
- protecting against the occurrence of an identified accident sequence in the ISA summary that could lead to an inadvertent nuclear criticality
- complying with the NCS performance requirements of 10 CFR 70.61

The reviewer should determine whether the applicant has identified responsibilities and authorities of individuals to implement and administer the NCS program. The following matters related to the applicant's organization and administration should be reviewed:

- the general organization and administration methods used by the applicant (see SRP Chapter 2)

- the areas of review listed in SRP Section 2.3 as they relate to NCS, including the experience, educational requirements, responsibilities, and authorities of NCS management and staff

5.3.3 Safety Program

The reviewer should determine whether the applicant has committed to the facility safety program including the process safety information, ISA, and management measures in 10 CFR 70.62 and whether the commitments demonstrate the applicant's ability to implement and maintain the NCS controls. The NCS review should cover the following specifications:

- process descriptions—narrative description of the site, facility, and processes with respect to criticality safety for normal operations. The criticality process description can include flow diagrams, major process steps, and major pieces of equipment with emphasis on the criticality safety controls. The ISA summary must include a reasonably simple description of each process (unit operations).

- criticality accident sequences—including unmitigated accident sequences involving licensed materials and interpretation of the sequence of events as described in the ISA summary.

- criticality accident consequences—identified in the ISA summary, including the assumption that all criticality accidents are high consequence and that the bases and methods the applicant used are based on using preventative controls.

- criticality process IROFS and sole IROFS—including a list of items relied on for criticality safety and a description of their safety function as described in the ISA summary.

- criticality IROFS management measures—including management measures to ensure the reliability and availability of the IROFS described in the ISA summary.

The following matters related to the applicant's ability to implement and maintain controls to assure availability and reliability should also be reviewed:

- the configuration management, maintenance, training and qualifications, procedures, audits and assessments, incident investigations, records management, and other quality assurance elements used by the applicant (see SRP Sections 11.3.1 through 11.3.8)

- management provisions for the following:

  – training and qualifications of NCS management and staff

  – auditing, assessing, and upgrading the NCS program

– maintaining current NCS safety basis documentation

– installing and maintaining a criticality accident alarm system (CAAS) to detect and annunciate an inadvertent nuclear criticality

– referring NCS deficiencies to the corrective action program

– retaining records of the NCS program, including independent reviews, audits, and documentation of corrective actions taken

Review Interfaces

In addition to Chapter 5 of the license application, the criticality safety reviewer should examine information in the following other areas to ensure that it is consistent with the information in Chapter 5 of the application:

- facility and process description applied to chemical safety as described in Chapter 1 of this Standard Review Plan (SRP).

- administration and organization of the criticality safety functions as described in Chapter 2 of this Standard Review Plan (SRP).

- safety program, ISA commitments, and ISA documentation applied to criticality safety under SRP Chapter 3.

- emergency plan applied to criticality safety under SRP Chapter 8.

- configuration management, maintenance, training and qualifications, procedures, audits and assessments, incident investigations, record management, and other quality assurance elements as described in (SRP) Chapter 11.

5.4 Acceptance Criteria

The applicant should provide NCS commitments and describe how the commitments will be met. Commitments and descriptions are expected when the acceptance criteria are relevant to the possession and use of nuclear materials and the materials to be licensed.

5.4.1 Regulatory Requirements

Acceptance criteria are based on meeting the relevant requirements of the following regulations:

- The general and additional contents of an application for criticality safety are given in 10 CFR 70.22, “Contents of Applications,” and 10 CFR 70.65, respectively. General information that must be included in the license application appears in 10 CFR 70.22. Information that must be included in the ISA summary, including the requirements for criticality monitoring and alarms, appears in 10 CFR 70.65.

- The requirements for the approval of the application are in 10 CFR 70.23.

- Requirements for new facilities or new processes at existing facilities that require a license amendment under 10 CFR 70.72, "Facility Changes and Change Process," appear in 10 CFR Part 70.64, including the requirement to adhere to the double contingency principle.

- Requirements to maintain and establish a safety program are found in 10 CFR 70.62, "Safety Program and Integrated Safety Analysis."

- The criticality safety review should be conducted to provide reasonable assurance of compliance with the performance requirements in 10 CFR 70.61.

5.4.2 Regulatory Guidance

The following additional guidance may be used to supplement the review of the NCS program:

- NUREG-1513, "Integrated Safety Analysis Guidance Document," May 2001.

- NUREG/CR-6410, "Nuclear Fuel Cycle Facility Accident Analysis Handbook," March 1998.

5.4.3 Regulatory Acceptance Criteria

The reviewer should find the applicant's criticality safety program information acceptable if it provides reasonable assurance that the acceptance criteria discussed below are adequately addressed and satisfied. The applicant may elect to incorporate some or all of the requested criticality safety information in the facility and process description (SRP Section 1.1) or in the ISA summary, rather than in this section. Either approach is acceptable, as long as the information is adequately cross-referenced.

5.4.3.1 License Application

The reviewer should consider the applicant's commitment to the CAAS requirements in 10 CFR 70.24 acceptable if the applicant or licensee has met the following acceptance criteria or has identified and justified an alternative in the application:

- The applicant describes a facility CAAS that meets the requirements of 10 CFR 70.24.

- The applicant commits to ANSI/ANS-8.3-1997, as modified by Regulatory Guide 3.71. Regulatory Guide 3.71 lists the following exceptions to the standard:

  – At or above the 10 CFR 70.24 mass limits, CAAS coverage should be required in each area where SNM is handled, stored, or used.

  – A requirement of 10 CFR 70.24 is that two detectors cover each area needing CAAS coverage.

  – A requirement of 10 CFR 70.24 is that a CAAS be capable of detecting a nuclear criticality that produces an absorbed dose in soft tissue of 20 rads of combined neutron and gamma radiation at an unshielded distance of 2 meters from the reacting material within 1 minute.

- The applicant commits to having a CAAS that is appropriate for the facility for the type of radiation detected, intervening shielding, and the magnitude of the minimum accident of concern.

- 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.

- The applicant commits to having a CAAS that is designed to remain operational during credible events such as a fire, an explosion, a corrosive atmosphere, and other credible conditions.

- 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.

- 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., limiting access, halting SNM movement) when the CAAS system is not functional.

- The applicant commits to the following emergency management provisions (see SRP Chapter 8):

  – The applicant commits to the requirements in ANSI/ANS-8.23-1997 as they relate to NCS.

  – The applicant either has an emergency plan or satisfies the alternate requirements in 10 CFR 70.22.(h)(1)(i).

  – The applicant commits to the provision of fixed and personnel accident dosimeters in areas that require a CAAS. These dosimeters should be readily available to personnel responding to an emergency, and there should be a method for prompt onsite dosimeter readouts.

  – The applicant commits to providing emergency power for the CAAS or provides justification for the use of continuous monitoring with portable instruments.

Using the reasonable assurance of safety standard as described in the introduction to this SRP, the reviewer should determine whether the applicant has met the requirements of 10 CFR 70.61. The introduction, as well as Section 3.1 of the SRP describing the review of the ISA and ISA summary, includes guidance on the level of detail needed to achieve this standard. The reviewer should consider the applicant's commitments to demonstrating that all nuclear processes will be subcritical under normal and credible abnormal conditions to be acceptable if the application includes the following acceptance criteria or identifies and justifies an alternative:

- As one approach, the applicant commits to the following national standards, as they relate to these requirements: ANSI/ANS-8.7-1975, ANSI/ANS-8.9-1987, ANSI/ANS-8.10-1983, ANSI/ANS-8.12-1987, ANSI/ANS-8.15-1981, and ANSI/ANS-8.17-1984. Alternatively, the applicant commits to base the safety limits on validated calculational methods.

- The applicant describes a program that ensures compliance with the double-contingency principle, where practicable (see Appendix A for detailed guidance regarding the double contingency principle). Processes in which there are no credible accident sequences that lead to criticality meet the double-contingency principle by definition. This principle, as given in ANSI/ANS-8.1-1998, states that at least two changes in process conditions must occur before criticality is possible. If there are no process changes leading to criticality, then the principle is satisfied. Each process that has accident sequences leading to criticality should have sufficient controls in place to ensure double-contingency protection. This may be provided by either (1) control of two independent process parameters or (2) control of a single process parameter, such that at least two independent failures would have to occur before criticality is possible. The first method is preferable because of the inherent difficulty in preventing common-mode failure when controlling only one parameter.

  The reviewer should note that the double-contingency principle requires two unlikely, independent, and concurrent changes in process conditions before criticality is possible. This does not necessarily mean that two controls are required. In some cases, it may be appropriate to credit the natural and credible course of events (e.g., unsintered powder cannot exceed a maximum density, there is no means of enriching beyond 5 wt% ^{235}U, the low historical likelihood of flooding) without establishing explicit controls. The reviewer should exercise judgment in determining whether the applicant has established sufficient means to ensure that occurrence of the contingencies is "unlikely." In addition, the term "concurrent" means that the effect of the first process change persists until a second change occurs. It does not mean that the two events must occur simultaneously. The possibility of an inadvertent criticality can be markedly reduced if failures of NCS controls are rapidly detected and the process rendered safe. If not, processes can remain vulnerable to a second failure for extended periods of time.

  In a very few processes, double-contingency protection is not practicable. In those rare instances, the applicant must provide adequate justification for why such cases are acceptable. The justification should demonstrate that there is sufficiently low risk that an exception is warranted. The reviewer should note that the double-contingency principle, as stated in ANSI/ANS-8.1-1998, is a recommendation ("Process designs should, in general, incorporate sufficient factors of safety…"). The more important requirement is the one incorporated in 10 CFR 70.61(d) ("it shall be determined that the entire process will be subcritical under both normal and credible abnormal conditions"). Thus, as long as the applicant can meet the underlying requirement to be subcritical under normal and credible abnormal conditions through other means, an exception may be justifiable.

- The applicant meets the acceptance criteria in SRP Chapter 3 as they relate to subcriticality of operations and margin of subcriticality for safety.

The ISA and supporting ISA documentation (such as piping and instrumentation diagrams, criticality safety analyses, dose calculations, process safety information, and ISA worksheets) would be maintained on site at an existing facility. For an applicant seeking a license before

completion of a facility, a full level of detail concerning hardware, procedures, and programs usually would generally not exist. However, at the time of the preoperational readiness review for a new facility, or a new process at an existing facility, such details must be available to demonstrate compliance with the safety program requirements of Subpart H, "Additional Requirements for Certain Licensees Authorized To Possess a Critical Mass of Special Nuclear Material," of 10 CFR Part 70.

The reviewer should consider the applicant's commitment to the baseline design criteria requirements in 10 CFR 70.64(a) acceptable if the applicant for a license has met the following acceptance criteria or has identified and justified an alternative in the application:

- The applicant commits to the double-contingency principle in determining NCS controls and IROFS in the design of new facilities or new processes at existing facilities that require a license amendment under 10 CFR 70.72.

The applicant must meet the performance requirements in 10 CFR 70.61(b) and (c), as well as the performance requirements in 10 CFR 70.61(d), which include the requirement to limit the risk of an inadvertent nuclear criticality by ensuring that all nuclear processes remain subcritical. The applicant's evaluation of NCS accident sequences may be performed in a manner consistent with the applicant's evaluation of non-NCS accident sequences used to meet 10 CFR 70.61(b) and (c); however, 10 CFR 70.61(d) requires the applicant to use prevention methods as the primary means to meet the performance requirements of 10 CFR 70.61(b) and (c). In addition, for new facilities and new processes at existing facilities, 10 CFR 70.64(a)(9) requires compliance with the double-contingency principle. This requires considerations in addition to those necessary to meet 10 CFR 70.61 for the noncriticality hazards.

The reviewer should consider the applicant's commitment to the requirements in 10 CFR 70.65(b) acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

- The applicant meets the acceptance criteria in SRP Section 3, as they relate to the identification of NCS accident sequences, consequences of NCS accident sequences, likelihoods of NCS accident sequences, and descriptions of IROFS for NCS accident sequences.

- The applicant should consider the upsets listed in Appendix A to ANSI/ANS-8.1-1983 in identifying NCS accident sequences.

The applicant may use the guidance in ANSI/ANS-8.10-1983, as modified by Regulatory Guide 3.71, in determining the consequences of criticality accident sequences. In general, such events should be considered "high consequence" events unless controls are in place to provide shielding or other isolation between the source of radiation and facility personnel. Consideration of events as other than high consequence should be justified in the ISA summary. The reviewer should note that the requirements of 10 CFR 70.61(d) are still applicable (i.e., criticality is to be prevented).

The application should also address the baseline design criteria (BDC) for new facilities or new processes at existing facilities that require a license amendment under 10 CFR 70.72. The baseline criteria must be applied to the design of new processes but do not require retrofits to existing facilities or existing processes; however, all facilities and processes must comply with

the performance requirements in 10 CFR 70.61. NUREG-1601, Section 2.4, contains a list of items that should be considered in an adequate facility design. For new facilities and processes in existing facilities, the design must provide for adequate protection against criticality accidents.

- The applicant describes how the ISA was performed for the new process and how the ISA, satisfies the principles of the BDC and the performance requirements in 10 CFR 70.61. The applicant also explains how it applies defense-in-depth to higher risk accident sequences. Acceptable principles for defense-in-depth of the criticality safety design are those that support a hierarchy of controls: prevention, mitigation, and operator intervention, in order of preference.

- The applicant describes proposed facility-specific or process-specific relaxations or additions to BDC, along with justifications for relaxations.

- The ISA summary describes how the criticality safety BDC were applied in establishing the design principles, features, and control systems of the new process.

5.4.3.2 NCS Program

The reviewer should consider the applicant's management of the NCS program acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

- The applicant describes and commits to implementing and maintaining an NCS program to meet the regulatory requirements of 10 CFR Part 70.

- The application states the NCS program objectives, which should include those objectives listed in this chapter.

- The application outlines an NCS program structure that is consistent with current industry practices (e.g., ANSI/ANS-8.1-1998 and ANSI/ANS-8.19-1996) and current industry practice that defines the responsibilities and authorities of key program personnel.

- The applicant commits to using the NCS program to establish and maintain NCS safety limits and NCS operating limits for fissile material use and possession and commits to maintaining management measures to ensure the availability and reliability of the controls.

- The applicant commits to preparation of NCS postings, to NCS training, and to NCS procedure training.

- The applicant commits to evaluating modifications to the facility or safety program for their impact on criticality safety.

Information related to NCS organization and administration acceptance criteria may be located in the organization and administration part of the application (see SRP Chapter 2). The reviewer should find the applicant's NCS organization and administration acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

- The applicant meets the acceptance criteria in SRP Section 2.4 as they relate to NCS, including organizational positions, functional responsibilities, experience, and qualifications of personnel responsible for NCS.

- The applicant meets the intent of ANSI/ANS-8.1 and ANSI/ANS-8.19 (see Regulatory Guide 3.71), as they relate to organization and administration.

- The NCS organization should be independent of operations to the extent practical.

- The applicant commits to provide distinctive NCS postings in areas, operations, work stations, and storage locations relying on administrative controls for NCS.

- The applicant commits to requiring its personnel to perform activities in accordance with written, approved procedures when the activity may impact NCS. Unless a specific procedure deals with the situation, personnel shall take no action until the NCS function has evaluated the situation and provided recovery procedures.

- The applicant commits to requiring its personnel to report defective NCS conditions to the NCS program management.

- The applicant describes organizational positions, experience of personnel, qualifications of personnel, and functional responsibilities.

- The applicant commits to designating an NCS program director who will be responsible for implementation of the NCS program.

Information related to NCS safety program acceptance criteria may appear in the ISA or management measures part of the application. The applicant's NCS management measures (required by 10 CFR 70.62) should be considered acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

- training (see SRP Chapter 11)

  – The applicant meets the intent of ANSI/ANS-8.19 and ANSI/ANS-8.20 as they relate to training.

  – The applicant commits to training all personnel to recognize the CAAS signal and to evacuate promptly to a safe area.

  – The applicant commits to providing instruction and training regarding the policy in the SRP guidance for NCS organization

- procedures (see SRP Chapter 11)

  – The applicant commits to ANSI/ANS-8.19-1996 as it relates to procedures.

- audits and assessments (see SRP Chapter11)

– The applicant commits to ANSI/ANS-8.19-1996 as it relates to audits and assessments.

– The applicant commits to conducting and documenting walkthroughs (i.e., observation of operations to ensure compliance with criticality limits) of all operating special nuclear material (SNM) process areas such that all operating SNM process areas will be reviewed at some specified frequency. The reviewer should consider the complexity of the process, the degree of process monitoring, and the degree of reliance on administrative controls in assessing the acceptability of the specified frequency. Identified weaknesses should be referred to the facility corrective action function and should be promptly and effectively resolved. A graded approach may be used to justify an alternate NCS walkthrough schedule.

– The applicant commits to conducting and documenting periodic NCS audits (such that all NCS aspects of management measures (see SRP Chapter 11) will be audited at least every 2 years. A graded approach may be used to justify an alternate NCS audit schedule.

The reviewer should consider the applicant's NCS technical practices acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

- NCS evaluations will be performed using industry-accepted and peer-reviewed methods.

- NCS limits on controlled parameters will be established to ensure that all nuclear processes are subcritical, including an adequate margin of subcriticality for safety.

- Methods used to develop NCS limits will be validated to ensure that they are used within acceptable ranges and that the applicant used both appropriate assumptions and acceptable computer codes.

- The applicant commits to demonstrating (1) the adequacy of the margin of subcriticality for safety by ensuring that the margin is large compared to the uncertainty in the calculated value of k-eff, (2) that the calculation of k-eff is based on a set of variables within the method's validated area of applicability, and (3) that trends in the bias support the extension of the methodology to areas outside the area or areas of applicability.

  The margin of subcriticality for safety is an allowance for any unknown uncertainties that have not been accounted for in validation and a measure of the degree of confidence that systems calculated to be subcritical are actually subcritical. The margin is used to define an upper subcritical limit such that:

  k-subcritical = 1.0 – bias – bias uncertainty – margin of subcriticality for safety

  The reviewer must use judgment in assessing whether the margin of subcriticality for safety is sufficient to provide reasonable assurance of subcriticality (in accordance with 10 CFR 70.61(d)). The reviewer should consider the following factors, as applicable, in making this judgment, as well as any other available information that provides the needed confidence:

- conservatism in the calculations, beyond that needed to accommodate uncertainties in the modeled parameters (e.g., geometric tolerances)

- confidence in subcriticality generated by the applicant's validation process, including the following:

  - similarity between the benchmark experiments and calculations to be performed

  - sufficiency of the benchmark data (both quality and quantity)

  - rigor of the validation methodology (e.g., trending, statistical testing)

  - conservatism in the statistical parameters (e.g., 95/95 lower tolerance limit)

- sensitivity of the system to changes in modeled parameters (and therefore to errors)

- corroborating evidence of subcriticality from other sources (e.g., knowledge of neutron physics for well-characterized systems such as finished fuel)

- risk considerations, including the likelihood of actually attaining an abnormal condition

In general, a margin of subcriticality for safety of 0.05 has been found acceptable for typical nuclear processes involving low-enriched uranium, without a detailed justification. The use of increasingly smaller margins should require increasingly more rigorous justification, and other physical systems should be evaluated on a case-by-case basis.

- The applicant includes a summary description of a documented, reviewed, and approved validation report (by NCS function and management) for each methodology that will be used to perform an NCS analysis (e.g., experimental data, reference books, hand calculations, deterministic computer codes, probabilistic computer codes). The summary description of a reference manual or validation report should include the following:

  - A summary of the theory of the methodology that is sufficiently detailed and clear to allow understanding of the methodology, including the method used to select the benchmark experiments, to determine the bias and uncertainty in the bias, and to determine the upper subcritical limit.

  - A summary of the physical systems and area(s) of applicability covered by the validation report. It is not necessary to include the full range of numerical parameters that defines the area of applicability; a general description (e.g., low-enriched homogeneous UO_2F_2 solutions, low-enriched fuel pellets and rods containing gadolinia) is sufficient.

- A description of the methods used to justify applying the methodology outside the area or areas of applicability.

- A summary of the plant-specific benchmark experiments used to validate the methodology. It is not necessary to include all benchmark experiments used; a brief description of the individual benchmark data sets will suffice.

- A description of the margin of subcriticality for safety and its justification.

- A description of the controlled software and hardware used.

- A description of the verification process used, including verification upon changes to the calculational system and upon some specified period.

- The applicant's validation methodology, as described above, should be found acceptable if either (1) the applicant commits to following ANSI/ANS-8.24-2006, as endorsed by Regulatory Guide 3.71, or (2) the methodology follows current industry practices in terms of selecting the benchmark experiments, assessing their applicability, determining the area(s) of applicability, extending the area(s) of applicability beyond the range of benchmark data, and statistically analyzing the data. This requires that the NCS reviewer remain cognizant of current practices in the area of criticality code validation.

The reviewer may examine the applicant's validation report to ensure that the methodology is sufficiently rigorous and that the methodology is being applied in a manner consistent with its assumptions (e.g., normal distribution of benchmarks).

- The applicant commits to incorporating each validation report into the facility configuration management program.

- The applicant commits to performing NCS analyses in accordance with documented and approved procedures, which incorporate the following principles:

  - NCS safety limits and NCS operating limits will be established assuming optimum credible conditions (i.e., the most reactive conditions physically possible or limited by written commitments to regulatory agencies) unless specified controls are implemented to control the limit to a certain range of values.

  - NCS safety limits, NCS operating limits, and limits on NCS-controlled parameters will be derived from the NCS analyses.

  - NCS operating limits will be derived from NCS safety limits by considering the uncertainty and variability in operating parameters to ensure that processes will remain subcritical under both normal and credible abnormal conditions.

  - The margin of subcriticality for safety for a process should be large relative to the uncertainty in the calculated value of k-eff.

Controlled parameters available for NCS control include the following: mass, geometry, density, enrichment, reflection, moderation, concentration, interaction, neutron absorption, and volume. The reviewer should consider the applicant's commitment to NCS technical practices acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

- The applicant's use of a single NCS control to maintain the values of two or more controlled parameters constitutes only one component necessary to meet double-contingency protection.

- The applicant commits to the preferred use of passive engineered controls to ensure NCS. In general, the applicant should commit to the following order of preference for NCS controls: (1) passive engineered, (2) active engineered, (3) augmented administrative, and (4) simple administrative. When using other than a passive engineered control, the applicant should justify the choice of the type and manner.

- When they are relevant, the applicant should consider heterogeneous effects. Heterogeneous effects are particularly relevant for low-enriched uranium processes, where, all other parameters being equal, heterogeneous systems are more reactive than homogeneous systems.

The use of mass as a controlled parameter should be considered acceptable in the following circumstances:

- When mass limits are derived for a material that is assumed to have a given weight percent of SNM, determinations of mass are based on either (1) weighing the material and assuming that the entire mass is SNM or (2) conducting physical measurements to establish the actual weight percent of SNM in the material.

- When fixed geometric devices are used to limit the mass of SNM, a conservative process density is assumed in calculating the resulting mass.

- When the mass is measured, instrumentation subject to facility management measures is used.

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

- Before beginning operations, all dimensions and nuclear properties that use geometry control are verified. The facility configuration management program should be used to maintain these dimensions and nuclear properties.

The use of density as a controlled parameter should be considered acceptable in the following circumstances:

- When process variables can affect the density, the ISA summary shows the process variables to be controlled by items relied on for safety (IROFS).

- Density is measured by the use of instrumentation subject to facility management measures.

The use of enrichment as a controlled parameter should be considered acceptable if the following apply:

- A method of segregating enrichments is used to ensure that differing enrichments will not be interchanged, or else the most limiting enrichment is applied to all material.

- Measurements of enrichment are obtained by using instrumentation subject to facility management measures.

The use of reflection as a controlled parameter should be considered acceptable in the following circumstances:

- In the evaluation of an individual unit, the wall thickness of the unit and all reflecting adjacent materials of the unit are considered. The adjacent materials should be farther than 30 centimeters (12 inches) from the unit.

- After all fixed reflectors are accounted for, the controls to prevent the presence of any transient reflectors (e.g., personnel) are identified as IROFS in the ISA summary.

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

- When using moderation, the applicant commits to ANSI/ANS-8.22-1997.

- When process variables can affect the moderation, the ISA summary shows the process variables to be controlled by IROFS.

- Moderation is measured by using instrumentation subject to facility management measures.

- The design of physical structures precludes the ingress of moderation.

- When moderation needs to be sampled, dual independent sampling methods are used.

- Firefighting procedures for use in a moderation-controlled area restrict the use of moderator material.

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

The use of concentration as a controlled parameter should be considered acceptable in the following circumstances:

- When process variables can affect the concentration, the ISA summary shows the process variables to be controlled by IROFS.

- Concentrations of SNM in a process are limited unless the process is analyzed to be safe at any credible concentration.

- When using a tank containing concentration-controlled solution, the tank is normally closed and locked to prevent unauthorized access.

- When concentration needs to be sampled, dual independent sampling methods are used.

- After identification of possible precipitating agents, precautions are taken to ensure that such agents will not be inadvertently introduced.

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

- To maintain a physical separation between units, engineered controls are used to ensure a minimum spacing; if engineered controls are not feasible, augmented administrative controls are used. The structural integrity of the spacers or racks should be sufficient for normal and credible abnormal conditions.

The use of neutron absorption as a controlled parameter should be considered acceptable in the following circumstances:

- When using borosilicate-glass raschig rings, the applicant commits to ANSI/ANS-8.5-1996.

- When using fixed neutron absorbers, the applicant commits to ANSI/ANS-8.21-1995.

- In the evaluation of absorber effectiveness, neutron spectra are considered (e.g., cadmium is an effective absorber for thermal neutrons but ineffective for fast neutrons).

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

- Fixed geometry is used to restrict the volume of SNM.

- When the volume is measured, the instrumentation used is subject to facility management measures.

The reviewer should consider the applicant's description of additional commitments for the NCS program acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

- The applicant commits to using the NCS program to promptly detect any NCS deficiencies by means of operational inspections, audits, or investigations and to refer to the facility's corrective action function any unacceptable performance deficiencies in IROFS, NCS function, or management measures, so as to prevent recurrence.

- The applicant commits to supporting the facility change mechanism process by performing NCS evaluations to evaluate changes to processes, operating procedures, criticality controls, IROFS, and management measures.

- The applicant commits to retaining records of NCS deficiencies and to documenting any corrective actions taken.

- The reviewer should consider the applicant's description of measures to implement the facility change process requirements in 10 CFR 70.72 acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

  – The applicant describes 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. The change process should be documented in written procedures and should ensure that all changes to 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 NCS controls, and on the NCS of connected processes. The change control process should include procedures for the review and approval of facility changes by the NCS function to determine the potential effects on NCS.
  – The change control process should be connected to the facility's configuration management system to ensure that changes to the NCS basis are incorporated into procedures, evaluations, postings, drawings, other safety basis documentation, and the ISA summary.

- The applicant's description of measures to implement the reporting requirements in Appendix A, "Reportable Safety Events," to 10 CFR Part 70 should be considered acceptable if the applicant has met the following acceptance criteria or has identified and justified an alternative in the application:

  – The applicant has a program for evaluating the criticality significance of NCS events and an apparatus in place for making the required notification to the NRC Operations Center. Qualified individuals should make the determination of significance of NCS events. The determination of loss or degradation of double-contingency protection should be made against the license and Appendix A to 10 CFR Part 70.

  – The applicant incorporates the reporting criteria of Appendix A to 10 CFR Part 70 and the report content requirements of 10 CFR 70.50, "Reporting Requirements," into the facility emergency procedures.

  – The applicant commits to issuing the necessary report based on whether the criticality controls and IROFS credited were lost (i.e., they were unavailable and

– If the licensee cannot ascertain within 1 hour whether the criteria of 10 CFR Part 70, Appendix A, paragraph (a) or (b) apply, the applicant commits to treating the event as a 1-hour reportable event.

The applicant may use standards as a means to meet regulatory requirements. The U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 3.71, "Nuclear Criticality Safety Standards for Fuels and Materials Facilities," issued August 1998, endorses the American National Standards Institute/American Nuclear Society (ANSI/ANS) Series-8 national standards with some exceptions. NRC endorsement of these standards means that they provide procedures and methodology generally acceptable to the NRC staff for the prevention and mitigation of nuclear criticality accidents. However, application of a standard is not a substitute for detailed nuclear criticality safety analyses for specific operations.

If the applicant intends to conduct activities to which an NRC-endorsed standard applies, then the applicant should meet the intent of the standard. The applicant meets the intent of an NRC-endorsed standard by satisfying the following acceptance criteria:

- The license application contains a commitment to follow the requirements (i.e., "shall" statements) of the standard, subject to any exceptions taken by the NRC. The application clearly specifies the version of the standard and the specific provisions to which the applicant is committing.

- If there are requirements in a standard that the applicant does not commit to, the applicant provides sufficient information for the staff to determine if the requirements are not relevant to the applicant's activities or the license application contains other commitments that are equivalent.

If the licensee commits to a standard that has not been endorsed by the NRC, is not the most current version endorsed by the NRC, or is an unendorsed version of a previously endorsed standard, the license application should include justification for this commitment.

Regulatory Guide 3.71 endorses, in part or in full, the ANSI/ANS-8 national standards listed below.

- ANSI/ANS-8.1, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," 1998

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

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

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

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

- ANSI/ANS-8.9, “Nuclear Criticality Safety Criteria for Steel-Pipe Intersections Containing Aqueous Solutions of Fissile Materials,” 1987 (Reaffirmed in 1995)
- ANSI/ANS-8.10, “Criteria for Nuclear Criticality Safety Controls in Operations With Shielding and Confinement,” 1983 (Reaffirmed in 1988)
- ANSI/ANS-8.12, “Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors,” 1987 (Reaffirmed in 1993)
- ANSI/ANS-8.15, “Nuclear Criticality Control of Special Actinide Elements,” 1981 (Reaffirmed in 1995)
- ANSI/ANS-8.17, “Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors,” 1984 (Reaffirmed in 1997)
- ANSI/ANS-8.19, “Administrative Practices for Nuclear Criticality Safety,” 1996
- ANSI/ANS-8.20, “Nuclear Criticality Safety Training,” 1991
- ANSI/ANS-8.21, “Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors,” 1995
- ANSI/ANS-8.22, “Nuclear Criticality Safety Based on Limiting and Controlling Moderators,” 1997
- ANSI/ANS-8.23, “Nuclear Criticality Accident Emergency Planning and Response,” 1997
- ANSI/ANS-8.24, “Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations,” 2007
- ANSI/ANS-8.26, “Criticality Safety Engineer Training and Qualification Program,” 2007

5.5.3.3 Safety Program

The reviewer should find the applicant’s criticality safety information acceptable if it provides reasonable assurance that the acceptance criteria presented below are adequately addressed and satisfied. The applicant may elect to incorporate some or all of the requested process information in the facility and process description (SRP Section 1.1) or the ISA summary, rather than in this section. Either approach is acceptable, as long as the information is adequately cross-referenced.

The regulation in 10 CFR 70.65(b)(3) requires a description of each process in the facility. This information must be included in the ISA summary. The applicant’s descriptions of the chemical processes are acceptable if they meet the following conditions:

- Process descriptions are sufficiently detailed to allow an understanding of the criticality to allow development of potential accident sequences

- Process descriptions are sufficiently detailed to allow an understanding of the theory of operation.

The regulation in 10 CFR 70.65(b)(4) requires information that demonstrates the licensee's compliance with the performance requirements including a description of the management measures.

The use of accident sequences for providing the demonstration of compliance is acceptable in the following circumstances:

- The applicant provides a general description of the accident sequences identified in the ISA process for criticality hazards.

- The ISA summary describes the hazards identified in the ISA. Each accident sequence identified by the applicant in the ISA should include a criticality hazard evaluation of potential interactions and key assumptions. vessels, process equipment, and facility personnel. The hazard evaluation should use appropriate accepted methods.

- The applicant provides reasonable assurance that measures to mitigate the consequences of accident sequences identified in the ISA summary are consistent with actions described in SRP Chapter 8. (Note that some facilities are not required to have an emergency plan.)

The criticality accident consequences are acceptable if the following apply:

- The applicant assumes that all criticality accidents result in high consequences.

- The application includes definitions of "unlikely," "highly unlikely," and "credible" as used in the evaluations in the ISA.

The regulation in 10 CFR 70.65(b)(6) requires a list briefly describing all IROFS in sufficient detail to understand their functions in relation to the performance requirements.

The applicant provides in the ISA summary a list of criticality safety controls (i.e., IROFS) suitable to prevent criticality accidents. This list must also briefly describe the IROFS, in sufficient detail to permit an understanding of their safety functions. The applicant must demonstrate that the likelihood of each credible high-consequence event will be reduced after implementation of IROFS, so that the event will be highly unlikely.

If the applicant takes a graded approach to safety in accordance with 10 CFR 70.62(a), the reviewer should establish that the grading of IROFS is appropriate and sufficient to protect against criticality risks. For example, the applicant should consider reliance on passive controls of active systems and defense-in-depth in accordance with 10 CFR 70.64(b). To reduce common mode failures, the applicant should favor design features that use independent sources of motive force for items such as control actuators, jet pumps, eductors, and ejectors. Fail-safe controls are preferred unless safety concerns preclude this approach.

The applicant must review management measures to ensure the availability and reliability of IROFS and sole IROFS when they are required to perform their safety functions. Management measures may be graded commensurate with risk.

The application must meet the following criteria:

- The application must describe the engineering approach, basis, or schemes employed for maintaining safety in normal operations.

- The ISA summary must identify the administrative and engineered controls to prevent a criticality hazard. The applicant should also explain how any safety grading of IROFS and management measures has been made and how such grading is commensurate with the reduction in risk that the IROFS are designed to achieve.

- The application should demonstrate the management measures proposed to ensure that IROFS are available and reliable by briefly describing the following:

  – procedures to ensure the reliable operation of engineered controls (e.g., inspection and testing procedures and frequencies, calibration programs, functional tests, corrective and preventive maintenance programs, criteria for acceptable test results)

  – procedures to ensure that administrative controls will be correctly implemented, when required (e.g., employee training and qualification in operating procedures, refresher training, safe work practices, development of standard operating procedures, training program evaluation)

5.5 Review Procedures

The reviewer should use the regulatory guidance of this chapter, references in this chapter, and the applicant's reports to the NRC (e.g., NRC Bulletin 91-01, 10 CFR 70.50, and 10 CFR 70.74).

5.5.1 Acceptance Review

The primary reviewer should review the applicant's NCS information for completeness with respect to the requirements in 10 CFR 70.22, 70.24, 70.61, 70.62, 70.64, and 70.65, and the acceptance criteria in Section 5.4. If deficiencies are identified, then either the reviewer should ask the applicant to submit additional material before the start of the safety evaluation or the application should be denied.

5.5.2 Safety Evaluation

After the application has been accepted, the primary reviewer should conduct a complete review of the application and determine if it meets the requirements for approval specified in Section 5.4. The primary reviewer should consult with the supporting reviewers as appropriate to identify and resolve any issues of concern related to the licensing review. The primary reviewer should also coordinate with other primary reviewers of SRP Chapters 2, 3, 8, and 11 to confirm that the application meets all acceptance criteria pertinent to NCS. The reviewer should also coordinate with other primary reviewers in radiation protection, chemical safety, and fire

protection, as well as other disciplines as appropriate (e.g., seismic), to ensure appropriate consideration of any cross-cutting issues.

5.5.2.1 License Application

The primary reviewer should review the applicant's NCS information in the license application for completeness with respect to the requirements in 10 CFR 70.22, 70.23, 70.24, 70.61, 70.62, 70.64, and 70.65, and the acceptance criteria in Section 5.4.

During the license application review the reviewer should identify and note any items or issues that should be inspected during an operational readiness review, if such a review will be performed. These items could include confirming that the commitments made in the license application are implemented though procedures and training.

If, during the review, the primary reviewer determines a need for additional information, the reviewer coordinates a request for additional information with the licensing project manager. The reviewer should ascertain that the criticality safety approach is consistent with other sections of the application, including those addressed by SRP Chapters 2, 3, 4, 6, 8, and 11.

For an existing facility, the reviewer may consult NRC inspectors to identify and resolve any issues related to the licensing review. These interactions should be coordinated through the licensing project manager.

The primary reviewer will prepare safety evaluation report (SER) input for the licensing project manager in support of the licensing action.

5.5.2.2 NCS Program

The reviewer should review all aspects of the applicant's NCS program including management, organization and technical practices. During the review the reviewer should identify and note any items or issues relating to the NCS program and commitments that should be inspected during an operational readiness review, if such a review will be performed. These items could include confirming that the commitments made in the license application are implemented though procedures and training.

If, during the review, the primary reviewer determines a need for additional information, regarding the NCS program the reviewer coordinates a request for additional information with the licensing project manager.

For an existing facility, the reviewer may consult NRC inspectors to identify and resolve any issues related to the NCS program commitments. These interactions should be coordinated through the licensing project manager.

5.5.2.3 Safety Program

The results of the ISA are the basis for the criticality safety evaluation. The reviewer should assess the criticality safety risks identified in the ISA summary and ensure that the level of safety is reflected in the design and the operational plans for the facility. The reviewer should establish that the applicant's facility design, operations, and IROFS for criticality safety provide reasonable assurance that they will function as intended, be available and reliable to perform

their safety function, and provide for the safe possession and use of licensed material at the facility.

5.6 Evaluation Findings

Note: SRP Chapter 3 contains the evaluation findings for the ISA summary requirements for 10 CFR 70.65.

If the staff's review verifies that the safety program description presents sufficient information to satisfy the acceptance criteria in SRP Section 5.4, the staff may document its review as follows:

> The staff has reviewed the Nuclear Criticality Safety (NCS) program and requirements for criticality safety for [name of facility] according to SRP Chapter 5. The staff has reasonable assurance that:
>
> - 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 and administration and management measures.
>
> - 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.
>
> - The applicant will develop, implement, and maintain a criticality accident alarm system in accordance with both the requirements in 10 CFR 70.24 and the facility emergency management program.
>
> - The applicant will have in place an NCS program that meets the performance requirements in 10 CFR 70.61(b), the subcriticality requirements in 10 CFR 70.61(d), and the baseline design criteria requirements in 10 CFR 70.64(a).
>
> - Based on this review, the staff concludes that the applicant's NCS program meets the requirements of 10 CFR Part 70 and provides reasonable assurance of the protection of public health and safety, including that of workers, and the environment.

5.7 References

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

R.A. Knief, "Nuclear Criticality Safety—Theory and Practice," American Nuclear Society, La Grange Park, IL, 1985.

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

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

W.R. Stratton (D.R. Smith Revisor), DOE/NCT-04, “A Review of Criticality Accidents,” U.S. Department of Energy, March 1989.

U.S. Code of Federal Regulations, Chapter I, Title 10, “Energy,” Part 70, “Domestic Licensing of Special Nuclear Material.”

U.S. Department of Energy, DOE Order 420.1 (Change 2), “Facility Safety,” October 24, 1996.