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**DEFENSE NUCLEAR FACILITIES SAFETY BOARD**

Washington, DC 20004-2901

March 15, 2018

The Honorable James Richard Perry
Secretary of Energy
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Secretary Perry:

The enclosed Defense Nuclear Facilities Safety Board Technical Report is provided for your information and use. It provides independent analysis and advice related to specific deficiencies and weaknesses in Department of Energy Standard 5506-2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities.*

On December 7, 2015, DOE issued a Project Justification Statement to revise DOE Standard 5506-2007. As of the issuance date of this Technical Report, DOE has not completed its revision of DOE Standard 5506-2007.

The Board plans to continue to track DOE's progress in revising DOE Standard 5506-2007.

Yours truly,

Bruce Hamilton
Acting Chairman

Enclosure

c: Mr. Joe Olencz

**DNFSB/TECH-43**

# DEFICIENCIES IN DOE STANDARD 5506-2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*

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## Defense Nuclear Facilities Safety Board

## Technical Report

**February 2018**

DNFSB/TECH-43

# DEFICIENCIES IN DOE STANDARD 5506-2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*


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## EXECUTIVE SUMMARY

The safe harbors to Title 10 Code of Federal Regulations (10 C.F.R.) Part 830, *Nuclear Safety Management*, provide detailed requirements and Department of Energy (DOE) expectations for the methodology to be used to calculate unmitigated dose consequences to the public and the workers to ensure their adequate protection. DOE Standard 3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*, describes one safe harbor methodology. DOE prepared Standard 5506-2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*, to provide supplemental information for applying the methodology described in DOE Standard 3009 to TRU waste handling and storage facilities.

The Defense Nuclear Facilities Safety Board's (Board) staff has found that, in some instances, DOE Standard 5506-2007 contains guidance and requirements that: (1) lack sufficient detail to ensure consistent and conservative application; and (2) lack adequate technical basis for the proposed analytical methods and values. The weaknesses associated with DOE Standard 5506-2007 could lead to non-conservative decisions when developing safety bases for TRU waste facilities. The three specific deficiencies listed below are discussed in detail in this Technical Report:

I. Statistical material at risk (MAR) methodology,
II. Source term determination, and
III. Vehicle and aircraft crash accident.

Two additional items are offered for DOE's consideration in the next revision of DOE Standard 5506. These items are not discussed in the same level of detail as the numbered items above, but are summarized to note them as other areas for consideration.

A. Plume buoyancy, and
B. Waste Isolation Pilot Plant (WIPP)-like event.

On December 7, 2015, DOE issued a Project Justification Statement to revise DOE Standard 5506-2007. As of the issuance date of this Technical Report, DOE has not completed its revision of DOE Standard 5506-2007[1].

[1] This Technical Report refers to DOE Standard 5506 because that is where the deficiencies currently exist. However, the Board's staff acknowledges that there may be alternatives to revising DOE Standard 5506 that would address the deficiencies and ensure that any changes made are implemented at existing and future TRU waste facilities.

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# 1. INTRODUCTION

The safe harbors to Title 10 Code of Federal Regulations (10 C.F.R.) Part 830, *Nuclear Safety Management*, provide detailed requirements and Department of Energy (DOE) expectations for the methodology to be used to calculate unmitigated dose consequences to the public and the workers to ensure their adequate protection. DOE Standard 3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*, describes one safe harbor methodology. DOE prepared Standard 5506-2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*, to provide supplemental information for applying the methodology described in DOE Standard 3009 to TRU waste handling and storage facilities.

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I. Statistical material at risk (MAR) methodology,
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III. Vehicle and aircraft crash accident.

Two additional items are offered for DOE's consideration in the next revision of DOE Standard 5506. These items are not discussed in the same level of detail as the numbered items above, but are summarized to note them as other areas for consideration.

A. Plume buoyancy, and
B. Waste Isolation Pilot Plant (WIPP)-like event.

## 2. BACKGROUND

DOE owns defense nuclear facilities that handle, package, and store TRU wastes. DOE employs contractors at numerous sites to prepare, maintain, and implement the safety basis for the operation of these TRU waste facilities. DOE developed and published DOE Standard 5506-2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*, to provide "detailed guidance for consistently analyzing hazards and selecting controls for TRU waste activities." DOE provides this guidance to contractors "so that contractors can formulate, implement, and maintain safety bases for TRU waste operations in a consistent manner that is compliant with 10 C.F.R. Part 830, Subpart B, requirements."

On December 7, 2015, DOE issued a Project Justification Statement (PJS) [1] to revise DOE Standard 5506-2007. In addition to noting the need to incorporate pertinent changes to other key DOE documents such as DOE Order 420.1C, *Facility Safety*, and DOE Standard 3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*, the PJS stated that the revised DOE Standard 5506-2007 would:

> *Reflect lessons learned from the February 2014 event at the WIPP, including those related to the types of credible events such as exothermic chemical reactions and potential magnitude of airborne releases.*

As of the issuance date of this Technical Report, DOE has not completed its revision of DOE Standard 5506-2007.

DOE is preparing an Accident Analysis Handbook that will contain best practices for development of hazard and accident analyses. The development of the Accident Analysis Handbook and the information it contains is a positive development. However, the Handbook will not clearly identify requirements that contractors must implement during the preparation, maintenance, and implementation of the safety basis for TRU waste facilities.

# 3. STATISTICAL MATERIAL AT RISK (MAR) METHODOLOGY — I

DOE Standard 3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis,* contains requirements for using a bounding MAR value when determining the radiological source term for hazard and accident analyses. Section 3.2.4.1 of DOE Standard 3009-2014 states the following:

> *The MAR is the bounding quantity of radioactive material that is available to be acted upon….*
>
> *The MAR may be the total inventory in a facility or a portion of this inventory in one location or operation….*
>
> *MAR values used in hazard and accident analysis…shall be bounding with respect to each accident being evaluated.*[7]
>
> Footnote 7 of DOE Standard 3009-2014 provides further guidance for determining a bounding MAR value for TRU waste containers using DOE Standard 5506-2007:
>
> [7]*For facilities that provide retrieval, handling, storage or processing of transuranic waste containers, a bounding MAR may be determined in accordance with DOE-STD-5506-2007, Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities.*

Table 4.3.2-1 in DOE Standard 5506-2007 summarizes a statistical methodology for determining bounding MAR limits for TRU waste operations. DOE Standard 5506-2007 describes the statistical methodology as a “reasonably bounding approach.” DOE Standard 5506-2007 presents formulas for various numbers of waste containers, and makes a distinction between waste containers with limited characterization and waste containers that are fully characterized.

The statistical methodology assumes an inventory of containers from which safety basis analysts may derive statistical metrics. For fully characterized waste containers, the methodology in Table 4.3.2-1 in DOE Standard 5506-2007 can be summarized by the following algorithm:

$$n = 1: \quad MAR = max$$
$$n > 1: \quad MAR = max + 95th + (n - 2) \times mean$$

where $n$ is the number of containers analyzed in a given accident, and $max$, $mean$, and $95th$ are the maximum MAR, mean MAR[2], and 95th percentile MAR, respectively, from the global

[2] Mean refers to the arithmetic mean, which is the total summation of MAR divided by the number of containers.

population of containers.

For waste containers with limited characterization, Table 4.3.2-1 in DOE Standard 5506-2007 contains a similar algorithm that uses the 99th percentile MAR in addition to $max$, $mean$, and $95th$ percentile MAR. The limited characterization algorithm provides for additional conservatism to account for the increased uncertainty when the waste containers involved in the accident are not fully characterized.

DOE Standard 5506-2007 provides three exceptions where the statistical MAR methodology is inapplicable:

1. Operations that intentionally commingle containers with the highest distribution of radioactive material in a facility's inventory.

2. Operations in which it cannot be distinguished whether containers with the highest distribution of radioactive material are commingled in a facility's inventory.

3. Containers that have been prepared for shipment in accordance with limits established in the WIPP waste acceptance criteria.

DOE Standard 5506-2007 also cautions that, when applying the statistical methodology, "[s]pecial attention should be given to whether the scope of container activities could unintentionally concentrate problematic containers, thereby invalidating the MAR methodology." In the opinion of the Board's staff, this particular situation would require an administrative control to protect the assumptions of the hazard analysis.

*Conservatism of Statistical MAR Methodology*—DOE Standard 3009-2014 requires the MAR to be bounding. The meaning of *bounding* is clear, referring to a value that bounds any actual condition. For TRU waste containers, DOE Standard 3009-2014 points to the statistical MAR methodology in DOE Standard 5506-2007 to obtain a *bounding* MAR. However, DOE Standard 5506-2007 considers the statistical MAR methodology to be *reasonably bounding*, and not actually bounding. Hence the statistical MAR methodology applied to TRU waste containers is not consistent with the bounding MAR requirement in DOE Standard 3009-2014.

The Board's staff evaluated the conservatism of the statistical MAR methodology and has the following observations:

- The method is clearly bounding for a single container ($n = 1$), since $MAR = max$.

- Given an inventory of $N$ containers, the method is clearly bounding for an accident involving all containers ($n = N$). This can be seen by rewriting the statistical MAR algorithm in terms of the total MAR ($Total \equiv N \times mean$) so that $MAR = Total + max + 95th - 2 \times mean$. Since the $max$ and the $95th$ are each greater than the mean, it follows that the computed MAR is greater than the total MAR in the inventory, and is therefore bounding.

- For all intermediate cases ($1 < n < N$), the degree of conservatism of the algorithm cannot be determined by inspection.

DOE Standard 5506-2007 does not provide or reference a technical basis for the statistical MAR algorithms. Hence, it is difficult to substantiate the degree of conservatism built into the algorithms, and whether the method indeed provides *reasonably conservative* results.

<u>*Statistical Tests*</u>—To explore the degree of conservativism of the statistical MAR methodology for practical cases of interest ($1 < n < N$), the Board's staff performed Monte-Carlo statistical sampling tests of the algorithm for well-characterized waste containers. The Monte-Carlo statistical sampling tests involved assuming a MAR inventory of $N$ containers, with some random distribution of MAR among the containers. Given an assumed distribution, the staff computed the $max,\ 95th$ percentile, and $mean$. The staff then took random samples of $n$ out of $N$ containers. The staff computed the actual MAR for the sample and the MAR from the algorithm. Consistent with the Monte-Carlo approach, the staff repeated the sampling process many times. The staff computed the MAR algorithm failure fraction (fraction of cases where the algorithm does not bound the actual sample) based on the sampling results.

Figure 1 shows the results of the staff's statistical test for the case of a uniform distribution of MAR within an inventory of waste containers. The staff considered two inventory sizes, $N = 100$ and $N = 1000$. The staff performed approximately 20,000 Monte-Carlo sampling trials to obtain each data point shown. The horizontal axis in Figure 1 shows the number of containers involved in the accident, $n$. The vertical axis shows the failure fraction of the statistical MAR algorithm. Figure 1 shows that the algorithm does not bound the sampled MAR anywhere in the range $1 < n < N$. Any time the failure fraction (fraction of cases where the algorithm does not bound the actual sample) is greater than zero, it means the algorithm does not bound the actual sample for a percentage of tests in the Monte-Carlo statistical sampling tests. The failure fraction exceeds 15 percent for a sample size of 11 to 89 drums out of a given inventory of 100 containers. The failure fraction exceeds 40 percent for a sample size of approximately 200 to 800 drums out of a given inventory of 1000 containers. The Board's staff also evaluated other distributions of MAR inventories, including Gaussian, lognormal, and skewed, and obtained similar results.

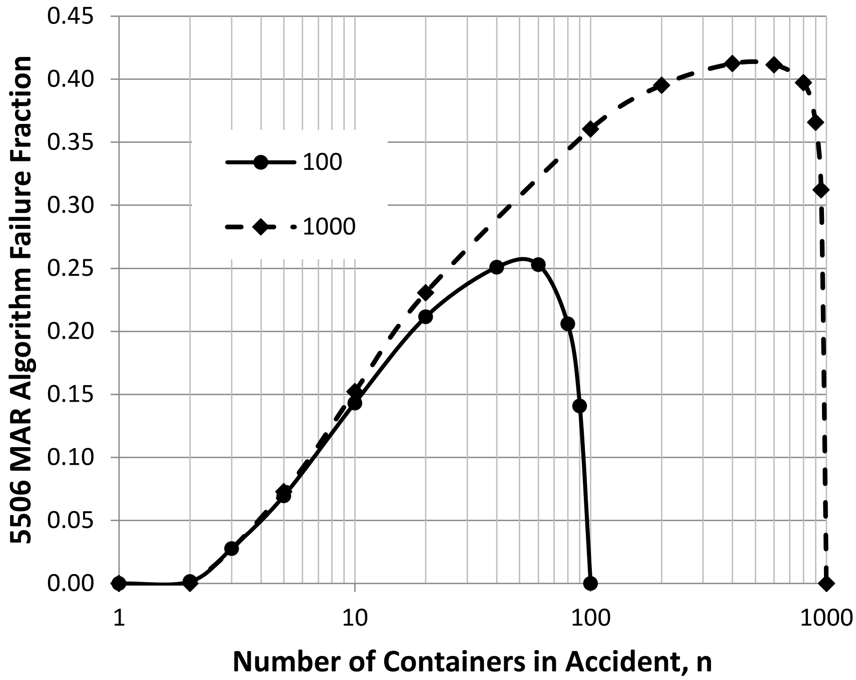


**Figure 1.** *Results of Monte-Carlo statistical sampling test of the MAR algorithm for the case of a uniform MAR distribution, using inventory sizes of* $N = 100$ and $N = 1000$.

*Evaluation of WIPP Inventory*—The Board's staff evaluated how the quantity of MAR in emplaced 55-gallon drums varies within the underground at WIPP. The staff calculated the mean MAR in 55-gallon drums for each of the 43 rooms in the WIPP underground. Figure 2 shows the calculated mean MAR in 55-gallon drums by room number. The dashed line shown in Figure 2 is the mean MAR for all 55-gallon drums at WIPP, 2.21 plutonium equivalent curies (PE-Ci). WIPP uses the mean MAR for all 55-gallon drums underground at WIPP when applying the statistical MAR methodology. However, Figure 2 shows that the mean MAR per room varies considerably in the WIPP underground. The Board's staff concluded the variability in MAR per room is not random statistical variation, since the rooms contain a large number of drums (approximately 2,000 per room on average). The results shown in Figure 2 suggest that bias associated with individual waste transfer campaigns from different sources contributed to the variation. The staff's conclusion calls into question the conservatism of the statistical MAR methodology, which relies on the global mean MAR to compute the MAR involved in a localized accident.

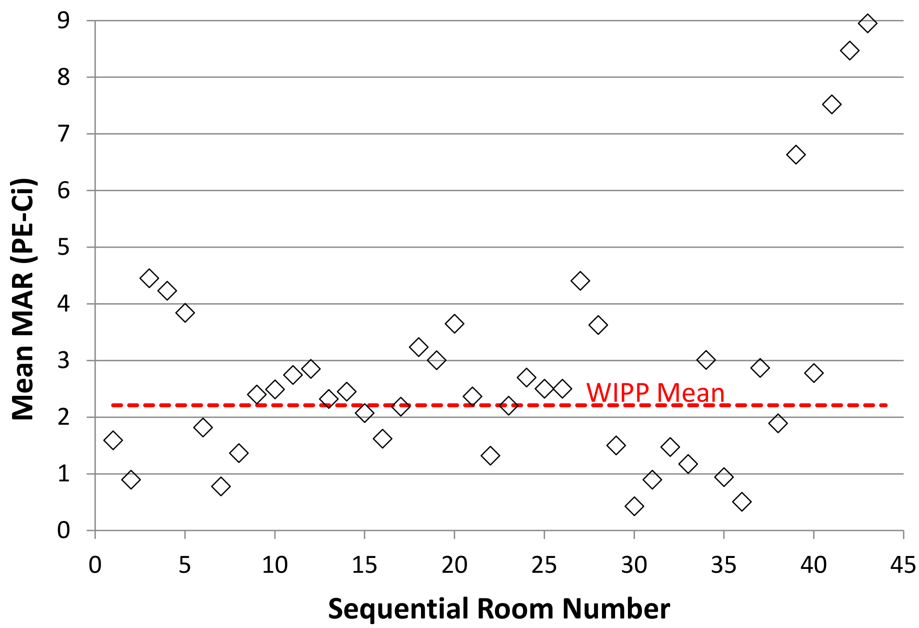


**Figure 2.** *Variation of the mean MAR among rooms at WIPP.*

*WIPP Documented Safety Analysis (DSA) Accident Analysis*—The Board issued a letter to the Secretary of Energy on March 28, 2016, forwarding a report by the Board's staff regarding revisions being made to the WIPP DSA to address deficiencies identified during DOE's investigations into the salt haul truck fire and radiological release accidents that occurred at WIPP in February 2014 [2]. The staff's report evaluated the draft DSA's use of the statistical MAR methodology outlined in DOE Standard 5506-2007 to compute MAR values for accident analyses. The staff's report noted that the draft DSA did not establish any controls to ensure the actual MAR involved in WIPP operations was less than the statistically derived MAR values assumed in the safety analysis.

The staff's report summarized an independent analysis performed by the Board's staff that identified clusters of problematic containers that would result in higher source terms (i.e., more severe releases with higher consequences) than the draft DSA analyzed. The Board's staff used the lube truck pool fire scenario postulated in the draft DSA as the basis for the independent analysis and calculated radiological release source terms for appropriately sized pool fires in each underground room and panel location. The staff analysis used the same analytical assumptions on damage ratios, airborne release fractions, and respirable fractions as the draft DSA. Based on the analysis of historical waste emplacement at WIPP, the Board's staff concluded that if the statistical MAR methodology outlined in DOE Standard 5506-2007 continued to be employed in the accident analysis without further administrative controls, there would be a high likelihood that future waste operations would unintentionally concentrate problematic waste containers and create the potential for accidents with higher consequences than those analyzed in the draft DSA. In response to these findings, DOE and the WIPP contractor, Nuclear Waste Partnership, LLC, established a key element in the DSA to protect key analytical assumptions associated with the MAR statistics used in the accident analysis.

*Summary of Staff Observations*

- The Board's staff determined that the statistical MAR methodology outlined in DOE Standard 5506-2007 is not bounding, and is therefore not consistent with DOE Standard 3009-2014, which requires a bounding MAR to be used in hazard and accident analysis. Statistical tests performed by the Board's staff suggest that the statistical MAR methodology may have a high fraction of cases where it fails to bound actual MAR values.

- The staff's analysis of MAR in the WIPP underground demonstrates that relying on global waste inventory for formulation of key inputs to the statistical MAR algorithm in DOE Standard 5506-2007 may not be appropriate.

- Evaluation of postulated scenarios in the WIPP DSA using the statistical MAR methodology indicates a likelihood that clusters of problematic containers exist, which would result in higher source terms (i.e., more severe releases with higher consequences) than those analyzed scenarios.

- Regardless of the conservatism inherent in the statistical MAR methodology, or any improvements made to the algorithm, a requirement that the analyzed MAR bound the actual MAR in a given location would remove the potential for a non-conservative statistical-based MAR.

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# 4. SOURCE TERM DETERMINATION — II

Guidance provided in DOE Standard 5506-2007 related to release of material from containers during accident scenarios must be supported by an adequate technical basis or, in the absence of an adequate technical basis, result in bounding values used to calculate the source term. This includes, but is not limited to, determination of damage ratio, airborne release fraction, respirable fraction, portion of containers that undergo lid loss, and reduction in source term due to overpacking. The Board's staff determined that guidance regarding source term determination for various waste containers subject to accident scenarios is not supported by an adequate technical basis. The following sections elaborate on the deficiencies in DOE Standard 5506-2007 regarding the lack of an adequate technical basis for source term determinations for various waste containers.

<u>*Pipe Overpack Containers (POC)*</u>—On June 16, 2015, the Cognizant Secretarial Officer of the National Nuclear Security Administration (NNSA) issued a memorandum titled *Request for Extent-of-Condition Assessment of Pipe Over-pack Container Use in National Nuclear Security Administration Facilities* [3], which stated, "NA-50 believes that, despite being an approved Technical Standard, DOE Standard 5506-2007 should no longer be used to justify applying a DR [damage ratio] of zero to POCs for fire scenarios."

Subsequent to this memorandum, DOE sponsored experimental testing to determine appropriate damage ratios and overall release fractions for POCs subject to fuel pool fires and facility fires [4]. Testing is still ongoing and insufficient data thus far exist to support a technically defensible estimate of the amount of radioactive material released (release fraction). Without a technically defensible release fraction, the calculated dose consequences could be non-bounding. Additionally, testing efforts are limited to a specific number of container types, configurations, and filter models, and do not encompass all design types present in the complex. Therefore, DOE will not be able to provide guidance regarding a technically defensible release fraction for all container types, configurations, or filter models existing in the complex today.

DOE Standard 5506-2007 states that "[f]or the Pipe Overpack Container (POC), pressure testing… showed that even if a hydrogen deflagration should occur, its magnitude would not be enough to damage the pipe component or significantly degrade its filter." This statement is contradicted by testing conducted at the Southwest Research Institute (SwRI) [5], which demonstrated failure and release of material through WIPP-certified filters during hydrogen deflagration scenarios.

<u>*Standard Waste Boxes (SWB)*</u>—DOE Standard 5506-2007 states the following:

> *For a Standard Waste Box (SWB), lid loss will not occur for [an internal] container deflagration, because the lid is very heavy and bolted onto the body of the box.… Overpacking a metal drum of sound integrity with a larger metal drum, a SWB, or a RH [remote handled] canister with nested metal drums can be credited to prevent*

*lid loss and ejection of contents. For the SWB, RH canister with nested metal drums, and the overpacked drum, a significant release from potential venting through the outer container seal is not expected. Any potential release from venting through the outer container would be bounded by the mechanical impact evaluations presented in Section 4.4.4 (e.g., spill-type release).*

The guidance above is based on expert judgment. Deflagration testing at SwRI [5] qualitatively demonstrated the potential for a sizeable release from the seals and filters of SWBs and other overpack containers during internal deflagration scenarios. Based on the SwRI deflagration testing, it would be appropriate for DOE to reevaluate whether the assumption that a spill-type release bounds venting through the outer container is valid.

DOE also relies on expert judgment to quantify material release from SWBs and other overpack containers during mechanical insult. DOE Standard 5506-2007 states the following: "[T]here has been no testing of the SWBs with 'bolted down' lids, overpacked containers, or the TRUPACT-II double-stacked seven-pack drum configuration. Therefore, engineering judgment must be used to extrapolate the available tests results to these configuration and accident scenarios."

<u>*Drums*</u>—Damage ratios for thermal and impact accident scenarios listed in DOE Standard 5506-2007 involving Department of Transportation Type A 55-gallon drums are based on engineering judgment and some testing. Impact scenarios include onsite vehicle collisions with drums, forklift tine punctures of drums, and drums falling from various stacked heights. Thermal events include combustible material fires, fuel pool fires, and deflagration events. Issues with exercising engineering judgment for the drum damage ratios for such scenarios are detailed below:

- *Effect of Waste Material Composition*—For accident scenarios such as forklift tine punctures of drums and drum falls from a fourth or fifth tier, DOE Standard 5506-2007 reports different damage ratios for drums based on the waste material type (e.g., solid waste or sand). DOE's past impact/drop tests did not represent the complete spectrum of waste material compositions that exist throughout the defense nuclear facilities complex. Therefore, safety basis analysts exercise expert judgment to make assumptions regarding the varying damage ratios with respect to waste material type.

- *Fuel Pool Fire*—DOE Standard 5506-2007 states that 25 percent of 55-gallon drums subjected to a fuel pool fire will eject their lids and allocates airborne release fraction values accordingly. However, recent POC testing has shown that a POC subjected to a fuel pool fire for three minutes or less will eject its overpack lid, along with the majority of packaging contents within the drum (e.g., fiberboard packaging material, inner pipe component, and polyethylene lining) [4]. As the design of a POC is essentially an internal pipe component within a 55-gallon drum, conclusions from these tests can be correlated to drums. Testing also has indicated that the likelihood of a drum ejecting its lid may be dependent on how tightly the lid is torqued onto the container, but testing performed prior to 2015 did not document consistent torque specifications. Based on the POC testing, assuming only 25 percent of drums subjected to a fuel pool fire eject their lids, when torqued appropriately, may not be defensible.

- *Deflagrations*—DOE Standard 5506-2007 only acknowledges the credibility of deflagration scenarios in drums that are unvented or contain failed vents. However, flammable gas accumulation in containers with properly working vents has been noted in drums containing wastes undergoing substantial radiolysis or gas producing reactions. DOE Standard 5506-2007 should acknowledge and provide guidance regarding deflagration scenarios in drums that contain wastes undergoing substantial radiolysis or gas producing reactions.

*Overpacked Containers*—DOE Standard 5506-2007 provides inconsistent guidance regarding damage ratios for overpacked containers in the following accident scenarios:

- DOE determined damage ratios for overpacked containers subject to deflagrations through testing with volatile organic compounds and a drum-in-drum overpack configuration. However, this testing may not be representative of all deflagration accidents due to differing contents and overpack configurations. Moreover, as discussed previously in the context of SWBs, DOE Standard 5506-2007 provides unsubstantiated guidance that lid loss will not occur for overpacked containers subject to deflagrations. DOE Standard 5506-2007 also applies this guidance regarding damage ratio and lid loss for overpacked containers subject to flammable gas deflagrations to overpacked containers subject to external fires.

- DOE determined the damage ratios for overpacked containers subject to impacts through engineering judgment. These damage ratios are unsupported by testing or documented analysis.

Additionally, the guidance provided in DOE Standard 5506-2007 does not clearly define what constitutes an "overpacked container." DOE Standard 5506-2007 provides the following examples of overpacked containers: "a metal drum of sound integrity nested within a larger metal drum or a SWB, or Ten Drum Overpack [TDOP], and POCs." However, DOE Standard 5506-2007 provides no requirements for overpack containers except that overpack containers should not be of suspect integrity. Crediting overpack containers for reduction in damage ratio values may be inappropriate if the overpack containers are not held to a set of minimum performance criteria.

*Deflagration-to-Detonation Transition (DDT) Accidents*—DOE Standard 5506-2007 assumes hydrogen gas DDT accidents are implausible given container dimensions and required run-to-detonation distances; therefore, it does not provide any guidance on source terms for DDT accidents. Several DOE facilities have identified credible DDT accident scenarios for TRU waste containers within their safety bases. The facilities determined DDT accidents to be credible based on the unique container contents and scenarios present at these DOE facilities. The lack of bounding source term guidance in DOE Standard 5506-2007 for DDT scenarios may result in inconsistent treatment of such accidents in safety bases across the DOE defense nuclear facilities complex. While DDT accidents may not be a credible hazard for all facilities, DOE Standard 5506-2007 should provide conservative guidance on source term values for facilities that identify a credible DDT hazard.

*Summary of Staff Observations*—Guidance provided in DOE Standard 5506-2007 related to release of material from containers is not always based on a sufficient technical basis to demonstrate that the recommended values result in a bounding source term. The parameters and assumptions used to determine the source term values include the following:

- determination of damage ratio,
- airborne release fraction,
- respirable fraction,
- portion of containers that undergo lid loss,
- portion of material ejected from container, and
- source term reduction due to overpacking.

The technical bases for the recommended values for the terms above must be specific to, or bounding for, each particular container type used and its associated waste contents. A non-bounding source term value could result in safety bases not designating the appropriate level or type of controls.

## 5. VEHICLE AND AIRCRAFT CRASH ACCIDENTS — III

The guidance in DOE Standard 5506-2007 for estimating a radioactive material release due to a vehicle crash or aircraft crash into TRU waste containers does not provide sufficient detail to ensure consistent and conservative application across all TRU waste facilities. Furthermore, the lack of detail has contributed to inconsistent application of damage ratio and airborne release fraction times respirable fraction (ARF×RF) values for vehicle and aircraft crashes. Figure 3 illustrates how aircraft and vehicle crash accidents have applied different combinations of damage ratio and ARF×RF as a function of impact velocity, based on interpretation of guidance provided in DOE Standard 5506-2007.

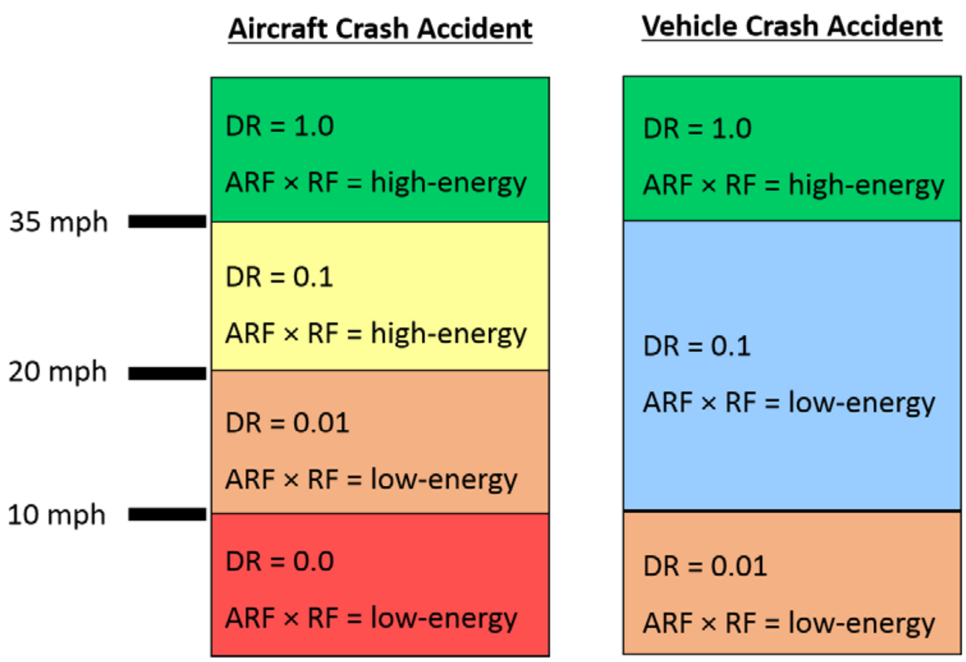


**Figure 3.** *DOE Standard 5506-2007 interpretation of aircraft and vehicle crash assumptions.*

*Low-Energy vs High-Energy vs Catastrophic Impacts*—The ARF×RF values cited in DOE Standard 5506-2007 can differ by an order of magnitude, based on whether they are classified as low-energy or high-energy impacts. DOE Standard 5506-2007 states that the high-energy impact ARF×RF values are applicable to a container fall from the fifth tier of stacked drums. This equates to a fall height of approximately 13.7 feet. A 13.7-foot fall height results in an impact velocity of approximately 20 miles per hour. A commonly used method in the aircraft crash accident analysis is to use the impact velocity calculated for a 13.7-foot fall height (i.e., 20 miles per hour) as the threshold above which high-energy impact ARF×RF values are applied.

When evaluating ground vehicle crash accidents, the high-energy impact ARF×RF values are generally not applied unless vehicle speeds are expected to be greater than 35 miles per hour, which is inconsistent with the 20 miles per hour threshold commonly used in aircraft crash analysis. For instance, the DSA of the Transuranic Waste Processing Center (TWPC) at Oak Ridge National Laboratory (ORNL) states that the nature of access roads around the TWPC site limits vehicles to less than 25 miles per hour [6]. In vehicle crash accidents at TWPC, only the low energy ARF×RF values are applied, even though the maximum speed of 25 miles per hour exceeds the 20 miles per hour threshold for high-energy impact ARF×RF values in aircraft crash analysis. Furthermore, TWPC performed a parametric vehicle barrier impact analysis to determine the weight requirements of the safety significant vehicle barriers and determined that for some vehicle classes a maximum speed above 25 miles per hour is possible at TWPC (up to 60 miles per hour for a car) [7]. Despite this result, the TWPC DSA still treats the vehicle crash scenario as a low-energy impact.

The damage ratios recommended in DOE Standard 5506-2007 differ by an order of magnitude, based on whether the impact is a result of a moderate to severe stress or a catastrophic stress. DOE Standard 5506-2007 assumes a catastrophic stress to be the result of an impact speed greater than 35 miles per hour. However, DOE Standard 5506-2007 does not offer guidance to the user on how to account for differing vehicle mass and size. The kinetic energy and momentum of the vehicle depends on both the mass and speed. Determination of the maximum possible vehicle speed at the facility is not standardized since DOE Standard 5506-2007 allows for speed restrictions due to the "physical layout of the facility/size and associated obstacles." While the physical layout needs to be considered to evaluate a credible event, a formalized process for determining the potential maximum speed would improve how the physical layout and/or obstacles are used to define the initial conditions of the event. Similar to the vehicle barrier analysis performed for TWPC [7], a parametric evaluation could be performed using the known distances available for vehicle acceleration before impacting a waste container. The parametric evaluation could consider the possible vehicle types and account for varying acceleration estimates for each vehicle type.

In addition, the application of a zero damage ratio for impacts occurring at less than 10 miles per hour has been inconsistently applied between aircraft and vehicle crash accidents. Aircraft crash accident analysis at ORNL–TWPC [6] applies a zero damage ratio once enough momentum has been transferred to waste containers to slow down the aircraft and impacted waste containers to 10 miles per hour. Application of a zero damage ratio for impact speeds less than 10 miles per hour is based on the 4 foot drop qualification for Department of Transportation Type A containers, which equates to an impact velocity of 10 miles per hour. Appendix C of DOE Standard 5506-2007 endorses the use of a zero damage ratio for drums that fall less than 4 feet. However, Appendix C then defines low speed vehicle impacts as occurring at less than 10 miles per hour and recommends applying a damage ratio of 0.01. As a result, the source term assumptions for low speed impacts (10 miles per hour or less) differ depending on whether the impact is initiated by an aircraft or a vehicle.

DOE Standard 5506-2007 should clearly provide the thresholds that determine which damage ratio and ARF×RF should apply to both the aircraft and vehicle crash accidents, such that application is consistent for all relevant accident scenarios. Multiple variables must be considered when evaluating a vehicle crash accident such as vehicle mass, vehicle maximum speed upon impact of a waste container, fuel capacity of the vehicle, and contents of the impacted waste containers. The values of these variables will contribute to the severity of the postulated accident. A comprehensive evaluation of possible bounding vehicle crash scenarios should ensure that sufficient controls are put in place.

Guidance for Aircraft Crash—DOE Standard 5506-2007 refers to DOE Standard 3014, *Accident Analysis for Aircraft Crash into Hazardous Facilities*, for evaluating credible aircraft crash events. However, DOE Standard 3014-2006 does not provide guidance for calculating the extent or severity of damage to containers and structures that typically exist at TRU waste facilities (i.e., stacked arrays of drums in non-robust enclosures). Furthermore, DOE Standard 5506-2007 does not offer guidance on how the accident analysis should calculate the number of waste containers impacted and the severity of the damage (i.e., material released). The lack of guidance for TRU waste facilities has resulted in the use of fundamentally different methods to determine the amount of TRU waste impacted by debris from an aircraft crash. TWPC at ORNL [6] uses a momentum-based approach. The Waste Storage Facilities at Lawrence Livermore National Laboratory (LLNL) [8] considers that only high density components of the aircraft, such as the engine block, are capable of damaging waste containers. The extent of damage is then based on a vehicle crash evaluation for the aircraft crash accident. LLNL references sensitivity calculations that further consider two scenarios of the engine block having a crushing impact on one or two drums. The Solid Waste Management Facility at Savannah River Site [9] uses a different method than those mentioned for ORNL and LLNL.

Summary of Staff Observations—The calculated dose consequences can increase by a factor of 10 depending on the assumptions discussed in this section and could impact the control selection for the facility. DOE should provide defensible and consistent guidance on evaluating the damage to waste containers due to impact stresses to ensure contractors select and implement appropriate controls. DOE Standard 5506 should have clear, consistent, and unambiguous guidance for:

- Establishing thresholds that define the severity of impact stresses, and

- Selecting assumptions and methods for evaluating vehicle and aircraft impacts on TRU waste facilities and containers.

## 6. OTHER ITEMS FOR CONSIDERATION

*PLUME BUOYANCY — A*

DOE Standard 5506-2007 states, “Plume buoyancy may only be used when modeling fires that are outdoors or venting through a large breach in the facility (use of plume buoyancy should not be credited in a non-conservative manner).” Crediting plume buoyancy in fire scenarios significantly reduces the calculated radiological dose consequences because the energy from the fire causes the radioactive plume to become buoyant and rise. As the plume rises, it spreads out both vertically and horizontally, which dilutes the concentration of the plume. A buoyant plume also will travel a greater distance before the plume impacts a receptor, compared to a neutrally buoyant plume. This process dilutes the radioactive concentration in the plume, leading to a reduced calculated radiological dose consequence.

DOE Standard 5506-2007 does not provide guidance regarding the situations in which plume buoyancy should be used in radiological dose consequence calculations (e.g., how big of a breach in the facility) or how to model it. The use of plume buoyancy for a release that originates inside of a building is complex. The pathway for release is impacted by several factors such as location of the breach, size of the breach, building volume, building geometry and layout, building material composition, desposition of entrained source term material within the building, and size of the fire. For example, during a fire, much of the fire’s energy is absorbed in the facility’s floor and walls, reducing the amount of buoyant plume rise that a release would experience. Further, the location of the breach (wall versus ceiling) and surrounding atmospheric conditions could significantly impact the height of the plume. The impact of plume buoyancy on calculated radiological dose consequence will be site-specific, but it could decrease the calculated radiological dose consequences by more than a factor of 10. A change in calculated radiological dose consequences that large could affect the control set. Accordingly, if plume buoyancy is allowed for use in safety analysis calculations, more explicit guidance on when it may be used and the bounds of the input parameters is needed.

*WASTE ISOLATION PILOT PLANT (WIPP)-LIKE EVENT — B*

Based on the 2014 radiological release accident at WIPP, DOE determined that a respirable release fraction (damage ratio×airborne release fraction×respirable fraction) of 0.205 is applicable to a WIPP-like exothermic chemical reaction that ejects the contents of a waste drum [10]. This respirable release fraction is significantly greater than values typically associated with TRU waste facility accidents.

In December 2015, DOE issued a PJS [1] for revising DOE Standard 5506-2007 that noted the need to include guidance on evaluating a WIPP-like event. The guidance is intended to “reflect lessons learned from the February 2014 event” and include “potential magnitude of airborne releases” [1]. Given that a WIPP-like event may challenge the evaluation guideline for TRU waste facilities, DOE Standard 5506 should provide guidance on when such an event needs to be considered to ensure appropriate control selection.

# 7. CONCLUSIONS

DOE Standard 5506-2007 covers a wide range of accidents and is applied at TRU waste facilities across the DOE defense nuclear facilities complex. As such, the weaknesses discussed in this Technical Report have implications complex-wide. These weaknesses affect various facets of DOE Standard 5506-2007 that may impact facilities in an unequal manner.

Correcting deficiencies in the guidance provided in DOE Standard 5506-2007 could be accomplished by increasing the level of detail, updating to current DOE expectations for complying with safe harbor provisions in 10 C.F.R. Part 830, *Nuclear Safety Management*, and ensuring an adequate technical basis.

This Technical Report describes how, in some instances, DOE Standard 5506-2007 contains guidance and requirements that: (1) lack sufficient detail to ensure consistent and conservative application; and (2) lack adequate technical basis for the proposed analytical methods and values. The deficiencies discussed in this Technical Report are ultimately used in the process of developing a safety basis and evaluating and selecting controls. Impacts on the control selection could change the functional classification, number, and type of controls.

## REFERENCES


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