



Session II – Hazard Analysis



Session II Overview

- DOE-STD-3009-2014, Section 3 provides detailed criteria and guidance for performing Hazard Analysis, Accident Analysis, and Hazard Control Selection
- Clarifies **requirements**, adding “**shalls**” to CN3 guidance
 - See handout “DOE-STD-3009-2014 Requirements Table”
 - **Red font** on slides highlight **requirements** if not already obvious
- **Session II Hazard Analysis Topics:**
 - Hazard Identification
 - Hazard Evaluation





Hazard Analysis Major Changes

- No significant change in philosophy
- “Hazard Analysis” is:
 - Hazard Identification,
 - Hazard Categorization, and
 - Hazard Evaluation.
- Clarifies methods for unmitigated and mitigated hazard evaluations and control selection
- Includes Co-located Worker receptor @ 100 m
- Clarifies treatment of standard industrial hazards
- Includes screening & evaluation of chemical hazards

Note: STD-3009-2014 Section number in upper right box.





Hazard Analysis Key Requirements

- **No significant changes, other than addition of clear “**shall**” statements**
 - Systematic Identification & Evaluation of Hazards
 - Nuclear and Nonnuclear Hazards
 - Complete Spectrum of Events (“hazard scenarios”)
 - Largely Qualitative
 - Hazard Analysis Forms Basis for Entire Safety Analysis





Hazard Identification

Major Changes

- **Clarifies Exclusion of Standard Industrial Hazards (SIH) and Chemical Screening**
 - Appendix, Section A.1 clarifies SIH screening
 - Appendix, Section A.2 clarifies chemical screening
- **Document Basis for Exclusions**
 - Examples: 10 C.F.R. 851.23, Safety & Health Standards; other codes
- **Use bounding inventories (radiological and hazardous materials)**
 - May use SACs to establish inventory limits
- **DSA Section [3.3.2.1] hazard ID summary tables or text**

Note: use of brackets [] refers to DOE-STD-3009-2014, Section 4





Appendix, Section A.1

Standard Industrial Hazards

- **Standard Industrial Hazards (SIHs) are hazards that are routinely encountered in general industry and construction.**
 - SIHs are addressed by 10 C.F.R. 851, *Worker Safety and Health Program* (issued 2006).
 - 10 C.F.R. 851 requires identification and assessment of worker hazards and compliance with safety and health standards that provide specific safe practices and controls.





Appendix, Section A.1

SIH Screening

■ SIH included in DSA Hazard Evaluation if:

- Initiate radiological or hazardous material (hazmat) accident
- Worsen consequences of radiological or hazmat accident
- Result from chemical or radiological hazards (e.g., shrapnel from explosion due to radiolysis in tank)
- Prevent Safety SSCs from providing its safety function

NEW

■ Unique Hazards not Excluded as SIH

- Unique to DOE applications or operations
- Larger quantities than typically used in general industry
- Affect entire work area or impact safe operations of facility (prevent implementing SAC)

NEW



Appendix, Section A.2 Chemical Screening

- **DSA not intended to deal extensively with chemicals that can be safely handled by Hazardous Material Protection Program**
- **Example chemical screening:**
 - No known or suspected toxic properties (listed by OSHA or EPA, has PAC-2 or PAC-3 value established)
 - NFPA 704 health hazard rating of 0 or 1
 - Commonly available and used by general public
 - Small-scale use quantities similar to intent of 29 C.F.R. 1910.1450
 - May exclude fire smoke but not process decomposition products





Appendix, Section A.2 Chemical Screening (Cont.)

- Extraordinary toxic hazard not excluded
- Chemicals included if:
 - Initiate or contribute to radiological or hazmat accidents, or
 - Prevent operators to safely manage facility





Hazard Evaluation Major Changes

- **Methodology**
 - Standardizes frequency, consequences, and risk tables
 - Appendix, Section A.3 clarifies initial conditions
 - Appendix, Section A.4 clarifies risk ranking
- **Mitigated Hazard Evaluation**
 - Effectiveness of Controls
 - Safety Functions
- **Facility Worker Hazard Evaluation**
- **Inadvertent Criticality Hazard Evaluation**
- **Chemical Hazard Evaluation**





Hazard Evaluation General

- The hazard evaluation **shall provide:**
 - (a) **Assessment** of the facility **hazards** associated with the **full scope of planned operations**
 - Normal ops (startup/shutdown, maintenance), abnormal conditions, accident conditions
 - (b) **Identification of controls** that can prevent or mitigate these hazards or hazardous conditions.
- **Operational Accidents, Natural Phenomena Hazards (NPH), Man-made External Events**
- **Graded Approach to select Haz. Eval. Technique**
 - **Rationale justified**





Hazard Evaluation General (cont.)

- **Unmitigated hazard evaluation of “hazard scenarios”**
 - Each initiating event by assuming absence of preventive or mitigative controls
 - Initial Conditions covered in Section 3.2.2 unmitigated analysis
- **Estimate Consequences**
 - Qualitative and/or semi-quantitative techniques
 - Shall address potential effects on Facility Workers (FW), Co-located Workers (CLW), and Public (Maximally-exposed Offsite Individual [MOI])
 - CLW is new requirement
 - Shall use Table 1 consequence levels

NEW

NEW





Hazard Evaluation General (Cont.)

- **Estimate Likelihoods Qualitatively**

NEW

- Shall use Table 2 likelihood bins

- **Use of risk binning optional**

NEW

- If risk rankings used, Tables 1 and 2 shall be used
- Appendix, Section A.4, Hazard Evaluation and Risk Ranking & Table A-1

- **Section 3.2.2 provides additional considerations**





Hazard Evaluation

Table 1 Consequence Thresholds

Consequence Level	Public	Co-located Worker	Facility Worker
High	≥ 25 rem TED or $\geq \text{PAC-2}$	≥ 100 rem TED or $\geq \text{PAC-3}$	Prompt death, serious injury, or significant radiological and chemical exposure
Moderate	≥ 5 rem TED or $\geq \text{PAC-1}$	≥ 25 rem TED or $\geq \text{PAC-2}$	No distinguishable threshold
Low	< 5 rem TED or $< \text{PAC-1}$	< 25 rem TED or $< \text{PAC-2}$	No distinguishable threshold





Hazard Evaluation

Table 2 Qualitative Likelihood Bins

Description	Likelihood Range (/year)	Definition
Anticipated	Likelihood $>10^{-2}$	Events that may occur several times during the lifetime of the facility (incidents that commonly occur).
Unlikely	$10^{-2} > \text{likelihood} > 10^{-4}$	Events that are not anticipated to occur during the lifetime of the facility. Natural phenomena of this likelihood class include: Uniform Building Code-level earthquake, 100-year flood, maximum wind gust, etc.
Extremely Unlikely	$10^{-4} > \text{likelihood} > 10^{-6}$	Events that will probably not occur during the lifetime of the facility.
Beyond Extremely Unlikely	Likelihood $<10^{-6}$	All other accidents.





Hazard Evaluation

Table 2 (Cont.)

- **May quantify frequency of occurrence to assign qualitative likelihood**
 - Probabilistic calculations not required to inform likelihood estimates
 - May use probabilistic risk assessment (PRA) per DOE-STD-1628-2013 to inform qualitative likelihood estimates
 - Use DOE-STD-3014-2006 for aircraft crash frequencies
- **Use of $<1\text{E-6/yr}$ (BEU) threshold not appropriate for Haz Eval**
 - Should not be used as an absolute cutoff for dismissing physically possible low probability operational accidents such as “red oil” explosions.
 - Hazard scenarios of operational accidents that are deemed not plausible per the criteria in Section 3.2.1 may be excluded from the hazard evaluation also.





Hazard Evaluation

Table A-1: Risk Ranking Bins

Consequence Level	Beyond Extremely Unlikely Below $10^{-6}/\text{yr}$	Extremely Unlikely 10^{-4} to $10^{-6}/\text{yr}$	Unlikely 10^{-2} to $10^{-4}/\text{yr}$	Anticipated Above $10^{-2}/\text{yr}$
High Consequence	III	II	I	I
Moderate Consequence	IV	III	II	II
Low Consequence	IV	IV	III	III





Hazard Evaluation Facility Worker

- **FW unmitigated consequences should be based on combination of the following:**
 - (1) Magnitude, type, and form of radioactive and hazardous materials involved in a hazard scenario;
 - (2) Type and magnitude of energy sources involved in scenario;
 - (3) Characteristics of hazard scenario such as duration and location where it may occur (e.g., in unmanned areas, such as tank vaults); and,
 - (4) Potential for a hazard to impact workers' mobility or ability to react to hazardous conditions.
- Mobility or ability to react to hazardous conditions should not be used as the sole or primary basis for determining FW impacts





Hazard Evaluation Facility Worker (Cont.)

- **May exclude FW consequences if solely due to SIH**
 - Include serious injury/fatality from SIH if due to the rad. or chemical hazard being evaluated (e.g., explosion, chemical burn)
- **May use scoping calculations, engineering judgment, historical experience**
 - Not expected to quantify FW rad. / hazmat inhalation consequences





Hazard Evaluation Co-located Worker

- Consequence determinations **shall** be supported by an **adequate technical basis**
 - Such as scoping calculations consistent with Section 3.2.4.
- Alternately, the quantitative evaluation CLW consequences used to compare to Table 1 thresholds may be performed in the accident analysis and reported in the DSA Section [3.4]





Hazard Evaluation

Hazard Controls

- For each of the unmitigated hazard scenarios, the **controls** (SSCs, administrative and/or programmatic) that can **prevent or mitigate** the hazard scenario **shall be identified**.
- **A mitigated hazard evaluation shall be performed to determine the effectiveness of safety significant (SS) controls** by estimating hazard scenario likelihood with preventive controls and consequences with mitigative controls.
 - Following the preferred hierarchy described in Section 3.3





Hazard Evaluation

Hazard Controls (Cont.)

- Evaluation of control effectiveness may be accomplished using one of the following two options:
 - (1) Perform mitigated analysis and include results for hazard scenarios directly in hazard evaluation tables; or,
 - (2) Perform mitigated analysis and include as a summary evaluation in DSA Section [3.3.2.3].
- In either case, include SS controls for hazard scenarios having:
 - high estimated chemical consequences to the public, or
 - high radiological or chemical consequences to workers
- **Control effectiveness**, along with **safety functions** for these controls, **shall be included** in the hazard evaluation,
 - unless determined as part of the Section 3.2 accident analysis





Hazard Evaluation

Hazard Controls (Cont.)

- Additional considerations for mitigated hazard evaluation are provided in:
 - Section 3.2.3, Mitigated Analysis
 - Section 3.3, Hazard Control Classification
- DSA hazard evaluation **shall also examine the potential for large-scale environmental contamination and identify preventive and mitigative controls to protect the environment**
 - Section 3.3 criteria for safety control selection are not based on environmental contamination
 - unless a significant spill to the environment outside the facility can contribute to radiological exposures as discussed in Sect. 3.2.4.2.

NEW





Hazard Evaluation Criticality Hazards

- Inadvertent criticality accident represents a special case for hazard evaluation
- Criticality safety evaluations per ANSI/ANS-8 series
- DSA hazard evaluation **shall include:**
 - Events where consequences **exceed the high rad. thresholds** for either the **co-located workers** or the **MOI**, and
 - Unless unmitigated criticality accident is not credible
 - Situations where an **active engineered control(s) is required** by the Nuclear Criticality Safety (NCS) analysis to ensure subcriticality





Hazard Evaluation

Criticality Hazards (Cont.)

- If the NCS program requires a criticality accident alarm system, then the **criticality accident alarm system shall be discussed** in the hazard evaluation and carried forward to evaluation in accordance with **Section 3.3**.
- Chapter 6 of the DSA will provide:
 - General discussion of criticality control strategies
 - General discussion of the parameters used for the prevention of inadvertent criticality





Hazard Evaluation Chemical Hazards

- Chemicals not screened (e.g., A.2) need to be considered for their possible impact on:
 - radiological or other chemical accident initiation or progression, or
 - potential adverse impact on safety systems
- Qualitative evaluation of chemical consequences is generally sufficient for comparison to Table 1
- Quantitative analysis should be performed to determine impacts to CLW and MOI (based on guidance in 3.2.4.3)





Hazard Evaluation

Chemical Hazards (Cont.)

- **Determination of chemical quantities sufficient to challenge the criteria may be supported by:**
 - Scoping calculations using the methods presented in Section 3.2.4.3, or by
 - Engineering judgment based on previous safety basis calculations, emergency planning calculations, or consensus standards.
- **Appendix, Section A.2 provides guidance on chemical exposure calculations**
 - Topic to be addressed in more detail in the DOE Accident Analysis Handbook





Hazard Evaluation Documentation

- **Section [3.3.2.3] Provides Expectations of Summaries**
- **Provide Hazard Evaluation tables or data sheets - either as a DSA appendix or supporting document(s).**
 - Note that hazard evaluation data are part of the DSA, whether included directly or by reference.
- **For each hazard scenario table or data sheets:**
 - Brief scenario summary, unmitigated likelihood and consequences, preventive and mitigative controls
 - Optional: unmitigated risk binning; mitigated likelihood, consequence, risk binning; and operational safety enhancements





Hazard Evaluation Documentation (Cont.)

- Provide summaries if large number of hazard scenarios by distilling from Hazard Evaluation tables or data sheets
- Present mitigated hazard evaluation if not included in DSA Section 3.4, Accident Analysis
- Other DSA Sections:
 - [3.3.2.4] Defense-in-Depth
 - Appendix, Section A.9 provides background on defense-in-depth philosophy
 - [3.3.2.5] Facility Worker Safety
 - [3.3.2.6] Environmental Protection

