NUCLEAR CRITICALITY SAFETY EVALUATIONS AND ANALYSES

PROGRAM APPLICABILITY: 2600

Note that, as discussed in 10 CFR Part 70.1 (d),(e), and Part 70.60, references in this procedure to 10 CFR Part 70.61 through 70.76 items relied on for safety (IROFS) and integrated safety analyses (ISAs) do not apply to 10 CFR Part 76 licensees/certificatees.

88016-01 INSPECTION OBJECTIVES

a. Determine whether the regulatee's nuclear criticality safety evaluations (CSEs) or analyses and related supporting calculations and models meet procedural, license, and regulatory requirements.

b. Determine whether the regulatee's CSEs make appropriate assumptions, identify appropriate criticality scenarios, establish nuclear criticality safety (NCS) limits for controlled parameters and establish IROFS and NCS control systems to assure that fissile material operations meet the performance requirements of 10 CFR Part 70.61.

c. Determine whether NCS evaluations are adequate for the equipment and processes covered and are based on validated methods.

d. Definitions. The following definitions apply to terms used in this procedure.

1. Accident pathway - a unique set of events, sequential or parallel in nature, which could lead to a nuclear criticality event.

2. Contingency - a change or failure of process equipment, measurement, or control systems; inadvertent human action; change in ambient conditions; or natural events which are considered unlikely.

3. Favorable geometry system - a system whose dimensions and shape are such that a nuclear criticality event can not occur for any credible combination of values of system parameters so long as selected sub-parameters (such as enrichment) are maintained within specified limits.

4. Pseudo control - for the purpose of this inspection procedure only, an NCS control intended and depended on to support defense-in-depth and which does not contribute substantively to the safety margin.

5. Safe geometry system - a system whose dimensions and shape are such that a nuclear criticality event can not occur for any combination of values of system parameters including but not limited to moderation; reflection; or nuclide mass, concentration, or enrichment.

88016-02 INSPECTION REQUIREMENTS

02.01 Selection of Areas for Review.

a. Determine what changes have occurred to the facility and operation since the most recent NCS inspection.

b. Identify risk-significant analyses for review.

c. Determine the adequacy of non-credibility determinations.

02.02 Nuclear Criticality Safety Limits and Controls.

a. Appropriate limits and controls are clearly identified in NCS analysis.

b. Limits and controls make operational sense for ease and effectiveness of implementation.

c. Adequate safety margin is ensured for affected parameters.

02.03 Nuclear Criticality Safety Evaluations.

a. Determine whether NCS evaluations exist for new or revised processes; that evaluations accurately reflect the existing plant configuration; and that evaluations have sufficient detail and clarity to allow an independent assessment.

b. Determine whether each process evaluation identifies and incorporates realistic and conservative assumptions for the process description and conditions.

c. Determine whether the evaluation provides complete accident pathway analyses for contingencies that could lead to nuclear criticality; that operations staff participates in the identification of contingencies; and that method(s) to identify the contingencies is (are) specified in the evaluation.

d. Determine whether specified NCS limits on controlled parameters and NCS control systems assure subcriticality by providing a defense-in-depth for each identified potential pathway for nuclear criticality. Determine whether analyses show that margins of safety on the NCS limits satisfy the plant and license or certificate requirements for subcritical margin. Determine that the reliance is placed on passive or active engineered NCS controls, when practicable, or that administrative controls are adequately justified.

e. Determine whether IROFS or other NCS control systems ensure that at least two unlikely, independent, and concurrent changes in process conditions must occur before criticality is possible. Determine whether each potential criticality accident pathway has been evaluated.

f. Determine whether the controlled parameters and their associated NCS limits are identified and that NCS limits, IROFS and NCS control systems are adequate to control the risk of nuclear criticality.

02.04 Independent Review of Nuclear Criticality Safety Evaluations. Determine whether independent reviews are completed and documented, reviewed material is identified in the documentation, and the reviews provide assurance that initial analyses were realistic. NCS limits for controlled parameters and NCS control systems are discussed with operating management and that operating management has agreed to and are implementing the limits and controls.

02.05 Subcritical Margin. Determine whether the analyses show that margins of safety on the NCS limits satisfy procedural and license or certificate requirements and assure that fissile material operations meet the performance requirements of 10 CFR Part 70.61.

02.06 Validation.

a. Determine whether, for all safety evaluations established (new or modified) since the last headquarters inspection, the regulatee uses only validated analytical methods. For analytical methods identified in the license or certificate and used since the last inspection, the methods are not modified after the validation process was completed. For new analytical methods, the methods are validated in accordance with the license and a validation report was written and is maintained.

b. Determine whether evaluations show that calculations will fall within the area of applicability of the validation and that final results meet the subcritical criteria established by the validation.

88016-03 INSPECTION GUIDANCE

03.01 Selection of Areas for Review.

a. New or changed evaluations should be the focus of the inspection effort.

b. If there are not sufficient new evaluations to review, select several older evaluations from higher risk areas of the plant for review during the inspection.

c. Review a sample of CSEs and related equipment, operations and processes, with fissile material operations wherein the regulatee has designated criticality not credible to determine whether the assumptions supporting the determination are adequate.

03.02 Nuclear Criticality Safety Limits and Controls.

a. Review of NCS analyses, plant and equipment drawings, operating procedures, confirmatory calculations, and staff interviews should demonstrate that appropriate NCS limits have been identified, are fully supported by the analytical basis, and clearly establish and maintain an adequate margin of safety for process parameters involved. Assure that assumptions are correct by record reviews, plant walkdowns, and interviews with technical staff. Assure that bounding assumptions are actually bounding.

b. Review of NCS analysis, interviews with NCS staff, and interviews with operators should demonstrate that NCS controls make sense for the parameters involved and equipment, process, or facility in which they are implemented. Specific controls should be selected for inspection beginning with new or changed NCS analysis or controls that need to be repeatedly inspected.

c. Assure that controls relied on for double contingency are robust and will actually support double contingency. For example, be alert for weak or pseudo-controls in defense-in-depth arrangements that will not effectively support double contingency if one of the more robust controls fails. Verify that NCS controls or sets of controls in any control scheme actually meet the criteria of unlikely. Special controls should be specified for solution transfers from favorable to nonfavorable geometry vessels, preventing the accumulation of fissile material in process equipment, verifying the isotopic content of incoming cylinders, and backflow prevention. Passive engineered controls are preferred to active engineered controls and active engineered controls are preferred to administrative controls. Passive engineered controls should be effectively implemented as specified in the NCS analysis including dimensional tolerance, material composition and surveillance.

03.03 Nuclear Criticality Safety Evaluations.

a. Process evaluations are expected to be provided in documentation that contains a description of the process physical, chemical, and equipment conditions; consideration of normal and off-normal conditions (process contingencies); analysis of criticality states for normal and abnormal conditions; and establishment of NCS limits, IROFS and control systems.

b. The description of process chemical, physical, and nuclear characteristics provides a basis for postulation of nuclear material states within the unit operation. Evaluations should consider heterogeneous effects particularly in low-enriched uranium (LEU) systems. Descriptions of material characteristics, equipment configurations, process operations, and potential internal and external events are used to identify possible normal and abnormal states of the process. Types of internal events that should be considered include, but are not limited to, fire, improper operation of equipment, and equipment failure. Types of external events that should be considered include earthquake, storms, and flooding.

c. Events or contingencies occurring in an accident pathway may be identified from operational experience or using hazard evaluation techniques. Common mode failures must be considered in developing accident scenarios. Acceptable hazard evaluation techniques include the What If, Checklist, Hazard and Operability (HAZOP), Failure Modes and Effects (FMEA), and Fault/Event Tree analyses. Besides the NCS staff, operations supervisors and operators are expected to contribute to the identification of contingencies. Contingencies for process conditions leading to potential criticality conditions are expected to be documented in the NCS evaluation.

d. Calculations that result in safety limits should clearly identify the normal and credible abnormal conditions for each accident sequence considered. Calculated results for the identified normal and upset cases should meet license requirements for subcritical margin. Evaluate acceptability of calculations resulting in safety limits using license and procedural requirements and the following general guidance:

1. Calculations identify the basic geometry of the problem including dimensions.

2. Calculations identify the material including atom densities.

3. Calculations identify cross section sets used.

4. Calculations describe arrays or repeated geometries or functions.

5. Calculations clearly identify the final result and basis for convergence or acceptability.

6. Models in calculations clearly bound the equipment system or process under analysis by assuming credible optimum conditions (most reactive conditions physically possible).

7. NCS controls resulting from calculations should make sense (i.e., should not be either frivolous or overly conservative or impossible to effectively implement).

Evaluate acceptability of mass as a controlled parameter using the following guidance:

1. When a given mass of material has been determined, a percentage factor is used to determine the mass percentage of fissile material.

2. When fixed geometric devices are used to limit the mass of fissile material, a conservative process density is used.

3. When the mass is measured, instrumentation is used.

4. When using double-batching of fissile material as a single parameter limit control from experimental data, and double-batching of fissile material is possible, the mass of fissile material is limited to no more than 45 percent of the minimum critical mass, based on spherical geometry.

5. When using double-batching of fissile material as a single parameter limit

control from experimental data and double-batching of fissile material is not possible, the mass of fissile material is limited to no more than 75 percent of the critical mass, based on spherical geometry.

Evaluate acceptability of geometry as a controlled parameter using the following guidance:

1. 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.

2. When using large single units as a single parameter control from experimental data, the margins of safety are 90 percent of the minimum critical cylinder diameter, 85 percent of the minimum critical slab thickness, and 75 percent of the minimum critical sphere volume.

Evaluate acceptability of density as a controlled parameter using license and procedural requirements and the following guidance:

1. When process variables can affect the density, the process variables are shown in the ISA Summary to be controlled by IROFS.

2. When the density is measured, the measurement is obtained by the use of instrumentation.

Evaluate acceptability of enrichment as a controlled parameter using the following guidance:

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

2. When the enrichment needs to be measured, the measurement is obtained by using instrumentation.

Evaluate acceptability of reflection as a controlled parameter using the following guidance:

1. When investigating 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 30.48 cm (12 inches) away from the unit.

2. After identifying potential reflectors, the controls to prevent the presence of the potential reflectors are identified as IROFS in the ISA Summary.

Evaluate acceptability of moderation as a controlled parameter (e.g., moderator exclusion) using the following guidance:

1. When using moderation, the applicant commits to American National

Standards Institute/American Nuclear Society (ANSI/ANS) 8.22, "Nuclear Criticality Safety Based on Limiting and Controlling Moderators," dated 1997.

2. When process variables can affect the moderation, the process variables are shown in the ISA Summary to be controlled by IROFS.

3. When the moderation is measured, the measurement is obtained by using instrumentation.

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

5. When moderation is needed to be sampled, dual independent sampling methods are used.

6. When developing firefighting procedures for use in a moderation-controlled area, restrictions are placed on the use of moderator material.

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

Evaluate acceptability of concentration as a controlled parameter using the following guidance:

1. When process variables can affect the concentration, the process variables are shown in the ISA Summary to be controlled by IROFS.

2. High concentrations of fissile material in a process are precluded unless the process is analyzed to be safe at any credible concentration.

3. When using a tank containing concentration-controlled solution, the tank is normally closed.

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

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

Evaluate acceptability of interaction as a controlled parameter using the following guidance:

1. When maintaining a physical separation between units, engineered controls to ensure a minimum spacing or augmented administrative controls are used. The structural integrity of the spacers or racks should be sufficient for normal and credible abnormal conditions.

2. When process variables can affect interaction, the process variables are shown in the ISA Summary to be controlled by IROFS.

Evaluate acceptability of neutron absorption as a controlled parameter using following guidance:

1. When using borosilicate-glass raschig rings, the regulatee commits to ANSI/ANS-8.5, “Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material," dated 1996.

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

3. When evaluating absorber effectiveness, neutron spectra are considered (e.g., cadmium is an effective absorber for thermal neutrons, but ineffective for fast neutrons).

4. When process variables can affect neutron absorption, the process variables are shown in the ISA Summary to be controlled by IROFS.

Evaluate acceptability of volume as a controlled parameter using the following guidance:

1. When using volume control, fixed geometry is used to restrict the volume of fissile material with engineered devices to limit the accumulation of fissile material.

2. When the volume is measured, instrumentation is used.

3. When process variables can affect the volume, the process variables are shown in the ISA Summary to be controlled by IROFS.

e. Each potential criticality accident pathway should be evaluated and NCS limits, IROFS or NCS control systems should be established as barriers for potential accident pathways identified in the NCS evaluation. Limits and controls should be reviewed by NCS staff to establish that two or more unlikely, concurrent, and independent changes in process conditions are required before criticality could occur. Control systems may be used as barriers for multiple pathways if they can be shown to be independent for each identified pathway.

f. Passive, active engineered, or administrative controls are used to determine whether conformance to the double contingency principle and should be identified in a formal process. Passive engineered controls are preferred to active engineered controls and active engineered controls are preferred to administrative controls. Use of only administrative controls in a control scheme should be justified. Preference should be given to diversity of controls to provide some measure of defense against common mode failure. Review of regulatee controls involving measurement should consider reliability of instruments and methods.

03.04 Independent Review of Nuclear Criticality Safety Evaluations. An independent review of each criticality evaluation should be required for NCS staff approval of the proposed process change. This requirement should be consistent with the double contingency principle in the sense that no single analytical error should allow unsafe conditions to occur. A clear, unambiguous description of the assumptions, analytical method, and results in an NCS evaluation should be the required basis for the review. The independent review must be performed and documented by a qualified NCS evaluator.

03.05 Subcritical Margin. Before start-up of any process, an NCS evaluation should be required to provide assurance that each unit and the entire process is adequately subcritical under both normal and abnormal operating conditions. Critical limits may be derived from experimental data or from validated analytical methods. The evaluation should show that margins of safety that satisfy plant safety requirements are applied to just critical or slightly subcritical limits. The margin of safety can be identified in plant safety criteria and in the NRC license or certificate. Normally, a failure limit is calculated to define the just-critical system as defined in the license, i.e., $k_{eff} + 2\sigma = 1.0 - ADM$ (where ADM is the approved administrative margin). A safety limit is determined to define the facility shutdown and investigation limit. An operating limit should be calculated to define the operating level for notifying plant management of nonroutine operation. The routine operating limit should be set by Operations staff to protect the safety limit. The margin of safety for any process should be large enough (including uncertainty) that engineered control systems and/or operators can detect that a safety margin has been lost, thereby allowing corrective action to be taken before criticality occurs. Operating limits should consider changes in operating parameters to ensure that processes will remain subcritical.

03.06 Validation. Use of experimental data should be the preferred method for establishment of NCS limits for a given process system. Validated calculational methods may be used without directly applicable experimental data. Validation means comparison of critical mass experimental results with mathematical predictions for the experimental systems to establish the bias and range of applicability. The bias and the uncertainty in the bias should be investigated and quantified. The area of applicability of the calculational method may be extended beyond or between the range of experiments by trending the bias between experimental and calculational results. The area of applicability of the validated method should be clearly defined. A report describing the experimental conditions, the calculational method, model data (cross sections, extrapolation lengths, etc.), calculational results, the bias, bias uncertainty, and range of applicability should be prepared and maintained. Installation and updating of computer codes should be controlled under a procedure that confirms mathematical operations and code predictions.

88016-04 RESOURCE ESTIMATE

An inspection performed using this inspection procedure is estimated to require 112 hours of inspector resources for Category 1 facilities, 68 hours of inspector resources for gaseous diffusion plants, 34 hours of inspector resources for Category 3 facilities, and 3.5 hours for small critical mass or fuel cycle facilities. This estimate is only for the direct inspection effort and does not include preparation for and documentation of the inspection.

88016-05 REFERENCES

ANSI/ANS-8.5-1986, “Use of Borosilicate-Glass Raschig Rings as a Neutron Absorber in Solutions of Fissile Material," American Nuclear Society, La Grange Park, IL, dated 1996

ANSI/ANS-8.21-1995, "Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors," American Nuclear Society, La Grange, IL, dated 1995

ANSI/ANS-8.22-1997, “Nuclear Criticality Safety Based on Limiting and Controlling Moderators," American Nuclear Society, La Grange Park, IL, dated 1997

END

ATTACHMENT 1

Revision History for IP 88016

Commitment Tracking Number	Issue Date	Description of Change	Training Needed	Training Completion Date	Comment Resolution Accession Number
N/A	07/28/06 CN 06-019	IP 88016 has been issued because of the need for a new Inspection Procedure for Nuclear Criticality Safety Evaluations and Analysis.	None	N/A	ML061730055