Development of Consistent Hazard Controls for DOE Transuranic Waste Operations

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ABSTRACT

This paper describes the results of a re-engineering initiative undertaken with the Department of Energy's (DOE) Office of Environmental Management (EM) in order to standardize hazard analysis assumptions and methods and resulting safety controls applied to multiple transuranic (TRU) waste operations located across the United States. A wide range of safety controls are historically applied to transuranic waste operations, in spite of the fact that these operations have similar operational characteristics and hazard/accident potential. The re-engineering effort supported the development of a DOE technical standard with specific safety controls designated for accidents postulated during waste container retrieval, staging/storage, venting, onsite movements, and characterization activities. Controls cover preventive and mitigative measures; include both hardware and specific administrative controls; and provide protection to the facility worker, onsite co-located workers and the general public located outside of facility boundaries.

The Standard [1] development involved participation from all major DOE sites conducting TRU waste operations. Both safety analysts and operations personnel contributed to the re-engineering effort. Acknowledgment is given in particular to the following individuals who formed a core working group: Brenda Hawks, (DOE Oak Ridge Office), Patrice McEahern (CWI-Idaho), Jofu Mishima (Consultant), Louis Restrepo (Omicron), Jay Mullis (DOE-ORO), Mike Hitchler (WSMS), John Menna (WSMS), Jackie East (WSMS), Terry Foppe (CTAC), Carla Mewhinney (WIPP-SNL), Stephie Jennings (WIPP-LANL), Michael Mikolanis (DOE-SRS), Kraig Wendt (BBWI-Idaho), Lee Roberts (Fluor Hanford), and Jim Blankenhorn (WSRC). Additional acknowledgment is given to Dae Chung (EM) and Inés Triay (EM) for leadership and management of the re-engineering effort.

INTRODUCTION

The DOE is responsible for the safe handling, packaging and ultimate disposal of TRU wastes at the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico. This waste originates from past legacy operations that supported the nuclear weapons mission, as well as newly generated waste from ongoing facility cleanup missions. TRU wastes are currently stored at numerous DOE installations across the United States. These wastes contain various types and quantities of residual radioactive materials, as well as other hazards such as flammable levels of hydrogen or volatile organic compounds that must be mitigated prior to shipment to WIPP. These waste materials could present significant harm to workers, the environment, and the public during accident scenarios if not adequately controlled.

Facility operations supporting the TRU waste disposal mission, while numerous and located at multiple locations, share a similarity in terms of the hazards and scope of operations. However, facilities often employ a variety of accident analysis assumptions and controls to manage the TRU wastes. Recognition of these inconsistencies led the DOE to develop a technical standard that lays out expectations for analyzing and controlling TRU waste hazards.

To support this effort, DOE had to overcome several challenges. Chief among them was that TRU wastes are located at both large and small sites and range from very low levels of radioactivity to those with significant radiological hazards. A one size fits all approach could be overly costly for smaller sites and not necessarily be in line with relative lower actual risks.

A second challenge was that TRU waste operations are conducted in both newly designed structures and existing buildings originally intended for other DOE missions. These older facilities typically don't meet current facility design requirements. Therefore, DOE had to recognize that protective features designed into new facilities are not always available and may be cost prohibitive for retro-fitting into existing buildings.

To support these strategies, a DOE working group collected hazard analysis and control data from many of its installations. This information was used to establish a baseline of minimum accidents that should be included with Documented Safety Analyses (DSAs) at TRU waste operations. The working group examined the numerous available tests and studies related to container behavior under various accident stresses in order to establish reasonably conservative assumptions to support hazard and accident analyses. DOE then conducted a series of working group meetings during which hazardous TRU waste events, necessary control functions, and proposed preferred and alternate controls could be established. These working group meetings involved operations and safety analysis personnel from each of its large sites. These meetings led to a consensus approach to support the development of the DOE Technical Standard [1], which is discussed in this paper.

HAZARD AND ACCIDENT ANALYSIS

Factors and Assumptions

An unmitigated receptor dose from accident sequences is used in a DSA to compare against evaluation guidelines and to determine the need for safety-related systems, structures and components. This concept helps establish the worth of a control by providing a perspective of consequence magnitude with no controls in place versus the mitigated consequence with controls in place. Though an unmitigated analysis does not credit controls, it does consider certain factors related to accident phenomenology.

Simplistically, receptor doses can be estimated by Equation 1 (assuming the inhalation pathway is the predominant exposure pathway since TRU waste contains predominately alpha emitters such as plutonium).

$$\text{Dose (rem)} = \text{ST} \cdot \chi/Q \cdot \text{DCF} \cdot \text{BR} \qquad \text{(Eq.1)}$$

Where:

ST = respirable source term (Ci)

χ/Q = atmospheric dilution factor (s/m^3)

BR = breathing rate (m^3/s).

DCF = inhalation dose conversion factor (rem/Ci)

The respirable source term is dependent on certain accident stresses and assumptions given in Equation 2.

$$ST = MAR \cdot DR \cdot ARF \cdot RF \cdot LPF \quad \text{(Eq. 2)}$$

Where,

MAR = material-at-risk is the amount of radionuclides available to be acted on by a given physical stress.

DR = damage ratio or fraction of the MAR that is impacted by the postulated accident scenario, unitless

ARF = airborne release fraction, unitless

RF = respirable fraction, unitless

LPF = leak-path factor, unitless

The values chosen for these factors can have a significant effect on the magnitude of estimated consequences and therefore a major impact on safety control decisions. The TRU Waste Standard addresses each of these factors and provides established values based either on confirmatory tests and studies or engineering judgment reached in a consensus forum.

With the exception of Leak Path Factors (LPF), a discussion of each Source Term factor is given in the following paragraphs. LPF values are assumed to be a value of one in unmitigated analysis because of the sophisticated analysis required to validate lesser values.

Material at Risk

The purpose of estimating the MAR is to identify a bounding value for the accident scenario being evaluated. TRU waste operations can involve hundreds, if not thousands of containers that range in radioactivity levels. The following example illustrates an approximate MAR distribution found at the Oak Ridge National Laboratory.

> *The current TRU waste population has approximately 4,000 containers. The drum with the highest radioactivity level contains 300 Plutonium-239 Equivalent Curies (PE-Ci). Only six containers have greater than 200 PE-Ci; 25 containers have greater than 100 PE-Ci; and less than one hundred containers have greater than 10 PE-Ci. Overall, 95% of the containers do not exceed 5 PE-Ci.*

In the above example, it would be overly conservative to assign a value of 300 PE-Ci to all containers involved in a multiple container accident given the container distribution. On the other hand, it is not conservative to assume the 95th percentile value of 5 PE-Ci for an accident involving a single container. The TRU Waste Standard addresses this situation by assigning an algorithm of MAR assumptions that is sensitive to the number of containers estimated to be involved in an accident. The algorithm, which is shown in Table I, also considers the level of knowledge and characterization associated with the given waste stream.

Table I- MAR Algorithm

MAR Description	Limited Characterization[1]	Fully Characterized [2]
Single Container	Maximum container +20%	Maximum container
Two Containers	One at Maximum container, one at 99th percentile	One at Maximum container, one at 95 th percentile
Three Containers	One at Maximum container, one at 99 th percentile, one at 95 th percentile	One at Maximum container, one at 95 th percentile, one at mean or median[4]
Four Containers	One at Maximum container, one at 99 th percentile, two at 95 th percentile	One at Maximum container, one at 95 th percentile, two at mean
Greater than four containers	One at Maximum container, one at 99 th percentile, two at 95 th percentile, Remainder at mean each, Or Applicable Facility/area/payload Limit [3]	One at Maximum container, one at 95 th percentile, remainder at mean each, Or Applicable Facility/area/payload Limit [3]
TRUPACT-II Payload	N/A	Fourteen containers at WIPP WAC Limit[3]

[1] Waste has limited characterization data and relies on measures such as process knowledge.

[2] Inventory is assumed to be fully characterized when contents of each container are known (e.g., meets requirements for WIPP compliant assay or other acceptable characterization of each container).

[3] Bounding MAR limit determined based on operational needs and inventory profile. If the maximum container limit to be shipped is well below the WIPP Waste Acceptance Criteria (WAC) limit, then the 14 containers shall be at the maximum inventory limit.

4 In cases where containers are intentionally grouped (e.g., separation of high or low inventory containers), statistics in this table shall be applied to each grouped population of containers.

The quantities of TRU material presented in Table I follow the general algorithm that a single container scenario assumes the presence of the single maximum loaded container, while multiple container accident scenarios assume the presence of some combination of containers containing the maximum container value, 99th, 95th, and mean quantities of TRU material, from the population of containers being evaluated. The algorithm also accounts for the extent of characterization associated with the inventory (limited or partial characterization, and fully characterized, e.g., WIPP compliant assay). The use of an additional 20% margin is recommended for single container events in which the drum is not characterized or has limited characterization (e.g., not fully WIPP compliant or otherwise acceptably characterized). The methodology also provides for additional conservatism to account for the increased uncertainty when the waste containers involved in the accident are not fully characterized.

Damage Ratios

The Damage Ratio (DR) is one of the parameters of the "five-factor formula" concept presented in DOE-HDBK-3010, *Airborne Release Fractions/Rates and Respriable Fractions for Nonreactor Nuclear Facilities* [2] as expressed in Equation 2 above. The DR is defined in the Handbook as the "fraction of the MAR actually impacted by the accident-generated conditions."

The DR is estimated based upon engineering analysis of the response of structural materials and materials-of-construction for containment to the type and level of stress/force generated by an accident event. Standard engineering approximations are typically used. These approximations often include a degree of conservatism due to simplification of phenomena to obtain a useable model, but the purpose of the approximation is to obtain, to the degree possible, a realistic understanding of potential effects.

The TRU waste standard addresses bounding DRs for drum deflagrations, fires, container impacts/spills, and natural phenomena events. Table II provides examples of damage ratios associated with container drops and impacts based various container tests and studies at Sandia National Laboratory, the DOE Hanford Reservation, and the DOE Rocky Flats Environmental Management Facility.

Table II-Sample of Damage Ratios for Container Drops and Impacts

Accident Stress (Container Drops and Impacts)	Damage Ratio (DR) Based on Container Types		
	Drum	Standard Waste Box and RH canisters	Pipe Overpack Container
1. Stress within container qualifications (i.e., <4 foot drop)	0	0	0
2. Minor stress causes breach, e.g.: - Single container or unbanded palletized containers dropped from 3rd tier in stacked array - Multiple containers impacted by low-speed vehicle (e.g., less than ~10 mph in congested or tight areas) - Containers containing closed pipes or welded containers that are dropped from 4th or 5th tier in stacked array	0.01	0.01	0
3. Container(s) punctured by forklift tines:			
- Contaminated solids	0.1	0.05	0.05
- Sand-like materials	1.0	0.5	0.1
4. Single container or unbanded[b] palletized containers dropped from 4th or higher tier in stacked array:			
- Contaminated solids	0.1	0.1	0
- Sand-like materials	0.5	0.25	0
5. Moderate to severe stress causes breach, e.g.: - Multiple containers impacted by vehicle traveling typical onsite speed limit for populated areas (> ~10 mph) - Vehicle crash affecting multiple containers, but not directly impacted by the vehicle (low or high speeds)	0.1	0.1	0
6.Catatrophic stress causes breach, e.g.: - Containers directly impacted by high-speed vehicle - Container(s) impacted by compressed gas cylinder traveling long distance and/or airborne - Container(s) impacted by tornado- or wind-generated missile	1.0	1.0	0

Airborne Release Fractions and Respirable Fractions

The airborne release fraction (ARF) and respirable fraction (RF) are key factors in estimating the amount of airborne materials generated from accidents involving solids, liquids, gases or surface contamination. ARF and RF values are given in DOE-HDBK-3010-94, and pertinent values from this handbook are clarified in the TRU Waste Standard.

ARF and RF values vary according to the form of material and type of accident stress. A breakdown of ARF*RF values based on TRU waste forms and accident types is discussed in the Standard and summarized below in Table III. The resulting product of ARF and RF values specified in the standard must be used, unless otherwise justified, for TRU waste operations.

Table III-ARF*RF Values for TRU Waste Operations

Waste Form[1] (surface-contaminated)		Explosion[2]	Over-Pressure[3]	Fire[4]	Mechanical Insults	
					Spill[5]	Impact[6]
Combustible – cellulose, plastics	Ambient Atm.	(see fire)[7]	---	1E-2[7]	---	---
	In container	(see fire)	1E-4	5E-4	1E-4	1E-3
	In-flight	1E-4	---	---	---	---
Grout – cement, concrete		3E-4[ED][8][9]		<1E-6	7E-5	7E-4
Sludge or liquid slurries		MR[10]	1E-4	2E-3	4E-5	MR[11]

Liquid		MR[10]	2E-3	2E-3	1E-4	4E-5
Soil/Gravel, Powder, Granules		2E-4[9]	7E-2	6E-5	6E-4	1E-3
Metal, Non-Combustible materials not subject to brittle fracture		MR[10]	1E-3[12]	6E-5[12]	1E-4[12]	1E-3[12]
HEPA filters	In-package	1E-2[13]	2E-3	1E-4	5E-4	1E-3
	Un-contained				1E-2	

[1] The event is assumed to fail any additional layers of plastic wrapping.
[2] Deflagration of H_2-air stoichiometric mixture that ejects lid and some fraction of the contents.
[3] Internal pressure that fails the container and expels some fraction of the contents at a pressure ≤500-psig.
[4] Thermal stress that ejects lid and some of the contents. Some fraction of the ejected combustible contents may burn as well as the residual contents that remain in the open drum.
[5] Some fraction of the contained powder and liquid contents are released from a location that is elevated to ≤3-m/10-ft and impacts a hard, unyielding surface.
[6] The container is impacted with a force postulated from falling debris during a seismic event, an errant blow from a vehicle crash, or free-fall spill >3m. The accident suspends and releases some fraction of the particulate contents.
[7] For the fraction ignited from a container due to deflagration event or ejection from thermal effects that burns to completion.
[8] Applied to the volume of grout/cement affected, ED = Energy Density, J/cm^3. Note: ARF*RF values vary according to drop height and material density. The density of concrete is used to approximate ARF/RF values. A drop height of 3 m is used to bound ARF*RF values for the "Spill" category. A drop height of 4 m (roughly 5th tier of array) is used to bound values for the "impact" category.
[9] This form does not generate a combustible gas/vapor and the value only applies if this form is combined with a material that does generate a combustible gas/vapor.
[10] Steindler and Seefeldt correlation for detonation on/or contiguous to material– Mass Ratio (MR) = mass inert, kg ÷ TNT Equivalent, kg. See Table 3-6, pg 3-46, in NUREG/CR-6410 for ARF & RF values. RF limited to RF of source material-of-concern.
[11] The [ARF][RF] can be estimated by calculating the energy imparted to the slurry and assuming a free-fall and impact from the height that would insert that energy into the material.
[12] Of loose, surface-contamination present. Metal fragmentation is not anticipated.
[13] Assumes deflagration blast passes through the High Efficiency Particulate Air (HEPA) filter prior to failure of container.

Minimum Set of TRU Waste Accidents

Contractors in charge of DOE installations are required by 10 CFR 830, Subpart B, to analyze the hazards from nuclear operations. As further explained in DOE directives, this process must consider a set of representative and unique design basis accidents. The concept of selecting bounding accidents is generally only applicable within a set of representative accidents that are expected to have similar controls. For example, it would not be acceptable to only analyze a building wide fire event that bounds all other fires when that event is not representative of a vehicle accident with fire that occurs in an outside waste staging area. The latter case would result in a different control set.

Based on this concept, a set of twenty-five accident events is established in the standard that applies to TRU waste operations. While other types of accidents beyond this list are possible, the standard focuses on representative and unique accidents that have the potential for postulated consequences significant enough to warrant explicit technical safety requirements (i.e., safety controls specified within the nuclear facility "licensing basis").

Table IV provides a listing of the twenty-five accidents addressed in the standard. Accident events are presented according to applicability during various TRU waste operational activity types. Areas of the table marked by “X’s” indicate potential applicability. Accident events are presented according to broad categories that include fires, explosion events, loss of confinement/containment, direct radiation exposure, criticality, externally initiated events, and natural phenomena events. These events are applicable to both contact and remote-handled TRU waste activities.

Table IV. Minimum TRU Waste Accidents

Hazard Evaluation Event	**Characterization**	**Container Handling**	**Venting and/or Abating/Purging**	**Staging and Storage**	**Retrieval and Excavation**	**Waste Repackaging**	**Type B Container Loading/Unloading**
Fire Events							
Fuel Pool Fire (Event 1)		X		X	X		X
Small Fire (Event 2)	X	X	X	X	X	X	X
Enclosure Fire (Event 3)						X	
Large Fire (Event 4)	X	X	X	X	X	X	X
Explosion Events							
Ignition of Fumes Results in an Deflagration/Detonation (external to container) (Event 5)		X			X	X	X
Waste Container Deflagration (Event 6)	X	X	X	X	X		
Multiple Waste Container Deflagration (Event 7)	X	X	X	X	X		
Enclosure Deflagration (Event 8)						X	
Loss of Confinement/Containment							
Vehicle/Equipment Impacts Waste/Waste Containers (Event 9)		X	X	X	X	X	X
Drop/Impact/Spill Due to Improperly Handled Container, etc. (Event 10)		X			X	X	X
Collapse of Stacked Containers (Event 11)		X	X	X			
Waste Container Over-Pressurization (Event 12)	X	X	X	X	X		
Direct Exposure to Radiation Events (Event 13)	X	X	X	X	X	X	X
Criticality Events (Event 14)	X	X	X	X	X	X	
Externally Initiated Events							
Aircraft Impact with Fire (Event 15)	X	X	X	X	X	X	X
External Vehicle Accident (Event 16)	X	X	X	X	X	X	X
External Vehicle Accident with Fire (Combustible or Pool) (Event 17)	X	X	X	X	X	X	X
External Explosion (Event 18)	X	X	X	X	X	X	X
External Fire (Event 19)	X	X	X	X	X	X	X
NPH Initiated Events							
Lightning (Event 20)	X	X	X	X	X	X	X
High Wind (Event 21)	X	X	X	X	X	X	X
Tornado (Event 22)	X	X	X	X	X	X	X
Snow/Ice/Volcanic Ash Build-up (Event 23)	X	X	X	X	X	X	X
Seismic Event (Impact Only) (Event 24)	X	X	X	X	X	X	X
Seismic Event with Fire (Event 25)	X	X	X	X	X	X	X

As indicated in the TRU waste activities descriptions, the handling and movement of TRU waste containers that are not in Type B containers is a container handling activity even when the container handling and movement is necessary for the completion of another activity. Therefore, when analyzing these events, one must consider the waste being handled as well as the waste that may be stored or staged in the vicinity of the dynamic activity.

HAZARD CONTROL SELECTION

The selection of safety controls flows directly from the results of hazard and accident analysis. Within the context of the DOE nuclear safety framework, safety controls can be preventive or mitigative and are either linked to active or passive systems, structures, or components (SSCs), specific administrative controls (SACs), or safety management programs. Accidents with significant consequences require explicit safety controls in the form of safety SSCs or SACs. Safety Management Programs (SMPs) are relied on for general worker protection from accidents with lesser consequences.

The TRU Waste Standard identifies explicit safety SSCs or SAC type requirements that would be expected when one of the 25 minimum accidents is postulated to have significant consequences. The term “significant” can be misunderstood and is therefore further defined within risk binning guidelines in the standard. Based on the guidelines and the applicable accident considered, specific safety controls are presented in the standard.

Risk Binning Guidelines

The numerical guidelines are not to be construed as either risk acceptance nor compliance criteria.

The risk ranking process ranks the results of unmitigated hazard and accident analysis for the maximally exposed offsite individual, collocated workers onsite, and facility workers. Table V identifies consequence levels and evaluation guidelines for each of these receptors. High, moderate and low consequence levels are quantitatively defined for the offsite public and collocated workers. High consequence levels are qualitatively established for facility workers consistent with DOE-STD-3009 [3] guidelines for a significant worker consequence. Moderate and low consequence levels are not established for facility workers, because qualitative analysis would not yield results that provide a meaningful comparison to a distinguishable threshold.

Table V. Consequence Levels and Evaluation Guidelines

Consequence Level	**Maximally Exposed Offsite Individual**	**Collocated Worker (at 100 meters)**	**Facility Worker** **Involved worker within facility boundary**
High	Considerable offsite impact on people or the environs. CHALLENGE 25 rem TEDE or > AEGL-2/TEEL-2	Significant onsite impact on people or the environs. > 100 rem TEDE or > AEGL-3/TEEL-3	For Safety Significant designation, consequence levels such as prompt death, serious injury, or significant radiological and chemical exposure, shall be considered.
Moderate	Only minor off-site impact on people or the environs. ≥ 1 rem TEDE or	Considerable on-site impact on people or the environs.	No distinguishable threshold

	> AEGL-1/TEEL-1	≥ 25 rem TEDE or > AEGL-2/TEEL-2	
Low	Negligible off-site impact on people or the environs. < 1 rem TEDE or < AEGL-1/TEEL-1	Minor on-site impact on people or the environs. < 25 rem TEDE or < AEGL-2/TEEL-2	No distinguishable threshold

Table VI identifies risk ranking bins that consider the consequence rankings from Table V together with the postulated accident frequency. Based on these factors, an accident is ranked as Risk Class I through IV. Risk Class I events must be protected with SSCs, SACs (where appropriately justified in the DSA) and associated Technical Safety Requirements (TSRs). For offsite public protection, Safety Class SSCs and TSRs are required for radiological events that challenge the 25 rem Total Effective Dose Equivalent (TEDE) offsite in accordance with Appendix A of DOE-STD-3009, Change Notice 3. Events resulting in high offsite radiological consequences must be moved forward into accident analysis for determination of safety classification, without consideration of frequency.

Risk Class II events must be considered for protection with TSRs and safety SSCs. The consideration of control(s) is based on the effectiveness and feasibility of the considered controls along with the identified features and layers of Defense in Depth (DID). Events resulting in high offsite radiological consequence must be included in subsequent accident analysis for determination of safety classification, without consideration of frequency.

Risk Class III events are generally protected by SMPs. These events may be considered for DID SSCs in unique cases. Risk Class IV events do not require additional measures.

For facility worker protection, hazardous events with significant consequences must be considered for safety SSCs or SACs in accordance with DOE-STD-3009, Change Notice 3 and DOE-STD-1186. Activity-specific controls (e.g., Personal Protective Equipment [PPE] and hot work permit) are developed as needed based on job hazard analyses as part of the work control process, not as a specific TSR control. The TSR commitment to SMPs is relied upon to provide general worker protection. The actual implementation of work control process should be reviewed as part of the Integrated Safety Management System (ISMS) verification.

Table VII. Qualitative Risk Ranking Bins

Consequence Level	**Beyond Extremely Unlikely Below 10^{-6}/yr**	**Extremely Unlikely 10^{-4} to 10^{-6}/yr**	**Unlikely 10^{-2} to 10^{-4}/yr**	**Anticipated 10^{-1} to 10^{-2}/yr**
High Consequence	III	II	I	I
Moderate Consequence	IV	III	II	I
Low Consequence	IV	IV	III	III

Safety Controls

Safety controls are presented in the standard according to each type of accident event. Where an accident event applies to multiple types of TRU waste operations, and the control set differs for each activity, the event is listed multiple times with each control set designated. If no specific TRU waste operation is designated in the accident description, then it applies to all TRU waste operations that are designated for the event. Table VII gives an example of controls established for a hydrogen deflagration accident.

The standard uses an approach that establishes minimum functional controls and the associated preferred means of meeting these functions. A set of alternate controls were also developed that provided acceptable protection in cases where preferred controls were unavailable. Control functions were established based on the principle that controls originate from and are based on the results of a hazard analysis. Therefore, the standard established a minimum set of hazardous events that apply to various TRU operations.

An example of hazard controls developed during this effort is illustrated for a hydrogen deflagration event that is possible when installing vents into TRU waste drums. A key control function is to reduce potential sparks and other initiators during vent installation. The preferred control is a Drum Venting System that is specifically manufactured to isolate and vent drums within a protective enclosure. These devices are not always available to a particular DOE facility. Therefore, an alternate set of controls would include the use of non-sparking tools; grounding and bonding of drums; use of cold drilling, speed drilling or drum punch to install vents; and control of static discharge from personnel.

The use of Alternate controls must be substantiated by a sound technical basis that is communicated and agreed upon with the DOE safety basis Approval Authority. The supporting rationale for selecting Alternate controls must demonstrate that Preferred controls are either not available or not appropriate for the given facility situation. The rationale shall be documented in the DSA or in the hazard analysis document supporting the DSA.

Table VII. Sampling of Safety Controls for Hydrogen Deflagration Accident

Accident	Minimum Control Functions	Preferred Controls	Alternative Controls
Waste Container Deflagration (Event 6) Multiple Waste Container Deflagration (Event 7) During Venting and Hydrogen Abatement Venting and/or Abating/Purging	Reduce potential sparks and other initiators during venting (P)	Drum Venting System (DVS)	Tools shall be of the type to prevent ignition (e.g., non-sparking tools; use cold drilling, speed drilling, or drum punch); grounding and bonding; control static discharge from personnel
	Minimize worker exposure during venting (M)	DVS; prevent unnecessary personnel within affected area	Blast resistant enclosure; prevent unnecessary personnel within affected area OR Remote activation; personnel exclusion area
	Reduce potential sparks and other initiators during hydrogen abatement (P)	Isolate/segregate container after venting until hydrogen concentration is below 8%; minimize container movement	
	Minimize worker exposure during hydrogen abatement (M)	Minimize worker contact with container; prevent unnecessary personnel within affected area	
	Limit interaction between containers during hydrogen abatement (M)	No stacking containers	
Waste Container Deflagration (Event 6) Staging and Storage	Minimize worker exposure (M)	Minimize worker contact with suspect container or containers with potential VOC concentration greater than LFL; prevent unnecessary personnel within affected area	

REFERENCES

1. Department of Energy, “DOE Technical Standard, Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities,” DOE-STD-SAFT-0113-2006, *Draft*
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