**Title: Nuclear Criticality Safety Computer Code Validation**

Description of Changes:

1. Major Rewrite

Reason for Change:

1. Revised NRC License Requirements

## Department Acknowledgements:

1. EHS NCS

**Title: Nuclear Criticality Safety Computer Code Validation**

## 1.0 PURPOSE:

1.1 The purpose of this procedure is to outline the process by which validation and verification of nuclear criticality safety analysis codes are performed, documented, maintained, revised, and reviewed. In particular, the verification and validation of nuclear criticality safety codes for use on the Westinghouse UNIX/LINUX computer clusters are explained.

## 2.0 POLICY and SCOPE:

2.1 This procedure defines the requirements for use of qualified NCS Computer Codes at the Columbia Fuel Fabrication Facility. It does not preclude the use of non-qualified NCS Computer Codes for scoping calculations or verification activities. This procedure is to be used in conjunction with procedure RA-104, Regulatory Review of Configuration Change Authorizations.

2.2 Nuclear Criticality Safety Calculations shall be performed in accordance with applicable NRC Regulations and License SNM-1107 criteria. They shall also conform to the guidelines of applicable American National Standards Institute (ANSI) standards.

2.3 This procedure covers the initial, periodic, and as required (e.g., after maintenance) verification of nuclear criticality safety analysis codes and the validation of these codes for use on designated computer systems.

## 3.0 DEFINITIONS:

**NOTE:**

In this document ***may*** is permissible without compromising the objective, ***might*** is a statement of possibility of occurrence, ***shall*** is essential to the objective, and ***should*** is desirable and recommended but not essential to the objective.

3.1 Acronyms

- CFFF – Columbia Fuel Fabrication Facility
- NCS – Nuclear Criticality Safety
-
-

-
-

3.2 Definitions

- Application – Model of CFFF system or process to be used with the computational methods for the nuclear criticality safety analysis.
-
-
- Computational Method – A combination of one or more of the following: computer software, computer hardware, data libraries, modeling technique, hand calculational techniques, and associated numerical parameters which yield the calculated results.
- Effective Multiplication Factor ($k_{eff}$) – The ratio of the total number of neutrons produced in a time interval (excluding neutrons produced by sources whose strengths are not a function of the fission rate) to the total number of neutrons lost by absorption and leakage during the same interval.
-
-
-
-

- Special Nuclear Material (SNM) – Material containing uranium enriched in the $^{235}U$ isotope.
- Upper Subcritical Limit (USL) – The maximum value of a computational method below which the analysis remains subcritical.
- Validation - Evaluating and documenting that a model as embodied in a computer code (i.e., for a specific data library set) is a correct representation of the process or system for which it is intended. Validation compares the computational method with documented critical experiments to determine any bias that might exist between the calculated reactivity of a given system and the actual conditions. This process determines and establishes computational method applicability, adequacy, and uncertainty.
- Verification – Providing assurance that the computer code correctly performs the operations specified. This is typically accomplished through comparison of the calculated results to an analytical solution or approximation.

## 4.0 RESPONSIBILITIES:

4.1 Nuclear Criticality Safety (NCS) Engineer Manager:

The NCS Manager has the responsibility:

A. To administer the NCS program.

B. To update and revise this program as required.

C. To ensure that the personnel performing NCS-related activities meet the qualifications specified in RAF-125-5.

D. To make assignments for the performance of evaluations and validation/verifications.

E. To act as an independent reviewer as necessary.

F. To monitor the progress of all evaluations/analyses.

4.2 Nuclear Criticality Safety Engineer

The NCS engineer completing the validation is responsible for the following:

A. To perform calculations using only computer platforms and analytical methods verified to perform their intended function.

B. To ensure that appropriate benchmark studies have been performed to provide validation and qualification of the methods being used in accordance with criteria described in Section 4.3 of ANSI/ANS-8.1-1983.

C. To ensure code revisions shall be <u>verified</u> to have no significant effect on the results of calculations.

D. To ensure that an independent verification is done for each code validation.

4.3 Technical Reviewer

The technical reviewer is responsible for the following:

A. Perform an independent technical review of the documentation using procedure RA-310, *Nuclear Criticality Safety Independent Technical Reviews*

B. Confirm the rationale for the assumptions made in the verification and validation documentation.

4.4 Westinghouse Engineering Computing

Westinghouse Engineering Computing in Pittsburgh is responsible for the following:

A. Installing the Criticality Safety Computer Codes on the UNIX/LINUX/PC computer.

B. Running the code vendor's sample test cases.

C. Documenting the sample test case results and resolving any failures to successfully execute.

D. Maintaining the Configuration Control of the hardware and software associated with the Criticality Safety Computer Codes.

## 5.0 REGULATORY REQUIREMENTS:

5.1 The entire procedure is of Regulatory Significance.

# 6.0 PROCEDURE:

> **NOTE:**
>
> The steps for completing Criticality Safety Computer Code verification and validation are illustrated in Figure 1 and detailed in the following procedure sections.

## 6.1 Selection of the Computational Method (Computer Code) to be Utilized for NCS Calculations

6.1.1 The first step in performing a validation is the selection of the code for criticality safety analysis. Two Monte Carlo code packages are currently used at the Westinghouse CFFF to perform criticality safety analyses; SCALE and MCNP.

6.1.2 The SCALE code collection provides a standardized method for criticality, shielding, and heat transfer analysis on workstations or personal computers (PCs). For criticality safety analysis, the code consists of several control sequences that execute functional modules in a specified order (e.g. CSAS25). The Nuclear Engineering Application Section (NEAS) of Oak Ridge National Laboratory (ORNL) maintains the controlled configuration of SCALE under its SCALE Configuration Management Plan. Notification of program errors and enhancements are made through distribution of the SCALE newsletter.

6.1.3 MCNP is a general purpose, continuous energy, generalized geometry, time dependent transport code that can be used for neutron, photon, electron or coupled neutron/photon/electron transport, including the capability to calculate $k_{eff}$ eigenvalues for critical systems. MCNP uses point-wise continuous-energy nuclear and atomic cross section data. The code treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces and fourth-degree elliptical tori. Important standard features that make MCNP very versatile and easy to use include a powerful general source, criticality source, and surface source; both geometry and output tally plotters; a rich collection of variance reduction techniques; a flexible tally structure; and an extensive collection of cross-section data. The MCNP code was developed and is maintained by the Los Alamos National Laboratory (LANL). Notification of program errors and enhancements are made through the distribution of the RSICC newsletter.

## 6.2 Installation and Verification of the Computational Method (Computer Code) to be Utilized for NCS Calculations

6.2.1 Once the appropriate code has been selected, it shall be installed on a Westinghouse UNIX / LINUX /PC computer platform by an authorized system administrator from Westinghouse Engineering Computing.

6.2.4 Software designated for use in nuclear criticality safety calculations on the computer platform shall be compiled into working code versions with executable files that are traceable by length, time, date, and version.

6.2.5 Compiled software code versions shall be verified by executing the sample problem calculations provided with each Monte Carlo code and ensuring no major differences occur between the results obtained and those provided with the code package.

6.2.7 Software verification documentation shall be accomplished in accordance with the appropriate Nuclear Fuel Engineering Procedures at the Westinghouse Energy Center in Monroeville, PA.

## 6.3 Selection of Appropriate Benchmark Critical Experiments

6.3.1 Once the Monte Carlo computer code has been selected, installed, and verified on the computer platform, benchmark critical experiments shall be selected for code validation.

6.3.3 Once the critical experiments have been selected, computer input files shall be constructed and calculations shall be performed on the computer platform that is under the configuration control authority of Westinghouse Core Engineering.

## 6.4 Statistical Analysis

- 
- 
- 
- 

## 6.13 Validation Documentation

6.13.1 Validation Documentation in the Westinghouse Criticality Safety Calc-note system and/or a separate Validation Report shall be performed and maintained by the Nuclear Criticality Safety Function.

6.13.2 An electronic version of the calculations and any relevant supporting documentation shall be placed in the criticality safety section on the network.

6.13.3 Validation documentation shall include:

A. Identification of the computational method being validated.

B. For computer code calculations the following shall be included: code name, code version, cross sections data libraries, computer hardware, and operating system on the computer being validated.

C. Copies of all input and output files.

D. Any additional calculations performed in support of the validation analysis (e.g., hand calculations or spreadsheets used).

H. Statement of the condition that must be satisfied for the calculated results to be considered safe (i.e., subcritical).

# 7.0 REFERENCES:

## 7.1 Controlled Procedures

7.1.1 This procedure replaces RA-305, rev. 6.

7.1.2 RA-104, Regulatory Review of Configuration Change Authorizations

7.1.3 RA-310, Nuclear Criticality Safety Independent Technical Reviews

7.1.4 RA-312, NCS Calc Note Generation, Format, and Content Requirements

## 7.2 Controlled Forms/Sketches

7.2.1 None

## 7.3 Miscellaneous

7.3.1 References

A. ANS/ANS-8.1 (1983), "American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors".

# 8.0 ATTACHMENTS:

8.1 None

**Title: NCS Calc Note Generation, Format, and Content Requirements**

Description of Changes:

1. Change section number of Open Items section in 6.2.B (5)

Reason for Change:

1. Fix typographical error

Department Acknowledgements

1. EHS NCS

**Title: NCS Calc Note Generation, Format, and Content Requirements**

# 1.0 PURPOSE

1.1 To provide format and content requirements for Nuclear Criticality Safety (NCS) calc notes.

1.2 To define appropriate initiation, authoring, review, approval, and publication requirements for NCS calc notes.

# 2.0 POLICY and SCOPE

2.1 The official NCS basis for a facility, process, or piece of equipment must be documented in a Criticality Safety Evaluation (CSE) (see Reference 7.1.2). NCS limits & controls, as well as conclusions regarding double contingency and margin of safety, may only be defined in a CSE.

2.2 This procedure defines the required format and content for Calc Notes containing NCS information, as well as the responsibilities and process used for the initiation, generation, review, approval and publication of Calc Notes containing NCS information.

2.3 This procedure does not apply to Calc Notes which are 1) generated by non-NCS Function organizations, and 2) do not contain NCS information.

# 3.0 TERMS/DEFINITIONS

3.1 Criticality Safety Evaluation (CSE) - The primary documentation of the NCS technical basis for a given process segment. NCS limits and controls are derived and defined in CSEs.

3.2 Calculation Note (or Calc Note) (CN) - Documentation of analyses performed in support of the CFFF safety basis.

3.3 NCS Calculation Note (or NCS Calc Note) (NCS CN) - A Calc Note which contains NCS information. NCS CNs may contain analyses referenced in one or more CSEs, but cannot define NCS limits or controls (unless those limits or controls are further summarized in a CSE).

3.4 NCS Engineer - A person who has met the qualifications specified by the NCS program (contained in Reference 7.1.3), who is knowledgeable of specific facility operations, processes and equipment, and who is assigned by management to provide nuclear criticality safety calculations, analyses, evaluations, reviews, and audits of designs and operations.

3.5 Senior NCS Engineer - A person who has met the qualifications specified by the NCS program (contained in Reference 7.1.3), who is knowledgeable of specific facility operations, processes and equipment, and who is assigned by management to provide technical reviews of nuclear criticality safety calculations, analyses, and evaluations in addition to the normal duties of a Nuclear Criticality Safety Engineer.

3.6 Technical Reviewer - Senior NCS Engineer who performs technical review of draft NCS calc notes per Reference 7.1.4.

## 4.0 RESPONSIBILITIES

4.1 NCS Engineering Manager

A. Ensure any NCS calc note is both required and appropriate

B. Assign qualified personnel as originators and technical reviewers for NCS calc notes

C. Arbitrate disagreements between originators and technical reviewers

D. Approve NCS calc notes

4.2 NCS Engineer

A. Author NCS calc notes, following the content and formatting requirements given herein

B. Approve NCS calc notes

C. Issue approved NCS calc notes

4.3 Senior NCS Engineer

A. All requirements for NCS Engineers

B. Perform technical reviews of NCS calc notes

C. Approve NCS calc notes

## 5.0 REGULATORY REQUIREMENTS

5.1 This entire procedure is of Criticality Safety Significance.

5.2 This entire procedure is designed to provide guidance for the production of NCS calc notes that satisfy the requirements of license SNM-1107.

## 6.0 PROCEDURE

**NOTE:**

Revisions to NCS Calc Notes are processed in the same manner as original versions, using the steps included herein.

6.1 Initiate NCS Calc Note – NCS Engineering Manager

A. Once the need for a specific NCS calc note is identified (internally or externally), perform the following steps:

   1. Ensure that an NCS calc note is the appropriate documentation for the analysis (e.g., if the analysis will define NCS limits or controls, the analysis must be documented or summarized in a CSE).

   2. Assign a qualified NCS Engineer as originator of the NCS calc note.

   3. Assign a qualified Senior NCS Engineer as technical reviewer of the NCS calc note.

6.2 Author NCS Calc Note – Originator

A. Perform all required analyses, and author the NCS calc note.

B. Each NCS calc note shall include the following sections. Note that the analyses documented in NCS calc notes shall be sufficiently detailed as to purpose, method, assumptions, input, references, and units, such that a person technically qualified in the subject can review and understand the analyses, and verify the adequacy of the results, without recourse to the originator.

   1. Cover Sheet: Each NCS calc note shall include a cover sheet that includes the following:

      - Document number and revision number
      - Document title
      - Originator name, signature, and approval date
      - Technical reviewer name, signature, and approval date
      - NCS Engineering manager name, signature, and approval date
      - Total number of pages (including attachments)
      - Brief summary of objectives and results

   2. Revision Log: A listing of all revisions of the NCS calc note, including the reason for the revisions, and a summary of significant changes for each revision. If the changes are very significant, the revision log may indicate that a complete revision was performed.

   3. Introduction (Section 1.0)

      - Background/Purpose (Section 1.1): A brief statement of the objective of the analyses documented in the calc note, a brief description of the process being modeled, and a brief discussion of the background of the analyses/process, as applicable.

- 

4. Conclusions (Section 2.0): Any conclusions drawn from the results, with appropriate justification.
5. Assumptions and Open Items (Section 3.0)
   - Assumptions (Section 3.1): A listing of all assumptions applicable to the documented analyses. For each assumption, justification shall be provided to demonstrate that the assumption is reasonable and bounding.
   - 
6. Acceptance Criteria (Section 4.0): A description of the acceptance criteria used in the analyses, including the effects of any applied code biases.
7. Computer Codes Used in Calculation (Section 5.0): A description of any computer codes employed in the analyses.

8. References (Section 6.0): A listing of all references employed in the NCS calc note, with sufficient detail to allow the references to be retrieved at a later date. If a reference is not retrievable, it shall be included in whole as an attachment.
9. Calculations (Section 7.0)
   - Method Discussion (Section 7.1): A description of the calculational methodology employed.
   - Input (Section 7.2): A listing of all technical input used in the analyses documented in the calc note, including NCS-

significant tolerances and uncertainties, and appropriate references.

- Evaluations, Analysis and Detailed Calculations (Section 7.3): The results of the analyses. If codes are employed, each individual case shall be listed, with the associated results and a detailed description of the configuration modeled.

10. Appendices: As applicable, any supplementary data necessary to review or understand the analyses documented in the calc note, which are not included in the main body of the calc note, shall be included as attachments (e.g., technical verification checklists, raw data, emails, etc.). In addition, if codes are employed, a representative set of input files shall be included as an attachment.

C. Satisfy the following formatting requirements for each NCS calc note:

- Page numbers on every page
- Document number and revision number on each page
- No handwritten corrections
- Sufficient legibility such that the calc note may be read at a later date, even after being photocopied

D. After completing the draft NCS calc note, submit it to the identified technical reviewer.

6.3 Technically Review NCS Calc Note – Technical Reviewer

A. Perform a technical review of the draft NCS calc note, per Reference 7.1.4.

B. Review the draft NCS calc note, per the format and content requirements given herein.

C. Resolve comments with originator. In the case of a disagreement between the originator and technical reviewer, the NCS Manager shall arbitrate.

6.4 Approve NCS Calc Note - All

A. Once the originator and technical reviewer have resolved all comments, they shall both approve the calc note by signing the cover sheet.

B. The NCS Engineering manager shall review and approve the NCS calc note, by signing the cover sheet.

6.5 Issue the NCS Calc Note – Originator

A. Once the calc note has been approved by the originator, technical reviewer, and NCS Engineering manager, the originator submits the calc note to document control per Reference 7.1.5.

B. The originator shall retain paper and electronic copies of the approved calc note. If codes are used, the originator shall also retain electronic copies of all input and output files.

## 7.0 REFERENCES

7.1 Controlled Procedures

7.1.1 This procedure replaces RA-312, rev. 1.

7.1.2 RA-313, Criticality Safety Evaluations (CSEs)

7.1.3 RA-125, Indoctrination, Training, and Qualification of EH&S Personnel

7.1.4 RA-310, Nuclear Criticality Safety Independent Technical Reviews

7.1.5 RA-101, Environment, Health and Safety Record Generation, Retention and Control

## 8.0 ATTACHMENTS

8.1 None

**Title: Criticality Safety Evaluations (CSEs)**

Description of Changes:

1. Changed reviewer for CCFs to NCS Engineering Manager or designee.

Reason for Change:

1. Nuclear Criticality Safety Improvement Project

## Department Acknowledgments:

1. EHS NCS

**Title: Criticality Safety Evaluations (CSEs)**

# 1.0 PURPOSE

1.1 To establish general requirements for Criticality Safety Evaluations (CSEs) at the Westinghouse Columbia Fuel Fabrication Facility (CFFF).

# 2.0 POLICY & SCOPE

2.1 This procedure applies to CFFF and subcontractor personnel involved in the preparation, review, approval, and cancellation of criticality safety evaluations.

2.2 CSEs are performed for all fissile material systems and operations at CFFF. The CSE establishes the criticality safety limits and criticality safety significant controls for those fissile material systems and operations.

2.3 CSEs also provide the nuclear criticality safety input to the Integrated Safety Analysis (ISA) documentation.

2.4 This procedure provides requirements and guidance, with regard to CSEs, in the following areas:

A. Identification of the need for a CSE

B. CSE format and content

C. The process for CSE development

D. Review and approval of CSEs

E. Cancellation of CSEs

F. Expectations for technical information serving as input to CSEs

# 3.0 TERMS & DEFINITIONS

3.1 Acronyms

- AEC: Active Engineered Control
- CFFF: Columbia Fuel Fabrication Facility
- CSE: Criticality Safety Evaluation
- SSC: Safety Significant Control
- SNMO: Special Nuclear Material Operation
- NCS: Nuclear Criticality Safety
- Non-SNMO: Non-Special Nuclear Material Operation
- PEC: Passive Engineered Control

3.2 Definitions

A.

B. Configuration Change Control Form (CCF) – This form (TAF-500-1, Reference 7.2.1) is used to document proposed new processes and proposed process/plant configuration changes, in accordance with the requirements of Reference 7.1.9. Any proposed changes that involve design safety basis structures, systems, and components with health, safety, or environmental protection significance must also undergo an integrated safety review per Reference 7.1.10. In such cases, form RAF-104-2 (Reference 7.2.3) will be attached to the CCF form (at a minimum).

C. Contingency – Possible, but unlikely, change in a condition/control important to the nuclear criticality safety of a fissile material operation that would, if it were to occur, reduce the number of barriers (either administrative or physical) that are intended to prevent a nuclear criticality accident.

D. Credible – Offering reasonable grounds for being believed on the basis of commonly accepted engineering judgment.

E. Criticality Accident Alarm System (CAAS) – A system capable of providing an immediate emergency evacuation alarm signal (usually audible, but may also encompass a visual component) after detecting (usually by the detection of gamma or neutron radiation) a criticality accident.

F. Criticality Safety Evaluation (CSE) – Documented rationale demonstrating the nuclear criticality safety of a process or operation that contains fissile material. Nuclear criticality safety personnel develop the evaluation, with input from line management, operations, project/process engineering, and other applicable disciplines. It provides sufficient description of the facility equipment and fissile material processes to determine normal operating conditions and identify all credible criticality scenarios. The evaluation may reference or contain technical, computational or comparative results that provide the bases of nuclear criticality safety limits, and the controls necessary to ensure that the limits are not exceeded. The evaluation provides documented compliance with the Double Contingency Principle, and the requirements of 10CFR70.61.

G. Criticality Safety Evaluation Implementation – The process of ensuring that the limits and controls specified in a CSE are appropriately captured and applied in the procedures, equipment, training documents, drawings and postings associated with special nuclear material operations (SNMOs) and processes.

H. Criticality Safety Limit – Bounding values on important NCS parameters (e.g., mass, moderation, geometry) as determined in a CSE, that are necessary to establish and maintain the nuclear criticality safety basis for a process or operations.

I. CSE Revision – A change made to an existing CSE, which requires the same level of approval as the original CSE.

J. Criticality Safety Posting – An operator aid (e.g., sign) that serves as an enhancement to administrative controls specified in a CSE. A posting is a work control document that summarizes key criticality safety controls and limits, designates work and storage areas, or provides other instructions to personnel.

K. Double Contingency Principle – Process designs shall incorporate a sufficient factor of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible. Protection is provided by either: the control of two independent nuclear process parameters (which is the preferred approach, if practicable), or a system of multiple (at least two) controls on a single parameter. In all cases, no single credible failure shall result in the potential for a criticality accident.

L. Effective Multiplication Factor ($k_{eff}$) – The ratio of the total number of fission neutrons produced in a time interval to the total number of neutrons lost by absorption and leakage during the same interval.

M. Fissile Material – A material that is capable of sustaining a nuclear fission chain reaction.

N. Non-Special Nuclear Material Operation (Non-SNMO) – An operation that does not involve significant amounts of fissile material.

O. Non-SNMO Listing – A controlled listing of process operations that meet the definition for a Non-SNMO, and have been shown to not require a CSE.

P. Nuclear Criticality Safety Engineer – A person who has met the qualifications specified by the NCS program (contained in Reference 7.1.3), who is knowledgeable of specific facility operations, processes and equipment, and who is assigned by management to provide nuclear criticality safety calculations, analyses, evaluations, reviews, and audits of designs and operations.

Q. Nuclear Criticality Safety Parameter – Fissile material operation characteristics over which control is exercised to ensure nuclear criticality safety. Parameters (singly or in combination) include mass, enrichment, volume, geometry, concentration/density, moderation, interaction, reflection, and neutron absorption.

R. Preferred Design Approach (PDA) – The preferred hierarchy for establishing criticality control of fissile material operations which emphasizes the following order of preference:

1. Favorable geometry/safe volume through limited dimensions
2. Other passive design features
3. Active engineered controls
4. Administrative controls

S. Process Upset – An event involving a deviation in a controlled process parameter or a condition outside of the normal operating range.

T. Senior Nuclear Criticality Safety Engineer – A person who has met the qualifications specified by the NCS program (contained in Reference 7.1.3), who is knowledgeable of specific facility operations, processes and equipment, and who is assigned by management to provide technical reviews of nuclear criticality safety calculations, analyses, and evaluations in addition to the normal duties of a Nuclear Criticality Safety Engineer.

U. Significant Amount of Fissile Material – The quantity of fissile material for a given set of process conditions judged, by qualified NCS Engineering personnel, to not require NCS controls. In the absence of any other data, one-tenth of a minimum critical mass for the process of interest is judged to be an acceptable definition of "significant".

V. Subcritical Limit – The limiting value assigned to a controlled NCS parameter that results in a subcritical system under specific conditions. The subcritical limit allows for uncertainties in the calculations and experimental data used in its derivation, but not for contingencies such as double batching or failure of analytical technique to yield accurate values.

W. Technical Reviewer – Senior NCS Engineer who performs technical review of draft CSEs per Reference 7.1.4.

X. Unlikely Event – An event is described as "unlikely" if its frequency of occurrence is sufficiently low to exclude it from normal case conditions. In general, when quantitative analysis is performed, a probability of less than or equal to $10^{-2}$ per year is considered sufficiently low for an event to be considered "unlikely".

# 4.0 RESPONSIBILITIES

4.1 Nuclear Criticality Safety Engineer

A. The NCS Engineer is responsible for the following:

- Reviews each assigned CCF for determination if a CSE is necessary

- Develops new and revised CSEs
- Prepares calculational documents as necessary to support the CSE

4.2 Senior Nuclear Criticality Safety Engineer

A. The Senior NCS Engineer is responsible for the following:

- All requirements for NCS Engineers
- Performs independent technical reviews of CSEs, in accordance with the requirements of Reference 7.1.4
- Ensures that the format and content requirements of this procedure are satisfied
- Serves in mentor and technical oversight roles for NCS Engineers and other unqualified NCS staff

4.3 Nuclear Criticality Safety Engineering Manager

A. It is the responsibility of the NCS Engineering Manager:

- To ensure that the personnel performing NCS-related activities meet the qualifications specified in Reference 7.1.3
- To make assignments for the performance of CSEs
- To act as a technical reviewer as necessary (when qualified as such)
- To monitor the progress of all evaluations/analyses
- To facilitate resolution of technical issues between reviewers, engineers, and plant personnel
- To ensure CCFs are assigned to be worked consistent with plant needs and priorities
- To review the CSE for compliance with applicable standards, procedures, and programmatic requirements

4.4 Organizations Supporting CSE Development

A. Managers of organizations providing developmental and review support for CSEs are responsible for:

- Ensuring that a CCF is generated for each new or revised CSE impacting their organization. The generating organization's manager must approve the draft CCF prior to submitting the CCF for further consideration by NCS personnel.
- As requested by the NCS Engineering Manager, providing qualified personnel to support the CSE developmental process.

- As required by this procedure, or requested by the NCS Engineering Manager, performing reviews of each CSE and providing approval, as appropriate.

## 5. REGULATORY REQUIREMENTS

5.1 This entire procedure is of Criticality Safety Significance.

5.2 This procedure is designed to provide guidance for the production of CSEs that satisfy the requirements of license SNM-1107.

## 6.0 PROCEDURE

6.1 Identification of the Need for a CSE

**NOTE**

The need for a CSE (or a change to an existing CSE) may be identified by someone other than the Area Manager. However, the Area Manager is responsible for all CCF submissions from their functional area.

If an Area Manager is unsure if an operation qualifies as a SNMO, they should contact the NCS Engineering Manager for assistance.

A. The Operations Area Manager shall ensure that all SNMOs under their purview are performed under a documented CSE.

B. For each CCF or other identified change to a CSE, the NCS Engineering Manager (or designated Senior NCS Engineer) performs the following:

- Confirms that a RAF-104-2 form (Reference 7.2.3) has been attached to the CCF, and that it has been filled out appropriately.
- Confirms that a tracking number has been assigned to the CCF.
- Assigns the CCF to an NCS engineer for disposition, based on available resources and plant priorities.

C. The NCS Engineer reviews the CCF and associated forms to ensure that they contain sufficient information to determine if a CSE is required. The NCS Engineer should use the guidelines in RAF-104-3 (Reference 7.2.2) to perform this review and determine if a CSE, or a modification to a CSE, is required.

D. If a CSE is not required, perform the following:

1. The NCS Engineer documents the basis for no CSE required on the CCF and associated forms, in accordance with References 7.1.9 and 7.1.10.

2. The NCS Engineer obtains approval from the NCS Engineering Manager (or designated Senior NCS Engineer).
3. The NCS Engineer then revises the non-SNMO listing as appropriate to reflect the decision.
4. If applicable, when reviewing procedures that govern non-SNMOs, provide comments to the procedure owner to ensure that the procedure contains explanatory notes or other identifiers (in accordance with Reference 7.1.8) at key steps required to maintain the operation as a non-SNMO. The intent of this is to ensure that such procedure steps are **not** inadvertently changed at a later date, potentially creating an unanalyzed SNMO.

E. If the request involves a SNMO and a new or revised CSE is required, the NCS engineer performs the following:
1. If a CSE exists, review the CSE to determine if the safety basis is adversely affected.
2. If a new CSE or a revision to an existing CSE is required, generate the CSE in accordance with Sections 6.2 through 6.5 of this procedure.

6.2 Performance of the CSE

**NOTE**

The following steps in Section 6.2 are performed by the NCS Engineer, unless otherwise indicated.

During a revision to an existing CSE, the steps outlined below should focus on the aspects of the requested change.

A. Determine Scope: Determine the scope of the evaluation (with the assistance of the subject matter experts), and as feasible (based on preliminary judgment) provide to the originator an estimate of (1) the time required to process the change and (2) the anticipated new or modified criticality limits necessary for the change.

B. Form CSE Team:

- Using the support of the originator, the NCS Engineer determines what organizations (including support organizations) will be affected by the operation.
- Ensure affected organizations are involved in the evaluation process, including participation in walk-downs, hazard identification, CSE reviews, and field verifications as appropriate. As a minimum, composition of the CSE Team should include: 1) a team manager and/or a hands-on person from the affected

organization(s), 2) the appropriate system/process engineer for the system being evaluated, and 3) the NCS Engineer.

C. Gather Data:

1. Contact the CCF originator and other subject matter experts as needed to obtain or verify information.
2. Obtain or confirm data as appropriate. See Reference 7.3.1 for additional guidelines.
3. Review the data, and determine questions to be asked and items to verify with the process subject matter experts during the walk-down.

D. Perform Process Walk-Downs: The CSE Team walks down the process (including a representative sample of affected structures, systems, and components) with subject matter experts, and gathers information for NCS hazard identification. Walk-downs should include the following:

- Measurements of hardware and features as necessary and feasible
- Inspection of system components for differences between the various process lines
- Evaluation of potential for interacting systems and containers (including potential for interaction with items outside the area being evaluated)
- Confirm information previously obtained (as feasible)

E. Develop Process Description: Develop or revise (as appropriate) a detailed process description of the operation being evaluated, using the guidelines provided in Reference 7.3.1.

F. Demonstrate Normal Case Subcriticality: Demonstrate that normal conditions and anticipated process upsets are subcritical, using the methods described in Reference 7.3.1.

G. Identify Potential Upset Conditions: The CSE Team shall identify and document potential upset conditions that may affect NCS, using one of the methods described in Reference 7.3.1 (the choice of method requires concurrence by the NCS Engineering manager). As required by the CCF and associated forms, the CSE Team shall participate in a multi-discipline Process Hazard Analysis per Reference 7.1.11.

H. Evaluate Criticality Scenarios: For each process upset that affects NCS, develop the scenario that could result in a critical configuration, and evaluate its credibility and potential to actually result in criticality. Additional guidance is provided in Reference 7.3.1.

**NOTE**

Double contingency requires the occurrence of two independent, concurrent, and unlikely process upsets before a criticality is possible.

I. Identify Criticality Safety Significant Controls: Using the methods described in Reference 7.3.1, analyze for double contingency all credible process upsets that can independently lead to criticality, and identify required criticality SSCs. Selected criticality SSCs must be evaluated for reliability and potential common mode failures.

J. Demonstrate Credible Upset Subcriticality: Establish the basis for subcriticality for each credible process upset for which double contingency has been established, using one of the methods described in Reference 7.3.1.

K. CAAS Coverage: Ensure the CAAS coverage is adequate for the operation or is to be excluded by design intent and documented in the CSE. If CAAS coverage is to be excluded by design intent and is not covered by an existing exemption request, perform the following:

- Describe for license amendment request and regulator approval the area to be excluded from CAAS coverage. Include in submittal the measures that will be utilized to ensure against criticality, including kinds and quantities of material that will be permitted and the measures that will be used to control them.
- Provide justification for excluding the operation from CAAS coverage.
- Establish requirements for transportation of material outside of CAAS coverage as necessary.

L. Calculations: If $k_{eff}$ calculations are utilized, perform the following:

- Summarize the calculational analysis in the CSE, if the analysis itself is not included in the CSE. Include sufficient detail to permit independent review of the basis for why the analysis is applicable to, and bounds the conditions in, the CSE. If the analysis is documented in the CSE itself, at a minimum include the information described in the following sections of Reference 7.1.6: Assumptions, Acceptance Criteria, Computer Codes Used in Calculation, Calculations (Method Discussion; Input; and Evaluations, Analyses and Detailed Calculations), and Appendices (if applicable).
- Ensure the evaluated NCS parameter is bounded by the subcritical limit for a corresponding parameter established either in a

previously approved calculational analysis (or reference document) or through calculations performed in support of the CSE.

M. Format: Format the CSE in accordance with the guidelines provided in Section 8.1, and ensure the Document Control requirements for quality records are satisfied (Reference 7.1.2).

N. CSE References: Ensure that any references used in a CSE meet the requirements described in Reference 7.3.1.

O. Anomalous Conditions: If, when revising a CSE, the NCS engineer identifies a new or more conservative control necessary for NCS during normal operations or during a credible process upset, respond in accordance with Reference 7.1.7.

P. Consistency Review: Compare proposed NCS requirements against requirements in interfacing CSEs, in order to ensure appropriate commonality of limits and consistency in the control wording. Wherever practical, inconsistencies shall be eliminated by revising controls.

Q. Independent Verification: Evaluate the need for Independent Verification as described in Reference 7.3.1.

R. Organization Review of CSE:

1. Submit a draft of the CSE for review by the affected organizations. This review shall include a review of the process description and the hazard identification /analysis, and the implementability of the SSCs.
2. Resolve/incorporate any comments from affected organizations as appropriate.

6.3 Technical Review of CSEs

A. The NCS Engineer submits the draft CSE for technical review.

B. A Senior NCS Engineer performs the technical review of the CSE in accordance with the requirements of Reference 7.1.4.

C. In addition, the technical reviewer reviews the CSE against the format and content requirements provided in this procedure.

6.4 Management Review and Approval of CSEs

A. Following resolution of technical review comments, the NCS Engineer submits the draft CSE to the NCS Engineering Manager for review.

B. If the CSE does not meet the following minimum acceptance criteria, the NCS Engineering Manager notes comments and returns the CSE to the NCS Engineer for comment resolution:

- CSE was prepared in accordance with the appropriate procedures and signed by qualified personnel.

- The CSE is consistent with NCS program requirements and expectations.

C. If the draft CSE is acceptable, the NCS Engineer, Senior NCS Engineer/Technical Reviewer, and the NCS Engineering Manager sign the CSE.

D. The NCS Engineer obtains the signature of the Area Manager(s) from all affected organizations. The signature of the Area Manager(s) indicates agreement that the affected organizations are capable of complying with the limits and controls in the CSE. Note that higher-level managers can sign for multiple affected organizations under their direction.

E. The NCS Engineer provides the approved CSE to the designated implementation manager (typically the Area Manager or designee) for the purpose of identifying and marking up affected procedures.

F. Implementation of the CSE shall be done in accordance with Reference 7.1.5.

6.5 CSE Document Control

A. The approved CSE shall be stored and maintained in accordance with the document control requirements contained in Reference 7.1.2.

B. The NCS Engineer shall retain paper and electronic copies of the approved CSE. If codes are used, the originator shall also retain electronic copies of all input and output files. Electronic copies of this information will be retained in an approved and controlled NCS network storage location.

6.6 Cancellation of CSEs

A. The NCS Engineer completes the Verification Checklist for CSE Cancellation (Reference 7.2.4).

B. The NCS Engineer obtains NCS Engineering Manager concurrence and approval signature on the checklist.

C. The NCS Engineer obtains affected organization Area Manager concurrence and approval signature on the checklist.

D. Update document control records to show the CSE as cancelled.

# 7.0 REFERENCES

## 7.1 Controlled Procedures

7.1.1 This procedure replaces RA-313, rev. 2.

7.1.2 RA-101, Environment, Health and Safety Record Generation, Retention and Control

7.1.3 RA-125, Indoctrination, Training, and Qualification of EH&S Personnel

7.1.4 RA-310, Nuclear Criticality Safety Independent Technical Reviews

7.1.5 RA-314, Implementation of Criticality Safety Evaluations

7.1.6 RA-312, NCS Calc Note Generation, Format, and Content Requirements

7.1.7 RA-121, Redbook Internal Reporting System

7.1.8 CA-002, Columbia Plant Procedure System

7.1.9 TA-500, Columbia Manufacturing Plant Configuration Control

7.1.10 RA-104, Regulatory Review of Configuration Change Authorizations

7.1.11 RA-124, Process Hazard Analysis

7.1.12 RA-108, Safety Significant Controls

## 7.2 Controlled Forms/Sketches

7.2.1 TAF-500-1, Columbia Plant Configuration Change Control Form

7.2.2 RAF-104-3, Nuclear Criticality Safety Guidelines & Check Sheet

7.2.3 RAF-104-2, EH&S Change Authorization Action Item Summary

7.2.4 RAF-313-1, Verification Checklist for CSE Cancellation

## 7.3 Miscellaneous

7.3.1 NCS-002, NCS Manual: Criticality Safety Evaluation (CSE) Guidelines

# 8.0 ATTACHMENTS

8.1 Required Format for CSEs

# Section 8.1: Required Format for CSEs

This section provides requirements for the documentation of CSEs. The information discussed in the sections below represents the minimum items to be considered for inclusion in a CSE. The NCS Engineer may include additional information as necessary to demonstrate that subcriticality is ensured. The omission of individual sections is only acceptable with NCS Engineering Manager concurrence.

**Title Page**

The title page shall include the following information:

- The title of the evaluation
- CSE number and revision number
- Date
- Author's name
- Technical reviewer's name
- Team member's names (if applicable)

Note: Page numbering must begin on this page and continue on all subsequent pages. The page numbering shall include the total number of pages.

**Signature Page**

The signature page shall include the following information:

- The title of the evaluation
- CSE number and revision number
- Author signature and date line
- Technical Reviewer signature and date line
- NCS Engineering Manager signature and date line
- Operations Area Manager signature and date line
- Any additional signatures determined to be necessary by the NCS Engineering Manager

**Revision Log**

This page lists the revisions to the CSE, including a summary of major changes for each revision, and the reason for each revision. This section is not necessary for initial issuances (i.e., Revision 0).

**Table of Contents**

This page lists the major sections of the document and the pages where they may be found.

**Introduction (CSE Section 1.0)**

This section of the CSE introduces the document, describes the equipment or processes being analyzed, states the purpose for the analysis, and provides relevant background information, as applicable. This section should be no more than a brief paragraph in most cases.

**Normal Case Operating Conditions (CSE Section 2.0)**

This section should describe the normal case operating conditions based on a detailed discussion of process flow, process theory, and equipment description. This process description should be derived from operating procedures, discussions with personnel, and walk-downs of the proposed operation. Normally expected deviations from the design intent of the process shall also be considered. The basis for safety of the normal operating conditions should be presented by referencing data, publications, calculations, or bounding analyses contained in this CSE or other approved CSEs. This section must demonstrate that normal case operations, and expected upset conditions, will remain acceptably subcritical.

**Criticality Hazard Identification (CSE Section 3.0)**

This section includes the following subsections

Hazard Identification Method (CSE Section 3.1)

The method to be used to identify NCS hazards (e.g., What-If, HAZOP study, NCS Parameter Checklist or other alternate CFFF-approved methods), and the justification for the method chosen.

Hazard Identification Results (CSE Section 3.2)

A listing or discussion of the NCS hazards identified using this method. References may be made to other sections of the CSE or to external documents, rather than repeating results in this section. However, if external references are used, the hazard identification results should be summarized in this section.

If no credible NCS hazards are identified for the process, these subsections may be replaced by a brief discussion that describes and justifies the lack of any credible hazards.

**Double Contingency Analysis (CSE Section 4.0)**

The upset conditions identified in the previous section as requiring further analysis are evaluated in this section. This section addresses each hazard to demonstrate double contingency or non-credibility, and identifies required SSCs for each credible criticality scenario. This section includes four subsections: Credible Criticality Scenarios (Section 4.1), Incredible Criticality Scenarios (Section 4.2), NCS Parameter Table (Section 4.3), and Defense Table (Section 4.4). The required content for each section is described below.

Credible Criticality Scenarios (CSE Section 4.1)

In this section, individual subsections are presented for each credible criticality scenario. If several scenarios involve the same top level contingencies, they may be grouped together for evaluation, and included in a single subsection. Each subsection is identified as an individually numbered subsection of Section 4.1 (e.g., Section 4.1.1, 4.1.2, etc.), and includes a descriptor or title that describes the scenario. Each credible criticality scenario subsection includes the following (unnumbered) subsections: Description, Primary Contingency, Secondary Contingency, Common Mode Failure Potential, and Summary. Additionally, a section may be added to discuss Defense-in-Depth, as applicable. A minimum of two unlikely, concurrent, and independent contingencies must be described (Primary and Secondary), but more may be included (Tertiary, etc.) as appropriate. Each of these subsections is described below.

*Description*: Each credible scenario subsection begins with a general description of the critical configuration. This description may include the potential causes of the hazard, system responses (if applicable), and the ultimate consequence of the upset condition's occurrence (e.g., what controlled parameter is affected).

This description is then expanded to define the necessary contingencies that would have to occur before the critical configuration could occur, including any associated subcritical limits and their basis. These contingencies may be violations of NCS parameter limits, unlikely process changes, violations of controls proposed for the process, or combinations of these factors. Any conservative assumptions regarding uncontrolled NCS parameters are described here, as well.

An example of the text in this subsection is included in Reference 7.3.1

*Primary Contingency ("Affected NCS Parameter or Condition")*: This subsection begins by summarizing the primary contingency, and then describes the required failures for this contingency to occur. The description must clearly state when multiple failures must occur coincidentally for the contingency to progress or when only one of several failures is necessary for the contingency to progress

The individual equipment failures, procedural failures, or unlikely conditions that may contribute to a contingency are identified as the SSCs for that contingency. These SSCs are then described, including their unique ID number, type (PEC, AEC, or Administrative), intended function, failure modes, and any conclusions with regards to reliability.

Finally, based on the information provided in this section, it must be clearly concluded that this contingency is unlikely to occur, with an appropriate technical basis.

An example of this subsection is included in Reference 7.3.1.

*Secondary Contingency ("Affected NCS Parameter or Condition")*: This subsection contains the same information as the Primary Contingency section, but for the Secondary Contingency described in the Description section.

*Common Mode Failure (CMF) Potential*: This subsection described the potential for common mode failure between the different contingencies, and within any individual contingency. Where minor CMF potential exists, mitigating arguments must be presented.

*Summary*: This subsection summarizes the results from the previous subsections. Specifically, the two contingencies should be repeated, with each concluded to be unlikely; the overall frequency of criticality should be concluded to be highly unlikely; the potential for CMF should be concluded to be acceptable; and a statement should be clearly made that the double contingency principle is met for this scenario. Finally, a summary table of the SSCs identified for this scenario should be presented (with no more information than the SSC name, ID, and type).

Incredible Criticality Scenarios (CSE Section 4.2)

In this section, individual subsections are presented for each incredible criticality scenario. If several scenarios share the same basic reasons for being incredible, they may be grouped together for evaluation, and included in a single subsection. Each subsection is identified as an individually numbered subsection of Section 4.2 (e.g., Section 4.2.1, 4.2.2, etc.), and includes a descriptor or title that describes the scenario. Each incredible criticality scenario subsection must provide the technical basis for the incredibility determination. This technical basis could be in the form of qualitative arguments about the conditions that have to be met for the scenario to occur. The basis may also be in the form of either a qualitative or quantitative accident analysis . Note that a determination of incredibility must clearly either require items as criticality SSCs if relied upon for incredibility, or rely solely upon failsafe mechanisms that are dependent on the configuration control program or major process changes.

NCS Parameter Table (CSE Section 4.3)

This section of the evaluation presents a table of the NCS parameters, discusses whether they are controlled or not controlled, and provides a cross-reference between the parameters and the credible criticality scenarios from Section 4.1. If a specific parameter is not controlled for the fissile material operation being evaluated, a brief basis for why the parameter is not controlled should be provided.

Additional guidance is provided in Reference 7.3.1.

Defense Table (CSE Section 4.4)

This section presents a table that describes the contingencies and SSCs for each credible criticality scenario described in Section 4.1. Additional guidance is provided in Reference 7.3.1.

**Criticality Accident Alarm System (CSE Section 5.0)**

This section documents consideration of the need for CAAS coverage for the fissile material operation being evaluated. Coverage is required for operations involving fissile material unless an exclusion has been approved. Documentation that demonstrates coverage for the operating area should be briefly summarized and referenced in this section of the evaluation. All facets of the operation included in the CSE must be considered. If CAAS coverage is required, but cannot be demonstrated, the CSE cannot be issued until an exemption is approved or adequate coverage is provided. If CAAS coverage is not required, this section should document why it is not required, or refer to other documentation for this basis.

**Double Contingency Controls (CSE Section 6.0)**

This section lists the controls, both engineered and administrative, necessary for double contingency and to ensure an acceptable risk of operation. The controls are taken from the double contingency analysis documented in CSE Section 4.0. It is imperative that the CSE controls be rigorously constructed and carefully worded to ensure clarity and avoid confusion at the operating level.

Within this section, there should be separate sections for Passive Engineered Controls, Active Engineered Controls, Administrative Controls, and General Requirements. Administrative controls that apply to different organizations, such as operations and maintenance, should be broken out separately into separate Administrative Control subsections. Controls should be numbered sequentially across subsections. For example, double contingency controls 1, 2, and 3 may appear in the subsection for Passive Engineered Controls, controls 4 and 5 may appear in the subsection for Active Engineered Controls, and controls 6 through 8 may appear in the subsection for Administrative Controls. Each of these subsections is described below.

Note that, if no controls are identified in the CSE (i.e., criticality is concluded to be incredible with no reliance on any administrative or engineered controls), these sections may be replaced by a brief statement indicating that no controls are identified or required.

Passive Engineered Controls (CSE Section 6.1)

This subsection lists the passive physical controls necessary for criticality safety. Examples of this type of control include (but are not limited to):

- Pipe Diameter
- Dike Height
- Physical volume limitations of pump oil reservoirs
- Air gaps installed to prevent backflow
- Spacing between fixed components

After each PEC is listed, a brief basis statement shall be provided. This basis describes the reason the item is important to safety in terms that can be understood by the applicable implementation and operations personnel. If there are no PECs applicable to the operation, write "None Applicable" under this heading.

Active Engineered Controls (CSE Section 6.2)

This subsection lists the active physical controls necessary for criticality safety. Examples of this type of control are systems that automatically actuate and take protective measures during an upset condition.

After each AEC is listed, a brief basis statement shall be provided. This basis describes the reason the item is important to safety in terms that can be understood by the applicable implementation and operations personnel. If there are no AECs applicable to the operation, write "None Applicable" under this heading.

Administrative Controls (CSE Section 6.3)

This subsection lists the controls associated with actual operation of the process that rely on operating procedures or other operator-dependent systems for implementation. In general, the guidelines for the administrative controls are summarized below.

- Administrative controls should be written to clearly specify the intent or success criteria for the requirement. Do not use ambiguous terminology; word the control such that an interpretation of what is being required is not needed. When implemented, it should be clear to operations, NCS Engineering, and to the regulator whether or not the operation is being conducted in accordance with the control.

- Each numbered item should contain only one limit or control to the extent possible. If there are multiple requirements within the same control, these should be broken down into subsections of the control.

- Sufficient detail must be provided in the requirement to ensure that the control is reliable and verifiable. For example, it is not sufficient to require that a component be "controlled to prevent the entry of significant moderation," because this does not clearly specify the success criteria for the requirement.

- A brief basis statement for each of the administrative controls must be included. This basis statement summarizes the specific role that the control plays in ensuring the criticality safety of the operation. The basis statement should be written in terms that can be understood by the personnel responsible for implementing and operating to the CSE.

General Requirements (CSE Section 6.4)

This section of the CSE lists any requirements that are general in nature, and are intended to ensure a consistent interface with other programmatic requirements such as fissile material transportation, CAAS coverage, and other program elements. This section should document controls that are not strictly necessary for double contingency. Examples of requirements that might be included in this section include (but are not limited to):

- Identification of SSCs that require periodic verification (note that, per Reference 7.1.12, AECs and administrative controls with computer or alarm assist which require periodic verification shall be verified on an annual basis at a minimum, and administrative controls requiring periodic verification shall be verified on a biennial basis at a minimum)
- Firefighting restrictions
- NCS Postings
- Requirements to log certain activities
- CAAS requirements specific to the operation
- Good practice items (if agreed to by the operating groups)

If there are no general requirements applicable to the operation, this section may be omitted.

**Conclusions (CSE Section 8.0)**

This section provides a brief summary of the technical basis for criticality safety for the subject fissile material operation. The conclusion also contains either a positive statement that the double contingency principle is met, or that criticality is incredible for the process being analyzed. If the operation as a whole meets double contingency, then also state that the evaluation concludes that the operation will remain subcritical for credible normal and abnormal events and that this is assured through adherence to the controls identified in the CSE. This section also includes any applicable restrictions to the conclusions (i.e., material form, line #, etc.).

**References (CSE Section 9.0)**

Provide references for all sources of data, information, and calculations to permit traceability and allow for reproduction of the results of the evaluation as necessary. As a minimum, references should list the document number, author(s), title, revision number, and date. Do not use personal communications or other informal, irretrievable references. If it is necessary to refer to an informal document, it should be included in the CSE as an appendix.

**CSE Appendices**

Appendices should be used as appropriate for supporting materials and information. This could include detailed criticality calculations, accident analysis results, and informal or letter references required by the evaluation.

# NCS Manual
# NCS-002: Criticality Safety Evaluation (CSE) Guidelines

## 1.0 PURPOSE

This section of the NCS Manual provides expanded guidelines for performing and documenting CSEs. These guidelines are to be used in conjunction with the requirements of Reference 4.1.2.

## 2.0 PERFORMING THE EVALUATION

This section provides additional guidelines and requirements for the actual performance of criticality safety evaluations.

### 2.1 Gather Data

The type of data gathered for a particular CSE depends on the nature of the process, potential interfaces, and other factors. At a minimum, the data gathered should include the following:

Materials involved in the process, particularly fissile materials

- Physical states of the material (e.g., solid, liquid, gaseous, granular, or metal) throughout the process
- Quantities, volumes, and processes, both physical and chemical (e.g., weight, volume, solution components and concentrations, reactions with other materials in the system)
- Sources of the fissile material (e.g., drums, overhead transfer lines)
- Enrichment of the material
- System drawings necessary for performing evaluation
- Potential differences among the various process lines
- Potential accumulation areas (including floor drains and pits)
- Proximity of nearby moderators (e.g., fire sprinklers, process water lines).
- Presence of nearby systems that could impact the operation (e.g., water lines, other SNMOs, chemicals storage, etc.)
- Waste stream information (e.g., what types of waste are generated, how are they handled, etc.)
- CCF (if applicable)
- A listing of organizations impacted by the operation
- Procedure(s) governing the operation to be evaluated
- If a CSE already exists, the current CSE

### 2.2 Develop Process Description

The process description should be developed using the following guidelines:

- The process description should contain sufficient detail to describe the aspects of the operation important to NCS.

- Additional details that are not related to criticality safety should not be included.
- At a minimum, this process description should include equipment and material descriptions, a description of the process flow, and a definition of the scope of CSE coverage (system boundary).

## 2.3 Demonstrate Normal Case Subcriticality

**2.3.1** Establish normal case conditions, and anticipated process upsets, based on available information.

**2.3.2** Use any of the following means to demonstrate subcriticality for the normal case and expected process upsets. If normal case subcriticality cannot be demonstrated, work with the affected organizations to redefine normal case conditions and reattempt to show subcriticality. Process changes or equipment modifications may be required.

## 2.4 Identify Potential Upset Conditions

**2.4.1** The CSE Team shall identify and document potential NCS-related upset conditions that may result in NCS concerns using one of the following methods:

- NCS parameter checklist analysis
- What-If checklist analysis
- Hazard and Operability (HAZOP) study
- Failure Mode and Effect Analysis (FEMA)
- Other generally recognized and accepted safety analysis techniques

Justification for the method used should be documented in the CSE.

**2.4.2** Use engineering judgment to determine independence of events, and document the bases in the CSE. If NCS-related process upsets are identified that are not independent, both conditions must be considered to exist as a result of the initiating process upset.

**2.4.3** Identify which process upsets affect one or more of the NCS Parameters (see Step 3.2.19 of Reference 4.1.2). In addition consider other parameters, such as heterogeneity, CAAS coverage, etc.

## 2.5 Evaluate Criticality Scenarios

**2.5.1** Screen the process upsets to determine if the upset conditions identified can be dismissed due to their inability to result in a critical configuration or due to their incredibility.

- Eliminate conditions from consideration that do not result in any consequences of criticality concern (i.e., NCS parameter is not affected such that control could be lost). Provide a brief justification for the basis of the dismissal of these conditions in the evaluation.
- For process upsets that cannot result in a critical configuration due to geometry, volume, or another NCS parameter, eliminate the events from consideration by performing a confirmatory computational analysis or by identifying the basis in existing reference documents.
- Dismiss upsets from consideration that can easily be shown to be incredible based on either qualitative or quantitative analysis. Provide an appropriate technical basis in the evaluation for determination of incredibility.

**2.5.2** Acceptable methods of evaluating criticality scenarios include (but are not limited to):

- Reference to data derived from experiments (list experiments)
- Reference to accepted publications for subcritical limits (list publications)
- Reference to approved CSEs (list CSEs)
- Computational analysis (list referenced calculational documents, or describe the methods used if analysis is to be documented within the CSE)

**2.5.3** Consider the use of qualitative or quantitative accident analysis techniques for technical support of the criticality scenario evaluation.

## 2.6 Identify Criticality Safety Significant Controls

**2.6.1** Analyze credible process upsets that can independently lead to a criticality. Identify criticality SSCs consistent with the requirements herein, and verify that conditions or requirements exist that make it necessary for two independent, concurrent, and unlikely process upsets to occur before a criticality is possible.

**2.6.2** Identify in the evaluation any assumptions and equipment used as the basis for double contingency arguments, or normal operation subcriticality, including physical controls.

**2.6.3** When performing a double contingency analysis on the credible process upsets, the following considerations apply:

- The basis for the unlikelihood of a credible process upset may be a passive or active engineered feature, administrative control, the natural and credible course of event, or any combination of these or other means necessary to ensure the initiating event is unlikely to occur. The parameters or conditions relied upon and the limits must be established in the CSE.
- If a credible process upset is determined to be likely and no reliable controls can be formulated to prevent it, either the upset should be considered as part of the normal

case and shown to be subcritical, or else it should be treated as a likely hazard. In a case such as this, double contingency may be demonstrated by establishing two reliable and independent controls to prevent a criticality in the event of the upset.

**2.6.4** Utilize the Preferred Design Approach (PDA) (see the Definitions section of Reference 4.1.2) when developing controls:

- Where practical, equipment design in which dimensions are limited shall be relied upon.
- Equipment designs for new SNMOs and modifications to existing equipment shall be reviewed as part of the CSE process to ensure favorable geometry and engineered controls are utilized to the greatest advantage. Ensure sufficient guidance for implementation of passive and active engineered controls is provided to ensure that loss of the control will be unlikely through consideration of the following:
    - Controls must be (and remain) functionally available
- Credible failure modes of identified controls must be considered. For example, if a valve is credited as a control (to prevent the movement of fissile material or to prevent the addition of moderator to a system), credible and acceptable leakage rates must be defined in the CSE or supporting analyses.
- In all cases, effort should be made to ensure the controls relied on for double contingency are diverse. In other words, if two controls are required to demonstrate double contingency and one utilizes mass control, the second should ideally control a parameter other than mass.
- If two controls are implemented on one parameter, ensure the violation scenarios or failure scenarios of the control are independent.

**2.6.7** If administrative controls/limits are utilized to meet double contingency, ensure sufficient guidance for implementation of these controls is provided to ensure that loss of the control will be unlikely through consideration of the following:

- Controls must be (and remain) functionally available
- Established criteria of use (e.g., in an operating procedure)
- Documented training of personnel involved with the operation

## 2.7 Demonstrate Credible Upset Subcriticality

For each credible process upset, for which double contingency has been established, demonstrate that the upset is subcritical, using any of the following methods:

- Perform computational analysis
- Use hand calculations

## 2.8 CSE References

The following requirements apply to CSE references that are utilized to support the safety basis of a CSE:

- If a reference is an internally generated calculation, the calculation shall be documented in an NCS Calc Note, per Reference 4.1.1.

## 2.9 Independent Verification

**2.9.1** Evaluate the need for Independent Verification as outlined in Attachment A, each time an administrative control is utilized.

# 3.0 DOCUMENTING THE EVALUATION

This section provides additional guidelines and requirements for the documentation of CSEs.

## 3.1 Double Contingency Analysis (CSE Section 4.0)

General notes on the use of calculations in this section:

- In cases where calculations are used to support double contingency or non-credibility arguments, reference to the appropriate calculation document must be provided (see Reference 4.1.1). The CSE should briefly summarize the calculations and the results, and include specific discussion that the license acceptance criteria (i.e., 0.95 for normal and anticipated upsets and 0.98 for credible process upsets) have been met. Specifically, each calculational model should be described such that it is apparent to the reader/reviewer that the calculations bound the upset conditions being analyzed in the CSE.

  Finally, the limiting $k_{eff}$ +2σ results should be presented.

- In cases where mathematical hand calculations (i.e., either $k_{eff}$ or non-nuclear related calculations) are used to support double contingency or non-credibility arguments, the calculations must be presented in sufficient detail to ensure that the calculations could be independently reproduced if needed. Lengthy calculations may be placed in an appendix of the CSE, or in a separate approved NCS calculation document (e.g., an NCS Calc Note, see Reference 4.1.1) as necessary to ensure a smooth flow of the double contingency arguments. Sources for the specific data used in the calculations, such as densities, chemical properties, etc., shall be appropriately referenced.

- There will be upset conditions where calculations or appropriate referenced data demonstrate that the result of the accident sequence is a configuration that remains subcritical. In these cases, the Secondary Contingency should state that the calculations or referenced data demonstrate that the resulting configuration is adequately subcritical, and that some other unlikely event (give one or more examples) would have to occur for a criticality to be possible.

## 3.2 Credible Criticality Scenarios (CSE Section 4.1)

Selected examples for the Description and Primary Contingency subsections are presented below (note that the Description section must also include a qualitative fault tree, which is not shown here):

*Description*: This scenario postulates that the upstream filter fails, without being detected, allowing fissile material to accumulate undetected in the glovebox. For a criticality to occur, two separate contingencies are required to occur: 1) at least 38.7 kg UO2 would have to accumulate in the glovebox, and 2) at least 20.4 liters H2O would have to be available in the glovebox

*Primary Contingency (Mass)*: The primary contingency for this scenario is that at least 38.7 kg UO2 accumulates in the glovebox. For this contingency to occur, two potential failure mechanisms must occur: the neutron flux monitor must fail to alarm (thus preventing the detection of any buildup) and the safety release trap door must fail to open (thus preventing the mass from being sent to a FGV). The safety release trap door is credited as an SSC:

> SSC-ID-001-GLOVE (PEC): The safety release trap door is a simple mechanical door that serves as the bottom surface of the glovebox. The door is secured by two spring-loaded hinges, which are designed to release the door when a mass of over 30 kg is applied to the door. Any mass in the glovebox would then fall directly into Tank Beta, which is a FGV, as described in the criticality scenario presented in Section 4.1.2. Periodic calibration.... Possible failure modes include.... The following preventative and operational maintenance programs are implemented as management measures for this item... Based on the failure mode discussion above, and the maintenance activities currently in place, it is judged to be unlikely that this item will fail.

For the flux monitor to fail, one of two possible failures must occur: either the flux monitor itself must fail, or the alarm circuit must fail. Both of these items are credited as SSCs:

> SSC-ID-002-GLOVE (Admin, with alarm assist): The neutron flux monitor is designed to detect buildups of fissile material in the glovebox. It may fail in several different ways, such as.... The following preventative and operational maintenance programs are implemented as management measures for this item... Based on the failure mode discussion above, and the maintenance activities currently in place, it is judged to be unlikely that this item will fail.
>
> SSC-ID-003-GLOVE (Admin, with alarm assist):...

In addition to the SSCs described above, several other items would have to fail as well, and these items are credited as Safety Margin Improvement Controls, although they are not necessary to demonstrate double contingency. First, the safety release trap door system monitor acts to....

Based on this discussion, it is judged that the frequency of this contingency is at least unlikely.

## 3.3 NCS Parameter Table (CSE Section 4.3)

Following is a sample NCS Parameter Table:

| Nuclear Parameter | Controlled (Y/N) | Basis/Bounding Assumption | Applicable Credible Scenario ID Nos. |
|---|---|---|---|
| Mass | Y | Controlled to less than safe mass based on batch limits | 1, 10, 17 |
| Enrichment | Y | Maximum operating enrichment is 5.0% | 2, 3 |
| Volume | N | The component has an unfavorable volume. | None |
| Geometry | N | The component has an unfavorable geometry | None |
| Concentration or Density | N | Full theoretical density assumed | None |
| Moderation | N | Optimum moderation assumed | None |
| Interaction | Y | 2-ft spacing control on interaction with other fissile material | 4, 5, 7 |
| Reflection | N | Full water reflection is assumed | None |
| Neutron Absorption or Poison | N | No credit taken for neutron absorption in structural materials | None |
| Other Factors | N | None identified | None |

Additional information on NCS Parameters is included in Attachment B.

## 3.4 Defense Table (CSE Section 4.4)

Following is a sample Defense Table:

| | Primary Contingency | Secondary Contingency |
|---|---|---|
| Scenario ID# 4.1.1 | Mass | Geometry |
| | SSC ID #04, 05, 06 | SSC ID #07, 08 |
| Scenario ID# 4.1.2 | Mass | Moderator |
| | SSC ID #09, 10 | SSC ID #11, 12, 13 |

# 4.0 REFERENCES

## 4.1 Controlled Procedures

**4.1.1** RA-312, NCS Calc Note Generation, Format, and Content Requirements

**4.1.2** RA-313, Criticality Safety Evaluations (CSEs)

# 5.0 ATTACHMENTS

**5.1** Attachment A, Independent Verification Guidelines

**5.2** Attachment B, NCS Parameters

# ATTACHMENT A:

# ATTACHMENT B: NCS Parameters

Nuclear criticality safety of fissile materials may be provided by maintaining any one of the single parameter limits set forth in the latest revision of ANSI/ANS-8.1. Although the single parameter limits are adequate for many purposes, they are inconvenient and uneconomical for many others. In many cases, simultaneous limitation of two or more parameters may allow more flexible operational control.

Application of parameters at CFFF is described in the following text. The basic control parameters for NCS outlined in this discussion shall be considered.

Mass

Mass controls are applied on a case-by-case basis depending on the fissile material operation involved. The acceptable mass is determined based on the CSE performed for the operation. The safe mass value depends on many factors including the geometry, enrichment, reflection, material composition, etc. The safe mass values are then communicated for the operation via the CSE limits. Routine radiation surveys may be specified as a control for areas where uranium accumulations might occur in unfavorable geometries. A maximum mass of 700 grams $^{235}U$ is considered subcritical (regardless of enrichment), as recognized by ANSI/ANS-8.1. If under upset process conditions the total mass would not exceed 700 grams $^{235}U$, the operation would be considered subcritical.

Enrichment

The maximum $^{235}U$ enrichment normally expected at CFFF is approximately 5.0 weight percent. Smaller sources of slightly higher enrichment in fixed sources may also be present at CFFF. For the majority of cases, CSEs generated at CFFF are bounded by the anticipated 5.0 weight percent enrichment limit as the maximum credible enrichment.

Volume

Where volume is used as a control, corresponding volume limits are obtained from referenced handbooks or other evaluations performed at CFFF. The bases for various container sizes permitted for use at CFFF are provided in the applicable CSE for that operation requiring the container.

Geometry

Geometry control is applied by limiting equipment dimensions for those systems that depend on geometry for criticality safety. The geometry is determined in the CSE that is performed for each system and depends on the normal and abnormal process upset conditions related to the specific system. Where geometry is used as a control, corresponding geometry limits are obtained from referenced handbooks or other evaluations performed at CFFF. The bases for various limits (e.g., cylinder radius) permitted for use at CFFF are provided in the applicable CSE for the system being evaluated.

Concentration

Concentration controls are typically applied on a case-by-case basis. When the criticality safety of an operation is dependent on the concentration of fissile material, either multiple sampling results are required or an active engineered feature (e.g., an inline monitor) is utilized to ensure the concentration is maintained. The specific limits and applicable controls are delineated in the CSE for the operation in question. A concentration of 11.6 grams/liter $^{235}U$ is considered subcritical (regardless of enrichment), as recognized by ANSI/ANS-8.1. Thus, if under all credible process upsets, the concentration would always be less than 11.6 grams per liter $^{235}U$, then the operation would be considered subcritical.

Density

The density of materials used in a given operation is justified in the CSE for the operation being evaluated. If the density must be controlled to maintain compliance with the double contingency principle, it will be documented in the CSE for the operation.

Moderation

Water and oil are considered to be the most efficient moderators commonly found at CFFF. When moderation is not controlled, either optimum moderation or worst credible moderation is assumed as the normal case when performing analyses. When moderation is controlled, credible abnormal process conditions shall determine the worst-case moderated conditions.

Interaction

Interaction is controlled by spacing items bearing fissile material, when those items could result in a criticality if not properly spaced. The spacing necessary to maintain a safe array of fissile material units is determined in the CSE performed for the array. The amount of spacing needed between items is determined based on the analysis of the normal and credible abnormal process upset conditions for the operation in question. The technical bases for the required spacing are provided in the CSE for the operation. An example of another type of interaction requirement may include limiting the number of containers in motion within an operating area to one at a time. This type of control may be employed to prevent simultaneous multiple spacing violations in an area.

Reflection

Normal and credible abnormal reflection is considered when performing a CSE. The possibility of full water reflection (usually 12 inches of tight fitting water) is considered when performing an analysis. It should be recognized that concrete and other hydrogen rich materials (e.g., oil), as well as the materials of construction (e.g., steel walls), can provide more efficient reflection, and nearby sources of these materials need to be considered.

Neutron Absorption

When neutron absorbers are utilized to establish the criticality safety of an operation, the required distribution and concentrations under both normal and credible upset conditions shall be established in the applicable CSE. One general requirement for ensuring an adequate level of the absorber is maintained includes performing representative sampling of the absorber at a frequency that ensures that depletion would be observed in a timely fashion. A CSE can take credit for the neutron absorption properties of materials (1) specifically added for the purpose of absorbing neutrons and (2) of construction, provided an allowance has been made for manufacturing and dimensional tolerances, corrosion, chemical reactions, and uncertainties in the neutron cross-section. The material must also be covered under the Area of Applicability for the specific validation reference relied on.

Heterogeneity

Heterogeneous configurations are considered for those operations that involve small amounts of fissile material and interspersed moderators. Examples of this involve the handling of multiple small sample containers, or fissile materials with particle sizes greater than 150 microns in an otherwise homogenous mixture.

# NCS Manual
# NCS-005:

## 5.0 REFERENCES

### 5.1 Controlled Procedures

**5.1.1** RA-312, NCS Calc Note Generation, Format, and Content Requirements

## 6.0 ATTACHMENTS

None