June 23, 2020

To: Angela Chambers, Manager, US DOE Nuclear Criticality Safety Program (NCSP)

From: D. G. Erickson, Chair, US DOE NCSP Criticality Safety Support Group (CSSG) dge

Subject: Response to CSSG Tasking 2020-03: CSSG Review of DOE Order 420.1C, III.3.f

In Tasking 2020-03, the CSSG was directed to review DOE Order 420.1C, III.3.f, define/identify the issues, and propose resolutions to the identified issues.

K. D. Kimball developed the draft for review. The entire CSSG performed a review with most suggestions incorporated.

The CSSG is available to answer any questions that may arise regarding this tasking and response.

cc:

CSSG Members

L. Scott

M. Henley

Attachments:

1. Tasking 2020-03 Final Report

Attachment

Tasking Report 2020-03 - CSSG Review of DOE Order 420.1C, III.3.f

Department of Energy Criticality Safety Support Group
June 2020

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Acronyms

ANS	American Nuclear Society
CSSG	Criticality Safety Support Group
CTA	Central Technical Authority
DOE	Department of Energy
DSA	Documented Safety Analysis
NCS	Nuclear Criticality Safety
NDC	NPH Design Category
NNSA	National Nuclear Security Administration
NPH	Natural Phenomena Hazards
PC	Performance Category
SSC	Structures, Systems, or Components

Executive Summary

Department of Energy (DOE) Order 420.1C, Chapter III, 3.f, has not been changed to reflect recent revisions in the standards associated with the application of Nuclear Criticality Safety (NCS) for Natural Phenomena Hazards (NPH). The Chapter III.3.f requirement invokes actions beyond the NCS process analysis requirement and requires approval of deficiencies in design to be different than that for all other NPH design deficiencies noted in Chapter IV of the Order. The requirement is also inconsistent with DOE-STD-1020-2016 consequence criteria regarding application to safety SSCs. This tasking response provides simple, but specific recommendations for revising DOE Order 420.1C and DOE-STD-3007-2017. Revisions to other DOE directives are not required. These recommended changes will bring consistency between the Order and recent revisions to DOE standards pertaining to the NCS analysis of NPH events.

Purpose of Review

The purpose of this Criticality Safety Support Group (CSSG) tasking report is to review an issue regarding the treatment of design basis events within nuclear criticality safety as directed by Department of Energy (DOE) Order 420.1C, *Facility Safety*. This Order has not been revised since various DOE Standards have been changed that provide guidelines in this area. A review of the evolution of DOE Orders and Standards related to the evaluation of Design Basis Events (DBE) (specifically Natural Phenomena Hazards (NPH)) as it applies to the field of Nuclear Criticality Safety (NCS) is provided. This historical review is used to put context to the issue related to the application of DOE Order 420.1C requirements. A discussion of the issue and a recommendation for resolution are then presented in this tasking report.

Historical Evolution of DOE Orders/Standards Regarding Nuclear Criticality Safety and Design Basis Events

DOE Order 420.1C, Section III, 3.f states:

> *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.*

The first part of the requirement is a restating of the process analysis requirement of ANSI/ANS-8.1-2014 (R2018), Section 4.1.2 that has been in effect since the issuance of the first NCS consensus standards. The addition of the phrase regarding design basis events, however, has generated confusion within the nuclear criticality safety community because design basis events have very little explicit treatment in the American Nuclear Society (ANS) 8-series of standards. The views among the DOE NCS community range from treating design basis events as an abnormal change in process condition requiring the use of the double contingency principle to fulfill the Process Analysis requirement, to the position that a design basis event is entirely outside the scope of a change in process condition and shouldn't be evaluated. An example of this confusion is presented in a recently submitted exemption request by a DOE facility and the subsequent issuance of a National Nuclear Security Administration (NNSA) memorandum (dated July 15, 2019) documenting the Central Technical Authority (CTA) position to try to clear up the requirement. Regardless of the position taken by NCS engineers, the requirement to address design basis events is clearly stated in DOE Order 420.1C.

A historical review of the DOE orders and the associated DOE standards is necessary to understand the root of the confusion regarding design basis events and nuclear criticality safety. The following sections provide information on how the directives have evolved.

Historical Changes to DOE Orders

DOE Order	Relevant Requirement on Design Basis Events and NCS	Impact on the NCS Analysis Process for NPH or DBE
O5480.24 (1992)	The order does not explicitly address design basis events or natural phenomena hazards in the NCS section. However, this order contains many deviations from the ANS-8 standards that created confusion in developing nuclear criticality safety evaluations. The major deviation was a rewording of the double contingency principle.	DBEs or NPH events as typically applied in the Documented Safety Analysis (DSA) process (i.e., a bounding consequence event) were not typically addressed in NCS evaluations. However, some DBEs were typically addressed on the process level under the concept of changes to process conditions. For example, loss of container spacing due to a variety of initiators, including an earthquake short of building collapse, or a localized fire that introduced moderation. However, other design basis events such as tornado strikes were not typically addressed.
O420.1 (9/1995)	Replaced DOE Order 5480.24; however, direction was essentially the same as the prior order. Section 4 of this Order, introduced general requirements regarding NPH events for new facilities that was not NCS specific. An evaluation was to be performed for existing facilities “when there is a significant degradation in the safety basis for the facility”. A plan was to be developed for deviations.	NCS was not specifically called out in the order under the section for NPH. Under a general review, NCS safety significant and safety class structures, systems, and components would be evaluated as part of the NPH evaluation. The existing facility evaluation required by the Order was not required to be in an NCS evaluation.
O420.1A (5/2002)	There were three changes to 420.1 prior to the issuance of 420.1A. None of these changes were significant with respect to NCS.	No new or changed requirements were made.

DOE Order	Relevant Requirement on Design Basis Events and NCS	Impact on the NCS Analysis Process for NPH or DBE
O420.1B (12/2005)	This revision implemented a major shift to use the ANS-8 series of national standards as is. Specific language regarding the double contingency principle and the mandatory implementation of recommendations in the ANS-8 series of standards was removed. However, language stating "No single credible event or failure can result in a criticality" remained.	No new specific NCS requirement with regards to NPH or design basis events were stated. Language in Chapter IV regarding NPH was modified to a minor extent, with the rewording of the primary requirement. The primary requirement now reads (emphasis added): "DOE facilities and operations must be analyzed to ensure that SSCs and personnel <u>will be able to perform their intended safety functions</u> effectively under the effects of NPH." The requirement to evaluate existing DOE facilities and establish a plan for mitigating deficiencies, remained in the order. While no specific mention of NCS is in Chapter IV, safety significant or safety class Structures, Systems, or Components (SSCs) relied upon for NCS would have been evaluated under Chapter IV, as required since the issuance of the original order. The NPH evaluation is not required to be addressed in an NCS evaluation.

DOE Order	Relevant Requirement on Design Basis Events and NCS	Impact on the NCS Analysis Process for NPH or DBE
O420.1C (12/2012)	This order invoked for the first time the application of DOE-STD-1020-2012 for new facility design and for evaluating an existing facility's ability to meet NPH criteria. A new requirement regarding NCS evaluation of design basis events was inserted into this version of the order.	Chapter III, 3.f was created that now requires design basis events (which includes NPH) to be specifically addressed in NCS evaluations. The common interpretation is to invoke the ANSI/ANS-8.1 process analysis methods to the initiating design basis event, making the design basis event potentially subject to evaluation under the double contingency principle of ANSI/ANS-8-1 (this is explained later in the report). The proper approach is to evaluate the impact that DBEs have on process conditions; not the application of the process analysis methods to the DBE itself. Furthermore the specific language of the Order precludes NCS SSCs from being approved under the mitigation plan of Chapter IV. Any non-conformance to Chapter III, 3.f is now subject to a formal exemption requiring concurrence by the Central Technical Authority.

Historical Changes to DOE Standards Specific to NPH

DOE Standard	Relevant Requirement on Design Basis Events and NCS	Impact on the NCS Analysis Process for NPH or DBE
STD-1021-93 (7/1993)	The standard does not address NCS SSCs explicitly. It provides information on how to categorize design criteria for SSCs in general.	This standard indicates that SSCs for NCS would be in the Performance Category (PC)-2 because the SSC "performs emergency functions to preserve health and safety of workers as defined in Section 2.4(d)." The event would not rise to PC-3 because dose would not exceed SSC evaluation guidelines (i.e., 25 rem at the public boundary).
STD-1023-95 (3/1995)	This standard established the NPH assessment criteria and loading factors to apply in design.	This standard has no specific requirements for NCS.

DOE Standard	Relevant Requirement on Design Basis Events and NCS	Impact on the NCS Analysis Process for NPH or DBE
STD-1020-2002 (1/2002)	The first issuance of this standard states NCS SSCs should be either PC-3 or 4 (Appendix B-2). This is based on reference to DOE G 420.1-2, Section 6.1, Paragraph 4, which states that PC-3 SSCs would prevent or mitigate criticality accidents. It is important to note that this standard and DOE G 420.1-2 separate out a criticality accident apart from the consequence based graded approach.	The standard applies a PC for SSCs, but the NCS process analysis method is not affected. However, the precedent is set for establishing the design criteria at PC-3. The CSSG issued Tasking Report 2010-01 that addresses this standard and provided recommendations to the DOE to address concerns.
STD-1020-2012 12/2012	This revision was invoked as a mandatory standard in DOE O 420.1C. Section 2.2.2 of the standard states that the NPH Design Category (NDC) is to be determined based on the severity of unmitigated consequences using the categorization methodology given in Appendix A of DOE-STD-1189-2008. These criteria would place a criticality accident at NDC-1 or 2, depending on the fissionable material process. Section 2.2.2 also states that the only time to consider NDC-3 for SSCs is if the worker is required to remain in the facility for safety related purposes. Contrary to Section 2.2.2, Section 2.3.7 provides explicit requirements for NCS. This section states that "Credible design basis NPH events for the purposes of criticality process analysis are those equivalent to NDC-3." The section then goes on to state: "… SSCs whose safety function establishes single contingency for NPH shall be designed to a NPH Design Category NDC-3 and appropriate limit states (i.e., SSCs whose NPH-initiated failure alone can lead directly to a criticality accident shall be designed to NDC-3 …" Also note that not all NCS SSCs were designated as either safety-significant or safety-class. These portions of the standard would apply to all NCS SSCs.	The combination of DOE O 420.1C and this standard set up a difficult set of analysis parameters for NCS. The statement that an NDC-3 event is credible (never mind that it is a design category with performance criteria), would mean that SSCs designed to PC-2 or NDC-2 could fail under the associated NPH event. It also invokes NPH events such as tornados that were not required to be evaluated for any other NDC-2 SSC. Furthermore, SSCs designed to NDC-2 may have to be upgraded to meet system interaction criteria if they could impact an NDC-3 NCS SSC. The CSSG provided some interim guidance regarding this standard in the Report for Tasking 2015-04, to aid NCS engineers in implementing this standard

DOE Standard	Relevant Requirement on Design Basis Events and NCS	Impact on the NCS Analysis Process for NPH or DBE
STD-1020-2016 (12/2016)	This version of the standard directly incorporated the categorization methodology given in Appendix A of DOE-STD-1189-2008. It also deleted all reference to NCS in recognition that the consequences of a criticality accident should drive the NDC in the same method as for all other nuclear safety SSCs.	Although this eliminated the NDC-3 "event", DOE O 420.1C still mandates that design basis events be analyzed in NCS evaluations as part of the process analysis requirement.

Historical Changes to DOE-STD-3007

DOE Standard	Relevant Requirement on Design Basis Events and NCS	Impact on the NCS Analysis Process for NPH or DBE
STD-3007-93 (11/1993)	This first issuance of the standard established guidelines for preparing criticality safety evaluations. There is no mention of "design basis accidents or events", or of NPH.	Establishes the first set of guidelines for NCS evaluations.
STD-3007-2007 (02/2007)	This version refined the guidelines, but as stated in Section 1, "… This standard imposes no new criticality safety requirements." The revision did add additional guidance on categorizing NCS SSCs as safety significant or safety class for the Documented Safety Analysis. Additionally, a section regarding "Beyond Design Basis" accidents was added. However, this section was limited to the criticality accident and its initiators.	No requirements or guidelines were specifically provided for NPH or design basis events.
STD-3007-2017 (12/2017)	This standard recognized the confusion created by other DOE standards regarding NCS and design basis events and that "The concept of "design basis events" is not explicitly addressed within the ANSI/ANS-8 series of standards under the process analysis requirement." This version of the standard provides guidelines on how to evaluate design basis or NPH events. These guidelines bring the NCS analysis of design basis events in line with other nuclear safety applications.	This is a major new set of guidelines for NCS.

Discussion of Issue

A review of the DOE Orders and Standards shows the following:

1. There has been a stated expectation, if not requirement, that NCS SSCs be designed to PC-3/NDC-3 from 2000 through 2016. This requirement is above and beyond how all other radiological hazards are categorized (by consequence).
2. In 2017, the DOE Standards relevant to NPH were revised to treat NCS the same as all other radiological hazards, by consequence severity. The formal recognition of NCS as fundamentally a worker hazard, establishes that the NDC for NCS SSCs is either NDC-1 or 2.
3. DOE Order 420.1C, Chapter III, 3.f, has not been changed to reflect the changes in the standards. The requirement invokes actions beyond the NCS process analysis requirement and requires approval of deficiencies in design to be different than that for all other NPH design deficiencies noted in Chapter IV of the Order. It is also inconsistent with DOE-STD-1020-2016 regarding application to safety SSCs.

Additional discussion on Item 3, follows.

For new construction, the radiological consequences determine the NDC, and for seismic events the safety function establishes the limit state. Under DOE-STD-1020-2016, this is true for all nuclear safety items, including NCS SSCs. However, the concept of identifying SSCs and their NDC and associated limit state is not addressed in the ANS-8 series of standards. DOE-STD-3017-2017 provides guidance on this topic and how to integrate the information from a design basis event into the process analysis. Additional guidance in DOE-STD-3007-2017 would be useful to clarify that not all NCS related SSCs are required to be designed to a specific NDC. The process analysis, informed by the effects on process changes by a design basis event, may conclude that subcriticality is still maintained regardless of the NDC of the SSCs.

For existing facilities, an NPH evaluation is performed to determine the performance capability of the SSCs, which is then compared to the consequence based NDC (or PC) that the SSCs should be at. If the analyzed performance matches the NDC, no further analysis is performed, and the design basis event is documented in the DSA. If the SSCs do not meet the NDC, a mitigation plan is developed in accordance with DOE Order 420.1C, Chapter IV, and the risk associated with the design basis event is documented in the DSA.

However, for NCS SSCs additional analysis is required by Chapter III, 3.f to evaluate NCS SSCs as part of the ANSI/ANS-8.1 process analysis requirement and documented in the NCS evaluation. Most NCS evaluations within the DOE complex rely on use of the double contingency principle to ensure subcriticality because the history of DOE orders and standards mandated that approach from 1992 (DOE-Order 5480.24) to 2017 (DOE-STD-3007-2017). As such, this method is ingrained in most, if not all DOE NCS programs. DOE-STD-3007-2017 now allows the use of other methods that demonstrate subcriticality, consistent with ANSI/ANS-8.1.

When it comes to NPH events (or other design basis events), the establishment of what constitutes a credible abnormal change in a process condition becomes problematic because the extent of the event may well affect many other SSCs through system interaction effects that are difficult to predict.

The performance criteria and the NPH Design Criteria establish targets for exceedance probabilities. A PC-2/NDC-2 is equivalent to a $4x10^{-4}$ exceedance probability. A PC-3/NDC-3 goal is $1x10^{-4}$. SDC-1, SDC-2,

and SDC-3 use a 2500-year (mean) return earthquake event but apply different design criteria. Figure 1 illustrates the seismic performance goal through a plot of exceedance probability against the peak ground acceleration. These exceedance probabilities may be construed in the process analysis to be credible upsets (i.e., failure of an SSC to meet its performance goal is credible), especially if using conventional nuclear safety definitions for frequency bins.

For other (non-NCS) nuclear hazards, the accident establishes a design category based on consequence and the DSA establishes that SSCs meeting the design category provide sufficient protection as allowed by DOE-STD-3009-2014. Any postulation of the SSC failing its design criteria or that the NPH event is a more severe hazard, constitutes a beyond design basis event evaluation. A beyond design basis is not a concept in the NCS process analysis methods. However, in NCS space, credible abnormal conditions are designated as those to which the facility was designed to meet. Events beyond this design (or evaluation) basis are not considered credible as part of the process analysis requirement in ANSI/ANS-8 standards. Accordingly, DOE-STD-3007-2017 provides guidance to address these topics.

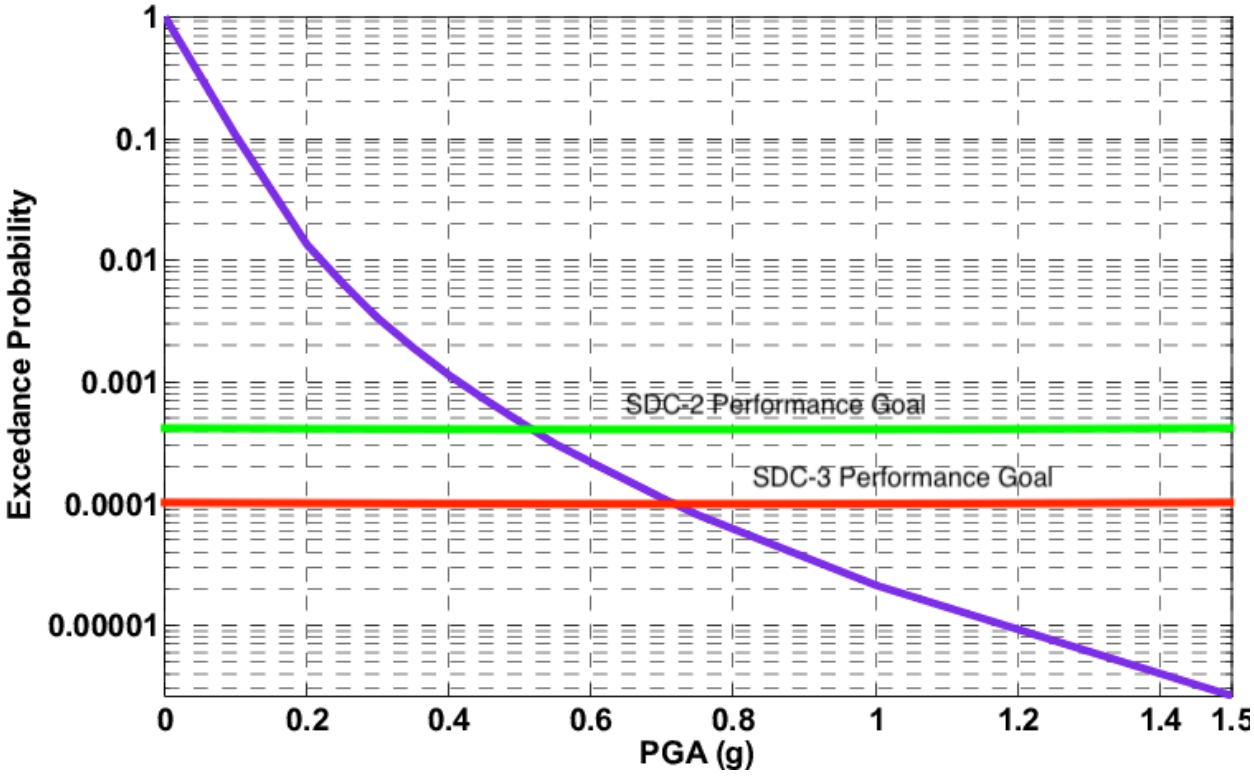

Figure 1 - Illustration of SDC performance goals.

An NDC-3 event was declared to be credible under prior DOE requirements. If a facility's evaluated performance or design criterion is less than NDC-3, the NCS engineer is placed into a near impossible position to evaluate a seismic event that could now cripple the building. This is beyond the concept of an NCS process analysis. One example response to this situation was a DOE nuclear facility that postulated in the DSA that the potential existed for a post seismic criticality accident in a facility may occur if the earthquake forces exceeded the structural design. The conclusion in the DSA was that a criticality accident could not be precluded. No further evaluation was performed. This was approvable in the DSA by the Head of Field Element prior to DOE Order 420.1C. After issuance of DOE Order 420.1C, such a conclusion requires an exemption and is no longer approvable by the Head of Field Element.

If an NCS analyst were to attempt to address a facility with less than an NDC-3 performance goal, the application of the double contingency principle (as defined in DOE standards at the time) could require some other nuclear parameter to be controlled post seismic. Such a requirement could drive the design to beyond an SDC-3 performance goal, which is contrary to DOE-STD-1189. Another possible impact is that it could drive many of the non-safety systems to SDC-3 to protect other nuclear parameters because of potential system interaction. Either approach is very expensive and contrary to how other radiological hazards are evaluated.

Furthermore, DOE Order 420.1C (and its predecessors), requires a 10-year review of NPH data, criteria, and assessment methods. The Chapter IV, Section 3.d(2) of the order states:

> *(2) If a new assessment of NPH indicates deficiencies in existing SSC design, a plan for upgrades must be developed and implemented on a prioritized schedule, based on the safety significance of the upgrades, time or funding constraints, and mission requirements. The upgrade plans must also be submitted to the DOE Head of Field Element for approval. Sections 9.3 and 9.4 of DOE-STD-1020-2016 contain guidance on performing upgrade evaluations.*

Any deficiencies in existing facilities are handled through this plan, as approved by the DOE Head of Field Element. However, if the deficiency involves an NCS SSC, this plan is not sufficient to comply with Chapter III, 3.f, which now requires an exemption because subcriticality may not be ensured through the process analysis. The treatment between NCS and other nuclear safety SSCs is inconsistent.

It is agreed to by the CSSG, that if NCS SSCs cannot meet the appropriate NDC for a criticality accident, either the basis for subcriticality must still be demonstrated (e.g., through analysis) or that the risk of the single-contingent event should be documented and addressed appropriately so that the DOE is advised of the risk. This does not mean that the NCS Evaluation is the only acceptable document for this purpose. A facility level document used as part of the NPH review specified in DOE Order 420.1C, Chapter IV.d could suffice. Presently, the wording of the Order implies that the evaluation of design basis events must be part of the NCS Evaluation.

The relevant DOE Standards (e.g., DOE-STD-1020, 1189, 3007, and 3009) have been revised to treat NCS hazards the same as other radiological hazards, including design basis events and NPH. DOE Order 420.1C has not been revised to address these changes.

Proposed Resolution

The CSSG recommends the following to the DOE to resolve the wording in DOE Order 420.1C:

1. Revise DOE Order 420.1C as follows:
    a. Change the approval authority for NCS analysis of design basis events to the Head of Field Element, consistent with the approval of all other nuclear safety analyses (e.g., DSA)
    b. Insert a provision that design basis events shall be evaluated by NCS and that an acceptable methodology is contained in DOE-STD-3007. The provision should also state that the method to document this evaluation could be described in the NCS Program Description Document required by DOE Order 420.1C, which would receive approval by the Head of Field Element.
    c. Insert a provision that for NPH events, any deficiencies may be addressed through the existing facility NPH assessment upgrade plans as allowed in Chapter IV.4. Any single

contingent Design Basis Events would also be documented in the DSA as required by DOE-STD-3009-2014.

d. Draft wording/changes to the Order are provided below to communicate intent:
    - Add to Chapter III, Requirement 3(b) the following sentences: "The CSP document must present the methodology to be used when evaluating a design basis event (or evaluation basis event) if the method differs from the guidance of DOE-STD-3007-2017. The CSP must also present how deficiencies in NPH design affecting SSCs with an NPH/NCS safety function will be addressed.
    - Delete Chapter III, Requirement 3.f. The first part of the requirement is the process analysis requirement (i.e., a SHALL statement) of ANSI/ANS-8.1, which must be committed to in the Criticality Safety Program (CSP) document required by Chapter III, 3(a) and (b), and is also required by DOE-STD-3007-2017. The second part of III.3.f regarding design basis events is addressed in the proposed wording change above.

2. Revise DOE-STD-3007 as follows:
    a. Perform a minor change to make the language consistent with the revision to the revised DOE Order 420.1C.
    b. Revise the design basis event guidelines, if necessary, to be consistent with how other radiological hazards establish design criteria and evaluate such events. (Note: the CSSG believes that such guidance already exists in DOE-STD-3007-2017 but a review is warranted.)
    c. Provide for the allowance that design basis event evaluations may be documented separately from the criticality safety evaluation described in DOE-STD-3007. This would allow for more efficient inclusion in the NPH review required by DOE Order 420.1C, Chapter IV.

The above recommendations would make the Order consistent with the approaches of the other DOE standards. No other DOE standard or sections of DOE Order 420.1 would require revision.

References

ANSI/ANS-8.1-2014 (R2018), *Nuclear Criticality Safety in Operations with Fissionable Material Outside Reactors*

DOE-STD-1023-95, *Natural Phenomena Hazards Assessment Criteria*

DOE Order 420.1, 402.1A, 420.1B, 420.1C, *Facility Safety*

DOE Order 5480.24, *Nuclear Criticality Safety*

DOE-STD-1020-93, -2002, -2012, -2016, *Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities*

DOE-STD-1189-2016, *Integration of Safety into the Design Process*

DOE-STD-3007-93, -2007, -2017, *Preparing Criticality Safety Evaluations at Department of Energy Nonreactor Nuclear Facilities*

DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*

NNSA Memo, James J. McConnell to Geoffrey Beausoleil, *Central Technical Authority Position on Considering Design/Evaluation Basis Events in Criticality Safety Evaluations per DOE Order 420.1C, Chg 2, Facility Safety*, dated July 15, 2019

Attachments

Attachment 1 – CSSG Tasking 2020-03, *CSSG Review of DOE Order 420.1C*

CSSG TASKING 2020-03
Date Issued: March 4, 2020

Task Title:

CSSG review of DOE Order 420.1C, III.3.f.

Task Statement:

Since its' inclusion in DOE O 420.1C, III.3.f, the phrase "… including those initiated by design basis events." has been problematic. The CSSG is directed to review DOE Order 420.1C, III.3.f, define/identify the issues, and propose resolutions to the identified issues. The final report will then be transmitted to the NCSP Manager for sharing within the greater DOE community as necessary.

Period of Performance:

The tasking report will be developed within forty-five days of the date the tasking is issued to the CSSG.

Resources:

Contractor CSSG members will use their FY20 NCSP CSSG support funding; DOE CSSG members will provide funding from their site offices.
CSSG emeritus members may be included on a voluntary basis.

Task Deliverables:

1. Kevin Kimball will develop draft white paper and distribute to CSSG by March 6, 2020.
2. CSSG to provide comments by March 27, 2020.
3. CSSG Chair and Deputy Chair address comments and issue final report to NCSP Manager by April 10, 2020

Task Due Date: April 10, 2020

Signed: Angela L. Chambers

Angela Chambers, Manager US DOE NCSP