28 February 2014

To: Dr. J. N. McKamy, Manager, DOE NCSP

From: Fitz Trumble, Chair, DOE CSSG

Subject: CSSG Tasking 2013-01 Response

The CSSG has completed its action on Tasking 2013-01 CSSG Position on Use of Water for Firefighting in Light of Criticality Constraints.

The drafting team consisted of the following CSSG members:

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The draft response was reviewed by the members of the CSSG and by Sharon Steele (NA-00-10, Fire Protection SME). Comments from that review were considered for the enclosed final version of the response that is attached to this memo. This version represents a consensus position by the entire CSSG.

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Response to CSSG Tasking 2013-01

CSSG Position on Use of Water for Firefighting in Light of Criticality Constraints for DOE Facilities

January 24, 2014

Executive Summary

The CSSG was directed to provide its professional judgment on the acceptable use of water as a firefighting medium in light of its potential for initiating a criticality accident. Three potential areas of conflict between fire protection and nuclear criticality safety have been identified and are addressed in this report: (1) moderation/reflection effects of sprinkler activation; (2) moderation/interaction effects and potential for redistribution of fissile material from manual firefighting; and (3) requirements for the collection of fissile material in sprinkler water runoff drains/tanks. In the majority of cases, these conflicts can be managed using an integrated engineering approach and realistic upset scenarios in the design and licensing of a facility without unnecessary restrictions on the use of fire suppression water.

This report includes responses to the four basic lines of interrogation posed in the tasking. The official tasking is provided as Attachment A.

1. *Evaluate under what conditions current regulations drive the requirements for the use of water in firefighting (DOE Orders, NFPA codes, etc.).*

    DOE O 420.1 does mandate the use of automatic suppression in significant facilities (a nuclear facility is considered significant). Water-based suppression is the most common automatic suppression system used at DOE facilities. However, ***there is no absolute mandate for installing water sprinkler systems in all facilities***. Both DOE standards and the NFPA codes indicate that water-based sprinklers are ***expected*** to be used in fissile material areas after considering the potential for criticality accidents. Any deviation from the expected use of sprinklers is required to have a ***compelling justification*** and to have exhausted other reasonable alternatives for controlling the criticality hazard. Not providing automatic suppression requires an ***exemption*** from the explicit requirement in DOE O 420.1. Not providing water-based suppression does NOT require an exemption.

    NFPA 801 requires defense-in-depth for fire protection at facilities handling radioactive material which includes both "controlling and extinguishing promptly those fires that do occur, thereby limiting damage and consequences." Automatic sprinkler systems are designed to control or suppress fires and are highly effective and reliable. However these systems are not fail-proof. "Based on fires reported to U.S. fire departments from 2002 through 2004, excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, sprinklers operate in 93 percent of all reported structure fires large enough to activate sprinklers. When they operate, they are effective 97 percent of the time, resulting in a combined performance reliability of 90 percent."[1] These numbers represent the commercial industry and are biased by cases in which the automatic sprinklers did not work. The inclusion of fire sprinklers as TSR-level controls

[1] NFPA Journal®, *March/April 2008,* John R. Hall, Jr.

within the DOE complex leads to the expectation that the probability sprinklers will fail to operate is highly unlikely. Sprinklers in the DOE nuclear facilities are effective more than 98% of the time[2]. Still, manual extinguishment by firefighters is relied on as the final defense in a robust fire suppression system.

American National Standard ANSI/ANS-8.1 requires that unlikely and credible upset/accident conditions be analyzed for their potential to cause a criticality accident. Water is very effective as both a moderator and a reflector and therefore is a concern for criticality safety. Therefore, the effects of fire sprinkler activation, manual firefighting with water (or other hydrogenous media) and material relocation resulting from fires or firefighting will be analyzed in a properly-prepared criticality safety evaluation (CSE)[3]. ANSI/ANS-8.22 has specific requirements for areas where operations are such that the limitation or control of moderators is deemed necessary to achieve criticality safety. Specific guidance is given in section 5.4 of ANSI/ANS-8.22 to address fire prevention and suppression for these areas. The results from these analyses should be referenced in the Fire Hazards Assessment (FHA) to help identify appropriate fire-fighting actions, including the decision to select automatic water-based suppression.

Requirements and guidance related to evaluating the impact of water on criticality safety also exist in NFPA 801. These requirements reflect the importance of integrating criticality safety and fire safety concerns. The specific requirements in NFPA 801 should be reviewed by a joint fire safety and criticality safety team. Those requirements that more appropriately apply to <u>how</u> to perform the analysis rather than describe <u>what</u> needs to be done to assess the potential impact of water intrusion on facility criticality safety (see item 4 below) should be reviewed and the appropriateness of maintaining this information in NFPA 801 be reconsidered.

2. *Evaluate the relative risk to the facility worker, the co-located worker and the public from the fire and the criticality accident. What other disciplines should be considered (operations; safeguards & security; industrial safety; radiation protection).*

   Criticality accidents in process operations are rare, localized events with significant health consequences only to the nearby worker in unshielded circumstances. Radioactive material dispersal impacting human health, either inside the facility or external thereto has been insignificant from the known 22 process criticality accidents. Fires can occur of any magnitude and with varying consequences to life, health and to radioactive contamination/dispersal. Major fires in nuclear facilities also have been rare, but could impact co-located workers and the public, largely from material contamination and dispersal, both radioactive and chemical. The paucity of data on the consequences of both types of accidents makes a formal risk analysis difficult and could produce results with high uncertainties.

   Under extreme conditions when despite all analysis, controls and planning, a fire grows beyond the capability of the fire prevention, detection and suppression features included in facility design and operations, the relative risk to the public and co-located workers should be the primary consideration in selecting the ultimate firefighting response. In such a scenario, the options are likely to be limited to two: (1) use manual firefighting (fire hoses) to fight the fire or (2) allow the fire to burn to prevent the criticality accident. A fire of this magnitude would

[2] Frank *et al.*: A review of sprinkler system effectiveness studies. *Fire Science Reviews* 2013 **2**:6.
[3] ANS/ANSI-8.1

require a risk-based command decision of the Fire Chief based on analysis of scenario-specific conditions.

3. *Provide guidance on the proper justification for restrictions on water for fighting fires within DOE facilities with regard to criticality safety (in keeping with words in DOE 0 420.1C).*

   Automatic fire suppression systems are mandated by DOE O 420.1C and generally involve water. For all process operations involving significant quantities of fissile materials ANSI/ANS-8.1 requires that unlikely and credible upset/accident conditions be analyzed for their potential to cause a criticality accident. Water from both sprinkler systems and from manual firefighting operations should always be explicitly addressed as a consequence of a credible fire and documented in the CSE or related facility safety documentation.

   If the results of the CSE indicate that firefighting water would likely result in a criticality accident and if workers, including firefighters or other emergency response personnel, could be expected to receive life threatening radiation doses from the criticality accident, then this would generally be an unacceptable situation and justification to preclude/restrict water-based fire suppression systems. Appropriate justification would include documentation that efforts had been taken to evaluate changes to the process and design to reduce the criticality accident risk to an acceptably low level and permit water-based systems. The use of alternate fire suppressants (non-aqueous or water-mist) would be required prior to seeking exemption from the DOE O 420.1 requirement for automatic suppression. The use of alternate fire suppressants and moderator restrictions will also require coordination with the pre-incident fire plan and local first responders regarding the use of fire hoses.

4. *Determine and suggest if there are changes that need to be made in either the criticality or fire protection standards to ensure harmonization of these requirements?*

   DOE O 420.1C provides little specific guidance concerning the harmonization of fire and criticality accident risks. However, it invokes both the ANSI/ANS-8 series of nuclear criticality safety standards and essentially all NFPA codes and standards. Implementing the ANSI/ANS-8 standards assures that water, including that from automatic sprinkler systems as well as from manual firefighting actions is considered in analyzing and documenting criticality accident risks, but the standards provide no specific guidance to fire prevention or firefighting operations. The NFPA codes, NFPA 801 in particular, do provide some specific requirements pertaining to criticality accident prevention. It is recommended that the criticality safety-related text be reviewed and the appropriateness of maintaining this information in NFPA 801 be reconsidered. Some examples and suggestions for text changes are given in Table 1.

   Development of requirements and guidance to train fire safety and criticality safety professionals about this important interface is highly recommended. The *Nuclear Criticality Safety Guide for Fire Protection Professionals in Nuclear Facilities* (1994 DRAFT version[4]) contains much valuable information for training fire protection professionals, but needs significant updating and then should be issued formally. The issuance could be in any of several forms: a stand-alone document, an annex to NFPA 801 or incorporated into DOE STD 1066, etc.

[4] There is no record of this document being issued and distributed as anything other than a DRAFT.

In order to promote harmonization, modifications to Appendix A of ANSI/ANS-8.1 are recommended to include firefighting scenarios as specific examples of "changes in process conditions" to be evaluated (see Attachment B).

It is recommended that a committee made up of one or two CSSG members and one or two DOE Fire Protection experts should be tasked with scrubbing the various NFPA codes for inappropriate guidance concerning criticality safety. This team should also note guidance statements that, while inappropriate in NFPA documents, might be helpful to criticality safety practitioners and pass them along to ANSI/ANS-8 for consideration for incorporation into ANSI/ANS-8.1 (see Attachment B for an example for incorporation) or other ANSI/ANS-8 standards.

1.0 Introduction

The CSSG was tasked to provide guidance on the acceptability of the use of both automatic and manual, water-based, fire suppression options for fighting fires when in the presence of significant quantities of fissile material. This includes overhead sprinkler systems, hand-held fire extinguishers and fire hoses that might be used by firefighters/emergency responders. There has not been, nor are there today, rigid regulatory directives that either mandate or prohibit the use of water on fires involving, or in the vicinity of, fissile materials. Local professional judgment, based on the particulars of the situation, has been the determinant.

It is well understood that water has the potential to exacerbate criticality hazards when acting either as a moderator or as a reflector. For example, the minimum critical mass of loose, dry powders of highly enriched uranium or plutonium is many tens of kilograms but when mixed with water the critical mass can decrease dramatically and the minimum critical mass (i.e., at optimally moderated and fully reflected conditions) can be less than one kilogram. This has led some facilities and process operations to restrict the use of water for firefighting operations and to not install automated, water-based, fire suppression systems such as overhead sprinklers in all locations. Decisions on whether to install sprinkler systems or whether to plan for the manual use of firefighting water or alternative firefighting methods (e.g., magnesium oxide or graphite powders for Class D metal fires) should be made based on available historical data and a multi-disciplinary analysis of current and planned operations.

The performance of water-based automatic sprinkler systems is well established and demonstrated to be highly effective in suppressing and extinguishing fires. Automatic sprinklers can also protect against a criticality hazard because they provide assurance that an analyzed geometry can be maintained compared with alternate fire-fighting methods that might utilize compressed gasses to distribute fire suppression agents.

There are many issues to be considered, even beyond those that involve the criticality safety and fire protection professionals. These include operations, industrial safety, health physics, safeguards and security, costs - both in facility and process designs as well as in on-going operation and maintenance, facility down-time and programmatic impacts, and the health and safety risks to workers in the immediate vicinity, co-located workers, and the public. Clearly, the decision on when and where to plan for the use of water for firefighting in fissile material process areas should be the result of a thorough analysis.

2.0 Discussion

The general issue of the appropriateness of the use of water for firefighting in areas with significant quantities of fissile material has been discussed and debated over the decades. It is generally agreed that there is not a one-size-fits-all, black and white answer. This tasking response delves into this issue by providing in-depth responses addressing the four lines of inquiry found in in Attachment A. Three potential areas of conflict between fire protection and nuclear criticality safety have been identified and are addressed in this report: (1) moderation/reflection effects of sprinkler activation; (2) moderation/interaction effects and potential for redistribution of fissile material from manual firefighting; and (3) requirements for the collection of fissile material in sprinkler water runoff drains/tanks.

2.1 Evaluate under what conditions current regulations drive the requirements for the use of water in firefighting (DOE Orders, NFPA codes, etc.).

The primary sources of requirements and guidance related to firefighting and criticality safety are:

1) DOE Order 420.1C, *Facility Safety*
2) NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials*, 2014 Edition
3) DOE STD 1066-2012, *Fire Protection*
4) ANSI/ANS-8.1, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside of Reactors,* (1998, Reaffirmed 2007)
5) ANSI/ANS-8.7, *Nuclear Criticality Safety in the Storage of Fissile Materials,* (1998, Reaffirmed, 2007)
6) ANSI/ANS-8.22, *Nuclear Criticality Safety Based on Limiting and Controlling Moderators,* (1997, Reaffirmed 2011)
7) *Nuclear Criticality Safety Guide for Fire Protection Professionals in DOE Nuclear Facilities*, Draft B, June 30, 1994
8) 2012 International Building Code, IBC, Section 903, *Automatic Sprinkler Systems*[5]

Requirements for all aspects of criticality safety and fire protection are established in DOE O 420.1C, *Facility Safety*. Through this Order, the requirements and recommendations of the ANSI/ANS-8 series of criticality safety consensus standards, DOE-STD-1066-2012, *Fire Protection* and applicable National Fire Protection Association (NFPA) codes and standards are established as requirements.

Chapter III of DOE O 420.1C contains few specifics on either criticality safety or firefighting. It basically requires adherence to the ANSI/ANS-8 criticality safety standards plus a requirement to coordinate firefighting plans for moderator-controlled areas. Chapter II of the DOE O 420.1C invokes the NFPA codes and standards, but gives DOE O 420.1C precedence in case of conflicts. Both chapters require NCS staff to review firefighting plans related to moderator-controlled areas.

Chapter II of DOE O 420.1C requires that technical justification be provided for restricting the use of water for fire suppression. Although not explicitly stated in the Order, this would typically be done in the applicable CSEs, in which ANSI/ANS-8.1 requires evaluation of off-normal situations such as activation of sprinkler systems or other potential water ingress scenarios.

There are multiple NFPA codes and standards that prioritize the use of automatic sprinkler systems based on the presence of specific hazards or as a tradeoff to other fire protection features. Key codes include:

- NFPA 30: Flammable and Combustible Liquids Code, 2012 Edition
- NFPA 45: Standard on Fire Protection for Laboratories Using Chemicals, 2011 Edition
- NFPA 101: Life Safety Code, 2012 Edition
- NFPA 400: Hazardous Materials Code, 2013 Edition
- NFPA 484: Standard for Combustible Metals, 2012 Edition
- NFPA 801: Standard for Fire Protection for Facilities Handling Radioactive Materials, 2014 Edition

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[5] The pertinent section of the IBC discussed later provides for criticality safety by inference (i.e. criticality safety is a condition where the application of water constitutes a serious life hazard).

- NFPA 80A: Recommended Practice for Protection of Buildings from Exterior Fire Exposures, 2012 Edition

Similar to the requirements of DOE O 420.1, the 2012 International Building Code (IBC), Section 903.3.1.1.1, provides for "exempt locations" [i.e. exempt from sprinkler coverage]. The guidance provided in the IBC for exceptions to sprinkler coverage includes spaces where the application of water, or flame and water, constitutes a serious life or fire hazard. Criticality safety concerns, similar to areas with water-reactive materials (e.g. NFPA 484) may in some circumstances fall under this description. Evaluation by subject matter experts in both criticality safety and fire protection is required to make a determination of relative risk.

Paragraph II.3.a.2.c of DOE O 420.1C provides a method to address conflicts which should be exercised to modify the fire protection requirements where a criticality accident is a valid concern. Effectively this paragraph sends the reader to the equivalency/exemption paragraphs 3.c of DOE O 420.1C. Consistent with DOE O 420.1C, NFPA 801 does not mandate [i.e. permits deviation from] the use of sprinkler systems in all areas that contain fissile material.

> ***NFPA 801, Annex C, C.2.2: "****. . .Some form of automatic protection, such as automatic sprinklers, is highly advantageous wherever combustibles are encountered. . .However, caution should be exercised to ensure that the hazards of criticality and reactivity are considered."* [emphasis added]

Automatic sprinklers are clearly recognized as highly effective in addressing multiple needs: property protection, mission protection, hazard mitigation, and design tradeoffs (versus other fire protection features). Requirements for property and mission protection are established through DOE O 420.1C. Hazard mitigation and design tradeoff requirements are also established through NFPA codes. Hazard mitigation is based on the use of the facility (e.g., laboratory as defined in NFPA 45) or the specific hazard (e.g., flammable liquids as defined in NFPA 30). Design tradeoff examples are substituting suppression for a reduced fire wall rating or longer exit travel distances. The hazards of other forms of automatic protection must also be considered in light of the fatalities at INL due to inadvertent activation of a CO_2 fire suppression system. Again, consideration of criticality safety hazards from sprinkler activation should always be considered in the CSE: thus this does not impose any new requirements for the criticality safety analyst.

Another concern that is highlighted in NFPA 801 addresses the collection of water from firefighting activities in fissile material handling facilities.

> ***NFPA 801, Section 5.10 CAUTION:*** *For facilities handling fissionable materials, areas where water can accumulate shall be analyzed for criticality potential.*

The criticality safety engineer must not only evaluate the effect of firefighting activities on the intact fissile material or arrays, but must consider the possibility that fissile materials may escape their containers, may oxidize in the fire and may result in slurries that collect in sumps, trenches or floors without drains. ANSI/ANS-8.7 has a specific requirement related to the accumulation of sprinkler water:

> ***ANSI/ANS-8.7, 4.2.8:*** *In fissile material storage areas equipped with sprinkler systems, consideration shall be given to the possibility of criticality occurring in an accumulation of runoff water from the sprinkler system.*

If the applicable CSEs for a facility are done properly, the potential effects will be considered as part of the fire scenario analysis. All sources of firefighting water must be considered in these evaluations. Automatic suppression systems are designed to control fires, but not necessarily to extinguish them unless it is a special system design. Therefore, manual firefighting is relied upon for defense-in-depth to extinguish fires even if a fixed sprinkler system is installed. The criticality safety analyst must address the possible impact on credible arrangements of the fissile material to evaluate the criticality safety risk from manual firefighting. Some guidance should be provided to the criticality safety analyst to define "credible" arrangements since manual firefighting is much more likely to lead to the dispersal rather than the collection of loose fissile material. NFPA 801, Section 5.10 establishes the design basis for drainage/containment of runoff water and thus provides an adequate basis for the volume and rate of water from sprinklers and fire hoses required to support the analysis in the CSE. Features for the drainage/accumulation of runoff water (from both manual firefighting as well as sprinklers) should be evaluated for criticality safety.

Although there may be some value in having this caution in the NFPA 801 text in order to alert the fire safety professional that this is an example of a condition that requires interfacing with local criticality safety staff, there is no actionable impact of the statement. The fire professional will not perform the analysis and the criticality safety professional is already required by ANSI/ANS-8.1 to perform the analysis. ANSI/ANS-8.1 is the overriding guidance for criticality safety professionals that, when followed properly, will result in firefighting issues of all kinds having been properly weighed in the design of fissile material operations (including storage) and in deriving their limits and controls.

2.2. Evaluate the relative risk to the facility worker, the co-located worker and the public from the fire and the criticality accident. What other disciplines should be considered (operations; safeguards & security; industrial safety; radiation protection).

There is no global answer to which accident carries a higher risk to people, but is dependent on individual facilities and operations. Criticality accident risks and the risks associated with large fires in nuclear facilities are not readily quantifiable due to the paucity of data. From a likelihood perspective, criticality accidents in process operations are very rare. There have been only 22 reported worldwide in the last 60+ years, with only 7 in the US. The last US criticality accident occurred in 1978, with 1999 being the year of the most recent accident reported worldwide.[6] Because of the small number of accidents, the data do not support direct development of a likelihood estimate. Other methods do exist to build likelihood estimates (e.g., event trees) but are often impractical to implement due to incomplete data for equipment and process failure rates and being resource intensive. The 7 US criticality accidents have all occurred with fissile material in process liquids and it is less likely that one would occur in a metal or dry powder. Both a metal criticality accident and a criticality accident in what were normally dry powder operations have occurred outside of the US. Therefore, the potential that the addition of fire-fighting water could to lead to a criticality accident must be evaluated for both solution and non-solution operations.

The consequences of a criticality accident, while situation-dependent and dependent on the number of fission events, are generally able to be bounded based on historical accident data and on experimental investigations. From the 7 US criticality accidents there have resulted 2 fatalities and no serious injuries.

[6] "A Review of Criticality Accidents - 2000 Revision", Los Alamos National Laboratory, Los Alamos, New Mexico, LA-13638, pp. 35-36 (May 2000.)

The mechanical damage associated with these accidents was minimal and did not result in the generation of hazards other than the prompt radiation from the fission process. It is unlikely that lethal radiation doses would be received by workers more than a few meters from a criticality accident or significant doses be received from distances more than several meters distant. Thus, it is generally accepted that a criticality accident is a worker-safety issue and not a health issue for either the co-located worker or the public.

Due to the minimal kinetic energy generated by the fission process in solutions there has not been, nor is there any expectation of, widespread dispersal of material, whether it is radioactive or chemical, resulting from a criticality accident. Thus, considering the totality of the accident, it is concluded that the criticality accident risk lies almost exclusively with the immediate worker.

Fires, while relatively common in a general sense, are much less common in nuclear facilities. Somewhat akin to criticality accidents, the frequency of significant fires in facilities that process fissile materials has been extremely low over the last few decades. Annual data compilations for fires of all sizes and consequences in nuclear facilities are available through the HSS website for the last few decades (since 1992[7]). Based on a review of the "Loss Summary Reports" in the Fire Protection Database[8] (1991 to 2012), it was concluded that small fires are not uncommon, but have not resulted in significant, reported consequences. No summary documentation for fire safety documentation prior to 1991 was identified. The last known major fire in a non-reactor nuclear facility occurred in 1969 at the Rocky Flats Plant.

While large fires can lead to major dollar and capability losses, they can also result in widespread contamination within the facility and outside, associated with the thermal plume. The contamination in the plume from a major nuclear facility fire could be chemical as well as radiological. A fire that breaches a nuclear facility could have some impact on the health and safety of the public dependent on the radiological inventory and the distance to the site boundary. Were plutonium the fissile material in the plume then the radiological contamination costs and possible public health issues would be orders of magnitude greater than were the fissile material uranium, all else being the same. However, while the radiological risk to the co-located worker or the public from uranium dispersal is much less than from plutonium, there could be significant costs involved in the recovery from soil contamination as well as from health concerns from the public, including psychological impacts as observed following the Fukushima accident[9].

One can conjecture that a fire could lead to a criticality accident and also the converse. If the CSE is thorough, then these possibilities will be explored and process operation or firefighting controls/restrictions implemented as needed. The use of a total (*sic* integrated) engineering approach to evaluate design options is essential to eliminating/mitigating any potential conflicts between criticality safety and fire safety[10]. The follow-on event, whether it be the fire or the criticality accident will be shown to be of acceptably small incremental risk via the Documented Safety Analysis (DSA) process before operations are authorized.

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[7] http://homer.ornl.gov/sesa/corporatesafety/fpreports.html

[8] https://fp.hss.doe.gov/Reports.aspx

[9] *The Health Effects of Fukushima,* World Nuclear News, 28 August 2012, http://www.world-nuclear-news.org/RS_The_health_effects_of_Fukushima_2808121.html

[10] Keigher, Donald, Fire Protection Work-Discussion Session, Nuclear Criticality Safety, Proceedings of a Short Course held at the D.H. Lawrence Ranch near Taos, NM, May 7-11, 1973, pp 143-152, TID-26286 (1974).

A comprehensive review of the consequences of firefighting water should always be performed and documented as a part of CSEs for process operations per ANSI/ANS-8.1 requirements. These evaluations may provide input to multi-disciplinary discussions and eventual conclusions as to the relative risk of fires and criticality accidents as well as other risks such as industrial safety, radiation exposures, etc., that might be impacted by either fires or criticality accidents.

Under extreme conditions when despite all analysis, controls and planning, a fire grows beyond the capability of the fire prevention, detection and suppression features included in facility design and operations, the relative risk to the public and co-located workers should be the primary consideration in selecting the ultimate firefighting response. In such a scenario, the options are likely to be limited to two: (1) use manual firefighting to fight the fire or (2) allow the fire to burn to prevent the criticality accident. A fire of this magnitude should be beyond design basis and therefore the recommendation would be a risk-based command decision of the Fire Chief. Although an extremely low probability event, the factors important to this decision process (assessing relative risk of a criticality accident and the spread of contamination) should be documented as part of the pre-incident fire plan or emergency response procedures and training.

2.3. Provide guidance on the proper justification for restrictions on water for fighting fires within DOE facilities with regard to criticality safety (in keeping with words in DOE 0 420.1C).

Due to its cost, ease of application and cleanup, and effectiveness in extinguishing fires, water is the preferred firefighting agent for nearly all applications, both for nuclear and non-nuclear operations. It is also well known that water is an excellent neutron moderator and reflector and can result in significant reductions in the fissile mass required to reach the critical state. For this reason all CSEs have to either explicitly or implicitly account for the likelihood and consequences of firefighting water being added to or reflecting the fissile material being processed.

In all non-reactor nuclear facility operations, the result of the evaluation is that controls (e.g. limited fissile mass, limited volume, use of neutron poisons) are identified such that the fissile material is determined to remain subcritical for credible additions of sprinkler water or fire extinguisher water. Nearly all fires are extinguished by these mechanisms. Fires that have grown large enough to require extinguishing by firefighters are more difficult to analyze from a criticality accident likelihood perspective. Considerations such as the movement of the fissile material by the water stream from a hose should be thoroughly discussed with firefighters or fire protection specialists to gain insight in order to properly judge the credibility of the criticality accident.

There may be occasions when it is judged that the application of fire suppression water, either from a sprinkler or from manual operations, would credibly cause a criticality accident. If cost-effective changes to the fissile material process are not able to be made to reduce the criticality accident to an acceptably low likelihood, then changes to the likelihood of the fire and/or the firefighting agent must be considered. Strict limits and controls on combustible loading have always been important for reducing the likelihood of the fire. In addition, for those areas where firefighting water must be limited for criticality safety, commonly denoted as moderator-controlled areas, other firefighting agents must be considered. It is important to note that the moderating effects of these alternatives must also be considered. Many of the gas systems discharge at such low temperatures that water condensation is also a consideration. The moderating effect of some dry chemicals may not be known. As is the case with water, the potential impact of these alternate fire suppression methods on criticality safety must be fully evaluated as part of the CSE process.

It is recognized that water is often the preferred fire-extinguishing agent. Therefore, in those instances when it is judged that restrictions need to be placed on its application (from a criticality safety perspective), the CSE or supporting analyses should document the input from the fire protection specialist that describes how the material is likely to be moderated, reflected, or rearranged. Then, with neutronic analyses performed by the criticality specialist, the evaluation should document that, due to the water, the critical state would or would not be exceeded. In this case, ANSI/ANS-8.22 (Section 4.1.6) provides guidance for fire-fighting plans. Alternative fire-fighting methods should be considered.

The graded approach and common sense must always be applied when arriving at reasoned, cost-effective risk control. In particular, if one were to conjecture a criticality accident resulting from the use of fire hoses or in the accumulation of a critical mass and geometry in firewater runoff, the analyst would have to attempt to judge material movements under extreme conditions. Although the water flow can be predicted, the movement and behavior of entrained fissile material would generally be very difficult to forecast.

The primary goal of the criticality safety program, following the ANSI/ANS-8 series of standards, is the protection of people from exposures to significant doses of radiation, preferably by prevention of the accident. If this can be accomplished by shielding inherent to the system, for example via ANSI/ANS-8.10, *Nuclear Criticality Safety in Operations with Shielding and Confinement*, then the CSE may be somewhat less rigorous in documenting subcriticality under extreme conditions.

While both DOE O 420.1 and ANSI/ANS-8.1 require a system be designed such that no single credible event can cause a criticality accident, it should be noted that this does not equate to a zero risk policy. Systems should be designed to remain subcritical for fires that are within a specified design basis, but not necessarily for events that exceed the design basis. The CSSG recommends that this clarification be placed in the next revision of DOE-STD-3007 and be provided to the ANSI/ANS-8.1 working group for consideration in the next revision of ANSI/ANS-8.1 as well.

Contractor management, and ultimately the DOE, makes the final risk acceptance decisions. The CSE with input from the fire protection specialists, as described above, should play an important role in assuring that the restrictions on water for firefighting are properly understood and agreed to by management and the DOE.

2.4. Determine and suggest if there are changes that need to be made in either the criticality or fire protection standards to ensure harmonization of these requirements?

ANSI/ANS-8.1 is the overriding guidance for criticality safety professionals that, when followed properly, will result in firefighting issues of all kinds having been properly weighed in the design of fissile material operations (including storage) and in deriving their limits and controls. In order to promote harmonization, modifications to Appendix A of ANSI/ANS-8.1 to include firefighting scenarios as specific examples of “changes in process conditions” to be evaluated (see Attachment B) are recommended.

NFPA 801 has several specific requirements related to radioactive materials and criticality safety. Some of these go beyond fire safety requirements, but need to be considered since DOE O 420.1C invokes the codes.

The most general requirement from NFPA 801 involving criticality safety is:

> ***NFPA 801, Section 6.1.5:*** *Fissile materials shall be arranged such that neutron moderation and reflection by water shall not present a criticality hazard.*

Obviously this requirement cannot be met cost-effectively in all facilities at all times. In this instance the process analysis requirement of ANSI/ANS-8.1 would be invoked to evaluate whether the presence of water as either reflector or moderator would create a criticality hazard and, if so, establish appropriate fissile controls or create moderator control areas per ANSI/ANS-8.22 and consider alternative firefighting methods. The primary goal is always to avoid the accident in the first place.

It is recommended that this requirement be removed from NFPA 801.

Table 1 presents a summary of the sections of NFPA 801 related to criticality safety that were reviewed and should be considered for change to promote harmonization.

Table 1. Summary of Comments on Harmonization of Fire Suppression and Criticality Safety Requirements

Reference	Section	Comment
ANSI/ANS-8.1-1998 (R2007) *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*	Appendix A	Specific examples related to firefighting as an initiator for "changes in process conditions" are proposed as presented in Attachment B to this document.
NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials*, 2014 Edition	5.10	Requires consideration for integration/training. Identifies possible Engineered features that have potential to accumulate fissile material as well as water if common mode failure exists for material containment. Also includes volumes/flow rates, should these be used for CSEs?
6.1.5 "Fissile materials shall be arranged such that neutron moderation and reflection by water shall not present a criticality hazard."	6.1	Recommend delete/modify 6.1.5 since meeting this requirement can only be accomplished by geometry, concentration, or preventing the accumulation of water as determined and documented in the CSE. This requirement cannot be met by actions of fire safety. Direction and guidance for criticality safety to meet the intent of this requirement to preclude a criticality accident is already given in the ANSI/ANS-8 standards.
	6.1.2	Recommend directly reference CSE for guidance here.
	6.7	Provides references to standards for alternate fire suppression systems. Some of these have the potential for criticality safety to be a concern but do not directly acknowledge criticality safety as a concern as does NFPA 801. Also, information from these may be important to the CSE.

	A4.8	Reference guidance for pre-incident fire plan per ANSI/ANS-8.22, Section 4.1.6.
	A5.1	Recommend delete reference to criticality accident here, although a true statement it seems misplaced.
	A6.1.4	Recommend revise and clarify. Under the conditions of a fire emergency, this guidance should be reconsidered. How is the fire fighter to know if the material is as it was "arranged to minimize the possibility of a criticality hazard"?
	A7.4.4	Seems only to say that a glovebox won't protect the fire fighter from a criticality accident, not certain of the purpose of this "guidance"; suggest delete, move to training and include additional guidance about appropriate features for inert gases in contrast to air boxes, also mention alternate methods (e.g., MET-L-X) as an effective extinguishing agent, installation of criticality drains in gloveboxes, etc.
	C2.2	Suggest delete reference to reactivity. Current wording suggests that criticality safety is inconsistent with automatic fire suppression and that if there is no automatic fire suppression, there is likely greater risk of radiation exposure to the fire fighter, needs clarification
	C2.5	Commendable but perhaps misplaced, where should more specific guidance for involvement of criticality safety expertise in emergency response planning be included?
	C.11	Provides the quantity of fuel (at 90% enrichment) required for a criticality accident, uncertain of the value/intent of this statement, suggest consider revising.
DOE-STD-1066-2012, *Fire Protection*		No recommendations noted

It is recommended that a committee made up of one or two CSSG members and one or two DOE Fire Protection experts should be tasked with scrubbing NFPA 801 guidance concerning criticality safety to integrate with the ANSI/ANS-8 standards. This team should also note guidance statements that, while inappropriate in NFPA documents, might be helpful to criticality safety practitioners and pass them along to ANSI/ANS-8 for consideration for incorporation into ANSI/ANS-8.1 (see Attachment B for an example for incorporation) or other ANSI/ANS-8 standards.

3.0 Conclusions

DOE O 420.1C is the current regulatory driver for considering the use of water in firefighting in facilities that contain fissile material. The Order mandates compliance with the NFPA standards/codes. Both DOE and the NFPA codes indicate that the use of sprinklers in fissile material areas should be used only after considering the potential for criticality accidents; there is no absolute mandate for installing sprinkler systems in all facilities.

There is no global answer to which accident carries a higher risk to people, but is dependent on individual facilities and operations. CSEs for operations with significant quantities of fissile materials are required by ANSI/ANS-8.1 to address all of the concerns and cautions in NFPA 801. Thus the primary regulatory driver is DOE O 420.1C which invokes ANSI/ANS-8.1 which in turn is applicable under all conditions that might or might not include the use of water for firefighting.

It is important that fire safety professionals continue to receive training related to criticality safety and the likelihood that a potential criticality incident could come from the use of water. The primary resource currently used for training fire protection professionals is *Nuclear Criticality Safety Guide for Fire Protection Professionals in Nuclear Facilities* (1994). This draft contains much valuable information, but needs significant updating and then should be issued formally. The two original co-authors are still active in their fields, but the window may not remain open long.

It is equally important that the criticality safety professional understand the likelihood and consequence of inadvertent (i.e. not in response to a fire) sprinkler actuation and the impact of imposing constraints (e.g. restricting use in specified areas, limiting to fog nozzles) on manual firefighting with hoses. The latter would include the most probable conditions for the use of fire hoses (e.g. after facility evacuation, water distribution and flow rates, etc.). Requirements (NFPA 801, 5.10.2) for facilities handling radioactive materials to accommodate the drainage and storage of large volumes of liquid from multiple sources including the fire suppression system require socialization to ensure these scenarios are addressed in the development of the CSE. Modifications to Appendix A of ANSI/ANS-8.1 could include these firefighting scenarios as specific examples of “changes in process conditions” to be evaluated (see Attachment B). Guidance to identify “credible” arrangements of fissile materials impacted by manual firefighting should also be suggested to ANS-8.

Training on the interface between criticality safety and fire safety is clearly warranted and should emphasize that the natural tension between these safety disciplines is recognized and that give and take by all parties is required to ensure that overall safety is achieved. Therefore, it is also recommended that a requirement and criteria to cross-train fire safety and criticality safety professionals about this important interface should be established and implemented across both disciplines.

A summary of the recommendations from this review are to:

Update and formally publish *Nuclear Criticality Safety Guide for Fire Protection Professionals in Nuclear Facilities* (1994). Alternatively, consider including the material from this document as an annex to NFPA 801.

Encourage ANS N16/Subcommittee 8 to modify Appendix A of ANSI/ANS-8.1 to include firefighting scenarios as specific examples of “changes in process conditions” to be evaluated (see Attachment

B). Guidance to identify “credible” arrangements of fissile materials impacted by manual firefighting and to address the collection of firefighting water should also be suggested to ANS-8.

Establish a committee made up of one or two CSSG members and one or two DOE Fire Protection experts to scrub the various NFPA codes for inappropriate guidance concerning criticality safety (see Attachment C for examples). Review requirements related to how a criticality safety professional would evaluate the impact of water and consider removing them from NFPA 801. As the Standards Developing Organization (SDO) accreditation authority, the American National Standards Institute (ANSI) should referee and concur with this recommendation. This team should also note guidance statements that, while inappropriate in NFPA documents, might be helpful to criticality safety practitioners and pass them along to ANS-8 for incorporation into ANSI/ANS-8.1 (see Attachment B for an example for incorporation) or other standards.

ATTACHMENT A

CSSG Tasking 2013-01

CSSG TASKING 2013-01
Date Issued: December 18, 2012

Task Title: *CSSG Position on Use of Water for Firefighting in Light of Criticality Constraints for DOE Facilities*

Task Statement:
The CSSG is directed to provide an opinion on the acceptable use of water as a firefighting media in light of the potential for a criticality accident via the introduction of moderator, reflector or via the potential for water driven rearrangement of fissile material due to fire fighting activities. This review should encompass:

1. Evaluate under what conditions current regulations drive the requirements for the use of water in firefighting (DOE Orders, NFPA codes, etc).
2. Evaluate the potential relative risk to the facility worker, the co-located worker and the public from the fire and the criticality. What other disciplines should be considered (operations; safeguards & security; industrial safety; radiation protection)
3. Provide guidance on the proper justification for restrictions on water for fighting fires within DOE facilities with regard to criticality safety (in keeping with words in DOE O 420.1C).
4. Determine and suggest if there are changes that need to be made in either the criticality or fire protection standards to ensure harmonization of these requirements?

Resources:
The CSSG will form a sub team to draft a response to this tasking. The draft response will be reviewed by the entire CSSG for concurrence. It is highly recommended that the CSSG drafting team be supplemented by a resource cognizant in the fire protection area. Contractor CSSG members of the team will use their FY13 NCSP CSSG support funding as appropriate; DOE CSSG members of the team will utilize support from their site offices. CSSG emeritus members may be included in the team on a voluntary basis.

Task Deliverables:
1. CSSG selected writing team members will produce a draft response by March 15, 2013.
2. CSSG to provide comments on draft to the CSSG Deputy Chair within 10 days of the issuance of the draft.
3. CSSG Deputy Chair to consolidate comments and provide back to the CSSG for concurrence five days later.
4. CSSG Chair briefs the NCSP Manager on the comments and response by April 15, 2013.
5. CSSG Chair transmits the CSSG response to NCSP Manager by April 30, 2013.

12/20/2012

Dr. Jerry N. McKamy, Director, NA-00-10
DOE NCSP Manager

ATTACHMENT B

Draft of Appendix A to ANSI/ANS-8.1 with proposed text **(in BOLD)** related to firefighting scenarios

Appendix A

(This Appendix is not a part of American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors, ANSI/ANS-8.1-2013, but is included for information purposes only.)

The determination, required by 4.1.2, that a process will be subcritical under normal and credible abnormal conditions requires careful study. The few criticality accidents that have occurred in industrial operations have resulted from failure to anticipate conditions that might arise; not one has resulted from a faulty calculation* of k_{eff}.

Appendix B includes further explanation of the application of the Double Contingency Principle and how it is used to support the Process Analysis requirement.

Typical examples of changes in process conditions include:

1) A change in intended shape or dimensions resulting from bulging, corrosion, or bursting of a container, or failure to meet specifications in fabrication;
2) An increase in the mass of fissionable material in a location as the result of operational error, improper labeling, equipment failure, or failure of analytical techniques;
3) A change in the ratio of moderator to fissionable material resulting from:
    a. Inaccuracies in instruments or chemical analyses,
    b. Flooding, spraying, or otherwise supplying units or groups of units with water, oil, snow (i.e., low-density water), cardboard, wood, or other moderating material **(e.g., as a result of firefighting activities),**
    c. Evaporating or displacing moderator,
    d. Precipitating fissionable material from solutions,
    e. Diluting concentrated solutions with additional moderator,
    f. Introducing air bubbles between rows of fuel assemblies in a storage basin,
    g. Hydrofluoric acid or water condensation following loss of temperature or pressure control (hydrofluoric acid condensation can occur in uranium hexafluoride systems or some oxide fluorination operations);
4) A change in the fraction of the neutron population lost by absorption resulting from:
    a. Loss of solid absorber by corrosion or by leaching,
    b. Loss of moderator,
    c. Redistribution of absorber and fissionable material by precipitation of one but not the other from a solution,
    d. Redistribution of solid absorber within a matrix of moderator or solution by clumping,
    e. Failure to add the intended amount of absorber to a solution or failure to add it with the intended distribution,
    f. Failure of analytical techniques to yield correct material quantities or concentrations,
    g. Change in neutron absorber uniformity due to chemical reactions between contaminants in the absorber material;
5) A change in the amount of neutron reflection resulting from:
    a. An increase in reflector thickness by adding additional material (e.g., water or personnel, **including such effects caused by firefighting activities**),
    b. A change in reflector composition such as loss of absorber (e.g., by corrosion of an outer casing of absorber);
6) A change in the interaction between units and reflectors resulting from:
    a. The introduction of additional units or reflectors (e.g., personnel),

b. Improper placing of units,
c. Loss of moderator and absorber between units,
d. Collapse of a framework used to space units;
e. Rearrangement of materials due to firefighting activities;

7) An increase in the density of fissionable material resulting from:
   a. Uranium compound solidification (e.g. UF_6) in systems designed for gas handling,
   b. Density changes due to loss of pH control or introduction of organics.

*See T. P. McLaughlin, S. P. Monahan, N. L. Pruvost, V. V. Frolov, B. G. Ryazanov, V. I. Sviridov, *A Review of Criticality Accidents, 2000 Revision*, LA-13638, Los Alamos National Laboratory (2000).

ATTACHMENT C

Detailed Excerpts and Comments from NFPA 801 and DOE STD 1066

This Attachment includes detailed excerpts and comments from NFPA 801 and DOE STD 1066.

Detailed Comments (**italics) on Criticality Safety-Related Excerpts from NFPA 801

Below is a list containing some of the sections from NFPA 801 that, while well intended, fall under the purview of the criticality safety practitioner and should be considered for deletion/modification.

5.10 Drainage.
CAUTION: For facilities handling fissionable materials, areas where water can accumulate shall be analyzed for criticality potential. *<u>**Highlights a process change that the criticality analyst should be aware of.</u>*
5.10.1* Drainage or containment shall be provided and accomplished by one or more of the following methods: *<u>**Engineered features that have potential to accumulate fissile material as well as water if common mode failure exists for material containment.</u>*

(1) Floor drains
(2) Floor trenches
(3) Open doorways or other wall openings
(4) Curbs for containing or directing drainage
(5) Equipment pedestals
(6) Pits, sumps, and sump pumps

5.10.2 The provisions for drainage design in areas handling radioactive materials and in any associated drainage facilities (e.g., pits, sumps, and sump pumps) shall be sized to accommodate all of the following: *<u>**Should these volumes/flow rates be used for CSEs? Do we need to develop additional guidelines for the criticality safety analyst and if so, where would we put these?</u>*

(1) The spill of the largest single container of any flammable or combustible liquid used or stored in the area
(2) The credible volume of discharge (as determined by the fire hazards analysis) for the suppression system operating for a period of 30 minutes where automatic suppression is provided throughout
(3) The volume based on a manual firefighting flow rate of 1893 L/min (500 gpm) for a duration of 30 minutes where automatic suppression is not provided throughout, unless the fire hazards analysis demonstrates a different flow rate and duration
(4) The contents of piping systems and containers that are subject to failure in a fire where automatic suppression is not provided throughout
(5) Credible environmental factors, such as rain and snow, where the installation is outside

5.10.3 Floor drainage from areas containing flammable or combustible liquids shall be trapped to prevent the spread of burning liquids beyond the fire area.
5.10.4 Where gaseous fire suppression systems are installed, floor drains shall be provided with seals, or the fire suppression system shall be sized to compensate for the loss of fire suppression agents through the drains.

6.1* General Considerations.
6.1.1 Automatic sprinkler protection shall be provided unless the fire hazards analysis in Section 4.2 *<u>**or CSE</u>* dictates otherwise.
6.1.2 As determined by the fire hazards analysis, special hazards shall be provided with additional fixed fire protection systems.
6.1.3* For locations where fissile materials might be present and could create a potential criticality hazard, combustible materials shall be excluded.

6.1.4 If combustible materials are unavoidably present in a quantity sufficient to constitute a fire hazard, water or another suitable extinguishing agent shall be provided for firefighting purposes.
~~6.1.5 Fissile materials shall be arranged such that neutron moderation and reflection by water shall not present a criticality hazard.~~ *<u>**Suggest delete/modify since not always achievable.</u>*

6.7 Fire Suppression Systems and Equipment. *<u>**Provides references to standards for alternate fire suppression systems. Some of these have the potential for criticality safety to be a concern but do not directly acknowledge criticality as a concern as does NFPA 801. Also, information from these may be important to the CSE.</u>*
6.7.1* Fire suppression systems and equipment shall be provided in all areas of a facility as determined by the fire hazards analysis.
6.7.2 Where fire suppression systems are required, the design, installation, maintenance, and testing of such systems shall be in accordance with the following NFPA standards,
as applicable: NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*; NFPA 12, *Standard on Carbon Dioxide Extinguishing*
Systems; NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*; NFPA 13, *Standard for the Installation of Sprinkler Systems*; NFPA 14, *Standard for the Installation of Standpipe, and Hose Systems*; NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*; NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*; NFPA 17, *Standard for Dry Chemical Extinguishing Systems*; NFPA 17A, *Standard for Wet Chemical Extinguishing Systems*; NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*; NFPA750, *Standard on Water Mist Fire Protection Systems*; and NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*.

6.7.3 The selection of the extinguishing agent system shall be based upon the following:
(1) Type of hazard
(2) Effect of agent discharge on equipment
(3) Health hazards
(4) Cleanup after agent discharge
(5) Effectiveness of agent in suppressing fire
(6) Cost of agent, including life cycle costs
(7) Availability of agent
(8) Criticality safety
(9) Environmental impact

A.4.8.1 Pre-incident fire plans should be developed with the assistance of the facility fire emergency organization. The pre-incident fire plans should include, but not be limited to, the following pertinent issues:
(1) Fire hazards in area
(2) Chemical hazards in area
(3) Radiation hazards
(4) Egress access
(5) Emergency lighting
(6) Fire protection systems/equipment in area
(7) Special firefighting instructions
(8) Ventilation systems/airflow path
(9) Utilities
(10) Special considerations on adjoining areas

Plans should be developed in accordance with NFPA 1620, *Standard for Pre-Incident Planning.*

*****Suggest add (11) Criticality Safety; Criticality safety shall be specifically addressed in pre-incident fire plan to describe risk related to the use of water or other fire suppression agents if they have been identified…consistent with A.6.1.4.***

A.4.8.3 Pre-incident fire plans should be made available to offsite fire departments as appropriate.

A.5.1 The design and installation of service facilities — such as light and power, heating, cooling, ventilation, storage, and waste disposal materials — might not present any unusual problems at facilities not handling radioactive materials; however, the introduction of radioactive materials into a facility poses additional hazards to both personnel and property that warrant special consideration of these services. Inadequate attention to the design features of such service facilities has contributed to the need for extensive decontamination following fires and explosions. Good practice demands detailed analysis of the design of each service for the purpose of determining its effect on the spread of contamination following a fire or criticality accident. An appraisal of the severity of contamination spread then can be used to determine the necessity for modifying the design of the service facility under consideration.***Recommend delete reference to criticality accident here, although a true statement it seems misplaced.*

A.6.1.3 In handling fissile materials, precautions should be taken not only to protect against the normal radiation hazard but also against the criticality hazard caused by the assembly of a ~~minimum~~ critical mass. To avoid criticality during fire emergencies, fissile materials that have been arranged to minimize the possibility of a criticality hazard should be moved only if absolutely necessary. If it becomes necessary to move such fissile materials, it should be done under the direction of a responsible person on the staff of the facility and in batches that are below the critical mass, or the materials should be moved in layers that minimize the possibility of a criticality occurring*. **Under the conditions of a fire emergency, this guidance should be reconsidered. How is the fire fighter to know if the material is as it was "arranged to minimize the possibility of a criticality hazard"? This should be clarified.*

C.2.2 Radioactive materials can be expected to melt, vaporize, become airborne, or oxidize under fire conditions. None of these alterations will slow or halt radioactivity. It is conceivable that certain radioactive materials under fire conditions might be converted to radioactive vapor or oxidized to a radioactive dust or smoke. This dust or smoke could be carried by air currents and subsequently deposited on other parts of the burning buildings or even on neighboring buildings or land.
These aggravated loss and personal injury characteristics of radioactive materials justify a high degree of protection against fire and explosion at those facilities where these potential hazards exist. The use of the least combustible building components and equipment is highly desirable in those areas where radioactive materials are to be stored or used. Some form of automatic protection, such as automatic sprinklers, is highly advantageous wherever combustibles are encountered.

The installation of automatic extinguishing systems reduces the need for personnel exposure to possible danger, starts the fire control process automatically, sounds an alarm, and makes efficient use of the available water supply. However, caution should be exercised to ensure that the hazards of criticality and reactivity are considered*. **Suggest delete reference to reactivity, suggests that criticality safety is inconsistent with automatic fire suppression and that if there is no automatic fire suppression, there is likely greater risk of radiation exposure to the fire fighter, needs clarification*

C.2.5 The property manager should keep the local fire department advised of the locations and general nature of radioactive materials available. Emergency planning is essential so that firefighters can function at maximum efficiency without exposure to harmful radiation and without unwarranted fears of the radiation hazard that can inhibit the firefighting effort. Where criticality incidents or exposure to radioactive materials is possible, mutual aid arrangements should maximize the use of on-site expertise. Specific provision should be made where necessary by the property manager and the fire department for monitoring service, protective clothing, and respiratory protective equipment, the need for which should be determined by the nature of the specific hazard. The radiation hazard usually can be anticipated in emergency planning studies*. **Commendable but perhaps misplaced, where should more specific guidance for involvement of criticality safety expertise in emergency response planning be included?*

C.11 Open Pool Reactor (Swimming Pool Reactor).
C.11.5 Criticality. In this type of reactor, a critical mass can be reached with about 2.7 kg (6 lb) of 90 percent enriched uranium fuel in a pool of the dimensions described. With lesser degrees of enrichment, more fuel would be required*. **Uncertain of the value/intent of this statement, suggest consider revising.*

Detailed Comments on Criticality-Related Excerpts from DOE STD 1066

Below is a list containing excerpts from some of the sections from DOE STD 1066 that, while well intended, fall under the purview of the criticality safety practitioner and should be considered for deletion/modification. Note that the acronym AHJ is the Authority Having Jurisdiction.

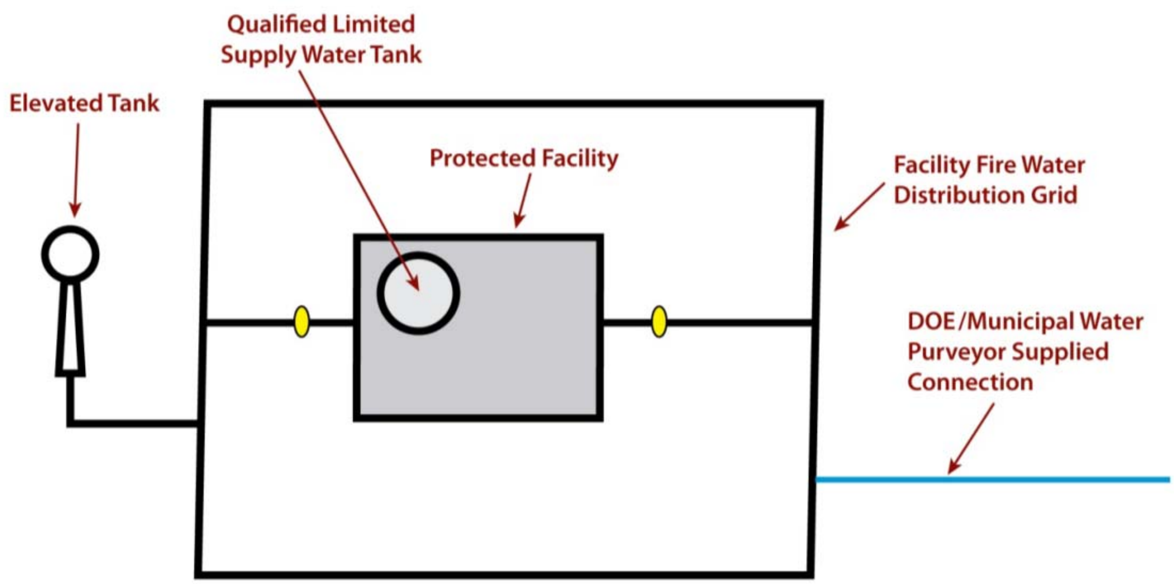
4.4.3.17 Water Supply Guidelines. Water for the deluge spray systems should be provided by two separate water supply connections for reliability (one may be a fire department connection, if acceptable to the AHJ.) Automatic and manual water spray system water supplies should be hydraulically calculated and capable of supplying a simultaneous flow of the automatic and manual water spray systems, as well as the overhead ceiling automatic fire sprinkler systems for the fire area providing air to the plenum for a minimum period of two hours. A minimum two-hour water supply is not required when a limited water supply system, discussed below, is justified and provided for criticality event reasons.

4.4.3.18.1 Water Drains. Water drains with traps and a means to eliminate drain trap evaporation should be provided in plenum floors to provide liquid run off control. Plenum drains should be piped to either a process waste system or to collection tanks. Process waste systems and collections tanks should be of sufficient capacity to capture all liquid from the water deluge spray systems for the densities and durations required herein. Criticality safety should be observed in all drainage and storage systems when the potential for impacting fissile materials is encountered.

4.4.3.18.2 Limited Water Supply Systems. Limited water supply systems for the deluge water supply should be permitted when a documented criticality potential exists in the final filter plenum. A documented criticality potential should be provided showing criticality calculations and the total amount of water allowed in the plenum enclosure before a limited water supply system is permitted.

Limited water supply can be accomplished by either limited capacity water tanks or system water flow control valves.

DOE STD 1066, Appendix A[11]
Water Supply Arrangement No. 5: Hazard-specific limited supply water system.
Water system flow and capacity for property protection, program preservation, life safety, etc., are specified by NFPA 1, *Safety Code*, NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials*, the *International Building Code*, NFPA 13, *Standard for the Installation of Sprinkler Systems*, or other general industrial standards. These standards typically require from several hundred thousand to several million gallons of water. None of these specify the amount of water needed to adequately protect an SC or SS special hazard. This shall be determined on a case-by-case basis and justified in the FHA or DSA, taking into account issues, such as criticality and spread of contamination. Nuclear safety objectives often can be achieved with much lower quantities of water, provided the system is independent of the general building system. For example, 500 gallons may be sufficient to meet the SC objective to protect a special hazard (e.g., a glovebox) in a given facility. Such a limited supply could be provided by a single, passive, self-contained pressure tank within the facility, qualified to seismic and other SC criteria (such as redundancy of active components), thus significantly limiting the SC boundary. An additional water supply, per the above codes and standards, would be required to meet other fire protection objectives, but that additional supply is not required to meet SC or SS criteria.



Appendix F
The resulting protection should be designed to ensure that a fire would be successfully controlled until such time that emergency response forces arrive to extinguish it. The fire hazards analysis (FHA) and the

[11] Acronyms in this section: SC-safety class; SS-safety significant; FHA-Fire Hazard Assessment; DSA-Documented Safety Analysis

safety basis documentation should specify any additional requirements beyond those for a standard wet pipe sprinkler system.

[23] 4.2.7.8 When the use of water sprinkler coverage is precluded because of nuclear criticality or other incompatibility reasons, nonaqueous extinguishing systems (e.g., inert gas, carbon dioxide, halon alternatives, etc.) that will be successful in extinguishing the anticipated fire, and which are not reactive to materials present, should be used. Additional precautions may be needed since these alternative systems are much less reliable than sprinklers and their limited supply of extinguishing agent may permit re-ignition.