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# Accelerating Nuclear Facility Mission Completion Through an Improved Chemical Hazard Control Strategy - 20460

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## ABSTRACT

Code of Federal Regulation (CFR) 10 CFR 830, *Nuclear Safety Management* [1], explicitly identifies hazardous materials in addition to radioactive materials when establishing the scope of materials that must be evaluated in Hazard Category (HC) 1, 2, and 3 nuclear facilities. This inclusion has led to a near decade-long progression of more and more rigorous application of chemical hazard controls in these facilities. The progressive addition of more rigorous chemical hazard controls has occurred across the Department of Energy (DOE) Complex, having been driven by contractors and regulators alike. However, chemical hazards in other DOE facilities have been, and continue to be, controlled using traditional industrial safety centered strategies. Thus, identical chemical hazards are controlled using dramatically different approaches based solely on the facility type. Not only are the controls different, the analysis and derivation rigor and requirements are also significantly different. In particular, chemical control derivation and application in non-nuclear facilities are much less onerous than the comprehensive hazard analysis process used in nuclear facilities, even in circumstances in which chemicals are not initiators to, or do not exacerbate a nuclear event. While the derivation and control approaches used in these two types of facilities are disparate, the safety results are similarly effective based on a review of reported chemical events from 2014 through 2018. While both approaches achieve comparable safety outcomes, the approach used in nuclear facilities results in significantly greater preparation costs and implementation costs. Furthermore, the problem with the differing approach is not relegated to the control preparation and implementation burden. The operational impact of potentially unnecessary controls slows mission completion without a corresponding increase in safety, not to mention the dilution of the importance of Technical Safety Requirements.

The proposed solution must first include a critical and thorough examination of DOE Complex and top-tier chemical industry chemical hazard control practices, coupled with a similar examination of the driving facility regulatory requirements. Results from the examination can then be used to fuel a bold departure from current chemical control practices in Hazard Category 1, 2, and 3 nuclear facilities. Development of an improved and consistent chemical hazard control process would follow, one that continues to ensure safety while accelerating mission completion and significantly reducing the burden associated with chemical hazard control development and implementation. The improved process must establish a hierarchy where radiological hazards are addressed using safety class and safety significant controls and chemical hazards are addressed using overarching safety management programs (with limited unique exceptions). The improved Hazard Category 1 ,2, and 3 nuclear facility chemical hazard control strategy, while compliant with 10 CFR 830 [1], would be founded on the requirements in 10 CFR 851, *Worker Safety and Health Program* [2], and the complementary DOE O 151.1D, *Comprehensive Emergency Management System* [3]. In this way, the Hazard Category 1, 2, and 3 nuclear facility chemical hazard control strategy would, wherever appropriate, be the same process used at other DOE Complex facilities. Ultimately, the improved process will maintain safety and significantly reduce costs and lifecycle risk through faster mission completion.

## INTRODUCTION

Chemical hazard safety controls used in DOE HC 1, 2, and 3 facilities and less than HC 3 and other facilities are inconsistently implemented. In particular, chemical hazard control derivation and application in less than HC 3 and other facilities are less onerous than in HC 1, 2, and 3 facilities. While the approaches used in these two types of facilities are disparate, the safety results are similarly effective based on a review of reported chemical events from 2014 through 2018.

With the differing control derivation and application as a backdrop, a team of nuclear safety practitioners assessed the chemical hazard control derivation and application process used in nuclear and non-nuclear facilities. The team examined current practices, regulatory requirements and subordinate documents, and several facility case studies. In addition, the team interviewed safety experts from the chemical industry and performed benchmarking activities to verify standard and good practices.

The goal of the team was to first develop an improved understanding of the factors driving differing control approaches, and then develop an improved strategy for chemical hazard control derivation and application in DOE HC 1, 2, and 3 facilities. The improved strategy seeks legitimacy, equity, and reasonableness by enhancing safety, reducing control inconsistency, and reducing development, implementation, and lifetime costs. The team concludes that an improved chemical hazard control derivation and application process within HC 1, 2, and 3 facilities can be achieved within the current regulatory framework.

## PROBLEM

In DOE HC 1, 2, and 3 facilities, 10 CFR 830 [1] requires radiological and other hazardous material to be addressed in the documented safety analysis (DSA).

*10 CFR 830.204*

*(b) The documented safety analysis for a hazard category 1, 2, or 3 DOE nuclear facility must, as appropriate for the complexities and hazards associated with the facility:*

..........

*(3) Evaluate normal, abnormal, and accident conditions, including consideration of natural and man-made external events, identification of energy sources or processes that might contribute to the generation or uncontrolled release of radioactive and other hazardous materials, and consideration of the need for analysis of accidents which may be beyond the design basis of the facility;*

Within these facilities, it is common practice to develop and implement controls for chemicals using the same methodology applied to radiological materials. That is, the uncontrolled release of chemicals is addressed through detailed hazard analysis, accident analysis, consequence comparison to evaluation guidelines, and then controlling the hazard through designation of safety significant (SS) controls (e.g. systems, structures, and components (SSCs), Specific Administrative Controls (SACs), etc.).

Contrarily, chemical hazards within DOE less than HC 3 and other facilities are not controlled through use of SS controls, rather they are controlled through reliance on standard industrial safety practices including piping and vessel standards, chemical management programs, chemical process safety standards, emergency planning, and industrial hygiene practices. As with the HC 1, 2, and 3 facility control strategy, the less than HC 3 and other facility chemical hazard control strategy is comparably effective. For instance, there were 77 Occurrence Reporting and Processing System (ORPS) reports concerning chemical events for calendar years 2014 through 2018. Four events were categorized with reporting criteria corresponding to an Operational Emergency with two occurring in HC 1, 2, or 3 facilities and two occurring in less than HC 3 or other facilities. The remaining reports primarily concern personal exposure to chemicals or minimal amounts of chemicals being released.

While both approaches achieve comparable safety outcomes, the approach used in HC 1, 2, and 3 facilities results in significantly greater preparation costs and implementation costs. From a HC 1, 2, and 3 facility perspective, the problem with the differing approach is not relegated to the control preparation and implementation burden. The operational impact of potentially unnecessary SS controls slows mission completion without a corresponding increase in safety. Furthermore, dilution of the importance of technical safety requirements (TSRs) must be considered.

For example, the DOE Waste Treatment Plant (WTP) Low Activity Waste Facility (LAW) in Richland Washington is classified as a HC 3 nuclear facility based on radiological material content and thus has a DSA that extensively reviews the facility hazards and establishes 44 SS SSCs and 16 SACs. A review of the DSA Chapter 3, Hazards and Accident Analysis, revealed the entirety of SS SSCs and SACs are driven exclusively by chemical consequences to facility workers, co-located workers, and in some cases public receptors. There are no controls driven by radiological hazards to any receptor. Thus, in this particular facility, the entire set of SS SSCs and SACs, with their significant development, implementation, and ongoing operational burden, would be controlled through standard industrial safety practices including piping and vessel standards, chemical management programs, chemical process safety standards, and industrial hygiene practices were it not for the radiological material content within the facility.

Another example, associated with the DOE Concentration, Storage, and Transfer Facilities (CSTF) at the Savannah River Site, centers around mercury hazards for the operational evaporators. The associated hazards analysis process identified that during operation of the evaporators, mercury accumulates in the Evaporator Overheads Receiver Systems and has the potential for chemical release during certain events. Because of these events, SS controls were established to minimize the quantity of mercury present at one time. To implement the only tenable control strategy, significant modifications to the mercury collection system were necessary to accomplish the required TSR surveillance requirements protecting mercury inventory limits. The SS design and installation costs were substantial (exceeding $2M) and, based upon the position provided in this paper, would be deemed unnecessary as the documented Safety Management Programs (SMPs) (e.g., Fire Protection Program, Chemical Control Program, Industrial Hygiene Program) with validation by the Contractor Assurance System are adequate to provide the requisite level of safety. The Effluent Treatment Plant at SRS (a Radiological Facility – not under 10 CFR 830, Subpart B [1]) illustrates this point as it contains mercury hazards that have been successfully "controlled" without the use of SS controls or TSR requirements.

## SOLUTION

An improved and consistent chemical hazard control development and implementation process within HC 1, 2, and 3 facilities is needed. The improved process must continue ensuring safety while accelerating mission completion and significantly reducing the burden associated with chemical hazard control development and implementation efforts which are better reserved for radiological hazards. To this end, the team proposes an improved process to address chemical hazards within HC 1, 2, and 3 facilities. A graphic depicting the proposed process is provided in Figure 1.

As required by 10 CFR 830 [1], the process considers both radiological and other hazardous materials. The improved process establishes a hierarchy where radiological hazards are addressed in the DSA using safety class (SC) and SS controls and chemical hazards are addressed in the DSA primarily using SMPs. The process addresses the possibility of chemical initiated radiological events and those events where a chemical hazard can exacerbate a radiological event by addressing the overarching radiological hazard using SC and SS controls (based on exceeding radiological evaluation guidelines). For example, SC or SS controls would be used when a chemical explosion serves as the initiator for a radioactive material release or a chemical release exacerbates radiological release consequences because the chemical impacts control room habitability impeding operator actions required during a radioactive material release. Thus, through the proposed process, it is possible to arrive at a SC or SS control for a chemically induced initiator, but only to prevent or mitigate a radiological consequence.

All chemical hazards in the facility or potentially in the facility regardless of quantity are subjected to the process depicted in Figure 1. For cases where a chemical hazard neither initiates nor exacerbates a radiological event, the improved process addresses the chemical hazard using SMPs established in the DSA which are founded on 10 CFR 851 [2] and the complementary DOE O 151.1D, Comprehensive Emergency Management System [3]. In this way, the HC 1, 2, and 3 facility chemical hazard control strategy would, where appropriate, be the same process used in less than HC 3 and other facilities. To further illustrate the recommended approach, Appendix A shows a more detailed graphic reflective of the graded-approach of the proposed evaluation and control strategy for radiological and chemical hazards.

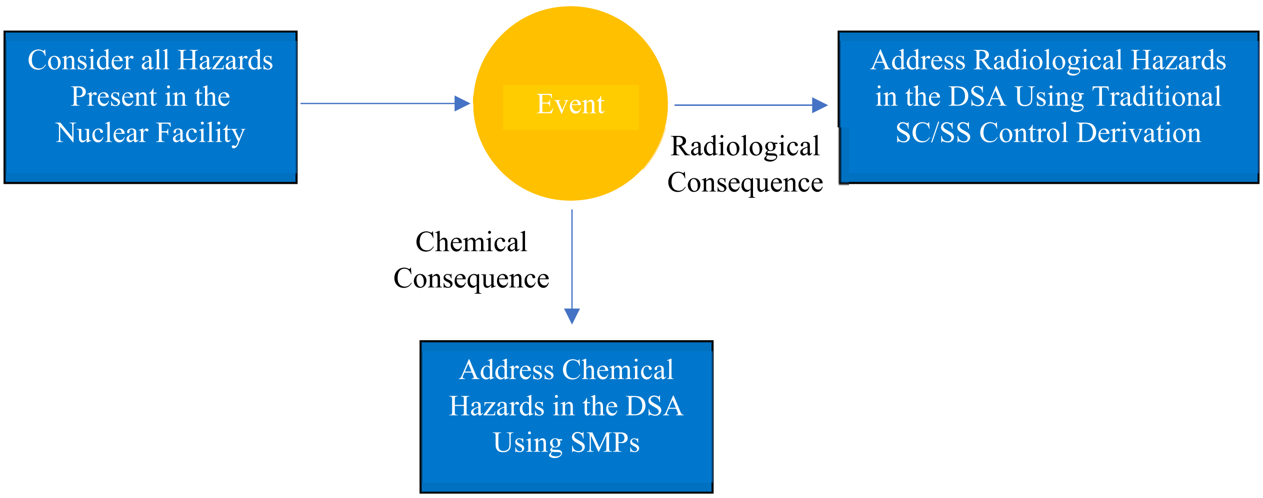


Fig. 1. Proposed Chemical Hazard Evaluation Process.

## ANALYSIS OF REQUIREMENTS

A comprehensive review of 10 CFR 830 [1] and subordinate standards and handbooks was performed by the team to develop a clear understanding of the regulatory requirements, recommendations, and guidelines as they relate to addressing chemical hazards within nuclear facilities to ensure the proposed process conforms to the regulatory framework. The review included 10 CFR 830 [1], DOE-STD-3009-94 CN 3 [4], DOE-STD-3009-2014 [5], DOE-STD-1189-2008 [6], DOE-STD-1189-2016 [7], DOE O 420.1C CN 2 [8], DOE G 421.1-2A [9], and DOE-HDBK-1224-2018 [10].

The overall conclusion from the team is that the proposed strategy is compliant with 10 CFR 830 [1], DOE-STD-3009-94 CN 3 [4], DOE-STD-1020-2012 [11], DOE-STD-1020-2016 [12], DOE O 420.1C CN 2 [8], DOE G 421.1-2A [9], and DOE-HDBK-1224-2018 [10] while DOE-STD-3009-2014 [5] and DOE-STD-1189-2008 [6] include passages that may prohibit implementation of the proposed strategy. It should be noted that DOE-STD-1189-2016 [7] is applicable only in facilities that have implemented DOE-STD-3009-2014 [5]. Although not explicitly included in the analysis of applicable regulatory documents since it is still in draft form, DOE-STD-1228, Preparation of Documented Safety Analysis for Hazard Category 3 Nuclear Facilities, was examined and it was confirmed the chemical hazard regulatory inconsistencies are carried forward into this new draft standard.

DOE-STD-3009-2014 [5] and DOE-STD-1189-2008 [6] tend to take a more dogmatic and overly restrictive approach with respect to addressing chemical hazards within HC 1, 2, and 3 facilities. Section 3.2 of DOE-STD-3009-2014 [5] explicitly identifies SS controls to address chemical hazard consequences for co-located workers and offsite chemical consequences.

*DOE-STD-3009-2014 (section 3.2)*

*For the purpose of identifying SS SSCs, an evaluation of collocated worker consequences and offsite chemical consequences is also required and is performed as part of either: (1) the hazard evaluation as described in Sections 3.1.3.1 and 3.1.3.3 of this Standard or (2) the accident analysis addressed in this section. The need for SS controls to protect the facility worker is determined by the qualitative hazard evaluation discussed in Section 3.1.3 of this Standard.*

*DOE-STD-3009-2014 (section 3.2.2)*

*The unmitigated consequence calculation determines the need for safety-designated controls and provides the framework for designating these controls. If the unmitigated consequences of a release scenario exceed established chemical or radiological thresholds in Sections 3.3.1 and 3.3.2, SC and/or SS controls will need to be established.*

Additionally, Section B.2 of DOE-STD-1189-2008 [6] explicitly states chemical exposure evaluation guidelines for SS control classification.

*DOE-STD-1189-2008 (section B.2)*

*Potential exposures to the public and collocated workers are estimated as described in Section B.3. These exposures can be compared to the following threshold levels for consideration of SSC classification as safety significant in facility design to prevent or mitigate these exposures.*

- *Public: Exposure > AEGL-2/ERPG-2/TEEL-2; and*

- *Collocated Worker: Exposure > AEGL-3/ERPG-3/TEEL-3.*

The team's proposal is that when the chemical hazard is exclusively chemical, the hazard would, for the most part, be controlled through DSA SMPs. Since Section 3.2 of DOE-STD-3009-2014 [5] and Section B.2 of DOE-STD-1189-2008 [6] do not appear to allow use of SMPs as the means for controlling the chemical hazard without additional guidance, HC 1, 2, and 3 facilities subject to DOE-STD-3009-2014 [5] and DOE-STD-1189-2008 [6] will have a more difficult time implementing the proposed approach.

The team's ultimate conclusion of the regulatory review is that HC 1, 2, and 3 facilities operating under DOE-STD-3009-94 [4] have the regulatory latitude to pursue the process depicted in Figure 1. There are several explicit statements used throughout 10 CFR 830 [1] and subordinate documents that support use of the proposed process. Importantly, 10 CFR 830 [1] recognizes multiple hazard control measures including physical design, structural, and engineering features as well as SMPs.

*10 CFR 830*

*G. HAZARD CONTROLS*

*1. Hazard controls are measures to eliminate, limit, or mitigate hazards to workers, the public, or the environment. They include (1) physical, design, structural, and engineering features; (2) safety structures, systems, and components; (3) safety management programs; (4) technical safety requirements; and (5) other controls necessary to provide adequate protection from hazards.*

The definitions section of DOE-STD-3009-94 [4] addresses SS SSCs in the context of being a major contributor to defense in depth and/or worker safety. A general rule of thumb is given for situations involving worker safety where consideration of SS SSC selection may be warranted. The proposed process would follow the direction of DOE-STD-3009-94 [4] in the following way. In situations where a radiological event is caused or exacerbated by a chemical hazard, SS or SC control selection would be carefully considered. In situations where the event in question exclusively involves chemical hazards, consistent with 10 CFR 830 [1], DSA SMPs would likely be relied upon to control the hazard similar to how the hazard would be controlled in less than HC 3 or other facilities.

*DOE-STD-3009-94*

*Definitions*

*Safety-significant structures, systems, and components (SS SSCs). Structures, systems, and components which are not designated as safety-class SSCs but whose preventive or mitigative function is a major contributor to defense in depth and/or worker safety as determined from safety analyses. [10 CFR 830]*

*As a general rule of thumb, safety-significant SSC designations based on worker safety are limited to those systems, structures, or components whose failure is estimated to result in a prompt worker fatality or serious injuries or significant radiological or chemical exposures to workers. The term, serious injuries, as used in this definition, refers to medical treatment for immediately life-threatening or permanently disabling injuries (e.g., loss of eye, loss of limb).*

*The general rule of thumb cited above is neither an evaluation guideline nor a quantitative criterion. It represents a lower threshold of concern for which safety significant SSC designation may be warranted. Estimates of worker consequences for the purpose of safety significant SSC designation are not intended to require detailed analytical modeling.*

DOE-HDBK-1224-2018 [10] provides the most recent and current guidance regarding accident analysis for chemical hazards. The handbook provides meaningful support for the proposed chemical hazard DSA process. For example, Section 2.2.4 provides guidance for situations involving standard industrial hazards (SIHs) that do not require analysis within the DSA. The guidance in this section is in keeping with the proposed process since it focuses on situations where chemical and industrial hazards result in a release of nuclear material. Additionally, Section 2.2.4 provides insight regarding situations where a chemical hazard may exacerbate a nuclear event by impairing or disabling control room operators.

*DOE-HDBK-1224, Section 2.2.4*

*The comprehensive hazard identification process in Sections 2.2.1 through 2.2.3 addresses all radiological and non-radiological hazards and energy sources. However, SIHs are not normally analyzed in a DSA hazard evaluation, unless chemical and industrial hazards result in a release of nuclear material, or an operator is incapacitated or prevented from taking credited action to prevent or mitigate a hazard scenario.*

*DOE-HDBK-1224, Section 2.2.4*

*The intended distinction is to ensure analysis of "other hazardous materials" outside the scope of 10 CFR Part 851 that could affect nuclear safety. If these unique hazards could impair or disable control room operators or make uninhabitable entire rooms where nuclear operations are conducted, such hazards should be evaluated in the DSA.*

Section 2.6.1.3 also provides significant support for the proposed process by offering a means for delineating between things that are adequately addressed by 10 CFR 851 [2], 10 CFR 835 [13], and integrated safety management system hazard analysis requirements and those situations where additional DSA controls are warranted.

*DOE-HDBK-1224, Section 2.6.1.3*

*For potentially serious injuries or fatalities, the event is assessed to determine whether the physical hazard associated with initiating or worsening a radiological or other hazardous material accident is a SIH or if it should be assigned a high consequence level. The primary consideration in determining whether the physical hazard is a SIH is if the regulated material (i.e., radioactive or other hazardous material) is not a primary cause or major contributor to the hazardous event, and that it is adequately addressed by 10 CFR Part 851 (and its adoption of OSHA and industry standards), 10 CFR Part 835, Occupational Radiation Protection, and Integrated Safety Management System HA requirements.*

## BENCHMARKING RESULTS

Discussions were held with a representative from a Nuclear Regulatory Commission licensed facility to understand how they address chemical hazards in nuclear facilities. Chemicals undergo an initial screening process; those that are not comingled with radioactive material are not considered in the Integrated Safety Analysis process (ISA). For those comingled chemicals, the licensees may credit a “see and flee” approach for chemicals such that their exposure time for an individual is 5 minutes or less. Material at risk is evaluated based on the available volume into which it will be dispersed and is “instantaneously dispersed” into that volume. Exposure for the limited time is then used to screen the consequence. If the worker or public criteria are not exceeded, then the chemical is considered to be low consequence within the ISA. Furthermore, the licensees use only two receptor classes – worker and public and the only pathway considered for chemicals is inhalation. Controls for a low consequence exposure are managed using a chemical management program.

Treatment of chemical process hazards in select Savannah River Site nuclear and radiological facilities was assessed against the practices of top tier chemical companies. Top tier chemical companies implement Process Safety Management (PSM) systems that exceed OSHA PSM requirements (29 CFR 1910 [14]) by following the “Risk Based Process Safety” guidelines published by the AIChE Center for Chemical Process Safety (CCPS). CCPS guidelines exceed legal requirements in the United States. The assessment showed that the nuclear and radiological facilities meet these guidelines. A table showing results of the assessment is provided in Table I. The assessment further indicated similarities in the hazard identification and risk assessments of the chemical industries best practices and those practices deployed at these nuclear and radiological facilities. It also highlighted some key differences including: a) chemical hazard screening practices, b) higher level of controls at a lower threshold, c) use of bounding conditions versus plausible credible deviations for scenario evaluations, and d) differences stemming from an environment of external oversight versus internal governance. A key difference was chemical hazard screening practices. Although, the top tier chemical companies utilize the OSHA PSM and EPA RMP (40 CFR 68 [15]) hazardous chemical listings for chemical hazard screening, they also use company proprietary indexes (for example, DOW uses an internal Chemical Exposure Index), as well as assessing specific toxic inhalation hazards of a chemical prior to consideration in an exposure scenario/event or quantitative analysis ensuring chemical hazards are only evaluated for true toxic inhalation hazards.

TABLE I. Comparison of "Risk Based Process Safety" Guidelines versus OSHA and Savannah River Practices

| CCPS Risk Based Process Safety Management System Elements (Top Tier Chemical Companies) | OSHA 1910.119 - Process Safety Management of Highly Hazardous Chemicals | Hazard Category 2 or 3 Facility | Radiological Facility |
|---|---|---|---|
| **Foundational Block: Commit to Process Safety** | | | |
| 1 - Leadership and Process Safety Culture | | √ | √ |
| 2 - Compliance with Standards | Process Safety Information (PSI) | √ | √ |
| 3 - Process Safety Competency | | √ | √ |
| 4 - Workforce Involvement | Employee Participation | √ | √ |
| 5 - Stakeholder Outreach | | √ | √ |
| **Foundational Block: Understand Hazards and Risk** | | √ | |
| 6 - Process Knowledge Management | Process Safety Information (PSI) | √ | √ |
| 7 - Hazard Identification and Risk Analysis | Process Hazard Assessment (PHA) | √ | √ |
| **Foundational Block: Manage Risk** | | √ | |
| 8 - Operating Procedures | Operating Procedures/ Safe Work Practices | √ | √ |
| 9 - Safe Work Practices | Hot Work | √ | √ |
| 10 - Asset Integrity and Reliability | Mechanical Integrity | √ | √ |
| 11 - Contractor Management | Contractors | √ | √ |
| 12 - Training and Performance Assurance | Training | √ | √ |
| 13 - Management of Change | Management of Change | √ | √ |
| 14 - Operational Readiness | Pre-startup Safety Review | √ | √ |
| 15 - Conduct of Operations | | √ | √ |
| 16 - Emergency Management | Emergency Planning and Response | √ | √ |
| **Foundational Block: Learn from Experience** | | | |
| 17 - Incident Investigation | Incident Investigation | √ | √ |
| 18 - Measurement and Metrics | | √ | √ |
| 19 - Auditing | Compliance Audit | √ | √ |
| 20 - Management Review and Continuous Improvement | | √ | √ |
| | | | |
| | Trade Secrets – Applies to PSI, PHA, Procedures, etc. | √ | √ |

## BENEFITS

Using the proposed process to address chemical hazards within HC 1, 2, and 3 nuclear facilities has several important benefits. Included among the benefits are:

- Equal treatment of chemical hazards regardless of facility type
- Shift analysis of hazards and development of controls to the appropriate subject matter experts and programs
- Eliminate redundant analysis in DSA and chemical safety programs
- Reduced nuclear safety analysis
- Reduced DSA/TSR volume
- Operational implementation savings
- Integral safety enhancement through reduced mission time
- Most importantly, risk reduction through improved mission completion timelines

## CONCLUSIONS

The regulatory framework, with the possible exception of certain statements within DOE-STD-3009-2014 [5] and DOE-STD-1189-2008 [6], support a more cost-effective approach to managing chemical hazards while maintaining safety margin. Most importantly, the proposed approach provides risk reduction through accelerated mission completion times. DOE EM issued a letter to the DOE EM sites (March 2019) clarifying the expectations as described in this document. Numerous sites are motivated to adopt these strategies, with many sites initiating implementation plans. If this is done it will maintain safety and significantly reduce costs and lifecycle risk through faster mission completion.

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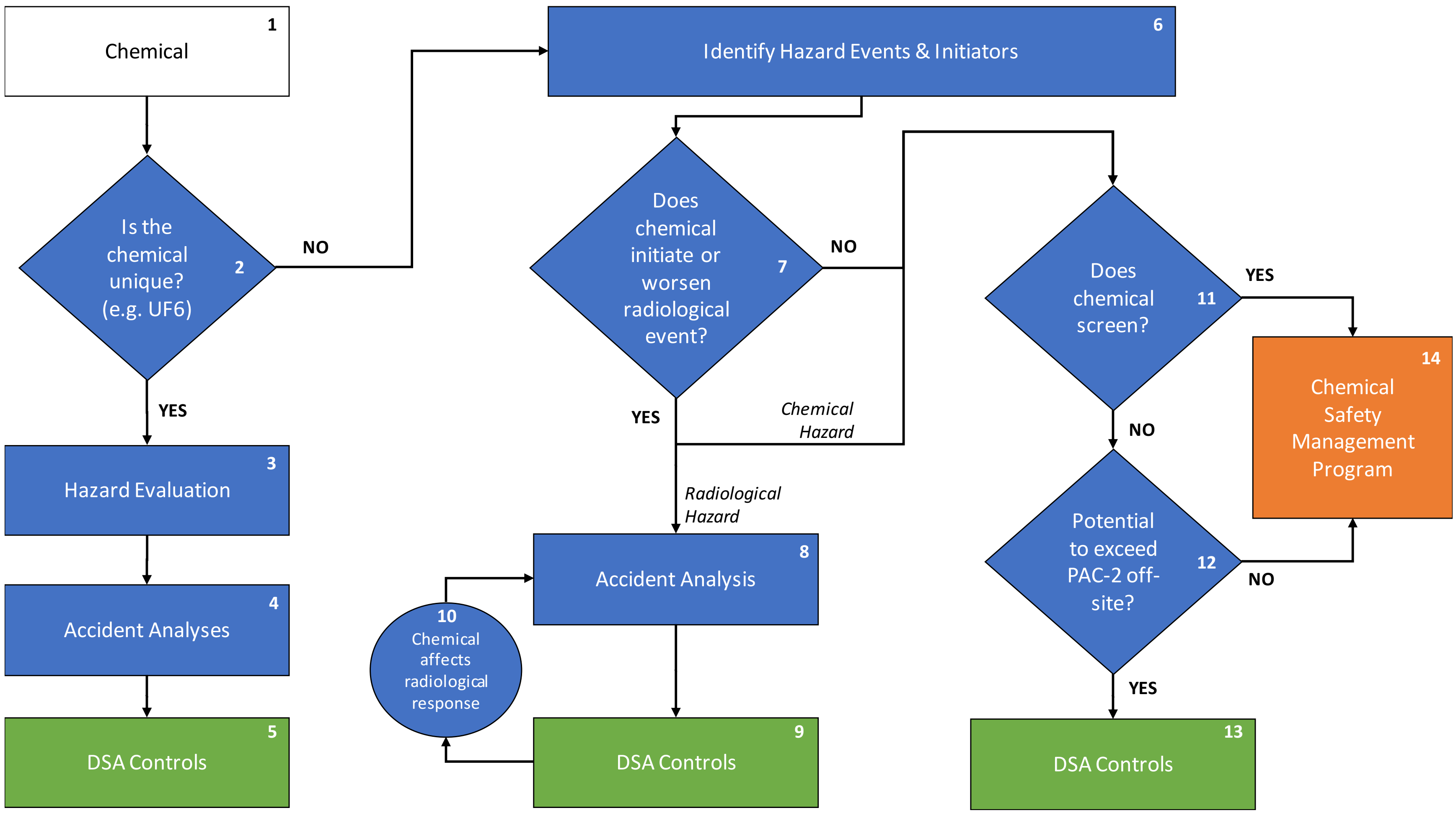
## ACKNOWLEDGMENTS

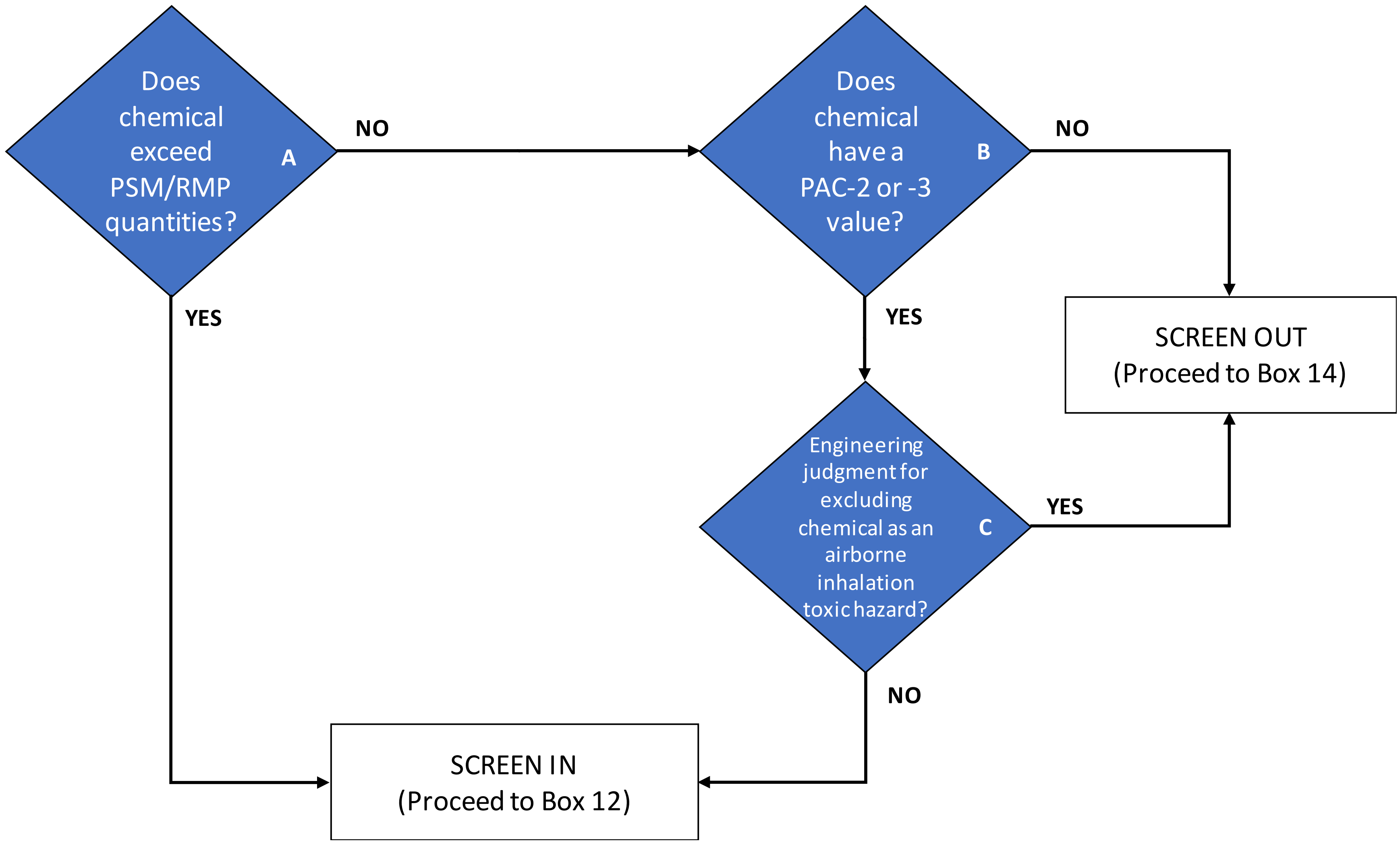
I would like to recognize the team, led by representatives from Savannah River Remediation (SRR), Washington River Protection Solutions (WRPS)-Tank Operation Contract (TOC), AECOM Technical Services (TS), and comprised of representatives from DOE (EM, AU, ORP, SR), Idaho State University (ISU), and other complex contractors (UCOR, SRNS, WTP, WTCC, INL), for their extraordinary efforts in developing this strategy. I would also like to acknowledge Dae Chung, Deputy Assistant Secretary for Safety, Security, and Quality Assurance, and his staff for their involvement with the team's efforts and championing this strategy across the DOE EM Complex.

**APPENDIX A**

**Chemical Hazard Implementation Strategy Flowchart**



**Chemical Hazard Implementation Strategy - Expanded Flowchart for Block 11**



**Legend for Implementation Flowchart**

**Box 1:** Includes chemicals currently identified by site; cold chemicals, chemicals generated from the process, chemicals as part of the mixed waste stream.

**Box 2:** Unique chemicals defined as "chemicals unique to nuclear industry and represent exceptional hazards as directed by EM Central Technical Authority". Currently, EM has only identified one unique chemical: UF6. Cases involving unique chemical hazards potentially requiring Technical Safety Requirements should be brought to the attention of the EM Central Technical Authority (Chung, 2019) or NNSA Central Technical Authority.

**Box 3:** Hazard Evaluation process as currently described by safe harbor standards (e.g., DOE-STD-3009-94, DOE-STD-3009-2014, DOE-STD-1189) and defined in site procedures.

**Box 4:** Consequence analysis process (offsite, onsite, facility worker) currently described for chemical consequences by safe harbor standards (e.g., DOE-STD-3009-94, DOE-STD-3009-2014, DOE-STD-1189) and defined in site procedures.

**Box 5:** Control selection and classification process as currently described by safe harbor standards (e.g., DOE-STD-3009-94, DOE-STD-3009-2014, DOE-STD-1189, DOE-STD-1186) and defined in site procedures.

**Box 6:** This activity is accomplished as part of the hazards analysis process. This element is focused on the hazardous events and initiators associated with chemicals that can initiate or worsen a radiological event, or may be a significant chemical hazard. For example, hydrogen explosion causing a release of radiological waste from a process tank, or a very large volume of chlorine released to the public (e.g, >PAC-2 offsite).

**Box 7:** Determination of chemical event causing or worsening a radiological release. If yes, radiological consequences are handled as part of the radiological consequence analysis. Regardless of determination, chemical consequences are addressed by Chemical Safety Management Program (Box 14).

**Box 8:** Radiological consequences determined as currently described by safe harbor standards (e.g., DOE-STD-3009-94, DOE-STD-3009-2014, DOE-STD-1189) and defined in site procedures.

**Box 9:** Control selection and classification process as currently described by safe harbor standards (e.g., DOE-STD-3009-94, DOE-STD-3009-2014, DOE-STD-1189, DOE-STD-1186) and defined in site procedures.

**Box 10:** Determine if chemicals negatively impact a safety function credited in the facility's Safety Basis (e.g., incapacitating a worker relied upon to perform a credited safety function, or affecting safety related SSCs) (Chung, 2019). Select additional controls or modify the proposed controls, as necessary, to ensure safety function is adequately implemented.

**Box 11:** This identifies an initial screening process for chemical hazards. It is intended to screen out chemicals that have no adverse offsite impact and can be safely managed through 10 CFR 851 and normal safety management programs at the site. This screening is done on an individual chemical basis.

A. Screen to determine if the chemical is listed per PSM (29 CFR 1910.119) and RMP (40 CFR 68) as described in DOE-HDBK-1101-2004, and is above respective PSM/RMP quantities. Site specific evaluation must provide technical basis demonstrating PSM/RMP quantities are not exceeded.

B. Screen to determine if the chemical has a PAC value listed on SCAPA website.
C. It is recognized that some chemicals have PAC values, but are not inhalation hazards at a distance. Documented engineering judgement may be used to screen. The basis for engineering judgement may include DOE-STD-1189-2008 or DOE-STD-3009-2014 screening criteria, laboratory reports, SME judgement, and external sources.

**Box 12:** Chemical consequence analysis process for the offsite receptor, currently described by safe harbor standards (e.g., DOE-STD-3009-2014, DOE-STD-1189-2008) and defined in site procedures. Consequence analysis may include sum of fractions methodology for chemicals that were not screened out in Box 11, and applicable accident parameters (e.g., ARF, RF) and site-specific parameters (e.g., atmospheric dispersion) as used in nuclear safety consequence analysis. Existing site calculations that include applicable chemicals may be used to evaluate the offsite chemical consequences.

**Box 13:** Control selection and classification process as currently described by safe harbor standards (e.g., DOE-STD-3009-94, DOE-STD-3009-2014, DOE-STD-1189, DOE-STD-1186) and defined in site procedures.

**Box 14:** Chemical consequences and controls are addressed by SMPs (e.g., Industrial Hygiene, Emergency Preparedness). Details of the Chemical Safety Management Program follows.

**Chemical Safety Management Program**

Implementation of 10 CFR 851 at specific sites is dependent upon implementation of many individual safety management programs (e.g., IH, EP, QA, Engineering, Fire Protection, Maintenance). The chemical safety management program is meant to umbrella the individual safety management programs.

In large measure, the content of DOE-HDBK-1139-2006, Chemical Management, provides the information necessary to establish an overall program to ensure the safe handling, processing, and storage of chemicals. In particular, compliance with requirements established in 10 CFR 851.21, Hazard Identification and Assessment as well as 10 CFR 851.22, Hazard Prevention and Abatement, is an essential part of ensuring the proper treatment of chemical hazards. Additionally, compliance with the requirements established in DOE O 151.1 [3] also plays an important role in ensuring the proper response to chemical hazardous events.

DOE-HDBK-1139-2006 (Volume 2 of 3) provides a flowchart for chemical safety lifecycle management. Effective implementation of the items identified on the flowchart provide ample assurance of comprehensive treatment of chemical hazards:

- Hazard Identification and Analysis
- Hazard Control

Additionally, DOE-HDBK-1100-2004, Chemical Process Hazards Analysis, provides the elements common to all process hazard analysis:

- Identify process hazards
- Review previous incidents
- Analyze engineering and administrative controls and consequences of control failures
- Consider facility siting
- Address human factors
- Evaluate effects of incidents on employees
- Decide when action items are warranted.

Furthermore, DOE-HDBK-1163-2003, Integration of Multiple Hazard Analysis Requirements and Activities, can be used to provide a resource to support planning, technical review, or conduct of hazard analysis activities.

- Acquisition
- Transportation
- Inventory and Inventory Tracking
- Storage
- Training
- Emergency Response
- Pollution Prevention

At the implementation level, multiple programs have specific elements that work together to ensure proper treatment of chemical hazards. Key among these programs is Industrial Hygiene and Emergency Planning. Notably, emergency planning includes a detailed hazard survey. Additionally, operations organizations, maintenance organizations, quality assurance organizations, fire protection, and engineering organizations work together from an Integrated Safety Management System perspective to ensure the proper treatment of chemical hazards. Evidence of facility specific implementation of the chemical safety management program is site dependent.

Two important considerations regarding ensuring proper treatment of chemical hazards are design and operations/maintenance. Compliance with applicable codes and standards, design hazards analysis, change control processes, and preparation and upkeep of system design descriptions help to ensure chemical hazards are adequately addressed in the design of the facility. From an operations and maintenance perspective, procedures, work packages, training programs, event investigations, and lessons learned all work together to ensure the proper treatment of chemical hazards. Coupled with design and operations/maintenance considerations, change control and configuration management along with process flow sheet development are an important part of ensuring proper treatment of chemical hazards.