Department of Energy

Portsmouth/Paducah Project Office
1017 Majestic Drive, Suite 200
Lexington, Kentucky 40513
(859) 219-4000

OCT 13 2017

Mr. William Kirby, Program Manager
Four Rivers Nuclear Partnership, LLC.
175 Freedom Boulevard, Suite 2
Kevil, Kentucky 42053

PPPO-02-4470805-18

Dear Mr. Kirby:

CONTRACT NO. DE-EM0004895: RESPONSE TO FOUR RIVERS NUCLEAR PARTNERSHIP, LLC., REVISION OF DELIVERABLE NO. 88 – NUCLEAR CRITICALITY SAFETY PROGRAM

Reference: Letter from W. Kirby to M. Fultz, "Four Rivers Nuclear Partnership, LLC., Revision of Deliverable No. 88—Nuclear Criticality Safety Program," (FRNP-18-0157), dated October 9, 2017

The U.S. Department of Energy (DOE) completed a review of the Four Rivers Nuclear Partnership, LLC., (FRNP) revision of Deliverable No. 88, Nuclear Criticality Safety Program. FRNP submitted CP2-NS-1000, FRev. 0 by following its bluesheet process to adopt the recently revised Fluor Federal Services, Inc. CP2-NS-1000, Rev. 2, *Nuclear Criticality Safety Program Description Document at the Paducah Gaseous Diffusion Plant*.

DOE hereby approves the FRNP Nuclear Criticality Safety Program Description Document.

If you have any questions or require additional information, please contact Tom Hines at (270) 441-6829.

Sincerely,

Robert E. Edwards III

Robert E. Edwards, III
Manager
Portsmouth/Paducah Project Office

e-copy:
allen.schubert@fourriversnp.com, FRNP
april.ladd@lex.doe.gov, PPPO
bill.kirby@fourriversnp.com, FRNP
brandy.mitchell@fourriversnp.com, FRNP
cory.hicks@fourriversnp.com, FRNP
daniel.lillard@lex.doe.gov, PPPO
jeff.holland@fourriversnp.com, FRNP
jennifer.woodard@lex.doe.gov, PPPO
kim.knerr@lex.doe.gov, PPPO
marcia.fultz@lex.doe.gov, PPPO
norm.sandlin@fourriversnp.com, FRNP
pad.rmc@swiftstaley.com, SSI
robert.edwards@lex.doe.gov, PPPO
tom.hines@lex.doe.gov, PPPO
tracey.duncan@lex.doe.gov, PPPO
virginia.matix@fourriversnp.com, FRNP

PGDP D&R Contractor Bluesheet Performance Document Acceptance Form

FRNP BLUESHEETED DOCUMENT ACCEPTANCE FORM		
Bluesheet Document Number: **CP2-NS-1000, FRev. 0**	Bluesheeted Document Title: **Nuclear Criticality Safety Program Description Document**	Bluesheet Effective Date: **10/20/2017**
Original Document Number: **CP2-NS-1000, Rev. 2**	Original Document Title: **Nuclear Criticality Safety Program Description Document**	

Approval Authority:
CP1☐ CP2 X CP3 ☐ CP4 ☐ CP5☐ Positions(s):

Document Bluesheeting Status Active X On hold [1] ☐

All Changes to the document are identified on the table on the succeeding page(s). The table identifies editorial or organizational revisions to the referenced original document which are necessary to ensure that the document accurately reflects requirements, roles and responsibilities established by the Paducah Deactivation & Remediation Contractor, including applicable DOE Orders and Standards defined in Section J, Attachment 1 of Contract Number DE-EM0004895 for the processes defined within the original document and to provide documentation of Deactivation & Remediation Contractor's acceptance of the document for continued use.

Does this document include any forms?	Yes ☐	No X

If yes, list below the Forms being bluesheeted with this document:

Acceptance for Use	
Preparer (printed name and signature): **Richard C. Williams**	**Date:** **10/9/2017**
Functional Manager Approval (printed names[s] and signature[s]): **Richard C. Williams**	**Date:** **10/9/2017**

[1] Documents bluesheeted as an "on hold" status will be suspended can only become active once a management review and the necessary approval process is completed.

FRNP BLUESHEETED DOCUMENT ACCEPTANCE FORM		
Bluesheet Document Number: **CP2-NS-1000, FRev. 0**	Bluesheeted Document Title: **Nuclear Criticality Safety Program Description Document**	Bluesheet Effective Date: **10/20/2017**
Original Document Number: **CP2-NS-1000, Rev. 2**	Original Document Title: **Nuclear Criticality Safety Program Description Document**	

Bluesheet Non-Intent Global Changes

Global Changes	Yes	No
Changes from FPDP to FRNP throughout document?	X	
Title Changes consistent with Transition Title Change Crosswalk?	X	
Changes to Contract number?	X	

Other Non-Intent Changes

Page	Section	Original Text or Reference	Bluesheet Text or Reference

Notes:

CP2-NS-1000/R2

Nuclear Criticality Safety Program Description Document at the Paducah Gaseous Diffusion Plant Paducah, Kentucky

This document is approved for public release per review by:

FPDP Classification Support — Date: 14 Sep 17

Nuclear Criticality Safety Program Description Document at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—September 2017

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FLUOR FEDERAL SERVICES, INC.,
Paducah Deactivation Project
managing the
Deactivation Project at the
Paducah Gaseous Diffusion Plant
under Task Order DE-DT0007774

THIS PAGE INTENTIONALLY LEFT BLANK

APPROVALS

Nuclear Criticality Safety Program Description Document
at the Paducah Gaseous Diffusion Plant
Paducah, Kentucky

CP2-NS-1000/R2

Ross Harding
Nuclear Criticality Safety Manager

9/14/17
Date

Andy Tisler
Chief Engineer

9/15/2017
Date

Bobby D. Smith
Program Manager

9/15/17
Date

DOE Approval Letter:_____ Date:_____

Nuclear Safety Documentation: Exemption # 7
9/15/17

THIS PAGE INTENTIONALLY LEFT BLANK

REVISION LOG

REVISION NUMBER	DATE	DESCRIPTION OF CHANGES	PAGES AFFECTED
0	9/30/14	Initial Issue	All
1	1/25/17	Updated Section 2.2 Responsibilities to reflect the current organizational reporting structure and titles. Added two additional controls to the Transportation of Material using Geometry Controls section.	6, 21
2	**TBD**	Updated to incorporate remediation scope, revise exemptions, remove extraneous detail, revise transfer requirements to be consistent with Technical Safety Requirements, and make editorial changes.	All

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

TABLES v

ACRONYMS .....

1. INTRODUCTION 1

2. PROGRAM OVERVIEW 1
   2.1 PURPOSE 1
   2.2 SCOPE 3
   2.3 PROGRAM OBJECTIVE 3
   2.4 STANDARDS 4

3. MANAGEMENT 6
   3.1 IMPLEMENTING MECHANISM 6
   3.2 RESPONSIBILITIES 6
   3.3 D&R CONTRACTOR DIRECTORS 7

4. DESIGN AND EVALUATION CRITERIA 10
   4.1 GUIDING PRINCIPLES 10
   4.2 DESIGN 11
   4.3 NUCLEAR CRITICALITY SAFETY EVALUATION 11
   4.4 FISSILE EQUIVALENT DETERMINATIONS 13
   4.5 NCS-EXEMPT CRITERIA 14
   4.6 CRITICALITY ACCIDENT ALARM SYSTEM 15
   4.7 CAAS EXCLUSIONS 16
   4.8 SOFTWARE VERIFICATION AND VALIDATION 21
   4.9 CONFIGURATION MANAGEMENT 22
   4.10 LINKAGE OF NCS CONTROLS TO SAFETY BASIS DOCUMENTS 23

5. OPERATIONS 24
   5.1 GUIDING PRINCIPLES 24
   5.2 WORK PERFORMANCE DOCUMENTS 24
   5.3 IMPLEMENTATION AND VERIFICATION OF NCSE/DS 25
   5.4 LABELING AND POSTING 25
   5.5 FISSILE INVENTORY TRACKING 25
   5.6 NCSE/D CANCELLATION OR CONTROL SUSPENSION 25

6. TRAINING AND QUALIFICATION 26
   6.1 NCS ENGINEERS AND CRITICALITY SAFETY OFFICERS 26
   6.2 OPERATING STAFF 27
   6.3 MANAGEMENT 28

7. SURVEILLANCES 28
   7.1 NCS STAFF WALK-THROUGHS 28
   7.2 PROGRAMMATIC SELF-ASSESSMENTS 29
   7.3 ORGANIZATIONAL SELF-ASSESSMENTS 29
   7.4 NCSP ASSESSMENTS 29
   7.5 METRICS REPORTING 29

8. NCS ANOMALOUS CONDITIONS 29
8.1 REPORTING NCS ANOMALOUS CONDITIONS 30
8.2 NCS ANOMALOUS CONDITION LEVELS 30
8.3 NCS ANOMALOUS CONDITION FOLLOW-UP 31

9. EMERGENCY RESPONSE 31
9.1 FIREFIGHTING PLANS 31
9.2 EMERGENCY RESPONSE PLAN 31

10. RECORDS MANAGEMENT 31

11. EXCEPTIONS 31
11.1 DOE O 420.1C COMPLIANCE 31
11.2 EXCEPTIONS TO REQUIREMENTS/RECOMMENDATIONS 34

12. REFERENCES 38

TABLES

1. Fissionable Material Control Limits * ..... **Error! Bookmark not defined.**
2. Qualifications/Training for NCS Engineers 27
3. NCS Qualifications/Training for Operations and Support Personnel 28
4. Compliance with DOE O 420.1C, Attachment 2, Chapter 3 32
5. Exceptions to DOE Orders, Standards, and ANSI/ANS-8 Consensus Standards 35

THIS PAGE INTENTIONALLY LEFT BLANK

ACRONYMS

AC	administrative control
ACR	anomalous condition report
ANSI/ANS	American National Standards Institute/American Nuclear Society
CAAS	Criticality Accident Alarm System
CCF	central control facility
CER	compliance evaluation report
CFR	*Code of Federal Regulations*
CM	configuration management
CSO	criticality safety officer
CSP	criticality safety program
DCP	double contingency principle
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
D&R	deactivation and remediation
DSA	documented safety analysis
EOC	Emergency Operations Center
FM	facility manager
FMO	fissile material operation
FMOM	fissile material operation manager
HC	Hazard Category
IEZ	Immediate Evacuation Zone
LLRW	low-level radioactive waste
NCS	nuclear criticality safety
NCSA	nuclear criticality safety approval
NCSD	nuclear criticality safety determination
NCSE	nuclear criticality safety evaluation
NCSP	nuclear criticality safety program
NCSPDD	nuclear criticality safety program description document
NDA	nondestructive assay
NMC&A	nuclear material control and accountability
NPH	natural phenomena hazard
NS	nuclear safety
PEH	planned expeditious handling
PM	program manager
PPPO	DOE Portsmouth/Paducah Project Office
QA	quality assurance
RCSE	request for criticality safety evaluation
RAC	radiation alarm cabinet
RP	radiation protection
S&M	surveillance and maintenance
SB	safety basis
SME	subject matter expert
SSC	structure, system, and component
TSR	technical safety requirements
UH	uncomplicated handling
USEC	United States Enrichment Corporation
USQ	unreviewed safety question
WPD	work performance document

THIS PAGE INTENTIONALLY LEFT BLANK

1. INTRODUCTION

The Paducah Site, located in western Kentucky has Hazard Category (HC) 2, HC 3, and radiological facilities. The Deactivation and Remediation (D&R) contractor is contracted by the U.S. Department of Energy (DOE) to operate and maintain the facilities. In these facilities, qualified personnel safely analyze, store, handle, and process the facilities' fissile material inventory. The D&R Nuclear Criticality Safety Program (NCSP) is implemented to ensure safe operations when analyzing, characterizing, staging, storing, handling, transporting on-site, and/or processing fissile material in accordance with DOE standards and regulations and national standards. The program does not cover shipping to or from off-site; this is covered by U.S. Department of Transportation (DOT) regulations.

This D&R NCSP Description Document (NCSPDD) is designed to meet the requirements of DOE Order (O) 420.1C, Facility Safety, dated December 2012. This NCSPDD describes the basic elements of the NCSP and describes how requirements from applicable orders and standards are satisfied by the NCSP.

Intent changes to the NCSPDD require DOE approval. An intent change is one that meets one or more of the following criteria:

- Adds, deletes, or modifies requirements, including the intent of text identified as a requirement from a source reference;
- Adds, deletes, or modifies the purpose or scope;
- Changes the sequence of steps;
- Deletes or modifies clarifications; or
- Adds, deletes, or modifies acceptance criteria or limits for safety or regulatory items.

2. PROGRAM OVERVIEW

2.1 PURPOSE

The D&R NCSP ensures that NCS hazards are evaluated and that NCS limits and controls are established and effectively implemented to provide safety to the public, workers, and the environment. The NCSP applies to all personnel involved in fissile material operations (FMO). In strict terms, fissile materials are radionuclides capable of sustaining a neutron-induced fission chain reaction [e.g., uranium-233 (U-233), U-235, plutonium-239 (Pu-239), Pu-241]. As applied to plant operations and for purposes of the D&R NCSP, fissile material is defined as (1) material enriched to greater than or equal to 1.0 wt. % U-235 isotope and in quantities greater than or equal to 15 grams of U-235; and (2) materials containing other fissionable radionuclides capable of sustaining a chain reaction in quantities greater than or equal to 1.6% of their maximum subcritical mass. Fissile material not meeting one of these definitions (e.g., material enriched to less than 1.0 wt.% U-235) is considered NCS-Exempt, but also may be termed nonfissile. Wherever fissile materials are present, the NCSP is implemented to prevent and, if necessary, provide proper response to an inadvertent nuclear criticality. Materials may be exempted from some or all of the requirements of the NCSP based on NCS-Exempt criteria provided in Section 4.5.

Key attributes of the NCSP are as follows:

- Establish responsibilities for NCS.
- The NCSP is maintained and implemented addressing the requirements of DOE O 420.1C and the applicable referenced American National Standards Institute (ANSI)/American Nuclear Society (ANS) standards to analyze and provide NCS controls for storage, handling, and processing activities. NCSP implementation details are described in NCS procedures.
- Training is required for persons who may be assigned to analyze, handle, process, store, or transport on-site more than NCS-Exempt quantities of fissile material.
- The NCSP complies with requirements for Criticality Accident Alarm Systems (CAASs), as described within DOE O 420.1C and ANSI/ANS-8.3, *Criticality Accident Alarm System*, except as noted in Table 6.
- FMOs are conducted such that at least two unlikely, independent, and concurrent changes in process and/or operating conditions must occur before a criticality accident is possible, or such that a criticality occurring due to a change in a process and/or operating condition is not credible.

NOTE:

There are two operations at the Paducah Site that do not meet the above requirement. These are considered singly contingent operations. These are discussed in further detail in Section 4.1.

- FMOs are evaluated and documented to demonstrate that all such operations are subcritical under both normal and credible abnormal conditions in compliance with ANSI/ANS-8.1, *Nuclear Criticality Safety in Operations with Fissionable Materials outside Reactors*. The details of the evaluation and review processes are described in NCS procedures.
- Unsafe accumulations of fissile material are prevented or identified and corrected.

The NCSP is described in NCS procedures that address NCS personnel responsibilities, adherence to NCS evaluation (NCSE) or NCS determination (NCSD) requirements, review and approval of FMOs, posting and labeling requirements, response to NCS violations, and NCS training requirements. Work performance documents (WPDs) are utilized to implement controls from NCSE/Ds. General guidelines for use of firefighting water or other moderators used to suppress fires near fissile materials are provided in facility emergency packets/pre-incident plans.

NOTE:

NCSEs for former uranium enrichment facilities referred to in this document also include associated NCS approvals (NCSAs). All other NCSEs or intent revisions (as defined in CP4-NS-1101, *Nuclear Criticality Safety Evaluations*) will be documented in an NCSE only (i.e., no NCSA).

2.2 SCOPE

The NCSP is applicable to all facilities and areas within the D&R contractor scope that process and handle fissile/potentially fissile material. Potentially fissile material refers to material that cannot be explicitly determined to be nonfissile based on process knowledge and that has not been confirmed to be fissile material based on measurements or other applicable methods. Operations subject to the requirements of the NCSP include on-site transportation, storage, handling, and processing of fissile material to support D&R contractor activities and surveillance and maintenance (S&M) activities at the Paducah Site.

2.3 PROGRAM OBJECTIVE

The objective of the NCSP is to prevent a nuclear criticality accident from occurring. This is accomplished by using a graded approach that takes into account the degree of the hazards in the D&R nuclear and radiological facilities. The NCSP meets the general and specific requirements of DOE O 420.1C, *Facility Safety*, Attachment 2, Chapter III, *Nuclear Criticality Safety*, as described in this NCSPDD.

The NCSP objectives include the following:

- Ensuring subcriticality of FMOs during normal and credible abnormal conditions;
- Ensuring FMOs comply with applicable regulations, industry standards, and safety basis (SB) documents;
- Ensuring that NCS takes precedence over schedule and cost consideration when applicable to work;
- Emphasizing safety to the public, workers, and the environment;
- Using engineering controls preferentially instead of administrative controls (ACs), where practicable;
- Promoting general awareness of NCS issues among on-site personnel;
- Ensuring management involvement and management assessment of the NCSP;
- Evaluating the need for CAAS and recommending detector locations based upon shielding and other engineering studies, and
- Evaluating the response to NCS-related emergencies including establishment of the Immediate Evacuation Zone (IEZ) boundary.

The NCSP includes proceduralized requirements for the following elements.

- Ensuring FMOs are evaluated and approved. NCSEs identify controls over NCS parameters, as needed. An NCSD may be used to govern certain FMOs wherein CAAS coverage and/or NCS controls applied within the FMO are determined unnecessary to preclude a nuclear criticality accident. If an operation is determined to be nonfissile or if the operation is bounded by an existing NCSE/D, the basis for not needing additional NCS controls may also be documented in a request for criticality safety evaluation (RCSE) disposition.

- Performing periodic reviews of operations and conditions to ensure limits and controls are effectively implemented, and process conditions have not been altered resulting in compromise of safety limits and controls.

- Identifying, reporting, tracking, and trending NCS anomalous conditions.

- Ensuring criticality safety software based calculations used to establish the safety basis or to demonstrate subcriticality of the analyzed operation are performed on a validated computing platform.

- Evaluating the need for CAAS and recommending detector locations based upon shielding or other engineering studies.

The NCSP also addresses the following:

- NCS interfaces, including programmatic administration, and document reviews;

- Training of workers, supervisors, and management;

- Qualification requirements of NCS engineers and criticality safety officers (CSOs).

The NCSP is implemented in NCSP procedures and CP1-NS-1001, *Nuclear Criticality Safety Policy*.

2.4 STANDARDS

DOE Orders and Standards, which provide interpreting guidance, and industry standards (i.e., ANSI/ANS) provide the requirements for the NCSP. Section 11 contains the list of exceptions to those requirements (both "shall" and "should" statements).

DOE regulations, Orders, and Standards applicable for establishing the NCS basis include, but are not limited to, the following:

- 10 *CFR* Part 830, *Nuclear Safety Management*; Subpart B, Safety Basis Requirements

- DOE O 420.1C, *Facility Safety*, Attachment 2, Chapter III

- DOE O 426.2, Change 1, *Personnel Selection, Training, Qualification, and Certification Requirements for DOE Nuclear Facilities*

- DOE-STD-1134-99, *Review Guide for Criticality Safety Evaluations*

- DOE-STD-1158-2010, *Self-Assessment Standard for DOE Contractor Criticality Safety Programs*

- DOE-STD-1186-2004, *Specific Administrative Controls*

- DOE-STD-3007-2007, *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Nonreactor Nuclear Facilities*

- DOE-STD-3009-94, CN 3, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*

Provided below are the ANSI/ANS standards in effect at the time of the issuance of DOE O 420.1C that are applicable to the current D&R operations and are incorporated into the D&R contractor NCS implementing documents. Exceptions and clarifications to the standards are identified in Section 11.

- ANSI/ANS-8.1-1998, *Nuclear Criticality Safety in Operations with Fissionable Material Outside Reactors*
- ANSI/ANS-8.3-1997, *Criticality Accident Alarm System*
- ANSI/ANS-8.7-1998, *Nuclear Criticality Safety in the Storage of Fissile Materials*
- ANSI/ANS-8.15-1981, *Nuclear Criticality Control of Special Actinide Elements*
- ANSI/ANS-8.19-2005, *Administrative Practices for Nuclear Criticality Safety*
- ANSI/ANS-8.20-1991, *Nuclear Criticality Safety Training*
- ANSI/ANS-8.21-1995, *Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors*
- ANSI/ANS-8.22-1997, *Nuclear Criticality Safety Based on Limiting and Controlling Moderators*
- ANSI/ANS-8.23-2007, *Nuclear Criticality Accident Emergency Planning and Response*
- ANSI/ANS-8.24-2007, *Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations*
- ANSI/ANS-8.26-2007, *Criticality Safety Engineer Training and Qualification Program*

The following ANSI/ANS standards in effect at the time of the issuance of DOE O 420.1C are not applicable to D&R planned operations.

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

  Basis: Raschig rings are not used at the Paducah Site for meeting double contingency.

- ANSI/ANS-8.6-1983, *Safety in Conducting Subcritical Neutron-Multiplication Measurements In Situ*

  Basis: No *in situ* experiments for determining neutron multiplication will be performed at the Paducah Site.

- ANSI/ANS-8.10-1983, *Criteria for Nuclear Criticality Safety Controls in Operations with Shielding and Confinement*

  Basis: Shielding and confinement are not used at the Paducah Site for the purposes of protecting personnel and the public.

- ANSI/ANS-8.12-1987, *Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors*

  Basis: The Paducah Site does not handle or process plutonium-uranium fuel mixtures.

- ANSI/ANS-8.14-2004, Use of Soluble Neutron Absorbers in Nuclear Facilities Outside Reactors

  Basis: Soluble neutron absorbers are not used at the Paducah Site for meeting double contingency.

- ANSI/ANS-8.17-2004, *Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors*

  Basis: Light water reactor fuel rods and units are not handled at the Paducah Site.

3. MANAGEMENT

3.1 IMPLEMENTING MECHANISM

This NCSP implements ANSI/ANS-8.19-2005, *Administrative Practices for Nuclear Criticality Safety*, requirements for management, supervisory, and NCS staff (NCS engineers and CSOs) responsibilities through written procedures. The NCSP is administered by an adequately trained staff and controlled through approved procedures.

The NCS staff will maintain familiarity with current developments in NCS practices, standards, guides, and computer codes. To the extent practicable, the NCS staff will be independent of the operating organization.

Facility managers (FMs) and FMO managers (FMOMs) will maintain knowledge and awareness of NCS requirements for their area of responsibility and will be directly responsible for implementation of the NCSP in their area(s).

3.2 RESPONSIBILITIES

The elements of the D&R contractor's organizational structure with primary NCS responsibility are presented below.

NOTE:

The various managerial positions are provided for information as of the time of approval of this document. It is not intended that changes to the organization outside of the NCS management chain require DOE approval.

3.2.1 Program Manager

The program manager (PM) has overall responsibility for the NCSP. The PM ensures that the NCS manager and staff are independent of the operating organization to the extent practicable.

3.3 D&R CONTRACTOR DIRECTORS

Reporting directly to the PM are D&R contractor directors, including the Chief Engineer (see Section 3.3.6 for specific Chief Engineer responsibilities), who lead the organizations with direct responsibility for project execution and project support functions. Directors are responsible for the following areas:

- Business Services
- Engineering
- Health, Safety, Support, and Quality
- GDP Facilities, Operations & Infrastructure
- Environmental Management
- Planning, Integration & Optimization

The directors ensure work is performed with emphasis on rigor of operations to provide environmental protection, work safety, and public protection. Directors ensure FMOs are identified and evaluated for NCS prior to initiation of the operation and ensure NCS requirements are implemented adequately.

Reporting to the directors are functional managers with responsibility for activities within their respective areas. Functional managers are responsible for ensuring that FMOs are identified and evaluated for NCS prior to initiation of the operation. In addition, they or their designees are responsible for ensuring NCSE/Ds are requested and for ensuring implementation of the requirements contained in the NCSE/Ds for these same operations.

3.3.1 Nuclear Safety Manager

The nuclear safety (NS) manager reports to the Chief Engineer. The NS manager has functional responsibility for the maintenance and enforcement of the NS/NCSP requirements. The NS manager also has responsibility for maintenance of nuclear facility safety basis documents and providing qualified staff to perform unreviewed safety question (USQ) reviews and USQ determinations.

3.3.2 Nuclear Criticality Safety Manager

The NCS manager reports to the NS manager and is responsible for establishing an NCSP that fully complies with all applicable DOE requirements. This includes reviewing the overall effectiveness of the NCSP; ensuring that NCS staff members are placed, trained, and qualified in accordance with written procedures; providing qualified NCS engineers to perform evaluation of proposed operations and facility modifications; and ensuring integration of the NCSP into appropriate SB documents. The NCS manager may utilize qualified CSOs to provide day-to-day guidance to the operating staff. The NCS manager assists responsible managers with the integration of the NCSP elements into their functional areas. The NCS manager is responsible for ensuring that NCS assessments are performed at the frequency specified by procedure, and noted actions are documented and tracked to completion. The NCS manager maintains performance metrics on NCS anomalous conditions to assist management in determining negative trends in performance and implementing necessary corrective actions. The NCS manager and staff are independent of the operating organization to the extent practicable.

3.3.3 Facility Managers and Fissile Material Operations Managers

Reporting to the directors are functional managers with responsibility for activities within their respective areas. Within each functional department are lower-tier managers or supervisors who manage the assigned work and workforce. This level of management typically includes FMs and FMOMs.

FMOMs include any level of manager providing oversight and direction for FMOs. FMs and FMOMs are responsible for ensuring that FMOs are identified and evaluated for NCS prior to initiation of the operation. In addition, they or their designees are responsible for ensuring NCSE/Ds are requested and for ensuring implementation of the requirements contained in the NCSE/Ds for these same operations.

FMs and FMOMs are responsible, in their respective roles, for overall project planning and for ensuring that personnel are made aware of the requirements and limitations established by approved NCSE/Ds through prejob briefings, required reading, training, and/or WPDs. They also are responsible for ensuring implementation of all applicable elements of the NCSP for their assigned operation(s). This includes ensuring that the supervisors are trained, that WPDs and postings are current, and that equipment satisfies all design and surveillance requirements.

FMOMs are responsible for ensuring fissile material handlers (i.e., personnel directly involved in FMOs) who fail any of the examinations associated with the NCS training are removed from jobs that involve handling of fissile material.

Other responsibilities include, but are not limited to, concurring with NCS implementation documents and NCS Implementation Checklists, supporting periodic assessments of FMOs, and ensuring proper actions are taken to adequately correct and prevent recurrence of NCS anomalous conditions.

3.3.4 Fissile Material Handlers

Fissile material handlers are qualified and certified to perform FMOs in accordance with NCS requirements in WPDs and are required to stop operations if unsafe conditions exist. Fissile material handlers are responsible for completing required training and understanding the basis for NCS controls.

3.3.5 NCS Engineers and Criticality Safety Officers

NCS engineers are specialists skilled in the techniques of NCS analysis and are familiar with nuclear and radiological facilities and their operations. The NCS engineer function is administratively independent of management responsible for operation of the nuclear and radiological facilities. Qualified NCS engineers, including NCS senior engineers, are responsible for performing the following functions:

- Providing NCSE/Ds for FMOs;
- Performing calculations in support of NCSE/Ds;
- Maintaining familiarity with NCS-related criticality codes, regulation, guides, standards, and best management practices;
- Performing walk-throughs of facilities that handle fissile material and advising appropriate management on any NCS concerns;
- Reporting NCS anomalous conditions and developing NCS anomalous condition reports (ACRs);
- Participating in the investigation of anomalous conditions involving NCS;
- Assisting in emergency preparedness planning;
- Analyzing CAAS detector placement;

- Participating in review of WPDs that involve FMOs to ensure NCS commitments have been incorporated effectively in WPDs; and

- Reviewing and providing technical input to engineering designs and equipment and process modifications that involve FMOs.

As does any employee, NCS personnel have the authority to halt any unsafe activity.

Qualified CSOs may also be used to provide day-to-day NCS field support to the FMOMs and workers.

The responsibilities of senior NCS engineers performing technical reviews of NCSE/Ds are specified in CP4-NS-1101, which are based on and implement the applicable requirements from DOE-STD-3007-2007, *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Nonreactor Nuclear Facilities*, and DOE-STD-1134-99, *Review Guide for Criticality Safety Evaluations*. These responsibilities include verifying that sufficient information is documented to allow independent analysis, verifying that all credible process upsets related to NCS are properly identified and evaluated, verifying compliance with the double contingency principle (DCP), checking for accuracy, verifying applicability of calculational methods, and reviewing controls to verify operability in the field.

This NCSP implements ANSI/ANS-8.19 requirements for management, supervisory, and NCS Staff (NCS engineers, senior NCS engineers, and CSOs) responsibilities through written procedures. The NCSP is implemented by procedures describing the NCSP and its implementation. Other procedures that are needed to perform functions in NCS include those providing configuration management (CM); records management and document control; procedure and work package development and approval; and problem and occurrence reporting. Software configuration control is addressed in the Software Quality Assurance procedure.

3.3.6 Chief Engineer

The Chief Engineer is responsible for incorporating NCS requirements into the system design and analysis of plant changes. The Chief Engineer is responsible for design and procurement of new structures, systems, and components (SSCs). With support from the NCS engineers, the Chief Engineer is responsible for design and procurement of the CAAS.

3.3.7 Training Manager

The training manager maintains the NCS training program for qualified and certified positions for nuclear and radiological facilities and others requiring NCS-related training. The training manager ensures a documented qualification and/or certification process is provided for applicable qualified and certified positions in accordance with DOE O 426.2.

3.3.8 Emergency Management Program Manager

The emergency management program manager is responsible for the interface and support of the overall direction and control of emergency responses at the Paducah Site. The D&R contractor provides these sitewide emergency response services and addresses all appropriate responses to emergencies.

3.3.9 Radiation Protection Manager

The radiation protection (RP) manager is responsible for developing and maintaining an effective RP program. The RP manager also is responsible to ensure RP interface and support in the overall direction

and control of emergency responses at the Paducah Site. The D&R contractor provides these sitewide emergency response services and addresses all appropriate responses to radiological emergencies (including a nuclear criticality).

3.3.10 Quality Manager

The quality manager provides a quality program that includes requirements applicable to design, analysis, procurement, receipt, installation, operation, and periodic review of SSCs that are credited in specific NCSE/Ds. The quality manager is responsible for ensuring assessments are performed on the NCSP such that all elements of DOE-STD-1158-2010, *Self-Assessment Standard for Contractor Criticality Safety Programs*, are reviewed triennially. The quality manager also ensures an effective system is in place for reporting, tracking, trending, and establishing corrective actions to address NCS anomalous conditions.

4. DESIGN AND EVALUATION CRITERIA

4.1 GUIDING PRINCIPLES

Before a new operation with fissile material is begun or before an existing operation is changed, it shall be determined that the entire process will be subcritical under both normal and credible abnormal conditions.

Operations must be evaluated, and the basis for ensuring subcriticality shall be clearly documented. ANSI/ANS-8.1, Section 4.2.2, states, "Process designs should incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before criticality is possible." A "process condition" is interpreted as the state of an operation or system involving fissile material, typically defined by specifying values or ranges of process parameters.

FMOs shall satisfy the DCP unless a deviation is documented, justified, and approved by DOE. The DCP may be satisfied by either (1) the control of two independent process parameters, or (2) a system of multiple independent controls on a single process parameter. If controls are implemented for only one parameter, the violation or failure scenarios of the controls shall be independent.

The D&R contractor definition of double contingency differs from that provided in DOE-STD-3007-2007. The basis for the definition of double contingency is provided in Section 11.

There are two operations at the Paducah Site in which a single change in process conditions potentially could result in criticality: (1) in-place cascade equipment with deposits greater than a safe mass at system conditions, and (2) the removal and handling of cascade equipment with greater than a safe mass of uranium outside the cascade. These two operations are discussed in more detail below.

For in-place cascade equipment, a large fire provides a single mechanism for a large breach to be exposed to direct water intrusion. In that case, criticality safety cannot be shown to meet the DCP. Technical safety requirements (TSR) controls are established to minimize the introduction of water into a breach in the cascade equipment. The TSR controls are documented in CP1-NS-3001, *Technical Safety Requirements for the U.S. Department of Energy Paducah Site Deactivation Project.*

Upon removal from the cascade, process equipment is categorized as either planned expeditious handling (PEH) or uncomplicated handling (UH) based on a nondestructive assay (NDA) mass determination, visual inspection, or favorable geometry. If the NDA indicates a deposit greater than a safe mass, the

equipment is categorized as PEH. The removal and handling of PEH from the cascade is singly contingent. Equipment removal controls minimize the potential for interaction that could result in a criticality by ensuring that a safe distance is maintained between PEH equipment and any other equipment or containers of fissile or potentially fissile material. Controls are also established to help prevent an accident where the equipment is disturbed in such a way that moderation of the PEH deposit could occur. TSR controls are established in CP1-NS-3001 for PEH equipment removal activities.

Engineered SSCs and operator actions relied upon to ensure subcriticality shall be clearly identified and adequately controlled. In addition, assumptions credited for criticality safety shall be adequately supported.

The preferred order of control is passive engineered controls, active engineered controls, and ACs. Controls include passive barriers (e.g., structures, vessels, piping); active engineered features; reliance on the natural or credible course of events (e.g., by relying on the chemistry of uranyl fluoride to maintain an acceptable hydrogen-to-uranium ratio under specified conditions); and ACs that require human actions to be taken in accordance with approved procedures or by other means that limit parameters within specified values.

All controls and requirements in NCSEs shall be evaluated for inclusion into the SB documents, as required by DOE-STD-3007-2007. The guidance used to examine controls from NCSEs for possible inclusion in the SB is described in Section 4.10.

4.2 DESIGN

The preferred design approach includes two goals. The first is to design equipment to be safe from nuclear criticality independent of the amount of internal moderation or fissile concentrations, the degree of interspersed moderation between units, the thickness of reflectors, the fissile material density, and the fissile material chemical form. The second is to minimize the possibility of accumulating fissile material in inaccessible locations and, where practical, to use favorable geometry for those inaccessible locations. The adherence to this approach is determined during the preparation and technical review of the NCSE performed to support any new equipment design. This preferred design approach is implemented as described in NCS procedures.

Process specifications shall incorporate margins of safety to protect against uncertainties in process variables and against a limit being accidentally exceeded.

Process equipment used in areas from which immediate evacuation is required shall be designed (where possible) so that leaving the equipment operating will not introduce additional significant risk.

Designs of fissile material equipment and processes shall be approved by NCS before implementation and will include the use of favorable geometry or engineered controls on mass, moderation, volume, concentration, interaction, or neutron absorption as the preferred design approach over the use of ACs. Credit may be taken for the nuclear and physical characteristics of process equipment and materials, provided control (e.g., CM control) is exercised to maintain them.

4.3 NUCLEAR CRITICALITY SAFETY EVALUATION

An NCSE is used to document safety of FMOs by describing the operation and determining parameters, limits, and controls required to maintain subcriticality for all normal and credible abnormal conditions.

NCSEs provide the bases for NCS-required engineered features and ACs. NCS requirements are incorporated into WPDs that govern operations.

New NCSEs shall meet the format and content requirements of DOE-STD-3007-2007. When intent revisions are made to existing NCSE/As, the NCSE shall be updated to include the content requirements of DOE-STD-3007-2007. An intent change is defined as any change to an NCSE that results in the deletion or noneditorial alteration of a previously approved NCS limit, control, or assumption or the addition of a new NCS limit, control, or assumption. Existing NCSAs and NCSEs may be maintained in the same format when nonintent revisions are performed. The evaluation and approval process is governed by CP4-NS-1101.

When an NCSE is needed for a particular operation, the organization responsible for performing the operation submits an RCSE. This request is approved and signed by the responsible manager or designee. The request is then submitted to the NCS manager for assignment. NCSEs are performed by qualified NCS engineers.

In response to the request, an NCSE is prepared to document the analyses performed as specified in CP4-NS-1101. Typically, a what-if analysis is used to identify and document potential upset conditions or contingencies presenting NCS concerns. Engineering judgment of the qualified NCS engineer may indicate the need for a more detailed study. For example, a HAZOP (i.e., hazard and operability study) may be used, if the operation is complex and involves multiple interacting systems, which requires substantial input from operations, maintenance, and other subject matter experts (SMEs) to identify the possible upset conditions. A contingency analysis is performed, in which subcriticality of a process, given the occurrence of the contingency, is assessed. To establish that a proposed system or process will be subcritical under normal and credible abnormal conditions, an analysis would be documented. This analysis demonstrates compliance with the DCP for the proposed operation. Singly contingent operations require the approval of DOE.

The basis for a parameter or process condition change that could lead to a criticality being unlikely must be documented in the NCSE. The basis may be an engineered feature, administrative control (AC), the natural or credible course of events, or any combination of these or other means necessary to ensure the change is unlikely to occur. The parameters or conditions relied on and the limits must be specified in the NCSE and controlled in the field.

Where the natural or credible course of events is relied upon in whole or in part to prevent a process condition change, the factors that influence the process must be described in sufficient detail in the NCSE as items related to NCS and programmatically controlled. For items that are established, maintained, and implemented by non-NCSP controls, credit for availability and reliability is established without the necessity to establish additional NCS controls. For situations where the NCS-credited controls do not provide adequate assurance of availability or reliability (i.e., situations where non-NCS programmatic and physical plant changes could adversely affect the intended NCS function of the items relied upon for NCS), specific NCS controls will be established, maintained, and implemented to ensure NCS.

The NCSE is performed by a qualified NCS engineer. The NCSE process involves (1) a review of the proposed operation and procedures, (2) discussions with the SMEs to determine the credible process upsets that need to be considered, (3) development of the controls, and (4) identification of the assumptions and equipment (e.g., physical controls) needed to ensure NCS.

Engineering judgment of both the analyst and the technical reviewer is used to ascertain independence of events and their likelihood or credibility. The basis for this judgment is documented in the NCSEs. Either qualitative or quantitative estimates of event frequency may be utilized to support the determination.

The NCSE then documents the NCS requirements (e.g., NCS controls) for the operation. NCS requirements include process conditions that must be maintained to meet the DCP or preserve the documented basis for NCS and restrict the modes of operation to those that have been analyzed in the NCSE.

The possibility of malicious or intentional damage is not considered in the evaluation of FMOs at the Paducah Site.

All NCSDs and NCSEs shall be peer reviewed for accuracy and completeness, using DOE-STD-1134-99, *Review Guide for Criticality Safety Evaluations*. The NCS staff member who performs the technical review is a senior NCS engineer who successfully has met the requirements specified in CP4-NS-1108, *Nuclear Criticality Safety Engineer Training and Qualification*. Upon approval of an NCSE/D by the NCS manager, the NCS controls, limits, evaluation assumptions, and safety items are verified and documented to be fully implemented in the field by NCS prior to final implementation of the NCSE/D.

Editorial changes require only the approval for implementation of the NCS manager. Editorial changes are defined as changes that do not change the technical basis of the NCSE/D.

All approved NCSE/Ds shall be maintained per the Document Control and Records Management procedures. Each completed NCSE/D is issued as a controlled document. Completed NCSE/Ds are archived and retrievable as permanent records in accordance with the records management system. The NCSE process provides assurance that operations will remain subcritical under both normal and credible abnormal conditions. The NCSD process is intended to demonstrate that a criticality is not credible for the evaluated FMO.

4.4 FISSILE EQUIVALENT DETERMINATIONS

The primary fissile material present at the Paducah Site is U-235. The quantities of U-235 are accounted for in the SB and controlled under the application of NCSEs. Other fissile nuclides listed in ANSI/ANS-8.1 and ANSI/ANS-8.15, *Nuclear Criticality Control of Special Actinide Elements*, may be present in small quantities (e.g., sources). These nuclides may be explicitly evaluated in NCSEs for the applicable operations, or they may be accounted for based on an equivalency determination as discussed below.

Fissile isotopes other than U-235 are present on the site. These are typically present in trace quantities such that they go undetected unless specifically looked for. These may be the result of processing uranium materials that were previously irradiated or due to past processes designed to recover transuranic elements. In all cases these other fissile isotopes would be expected to be present only in small amounts as compared to U-235. When found and upon a request from operations, NCS staff may determine U-235 equivalent values for these other fissile isotopes. These determinations may result in an equivalent U-235 mass or an equivalent U-235 enrichment. When performed, the equivalencies may be based on the factors provided in Table 1, or they may be based on another approved basis documented in an NCSE, NCSD, or NCSR as appropriate.

Table 1. Fissionable Material Control Limits *

Nuclide	FMCL (grams)	f35 (mass factor for U-235 fissionable equivalent mass)
U-233	185	1.40
U-235	350	1.00
Np-237	7100	0.035
Pu-238	1100	0.23
Pu-239	160	1.56
Pu-240	5300	0.047
Pu-241	70	3.5
Pu-242	14000	0.018
Am-241	5700	0.044
Am-242m	4.6	54
Am-243	8900	0.028
Cm-243	32	7.8
Cm-244	1100	0.23
Cm-245	11	23
Cm-247	320	0.78
Cf-249	3.6	70
Cf-251	1.8	140

*The data was generated from ANSI/ANS-8.1-1998 and ANSI/ANS-8.15-R1995.

4.5 NCS-EXEMPT CRITERIA

Certain fissile material items that involve very low mass, enrichments, or concentrations of fissile material may not require any NCS controls. These fissile materials are termed NCS-Exempt because they are exempt from NCS controls. For material considered NCS-Exempt, the fissile material involved must meet the mass, volume, enrichment, or concentration limits given below or provided in an NCS-approved document.

The effect of measurement errors and uncertainties shall be considered when establishing the upper-bound fissile mass, enrichment, or concentration present. The NCS engineer shall concur that these activities do not require an NCSE to ensure that no unanticipated conditions could invalidate the assumptions under which these exemptions apply. This concurrence is often formally documented in an NCSD.

Fissile-Exempt or NCS-Exempt labels or tags should be applied to containers or items that have fissile material present, but in such small quantities that no operator controls are required after filling.

4.5.1 Mass Exemption

If the total inventory of a facility can be shown and documented to be less than 350 grams U-235 or 250 grams U-235 if significant quantities of super-moderators (materials whose moderation properties are more effective than those of water, such as heavy water, oil, polyethylene, beryllium, and pure carbon [graphite]) are present, and said facility does not have interaction capabilities with other FMOs, then the facility does not require an NCSE or NCSD.

4.5.2 Mass/Volume Exemption

Movement and storage of items with an individual volume greater than or equal to 10.0 liters and each containing less than or equal to 15 grams U-235 are exempt from NCS controls.

4.5.3 Enrichment Exemption

Operations involving uranium materials listed in Table 2 with U-235 enrichment in compliance with the applicable limit from the table are exempt from NCS controls, provided there is no interchange of uranium with an enrichment that exceeds the applicable limit from Table 2.

Table 2. Enrichment Limits for NCS-Exempt Uranium Materials

Material	NCS-Exempt Enrichment (wt.% U-235)
Compounds of uranium and fluoride	Less than 1.0
Uranium metal	Less than or equal to 0.93
UO_2, U_3O_8, or UO_3	Less than or equal to 0.96

4.5.4 Concentration Exemption

If contaminated waste or soil can be shown to have a U-235 concentration that is less than 0.002 grams U-235 per gram of waste or soil and the fissile material is uniformly distributed across the material and does not contain concentrated deposits of fissile material, then the packaging, storage, handling, on-site transportation, and burial of this material are exempt from NCS controls.

4.5.5 Fixed Contamination Exemption

Areas or equipment with only external fixed contamination that is covered by the Radiological Protection Program are exempt from NCS controls.

4.5.6 Enrichment/Mass Exemption

If the fissile material of a facility can be shown and documented to have an enrichment of less than or equal to 5.5 wt.% U-235, a total inventory of less than or equal to 475 grams U-235, no significant quantities of super-moderators, and said facility does not have interaction capabilities with other FMOs, then the facility does not require an NCSE or NCSD.

4.6 CRITICALITY ACCIDENT ALARM SYSTEM

A CAAS is provided to alert personnel if a criticality accident occurs. The system utilizes a distinctive audible signal to notify personnel in the affected area to initiate evacuation, thereby reducing the total personnel exposure to emitted radiation over the course of the criticality accident.

The CAAS at the Paducah Site is designed to detect gamma radiation levels that would result from the minimum criticality accident of concern and to activate the building evacuation alarms and alarms in the C-300 Central Control Facility (CCF). The CAAS comprises numerous radiation detector instruments integrated into a single alarm system with primary annunciation on the radiation alarm system console in the CCF. The CAAS consists of the following subsystems and components: radiation detector cluster units, radiation alarm cabinets (RACs), alarm horn units, the building horn relay cabinets, and the annunciation system in the CCF. Radiation detector cluster units detect gamma radiation from criticality

events and initiate evacuation alarms and signals. A radiation detector cluster unit consists of three gamma detector modules, one logic module, and the housing. Activation of any two of the three detectors in a cluster will initiate evacuation alarms by sending a signal to the RAC. The RAC contains the circuitry used to initiate the operation of the evacuation horns, radiation warning lights, and any slave facility evacuation horns/lights, as well as to transmit the CAAS alarm signal into the CCF.

The CAAS cluster horn is credited with providing annunciation to workers within proximity of the criticality event [the entire IEZ]. In addition, the slave facility horns must also be operable for complete annunciation for the applicable IEZ. Any facility within the IEZ is designated as a "slave" facility. Work activities within the IEZ that create noise are evaluated to ensure CAAS annunciation can be heard over the work.

The CAAS provides detection coverage for postulated criticality events that would produce an absorbed dose in soft tissue of 20 rad of combined neutron and gamma radiation at an unshielded distance of 2 meters from the reacting material within 1 minute. The location of detectors and set points is based on results of dose calculations and detector tests performed at critical experiment facilities. These tests and calculations demonstrate that criticality accident detection requirements are satisfied.

The CAAS alarm coverage is provided in all areas where the combined neutron and gamma radiation absorbed dose in air is equal to or greater than 12 rad due to the maximum fission yield integrated over the duration of the accident. This forms the basis for defining the IEZ. Per ANSI/ANS-8.3, the maximum fission yield may be assumed not to exceed 2.0e19 fissions or a different basis shall be documented. In addition, shielding calculations (e.g., Monte Carlo N Particle) are updated and documented, as required, which confirm CAAS coverage in fissile material facilities that require coverage. The CAAS evaluation is peer reviewed by a senior NCS engineer.

The need for a CAAS shall be evaluated and documented in an NCSE/D for all D&R contractor activities in which the inventory of fissile materials in individual unrelated areas exceeds the threshold values of 700 g U-235, 500 g U-233, 450 g Pu-239, or 450 g of any combination of these three isotopes (ANSI/ANS 8.3). A CAAS is not required for FMOs involving fissile materials determined to be NCS-Exempt.

4.7 CAAS EXCLUSIONS

ANSI/ANS-8.3 states that the need for CAAS shall be evaluated for all activities in which the inventory of fissionable materials in individual unrelated areas exceeds 700 g U-235, 500 g U-233, 450 g Pu-239, or 450 g of any combination of these three isotopes. The United States Enrichment Corporation's (USEC's) NCS group evaluated the need for CAAS when developing NCSEs for FMOs. CAAS was required per ANSI/ANS-8.3, unless otherwise approved by the NRC. The NRC granted exclusions to the CAAS coverage requirements for specific operations at the Paducah Site. For these operations, additional ACs were provided to ensure the risk of a criticality remained sufficiently low. These additional controls were specifically implemented in plant procedures. The D&R contractor requests DOE approval of a subset of the previously approved CAAS exclusions needed to support deactivation and S&M activities. The D&R contractor will implement these CAAS exclusions to ensure the risk of criticality remains sufficiently low. Provided below is a summary of the NRC approved CAAS exclusions for which the D&R contractor requests DOE approval.

In the discussions that follow "transportation" and "transfer" refer to the transfer of fissile material between locations on-site.

4.7.1 Facilities C-754, C-754-A, and C-757

NCS spacing exempt liquid and solid low-level radioactive waste (LLRW) may be stored in the C-754 Low-Level Waste Storage Area and C-757 Solid and Low-Level Waste Processing Facility. NCS spacing exempt solid low-level waste may be stored in the C-754-A Low-Level Waste Storage Area. The C-757 facility may be utilized as a mixed waste shipment staging area. LLRW may be sorted and characterized for radiological content in this building. NCS spacing exempt waste is waste that has been quantitatively determined to contain less than 120 g U-235 and may be stored and handled without NCS spacing controls.

Because NCS spacing exempt waste contains nonprocess and process waste (low concentration and higher concentration), the requirement that each NCS spacing exempt waste drum contain no more than a maximum 120 g U-235 mass limit provides assurance that the fissile concentration of the waste stored is very low (i.e., less than 120 g U-235 per 5.5-gal waste drum or less than 6 g U-235/L). Assuming the entire inventory of NCS spacing exempt waste drums for a given facility was consolidated into a spherical and fully reflected system, a criticality would not be possible since the 6 g U-235/L concentration is less than the ANSI/ANS-8.1 11 g U-235/L subcritical limit providing adequate assurance that the likelihood of a criticality is very low. [See NRC CAAS Compliance Evaluation Report (CER), dated August 18, 2000.]

4.7.2 Waste Drum Transportation for Drums Containing < 120 g U-235

NCS spacing exempt waste is required to be transported between facilities for characterization and then stored in approved CAAS exempted LLRW facilities. Assuming the entire inventory of NCS spacing exempt waste drums being transported was consolidated into a spherical and fully reflected system, a criticality would not be possible since the 6 g U-235/L concentration is less than the ANSI/ANS-8.1 subcritical limit (11 g U-235/L) providing adequate assurance that the likelihood of criticality is very low. (See NRC CAAS CER, dated August 18, 2000.)

4.7.3 Transportation of Removed Process Uncomplicated Handling Equipment

Process gas equipment removed from the cascade is characterized as UH if it meets the favorable geometry criteria in the equipment removal NCSA or is determined by NDA measurements to be less than a safe mass for a given enrichment. The safe mass values at a given enrichment are found in the equipment removal NCSA. Equipment containing greater than a safe mass is characterized as PEH.

The number of UH items or groups of UH equipment transported per vehicle is limited to two, and the simultaneous transportation of UH equipment or a UH group with other fissile or potentially fissile material is not permitted. Because each UH piece or group contains no more than a safe mass of uranium, the total amount of uranium in any accident scenario involving UH equipment, is less than a minimum critical mass and cannot result in a criticality. (See NRC CAAS CER, dated August 18, 2000.)

Equipment classified as UH by geometry can contain greater than a safe mass of uranium. To ensure a criticality accident due to a significant vehicle accident resulting in a breach of fissile containment of the UH item is incredible, additional controls are required to transport a UH item by geometry. To transport a UH item safe by geometry, only one item may be transported at a time. The item must be securely fastened to the vehicle, and the vehicle speed is limited to a maximum of 10 miles per hour. These controls ensure that it is incredible for a vehicle accident to breach the fissile containment of an item classified as UH by geometry when being transported.

4.7.4 Transportation of Materials of Less than a Safe Mass or Safe Volume

Items, either single or multiple packages, which either cumulatively contain less than a safe mass or less than a safe volume, sometimes need to be transported between facilities outside of CAAS coverage.

Safe mass is defined as the amount of material that is just subcritical when double batched. The safe mass uranium loading accounts for optimal conditions such as spherical geometry, moderation, and full reflection. For 5.5 wt. % U-235, the equipment removal NCSA and the TSR control for PEH equipment removal provide the safe mass assuming optimum moderation, geometry, and reflection as approximately 30 lb uranium (13.6 kg U) or 750 g U-235. A vehicle accident when transporting items (single or multiple) under the safe mass category will not result in a configuration of more than 30 lb of uranium. The configuration will contain no more than one safe mass and cannot result in a criticality.

The term safe volume is defined as the volume that is just subcritical when double batched. The maximum subcritical volume is 3.7 gal or approximately 14 liters for uranium-oil mixtures and 21 liters for uranium non-oil mixtures. Therefore, the safe volume limit is 1.85 gal (approximately 7 liters) for uranium-oil mixtures and 2.7 gal (approximately 10 liters) for uranium non-oil mixtures. A vehicle accident will result in configuration containing no more than one safe volume and cannot result in a criticality. (See NRC CAAS CER, dated August 18, 2000.)

4.7.5 Transportation of Materials using Geometry Controls

Some equipment transported between facilities outside of CAAS depends on geometry for criticality safety. Geometry control is applied by limiting the equipment dimension.

A significant vehicle accident can result in a breach of fissile containment and potentially result in a criticality. Therefore, the following controls are required to ensure a criticality is not credible when transporting items safe by geometry:

- Only one item may be transported at a time;
- The item must be securely fastened to the vehicle, and the vehicle speed is limited to a maximum of 10 miles per hour;
- The designated transportation route will ensure the vehicle stays away from open ditches and excavations; and
- During transportation of the item, other vehicles are excluded from entering the designated transportation route.

These controls ensure that it is incredible for a vehicle accident to breach the fissile containment of the safe geometry item when being transported. (See NRC CAAS CER, dated October 18, 2001.)

4.7.6 Sample Transportation (Excluding Transportation of Trap Media Sample)

Samples may be taken from items associated with fissile/potentially fissile operations for uranium or enrichment characterization for the item or operation. Fissile samples are required to be handled, stored, and transported in batches in accordance with NCSA requirements.

To ensure that a critical configuration cannot form as a result of an upset scenario when transporting sample batches outside of CAAS coverage, additional controls are required. Sample batches (excluding

trap media samples) must be transported in accordance with previously approved safe mass or safe volume exclusions. An upset scenario, such as a vehicle accident when transporting sample batches (single or multiple) under the safe mass category or safe volume category, will result in a configuration of no more than one safe mass or one safe volume and therefore cannot result in a criticality. Transportation of samples (excluding trap media samples) in batches where the total mass is less than a safe mass or the total volume is less than a safe volume provides adequate assurance that the overall risk of a criticality is very low. (See NRC CAAS CER, dated October 18, 2001.)

4.7.7 Transportation of Trap Media Samples

Chemical traps associated with process equipment and laboratory equipment at times require samples to be obtained for uranium concentration or enrichment characterization prior to trap media change out. The samples may require transportation to another facility. Fissile/potentially fissile trap media samples are required to be handled, stored, and transported in batches in accordance with NCS requirements.

The maximum subcritical volume for uranium-trap media mixture is 37 liters and was determined under optimum conditions, including spherical geometry, optimum concentration, and full water reflection. A trap media sample batch is required to have a total combined volume that does not exceed 16.5 liters. Only one trap media batch can be transported at a time. Any upset condition, such as a vehicle accident, will result in a configuration containing no more than one safe volume for uranium trap media mixtures and cannot result in a criticality. (See NRC CAAS CER, dated October 18, 2001.)

4.7.8 Building C-710 Drain System, C-712 Acid Neutralization Pit, and the Storm Sewer Downstream of the Pit

The C-710 facility laboratories that process fissile material are housed on the first floor, and the drain systems from these laboratories empty into the C-712 acid pit located southwest of the C-710 facility. This pit's primary function is to collect acidic solutions originating from the various laboratories that handle fissile materials. The drain system from the C-712 pit ties directly into the sanitary (storm) sewer.

Controls are implemented for the associated laboratories that ensure the average uranium concentration discharged to the C-712 pit and storm sewer is less than 1 g U/L and credible abnormal concentrations to less than 11 g U-235/L (200 g U/L at 5.5 wt. % U-235). ANSI/ANS 8.1 lists the single parameter subcritical concentration limit for uranyl fluoride solutions as 11.6 g U-235/L. Because the C-710 drain system, C-712 pit, and storm sewer will not exceed 11 g U-235/L even under credible abnormal conditions, a criticality is not possible. (See NRC CAAS CER, dated October 18, 2001.)

4.7.9 Transportation of Potentially Fissile Waste, Fissile Vacuum Cleaners, or Drums Containing more than 120 grams U-235

Waste generated from potentially fissile operations is collected into NCS-approved waste drums or in NCS-approved vacuum cleaners. Until characterized, these waste containers are handled as though they contain greater than 120 g U-235 per container. These waste containers may require transportation to other facilities for characterization, storage, and clean out.

When transporting potentially fissile waste, vacuum cleaners, and approved waste containers that contain or are assumed to contain greater than 120 g U-235 per container, the following controls are required to ensure a low risk for criticality during transportation.

- Multiple waste containers may be transported to the characterization facility simultaneously provided NCS-approved physical restraints are used to ensure a 2-ft minimum edge-to-edge spacing is maintained at all times.

- No physical restraint system or containment pan is required when transporting a single waste container. The single waste container shall not be transported with other fissile material.

- Waste containers shall be removed from or loaded into the physical restraint system one drum at a time.

- The physical restraint system used for the simultaneous transportation of multiple fissile waste containers shall include provisions to positively restrain the container lids and the containers themselves in place during movement.

- There shall be no stacking of physical restraint systems during transportation of waste containers.

To ensure that the risk of a criticality associated with an accident severe enough that could breach multiple containers is very low, controls requiring the transportation vehicle not to exceed a speed of 10 miles per hour, and restraining mechanisms are required when transporting multiple containers. The physical restraint system is not required when transporting a single, subcritical volume container (i.e., less than or equal to 5.5 gal). Based on these controls and the structural integrity of the individual waste containers, the risk of criticality is very low. (See NRC CAAS CER, dated October 18, 2001.)

4.7.10 Transfer of Materials Which Do Not Fall Under One of the Approved Exclusion Categories (i.e., PEH Equipment)

The transfer of PEH equipment, equipment containing greater than a safe mass, does not fall into one of the other CAAS exclusions discussed above. Requirements are established to ensure the risk of criticality remains very low and to minimize the exposure risk from a criticality to personnel in the vicinity of the uranium bearing equipment involved in the transfer accident.

The following requirements apply when transferring PEH equipment outside of CAAS:

- Equipment shall be transferred one at a time.
- Equipment shall not be handled or transferred with any other fissile/potentially fissile materials.
- Equipment shall be restrained during movement.
- Equipment shall be transferred over a planned route.
- Other vehicle traffic shall be excluded from the immediate area of the vehicle during transfer.
- Transfer vehicle speed shall be restricted to 10 miles per hour or less.

These requirements are identified in the TSR control for PEH Equipment Transfers Outside CAAS Coverage from CP1-NS-3001. These requirements provide reasonable assurance that a vehicle accident severe enough to breach the restraining mechanisms will not result in a criticality due to shifting of transferred items. Because only one item is to be transferred at a time and restrained during movement, the shifting of the transferred items, alone, will not result in a criticality. Excluding other traffic from the area provides reasonable assurance that a vehicle accident severe enough to result in a criticality will not occur as a result of multiple vehicular collisions. The speed limit requirement provides reasonable assurance that a vehicle accident severe enough to result in a criticality will not occur due to a loss of vehicular control.

The TSR control for PEH equipment transfer in CP1-NS-3001 contains requirements to ensure the same reasonable assurance of low risk as provided by installed CAAS coverage. These requirements are as follows:

- Personnel involved in transfer of equipment shall wear personal alarming dosimeters and have a radio.
- Equipment shall be returned to CAAS coverage (within 12 hours).

In addition to the TSR control requirements noted above, PEH equipment transfer must meet requirements to minimize the exposure risk from a criticality for personnel in the vicinity of the uranium bearing equipment involved in a transfer accident. These requirements are as follows:

- Notify plant shift superintendent of the accident.
- Evacuate all unnecessary personnel within a 200-ft distance of PEH equipment if a criticality is suspected.
- If the introduction of moderator is suspected, NCS will evaluate prior to movement.
- Stabilize PEH equipment and verify covers are in place.
- Repair or replace transfer vehicle and move PEH equipment to vehicle, if applicable.

These requirements provide reasonable assurance that essential facilities and other facilities within 200 ft of the accident will be warned of the potential or actual occurrence of criticality resulting from a severe vehicle accident and assurance that personnel will be evacuated outside the 12 rad/200-ft boundary from the criticality in an expeditious manner that will not result in undue injury to personnel as a consequence of the evacuation itself. Returning the equipment to CAAS coverage within 12 hours provides reasonable assurance that PEH equipment will not remain indefinitely outside CAAS coverage areas.

The TSR controls provided in CP1-NS-3001 for PEH equipment transfer, and its associated action steps, provide reasonable assurance that the risk of criticality, in terms of both its likelihood for initiation and its consequences to workers, is very low. (See NRC CAAS CER, dated October 18, 2001.)

4.8 SOFTWARE VERIFICATION AND VALIDATION

Computer calculations of k_{eff} provide a method to relate analytical models of specific system configurations to experimental data derived from critical experiments. A critical experiment is defined as a system that is intentionally constructed to achieve a self-sustaining neutron chain reaction or criticality. Critical experiments which have specific, well-defined parametric values and are adequately documented are termed benchmark experiments. Computer codes are validated using experimental data from benchmark experiments, which, ideally, have geometries and material compositions similar to the systems being modeled.

The D&R contractor Quality Assurance (QA) Program addresses the software the NCSP uses to perform neutron and gamma transport calculations for criticality. Configuration changes to computer software or hardware used for NCS calculations shall be controlled per D&R Computer Software Management Program requirements. The requirements are consistent with DOE G 414.1-4, *Safety Software Guide*.

Computer codes used for criticality calculations shall be validated in accordance with ANSI/ANS-8.1 to determine appropriate biases and bias uncertainties for the area(s) of applicability needed in the evaluation. These biases shall be based on the results of critical experiments that are representative of the system being modeled. ANSI/ANS-8.24-2007, *Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations*, will be used to perform new validation analyses and revisions to existing validation analyses.

An additional safety margin (i.e., minimum subcritical margin) shall be applied to the calculated k_{eff} that is sufficiently large to ensure that the calculated conditions will actually be subcritical. The safety margin shall result in a k_{eff} upper subcritical limit that will ensure that there is a 95% confidence that 99.9% of all future k_{eff} values less than this value will be subcritical. The additional safety margin shall be justified.

The configuration control program used to maintain the computer codes and cross sections used in performing k_{eff} calculations meets plant change process and QA Plan requirements. The system administrator is responsible for controlling access to the software. The software configuration control and testing program is implemented through the software configuration control plan for NCS software.

4.9 CONFIGURATION MANAGEMENT

The D&R CM Program is an integrated management program that establishes and maintains consistency, identification, and control among design requirements, physical configuration, and facility documentation throughout the life cycle of a facility as changes occur. The CM program ensures that any change from an approved plant baseline configuration is managed so as to preclude inadvertent degradation of safety or safeguards. The CM program includes organizations and administrative processes to ensure that accurate and current design documentation match the plant's physical configuration while complying with applicable requirements. The CM program applies to NCS because a change to an SSC controlled by CM may require NCS approval and because the documents generated by the NCSP become controlled documents, subject to CM control.

Functional and physical characteristics of operations controlled for NCS are described in NCSE/Ds. The components and features that are identified in the NCSE/Ds are analyzed to determine the "boundary" of the system encompassing those items that are essential to ensure operability. The boundaries typically are identified on system drawings and the configuration verified to be as-built. These components and features are documented in the CM System. Each time a change to a facility is planned, the CM System is reviewed by the individual (e.g., design authority, systems engineer, facility management) planning the change to determine if the change affects SSCs relied on for safety. The design control process specifies the organizations required to perform reviews of changes to SSCs. The required approvals are obtained before the change is implemented. Engineering management verifies the required reviews have been performed before approval. If an item is relied on for the NCS of an operation, as a barrier for either double or single contingency, it will be identified through the work control process as an NCS SSC, and an NCS review and approval (potentially an NCSE) is required before implementing the change. NCS reviews the NCSE for this specific operation and determines if the change affects the analysis performed and the conclusions made in the NCSE. The change request will be approved by NCS only if the change is acceptable and meets NCSP requirements. In this way, modifications to controlled operations are evaluated and approved prior to implementation. The systems which require configuration change control are identified as Safety Class or Safety Significant (categorized as QL-1 or QL-2).

Document control is another element of the CM program. Procedures, documents, and records control programs provide for centralized control and issuance of documents critical to the maintenance of the design history and a repository for records to verify this maintenance. NCSAs, NCSEs, and NCSDs that

are required to be controlled are specifically included in the documents, which, in turn, are maintained by records management and document control.

4.10 LINKAGE OF NCS CONTROLS TO SAFETY BASIS DOCUMENTS

DOE-STD-3007-2007 provides specific guidance on the linkage between the NCSEs and the Documented Safety Analysis (DSA). It states that all controls necessary to prevent and/or mitigate criticality accidents shall be considered for inclusion in the DSA and TSR. The D&R contractor has established a process to examine the collection of controls developed in the NCSEs to determine their importance in the DSA.

A team of NCS and NS analysis personnel perform the selection of NCS controls for the SB document. Results are reviewed with personnel having operations experience.

All assumptions and controls in NCSEs are evaluated for inclusion in the SB documents. The assumptions that protect workers from a criticality accident are collectively reviewed for inclusion in the SB documents. There is no credible criticality accident that would result in a significant dose to the public.

DOE-STD-3007-2007 provides eight criteria that should be considered when performing the review to identify controls that should be elevated to the DSA and TSR. Based on the recommended criteria in DOE-STD-3007-2007, the D&R contractor established the following criteria for determining which fissile material activities and their associated NCS controls require linkage to the SB and approval by DOE's Portsmouth/Paducah Project Office (PPPO).

1. The NCSEs that cover the FMOs addressed by the DSA shall be examined to ensure that bounding assumptions or analysis conditions are considered as potential DSA/TSR controls.

2. When loss of a single control (engineered or administrative) could result directly in a criticality, the control shall be included in the DSA/TSR.

3. Where possible, two independent process parameters should be controlled. When two independent process parameters are controlled, the NCSE controls (engineered or administrative) are not elevated to the TSR.

4. When one process parameter is controlled but the scenario is shown to be subcritical by engineered features, then specific ACs are not required.

5. When only a single parameter is controlled and any of the engineering design features that are relied upon are active, those active design features must be elevated to the TSR if subcriticality cannot be assured in the event that the active design feature fails.

6. If it is not possible to control two process parameters and reliance upon ACs of a single parameter is necessary and a criticality accident is considered to be credible, consider the AC for inclusion if (1) the safety function were to be equivalent to a safety class or safety significant engineered control (as discussed in DOE-STD-1186-2004) or (2) general references to control philosophy (e.g., mass control, spacing control, or concentration control as an overall control strategy for the process without specific quantification of individual limits).

In general, ACs in the NCSE should not be contained explicitly in the SB. These controls are administered by the NCS program, which is credited in the SB. In some cases, ACs may be identified as specific credited elements in the TSR based on their importance to safety.

DOE PPPO is notified upon identification of any process not meeting double contingency. This notification will include justification for the deviation (from double contingency) request. DOE approval of the SB documents for the facility will constitute approval for the activity.

5. OPERATIONS

An FMO is any operation that involves the movement, storage, staging, handling, on-site transportation, transfer, mixing, processing, packaging, or configuration control change of fissile materials that have not otherwise been determined to be NCS-Exempt. The operation, evaluation, and related NCS requirements are documented in an NCSE/D. The evaluation and approval process is governed by written procedures.

In those activities involving source, standard, waste storage, or other activities in which insignificant quantities, enrichments, or concentrations of fissile material are involved (see Section 4.5), formal approval of an operation in the form of an NCSE/D is not required. For documentation purposes, the justification for not needing an NCSE/D may be provided by NCS in the evaluation for the RCSE or NCSR.

5.1 GUIDING PRINCIPLES

Operations that implement or could impact NCS controls shall be governed by written WPDs.

Where operations are conducted involving fissile material in a form that could inadvertently accumulate in significant quantities, the process shall be evaluated in an NCSE, and the NCSE shall be implemented in WPDs.

Guidelines for firefighting shall be established for areas that contain or process fissile material.

The NCS engineers evaluate and identify the NCS-related operational controls necessary to safely load, unload, and transport various forms of fissile material in containers or equipment and determine whether these activities have a requirement for CAAS coverage. The approved NCSE/D applies only to the transport of fissile material containers and contaminated equipment by various conveyances between facilities at the Paducah Site. NCSE/Ds do not cover shipping to or from off-site, which is covered by DOT regulations.

NCS provides support as requested on what constitutes an NCS exception or NCS exemption per DOT regulations.

5.2 WORK PERFORMANCE DOCUMENTS

ACs rely on human actions and judgment for their implementation. ACs may involve actions, restrictions, or verification steps that are incorporated in WPDs. WPDs include operating procedures, task instructions, and work packages. Steps in the WPDs that implement NCS controls are clearly identified in accordance with the NCS procedure. Because ACs are human based and therefore subject to error in

application, they are less desirable than engineered controls. ACs sometimes are accompanied or enhanced by equipment items or alarms that alert an operator to take action. NCSE requirements or NCSD assumptions are incorporated into WPDs as required by CP3-NS-1031, *Nuclear Criticality Safety Program.*

New and modified WPDs are reviewed by the appropriate safety organizations, including NCS. NCS reviews the WPDs to verify that the appropriate NCSE requirements or NCSD assumptions have been incorporated and to verify that the proposed operation complies with NCSP requirements. The changes to procedures are evaluated by the USQ process for impact on the SB.

5.3 IMPLEMENTATION AND VERIFICATION OF NCSE/Ds

NCS requirements governing FMOs are approved through a formal implementation process prior to initial operation. The verification process is performed by the operations organization and NCS personnel and includes walkdowns, review of training records, and verification of flowdown of NCS requirements into appropriate WPDs. Project supervision is responsible for implementing the requirements delineated in the NCSE/D through training and WPDs. Operational aids, such as postings, labels, boundaries for FMOs, and fissile material movement guidelines are provided. FMOMs ensure postings and labels are prepared and then verify they are installed properly. The WPDs are prepared or modified to incorporate NCSE requirements or NCSD assumptions. FMOMs are responsible for ensuring employees understand NCS requirements and/or assumptions before work begins. Documentation of this verification process is maintained as a quality record.

5.4 LABELING AND POSTING

Administrative aids include NCS signs, postings, and labels. Administrative NCS limits and controls for areas, equipment, and containers are presented through the use of postings and labels (including tags). Postings and labels are proposed, reviewed, and approved during the NCSE review and approval process. Approved NCS documents specify the wording for postings. Labels are prepared in accordance with procedures and used as required by NCS documents and procedures. Postings should supplement written WPDs.

5.5 FISSILE INVENTORY TRACKING

In some FMOs, the fissile inventory may be logged, computerized, or tracked by other means for NCS. Logs or computerized tracking are used in some laboratories to maintain fissile sample inventory within NCS limits.

5.6 NCSE/D CANCELLATION

If an NCSE/D is no longer needed, it may be cancelled. NCS provides the technical basis for cancellation and processes the cancellation as a revision to the NCSE/D. A checklist is completed to verify that WPDs are revised or deleted to remove NCS requirements, postings are removed, and the configuration management system is updated, as appropriate. Documentation of the cancellation is maintained as a quality record.

6. TRAINING AND QUALIFICATION

The NCSP is implemented through the qualification of personnel, training, required reading, staff assignments, and appropriate management oversight. Personnel with NCS responsibilities in the field are trained in their responsibilities as appropriate. For example, fissile material handlers are trained in their FMO responsibilities, including limits on nuclear criticality controlled parameters for their operation (e.g., NCSE-specific training). Personnel in or near facilities where FMOs take place are trained on evacuation procedures (including evacuation drills), as required by ANSI/ANS-8.19 and ANSI/ANS-8.23, *Nuclear Criticality Accident Emergency Planning and Response*. The NCS training program complies with the requirements in DOE O 426.2 and ANSI/ANS 8.20, *Nuclear Criticality Safety Training*.

6.1 NCS ENGINEERS AND CRITICALITY SAFETY OFFICERS

NCS engineers and CSOs undergo a formal training process per CP4-NS-1108, *Nuclear Criticality Safety Engineer Training and Qualification*. CSO training is less rigorous than NCS engineer training, commensurate with their operations oversight responsibilities. Although nuclear theory and facility experience requirements are the same for CSO and NCS engineer candidates, CSOs have apprenticeship requirements focused on operations surveillance rather than the NCS engineer apprenticeship that focuses on NCS evaluation, calculations, and technical reviews.

The D&R NCS engineer and senior NCS engineer qualification programs meet the requirements of ANSI/ANS-8.26-2007, *Criticality Safety Engineer Training and Qualification Program*. NCS engineer qualifications and training required by DOE Regulations, Orders, and Standards are summarized in Table 3. Best practices are provided by DOE handbooks and guides.

A CSO is required to have a subset of the training required by an NCS engineer with focus on rules, standards, and guides; CAAS; and process/facility knowledge. Process/facility knowledge is maintained as NCS personnel spend time in the field each month.

Table 3. Qualifications/Training for NCS Engineers

Item	Requirement	Order/Standard/Guide
Degree and Educational Background	1. BA/BS in science or engineering from an accredited college or university, or 2. At least 5 years of directly applicable experience, or 3. Equivalent combination of education and experience	DOE O 426.2 ANSI/ANS-8.26
Job-Related Experience	1 year if nuclear/physics degreed 2 years for other degreed	DOE O 426.2 DOE O 420.1C
Nuclear Experience	1 year	DOE O 426.2
NCS Calculation Methods	Calculation Techniques or Monte Carlo Calculations	ANSI/ANS-8.26
Critical and Subcritical Experiments (Hands-on) and Data	Lawrence Livermore National Laboratory Hands-on Experiments Class or similar	ANSI/ANS-8.26
Rules, Standards, and Guides	Required Reading of appropriate list of DOE Rules, Standards, and Guides; ANSI/ANS Standards; and Recognized Handbooks	DOE O 420.1C ANSI/ANS-8.19 ANSI/ANS-8.26
NCS Evaluations	NCSE Training	DOE-STD-3007-2007 DOE-STD-1134-99 DOE O 420.1C
SB	SB Training TSR Training Accident Analysis Methods	DOE O 420.1C DOE-STD-3009-94/CN3 ANSI/ANS-8.26
CAAS	CAAS Workshop or Required Reading	ANSI/ANS-8.26
Nuclear Material Control & Accountability (NMC&A) and NDA	NMC&A and NDA Required Reading	ANSI/ANS-8.26
Process/Facility Knowledge	Periodic Walk-downs and Required Reading	ANSI/ANS-8.19 ANSI/ANS-8.26

6.2 OPERATING STAFF

NCS training and qualification for operations and support personnel are dependent upon the extent of NCS controls that are required for the activities to be performed. This includes managers and supervisors who provide oversight of fissile material handlers and support personnel that perform units of work impacting the NCS of a facility. NCS qualification and training requirements for operations and support staff are summarized in Table 4. Best practices are provided by DOE handbooks and guides.

Fissile material handlers are trained, knowledgeable, and qualified to the Training Position Description established for their job classification (e.g., chemical operators, uranium material handlers, decontamination and decommissioning workers, waste handlers).

Each FMOM shall receive particular training related to the criticality safety of operations under their control. In addition, they shall be trained in general criticality safety principles, including the topics required by ANSI/ANS-8.20.

Table 4. NCS Qualifications/Training for Operations and Support Personnel

Who	Requirement	Order/Standard/Guide
FM/FMOM	NCS for Managers/ Supervisors Training	DOE O 426.2 DOE-HDBK-1119-99 ANSI/ANS-8.19 ANSI/ANS-8.20
Fissile Material Handlers	NCS Fundamentals Training	DOE O 426.2 DOE-HDBK-1002-96 ANSI/ANS-8.19 ANSI/ANS-8.20
Fissile Material Handlers and Line Supervision	Training or Briefing on NCS Requirements	DOE O 426.2 DOE-HDBK-1002-96 DOE-HDBK-1119-99 ANSI/ANS-8.19

Training shall be provided in accordance with ANSI/ANS-8.19-2005, Section 5.3. Each supervisor shall ensure that training is provided and shall require that the personnel under his or her supervision have an understanding of WPDs and safety considerations such that they can be expected to perform their functions without undue risk. FMOMs are responsible for removing fissile material handlers (i.e., personnel directly involved in FMOs), who fail any of the examinations associated with the NCS training, from jobs that involve handling of fissile material.

6.3 MANAGEMENT

Management is trained in NCS and ensures all appropriate personnel (i.e., fissile material handlers) receive NCS training, as specified in NCS procedures. This training provides personnel with the knowledge necessary to fulfill their NCS responsibilities.

Training records are controlled in accordance with the Document Control and Records Management procedures.

7. SURVEILLANCES

In order to ensure that the NCSP is properly implemented, the D&R contractor utilizes walk-throughs, programmatic and organizational self-assessments, and NCSP assessments.

7.1 NCS STAFF WALK-THROUGHS

NCS staff (NCS engineers and CSOs) shall periodically perform walk-throughs of FMOs to ascertain that limits and controls are effectively implemented, that WPDs are being followed, and that process conditions have not been altered so as to affect the applicable NCSE or the assumptions in the NCSD. Walk-throughs shall be completed and documented in accordance with CP4-NS-1107, *Nuclear Criticality Safety Oversight*. At a minimum, these walk-throughs are completed for each FMO annually (ANSI/ANS-8.19) and may be performed in conjunction with the assessments discussed in Section 7.3. NCS walk-throughs ensure that the two Integrated Safety Management Systems elements of "Analyze the Hazards" and "Provide Feedback and Continuous Improvement" are performed.

7.2 PROGRAMMATIC SELF-ASSESSMENTS

Programmatic self-assessments are performed by the NCS staff to verify programmatic effectiveness. The NCS staff performs and documents these assessments in accordance with CP4-NS-1107, *Nuclear Criticality Safety Oversight*.

7.3 ORGANIZATIONAL SELF-ASSESSMENTS

Self-assessments are performed by organizations operating with fissile materials in accordance with CP3-NS-1031, *Nuclear Criticality Safety Program*. The self-assessments include the inspection of facility modifications, operating procedures, and compliance with NCS controls. The self-assessments also include walkdowns of NCS required postings, labels, and tags to ensure the wording is clearly visible and readable. These assessments are carried out as part of the annual surveillance of all FMOs. These assessments are conducted and documented in accordance with CP3-NS-1031.

7.4 NCSP ASSESSMENTS

The NCSP is reviewed to ensure compliance with DOE-STD-1158-2010, *Self-Assessment Standard for Contractor Criticality Safety Programs*. The quality manager is responsible for ensuring assessments are performed on the NCSP such that all elements of DOE-STD-1158-2010 are reviewed at least once during a predetermined period. DOE-STD-1158-2010 indicates that an acceptable frequency for accessing the NCSP is once every three years, but that the three-year interval may be adjusted to meet specific site or facility needs.

7.5 METRICS REPORTING

The NCS manager collects performance metrics on NCS anomalous conditions to assist management in determining trends in performance and implement necessary corrective actions. The metrics should discuss NCS anomalous conditions, corrective actions, and root cause trends (if applicable); NCS surveillances performed; assessments performed on the NCSP; and a review of any applicable DOE lessons learned.

8. NCS ANOMALOUS CONDITIONS

Situations found to be out of compliance with NCS requirements are called NCS anomalous conditions. Identified NCS anomalous conditions or potential NCS anomalous conditions, including those identified in walk-throughs, assessments, and audits, are documented and corrected according to the corrective action program. The corrective action program provides a method of developing a corrective action plan, as needed, and a tracking system for any corrective actions. The data is trended to monitor and prevent repeat violations. Corrective actions also will be developed for adverse trends in accordance with the QA Plan Description.

8.1 REPORTING NCS ANOMALOUS CONDITIONS

NCS anomalous conditions (deviations from NCS requirements) shall be reported promptly in accordance with NCSP procedures. NCSP procedures address the NCS engineering response to an NCS anomalous condition or potential NCS anomalous conditions. The response includes assessment of the status of the DCP for the NCS anomalous condition and an evaluation of the severity of the NCS anomalous condition.

Emergencies arising from unforeseen circumstances can present the need for immediate action. Upon discovery of an NCS anomalous condition, the responsible manager takes action to prevent further changes in the configuration of the fissile material until the condition is evaluated by an NCS engineer. If the condition can be evaluated and corrected immediately, the NCS manager (if NCS engineer qualified) or NCS engineer can provide written instructions to bring the condition into compliance with applicable NCS requirements prior to completion of the NCS ACR. If NCS expertise or guidance is needed immediately to avert the potential for a criticality accident, direction will be provided orally or in writing by an NCS engineer. Documentation of the basis for any guidance provided will be prepared after the emergency condition has been stabilized.

8.2 NCS ANOMALOUS CONDITION LEVELS

NCS anomalous conditions are evaluated in NCS ACRs and assigned a severity level as follows.

- **NCS Level 1**—A criticality accident has occurred.

- **NCS Level 2**—NCS nonconformance such that no valid controls and/or process conditions are available to prevent a criticality accident.

- **NCS Level 3**—For operations involving fissile material that have been documented to be doubly contingent, an NCS nonconformance, or discovery of an unanalyzed criticality accident scenario, such that only one credible, unlikely, and concurrent change in process conditions could result in a criticality accident. For operations involving fissile material in which a criticality accident is documented not to be credible, an NCS noncompliance, or discovery of an unanalyzed criticality accident scenario, such that a criticality accident has become credible.

- **NCS Level 4**—For operations involving fissile material that have been documented to be double contingent, an NCS nonconformance, or discovery of an unanalyzed criticality accident scenario, that does not violate the DCP (i.e., conditions are such that two unlikely, independent, and concurrent changes in process conditions are required before a criticality accident is possible). For operations involving fissile material in which a criticality accident is documented not to be credible, an NCS nonconformance, or discovery of an unanalyzed criticality accident scenario, that does not cause a criticality accident to become credible.

- **NCS Level 5**—For nonconformances with administrative aids or changes in facility conditions (e.g., rainwater in-leakage) that do not impact the applicable criticality safety basis but which warrant a review by NCS. NCS or the organization responsible for the operation/facility will document and track the issue using the corrective action program. Nonconformances with administrative aids include, but are not limited to, posting wording issues, missing postings, missing labels/tags, inaccurate labels/tags, missing inventory log entries, and missing boundaries.

8.3 NCS ANOMALOUS CONDITION FOLLOW-UP

ACRs will be reported through occurrence reporting as appropriate. All ACR corrective actions shall be tracked through an approved issues and corrective action tracking system. The NCSP maintains a process to record, investigate, correct, track, and trend NCS anomalous conditions. NCS anomalous conditions are reviewed for trends by the NCS manager. The appropriate lessons learned will be incorporated into WPDs as appropriate.

9. EMERGENCY RESPONSE

9.1 FIREFIGHTING PLANS

A facility pre-incident plan is maintained for each facility. The facility pre-incident plan outlines the building hazards and includes NCS instructions for firefighting as needed. Specific NCS requirements, if any, for firefighting response are included in the NCSE for specific operations per ANSI/ANS-8.22, *Nuclear Criticality Safety Based on Limiting and Controlling Moderators*, as applicable.

9.2 EMERGENCY RESPONSE PLAN

The D&R contractor manages emergency preparedness as described in the Emergency Management Program. During an emergency, an NCS SME [Emergency Operations Center (EOC)-trained NCS engineer] responds to the EOC as directed.

10. RECORDS MANAGEMENT

All NCSEs, NCSDs, surveillance, and implementation review forms are created, identified, controlled, and managed per the Document Control and Records Management procedures.

11. EXCEPTIONS

11.1 DOE O 420.1C COMPLIANCE

DOE O 420.1C, Attachment 2, Chapter III, *Nuclear Criticality Safety*, establishes the requirements for developing and implementing an NCSP. The D&R NCSP was developed using the requirements established in DOE O 420.1C.

Many of the facilities were previously leased to USEC. USEC performed enrichment operations at the Paducah Site under an NRC certificate of compliance. The NCSEs were developed using NRC regulations, ANSI/ANS standards, and USEC-approved procedures. Remediation scope NCSE/Ds were developed using previous versions of DOE Orders and Standards. Although the NCSE/Ds were developed under rigorous NCSPs, the NCSE/Ds may not comply fully with the current DOE Orders and Standards.

Because the NCSE/Ds were developed under rigorous NCSPs, the NCSE/Ds will be accepted as is; however, all new NCSE/Ds and intent changes to existing NCSE/Ds will be performed to comply with the applicable DOE Orders and Standards with the exceptions noted in Table 6.

Each of the requirements identified in DOE O 420.1C, Attachment 2, Chapter III, is discussed in Table 5.

Table 5. Compliance with DOE O 420.1C, Attachment 2, Chapter III

Standard	Requirement or Recommendation	Comment
DOE Order 420.1C Chapter III Req 3.a	A criticality safety program (CSP) document must be developed and maintained that describes how the contractor will implement the requirements in this chapter, including the standards invoked by this chapter.	Compliance with DOE O 420.1C and the applicable standards are identified in Section11.1.
DOE Order 420.1C Chapter III Req 3.b	The CSP document must describe how the contractor will satisfy the requirements of the ANSI/ANS-8 consensus nuclear criticality safety standards in effect as of the date of DOE O 420.1C, unless otherwise modified or approved by DOE. The CSP document must include an explanation as to why any recommendation in applicable ANSI/ANS-8 standards is not implemented.	Compliance with the ANSI/ANS-8 consensus NCS standards is documented in Sections 11.2.
DOE Order 420.1C Chapter III Req 3.c	The CSP document must be submitted to and approved by DOE.	D&R NCSPDD will be submitted and approved by DOE.
DOE Order 420.1C Chapter III Req 3.d	Criticality safety evaluations must be conducted in accordance with DOE-STD-3007-2007, *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities*, or by other documented methods approved by DOE.	It should be noted that the NCSEs used to support enrichment operations at USEC-operated Paducah Gaseous Diffusion Plant facilities were developed using NRC regulations, ANSI/ANS standards, and USEC-approved procedures. Additionally, remediation scope NCSEs were developed under previous versions of DOE Orders and Standards. Although the NCSEs were developed under a rigorous NCS program, the NCSEs do not comply fully with the current DOE Orders and Standards. Because the existing NCSEs were developed under rigorous NCSPs, the NCSEs will be accepted as is; however, all new and intent changes to NCSEs will be conducted in accordance with DOE-STD-3007-2007 as implemented in CP4-NS-1101, with exception noted in Table 6.

Table 5. Compliance with DOE O 420.1C, Attachment 2, Chapter III (Continued)

Standard	Requirement or Recommendation	Comment
DOE Order 420.1C Chapter III Req 3.e	Fissile Material Accumulation Control. Facilities that conduct operations using fissionable material in a form that could inadvertently accumulate in significant quantities must include procedures for detecting and characterizing accumulations. The following national standards provide relevant guidance for procedure development: ASTM C1455, *Standard Test Method for Nondestructive Assay of Special Nuclear Material Holdup Using Gamma-Ray Spectroscopic Methods*; and any other NDA consensus or DOE standards applicable to the measurement technique selected.	The potential to accumulate significant quantities of fissile material is addressed in NCSEs developed in accordance with the NCSP. Controls are established, as appropriate, to detect and characterize accumulations. The controls are implemented in plant procedures.
DOE Order 420.1C Chapter III Req 3.f	Criticality safety evaluations must show that entire processes involving fissionable materials will remain subcritical under normal and credible abnormal conditions, including those initiated by design basis events.	Natural phenomena hazards (NPHs) were not explicitly evaluated in the documents that constituted the USEC NCS program. That program involved identification, evaluation, and control of a conservative and representative set of process upsets to prevent a criticality. That process resulted in identification of the same types of conditions that might result from NPHs, though the natural event that initiates a process upset may not be directly identified. An exception is requested for the historical NCSEs that do not explicitly address NPHs (See Table 6.). Additionally, remediation scope NCSE/Ds were developed under previous versions of DOE Orders and Standards. Although the remediation scope NCSE/Ds did evaluate NPHs, the evaluations may not be in compliance with current DOE Orders and Standards. When new NCSE/Ds are developed, the D&R NCSP will require that the NCSE/D document that the entire process will remain subcritical under normal and credible abnormal conditions, **including those initiated by design basis events.**
DOE Order 420.1C Chapter III Req 3.g	The criteria and process for developing the guidelines for firefighting in areas within or adjacent to moderator-controlled areas must be coordinated with firefighting pre-incident plans and procedures.	Specific NCS requirements, if any, for firefighting response are included in the NCSE for specific operations. The firefighting requirements are implemented in the facility pre-incident plan for each facility.

11.2 EXCEPTIONS TO REQUIREMENTS/RECOMMENDATIONS

According to DOE O 420.1C, the CSP document must describe how the contractor will satisfy the requirements of the ANSI/ANS-8 consensus NCS standards in effect as of the date of DOE O 420.1C, unless otherwise modified or approved by DOE. The CSP document must include an explanation as to why any recommendation in applicable ANSI/ANS-8 standards is not implemented.

The applicable DOE Orders and Standards and ANSI/ANS-8 consensus standards are identified in Section 2.4. The D&R NCSP implements the applicable orders and standards unless otherwise noted. Table 6 provides an explanation as to why specific portions of the orders and standards are not implemented.

Table 6. Exceptions to DOE Orders, Standards, and ANSI/ANS-8 Consensus Standards

Standard	Requirement or Recommendation	Comment
DOE Order 420.1C Chapter III Req 3.f	Criticality safety evaluations must show that entire processes involving fissionable materials will remain subcritical under normal and credible abnormal conditions, including those **initiated by design basis events.**	NPHs were not explicitly evaluated under the USEC NCS program. That program involved identification, evaluation, and control of a conservative and representative set of process upsets to prevent a criticality. That process resulted in identification of the same types of conditions that might result from NPHs, even though the NPH event that initiates a process upset may not be directly identified. The same spills, releases, water leaks, and spacing upsets that might result from a natural phenomenon initiator are addressed in the applicable USEC NCSEs. Those upsets are identified and controlled for initiating events far more common than the probability of occurrence of design basis NPH. A review was conducted to ensure that every FMO has been evaluated for the lower level conditions that might result from an NPH event. Those lower order events include fissile spills/releases, exposure to moderator spray, and the potential for interaction upsets. The review confirmed that each of these lower-order events was conservatively represented in every NCSE through direct hazard identification and contingency analyses or by incorporation of the resulting condition into the normal case for NCS. In many cases, the condition of flooding is conservatively represented by evaluating the fissile material under optimal moderation. In all cases interspersed moderation/reflection between and around fissile units was sufficient to represent sprinkler activation and spray from broken piping. The potential for complete flooding is not always evaluated because flooding is not credible in many areas such as the cell floor. Interaction is addressed through spacing exemptions, batch limit analyses, and spacing controls that are based on the worst-case spacing upset. That spacing upset is typically represented by a fully loaded and optimally moderated waste drum upset. While a seismic event might result in movement of multiple items, their random loading and configuration would still be conservatively represented by the fully loaded and optimally moderated waste drum upset. Based on this review, it is considered unlikely that any resulting configuration from NPH events would result in a system that is not conservatively represented by the current NCSE hazard analyses. Remediation scope NCSEs were developed under previous versions of DOE Orders and Standards. Although the remediation scope NCSEs did evaluate NPH events, the evaluations may not be in compliance with current DOE Orders and Standards. When new NCSEs are developed, the D&R NCSP will require that the NCSE show the entire process will remain subcritical under normal and credible abnormal conditions, **including those initiated by design basis events**.

Table 6. Exceptions to DOE Orders, Standards, and ANSI/ANS-8 Consensus Standards (Continued)

Standard	Requirement or Recommendation	Comment
DOE-STD-3007-2007 Section II.E, paragraph 1 and 2	As part of this effort, the CSE shall document that at least two unlikely, independent, and concurrent changes in **process conditions (i.e., changes in process parameters)** must occur before a criticality accident is possible. **The intent of ANSI/ANS-8.1-1998 regarding application of the Double-Contingency Principle is that two independent process parameters should be controlled**. It is not always possible to control two independent parameters for every process, thus ANSI/ANS-8.1-1998 does not make the Double-Contingency Principle a requirement. DOE O 420.1B also allows DOE to approve cases where the Double-Contingency Principle cannot be met. Therefore, in the case where a criticality accident is credible and only one parameter is controlled, the process does not meet the Double Contingency Principle.	DOE-STD-3007-2007 provides an interpretation of the ANSI/ANS-8.1 definition of the DCP that indicates that DCP cannot be met if only one parameter is controlled. DOE-STD-3007-2007 interprets "process conditions" in the ANSI/ANS-8.1 definition of DCP as meaning "process parameters." This interpretation of DCP is not consistent with that implemented at the Paducah Site. Additionally, ANSI/ANS-8.1-2014 recently was issued with an Appendix B that provides additional information on the DCP. It states, "The DCP, as written, does not refer to parameters or controls. The DCP refers to changes in process conditions, not changes in parameters, or to changes in or the loss of controls. The phrase 'changes in process conditions' is purposefully comprehensive and broader in meaning than the words 'parameter,' 'control,' or 'loss of control.' The phrases 'multiple controls on a single parameter' and 'multiple parameter control' have no bearing on whether the DCP is properly satisfied." NCSEs were developed at the Paducah Site using the definition of the DCP as contained in DOE O 420.1A. As such, some scenarios in an NCSE have multiple controls on a single parameter, and it is stated that the scenario meets the DCP. The ANSI/ANS-8.1-2014 supports the definition of DCP that has been used at the Paducah Site. The D&R NCSP will apply the DCP by implementing controls either on two different parameters or by implementing two controls on one parameter. If two controls are implemented for one parameter, the violation or failure scenarios of the controls shall be independent. This ensures that no single credible event can result in an accidental criticality or that the occurrence of events necessary to result in a criticality is not credible.
DOE-STD-3007-2007, Section II	Content Guidance for Criticality Safety Evaluations	While the essential information (i.e., process description, hazard assessment, and a clear presentation of the controls) is present in the legacy (i.e., USEC/NRC era) NCSA and NCSE for an operation, the format is different than prescribed in this standard, including having two documents (NCSA and NCSE) for an operation versus one document (NCSE). When intent changes are made to these legacy NCSEs, the content requirements of this standard shall be followed.

Table 6. Exceptions to DOE Orders, Standards, and ANSI/ANS-8 Consensus Standards (Continued)

Standard	Requirement or Recommendation	Comment
ANSI/ANS 8.1-1998 Section 4.22	Double Contingency Principle. Process designs should incorporate sufficient factions of safety to require at least two unlikely, independent, and concurrence changes in process conditions before criticality is possible.	There are two operations at the Paducah site in which a single change in process conditions could potentially result in criticality: (1) in-place cascade equipment with deposits greater than a safe mass at system conditions and (2) the removal and handling of cascade equipment with greater than a safe mass outside the cascade. TSR controls are established in the SB document for these operations. As noted above, the D&R NCSP applies the DCP by implementing controls either on two different parameters or by implementing two or more controls on one parameter.
ANSI/ANS 8.3-1997 Section 5.3	The system should remain operational in the event of seismic shock equivalent to the site-specific design basis earthquake, or equivalent value specified by the Uniform Building Code (UBC) that applies to the structure.	The CAAS was previously owned and operated by USEC. Most, if not all, vendors of a CAAS do not perform shake and vibration tests to certify the electronics of the system to design basis earthquake intensities. It is assumed that DOE will not require such testing for the system.
ANSI/ANS 8.3-1997 Section 5.5	The system shall be designed to produce the criticality alarm signal within one-half second of detector recognition of a criticality accident.	At the Paducah Site, not all CAAS alarms are capable of producing the desired signal within one-half second of activation by the minimum accident of concern. However, all CAAS alarms are capable of producing the alarm signal within two seconds of activation by the minimum accident of concern.
ANSI/ANS-8.3-1997 Section 4.2.1	The need for criticality alarm systems shall be evaluated for all activities in which the inventory of fissionable materials in individual unrelated areas exceeds 700 g of U-235, 500 g of U-233, 450 g of Pu-239, or 450 g of any combination of these three isotopes.	USEC evaluated the need for CAAS when developing NCSEs for FMOs. CAAS was required per ANSI/ANS-8.3, unless otherwise approved by the NRC. The NRC granted exclusions to the CAAS coverage requirements for specific operations at the Paducah Site. For these operations, additional ACs were provided to ensure the risk of a criticality remained sufficiently low. The D&R contractor requests DOE approval of a subset of the previously approved CAAS exclusions that will be needed to support deactivation and S&M activities. The CAAS exclusions requiring DOE approval are summarized in Section 4.7.
ANSI/ANS-8.7-1998 Section 4.2.7	Containers of fissile materials in areas with sprinkler systems shall be designed to prevent the accumulation of water.	Legacy containers in storage areas may not be watertight. Water in-leakage was determined to be subcritical for these containers in NCSEs, given credible flooding conditions.

12. REFERENCES

Note: Dates are provided for references that utilize a specific version that is not necessarily the latest approved version of the document. All others are the latest approved version.

10 CFR Part 830, *Nuclear Safety Management*; Subpart B, Safety Basis Requirements

DOE O 420.1C, *Facility Safety*, December 2012

DOE O 426.2, Change 1, *Personnel Selection, Training, Qualification, and Certification Requirements for DOE Nuclear Facilities*, July 2013

DOE-STD-1134-99, *Review Guide for Criticality Safety Evaluations*, September 1999

DOE-STD-1158-2010, *Self-Assessment Standard for DOE Contractor Criticality Safety Programs*, April 2010

DOE-STD-1186-2004, *Specific Administrative Controls*, August 2004

DOE-STD-3007-2007, *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Nonreactor Nuclear Facilities*, February 2007

DOE-STD-3009-94, CN 3, *Preparation Guide for U. S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, March 2006

DOE G 414.1-4, *Safety Software Guide for USE with 10 CFR 830 Subpart A, Quality Assurance Requirements, and DOE O 414.1C, Quality Assurance*, June 2005

ANSI/ANS-8.1-1998, *Nuclear Criticality Safety in Operations with Fissionable Material Outside Reactors*, September 1998

ANSI/ANS-8.3-1997, *Criticality Accident Alarm System*, May 1997

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

ANSI/ANS-8.6-1983, *Safety in Conducting Subcritical Neutron-Multiplication Measurements In Situ*, May 1983

ANSI/ANS-8.7-1998, *Nuclear Criticality Safety in the Storage of Fissile Materials*, December 1998

ANSI/ANS-8.10-1983, *Criteria for Nuclear Criticality Safety Controls in Operations with Shielding and Confinement*, September 1983

ANSI/ANS-8.12-1987, *Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors*, September 1987

ANSI/ANS-8.14-2004, *Use of Soluble Neutron Absorbers in Nuclear Facilities Outside Reactors*, May 2004

ANSI/ANS-8.15-1981, *Nuclear Criticality Control of Special Actinide Elements*, November 1981

ANSI/ANS-8.17-2004, *Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors*, November 2004

ANSI/ANS-8.19-2005, *Administrative Practices for Nuclear Criticality Safety*, May 2005

ANSI/ANS-8.20-1991, *Nuclear Criticality Safety Training*, May 1991

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

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

ANSI/ANS-8.23-2007, *Nuclear Criticality Accident Emergency Planning and Response*, March 2007

ANSI/ANS-8.24-2007, *Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations*, March 2007

ANSI/ANS-8.26-2007, *Criticality Safety Engineer Training and Qualification Program*, June 2007

CP1-NS-1001, *Nuclear Criticality Safety Policy*

CP3-NS-1031, *Nuclear Criticality Safety Program*

CP4-NS-1101, *Nuclear Criticality Safety Evaluations*

CP4-NS-1104, *Nuclear Criticality Safety Response to Off-Normal Conditions*

CP4-NS-1107, *Nuclear Criticality Safety Oversight*

CP4-NS-1108, *Nuclear Criticality Safety Engineer Training and Qualification*

CP1-NS-3001, *Technical Safety Requirements for the U.S. Department of Energy Paducah Site Deactivation Project*

Compliance Evaluation Report: Criticality Accident Alarm System Exclusion, NRC, August 2000

Compliance Evaluation Report: Criticality Accident Alarm System Exclusion, NRC, October 2001