EFFORTS TO UPDATE THE TRUPACT-II HYDROGEN AND GAS GENERATION MODEL

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ABSTRACT

The TRUPACT-II Safety Analysis Report (SAR) and the TRUPACT-II Authorized Methods for Payload Control (TRAMPAC) describe the assumptions and model currently used to address the U.S. Nuclear Regulatory Commission (NRC) limit on hydrogen concentration (less than or equal to 5 volume percent) during transportation of transuranic (TRU) waste. A recent U.S. Department of Energy (DOE), Carlsbad Field Office (CBFO) initiative recommended an evaluation of the current hydrogen and gas generation model in the TRUPACT-II SAR to determine whether changes are warranted to make the model more realistic and benefit shippability of the TRU waste under less restrictive conditions, without impacting the safety basis for the transportation conditions. The evaluation was performed by a team (the Panel) formed by the DOE-CBFO of individuals who have been involved in the gas generation program over the years and who understand the concepts driving the model, as well as site needs for relief from current restrictions.

During the course of the task, the Panel developed eight recommendations for potential changes in the TRUPACT-II gas generation model. Following the development of the eight recommendations, a benefit analysis was performed to determine the impact of each recommendation on waste shippability and to quantify the benefits of each recommendation. The Panel then held a meeting to discuss the original recommendations, explore any other ideas, and determine the path forward for each recommendation. The Panel provided a path forward for modifications to the TRUPACT-II SAR, which are being implemented in future TRUPACT-II SAR revisions.

The Panel conclusions were that upgrades to the Hydrogen and Gas Generation Model should focus on the shippability of Waste Type IV (solidified organic waste) for which both total gas generation and hydrogen gas generation are of concern. The model upgrades recommended by the Panel focus on pressure analysis consistent with the shipping time, longer duration tests for Waste Type IV, a reduced shipping period, and a path forward for testing containers other than 55-gallon drums.

BACKGROUND

The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, is the nation's first geological repository for the permanent disposal of TRU waste. The WIPP Land Withdrawal Act [1] requires all TRU waste shipments to WIPP to be made in Type B packagings certified by the NRC under the regulations of Title 10, Code of Federal Regulations (CFR), Section 71 (10 CFR 71) [2]. In 1989, the NRC certified the TRUPACT-II for the transport of CH-TRU waste based on the TRUPACT-II SAR. Since the opening of WIPP for receipt of waste in 1999, over 2,200 shipments of TRU waste to WIPP have been made in the TRUPACT-II packaging. The TRUPACT-II SAR has been amended numerous times to expand the allowable payload, including the use of more realistic assumptions related to gas generation and use of data collected in the TRU Program.

One of the issues addressed in the SAR for the TRUPACT-II packaging is the potential generation of hydrogen during transport, which can occur due to radiolysis of the waste materials or packaging materials (e.g., plastic bags). The NRC limit on hydrogen concentration during transportation is 5 (volume) percent [3]. The TRUPACT-II SAR [4] and TRAMPAC [5] describe the assumptions and model currently used to address this limit. The key assumptions and parameters of the model can be summarized as follows:

- The primary gas generation mechanism is radiolysis, which can be quantified conservatively by the use of "G values" (number of molecules of gas generated per 100 electron volts of energy absorbed).

- Hydrogen gas generation analysis is performed assuming a shipping time of 60 days, and pressure analysis is performed for a time period of one year. Typical shipping times for the TRUPACT-II are less than 10 days (controlled shipments from the Los Alamos National Laboratory (LANL) have been made in less than five days).

- Release rates of hydrogen can be quantified, given the packaging configuration for the waste (i.e., number and type of bag layers used to package the waste).

- Given the G value, the shipping time, and the release rates, the hydrogen limit can be met by imposing a decay heat limit on the payload containers. If the decay heat limit is exceeded or if a bounding G value does not exist for the waste (Waste Type IV or solidified organics), measurement or testing of the hydrogen in the payload container are options for complying with the NRC limits on gas generation.

In light of the characterization and gas generation data gathered at the DOE TRU waste sites over the past several years and experience with over 2,200 TRUPACT-II shipments, the DOE-CBFO commissioned an initiative to reevaluate the hydrogen gas generation model in the TRUPACT-II SAR. The DOE-CBFO formed a Panel consisting of experts in the area of gas generation and TRU waste transportation and tasked the Panel with evaluating the Hydrogen and Gas Generation Model in the TRUPACT-II SAR to determine whether changes were warranted to make the model more realistic and allow shipment of TRU waste under less restrictive conditions, without impacting the safety basis for the transportation conditions. The Panel consisted of a DOE-CBFO sponsor and representatives from four of the DOE sites [Argonne National Laboratory-West, Idaho National Engineering and Environmental Laboratory, LANL, and Rocky Flats Environmental Technology Site (RFETS)], as well as DOE subcontractors with extensive experience with the TRUPACT-II Hydrogen Gas Generation Model.

PANEL OBJECTIVES

Over a period of several weeks, the Panel reviewed the information in the TRUPACT-II SAR and TRAMPAC, as well as specific summaries and sensitivity analyses to show benefits and impacts of different variables (e.g., shipping times, void volumes, etc.). Conference calls were held as needed to answer Panel member questions and to provide clarifications. The first objective of the Panel was to develop a set of recommendations for areas of potential changes in the TRUPACT-II gas generation model. Based on a review of the TRUPACT-II SAR and TRAMPAC, the Panel developed eight recommendations for further review. Following the development of the eight recommendations, a benefit analysis was performed to determine the impact of each recommendation on waste shippability and to quantify the benefits of each recommendation. The Panel then held a meeting to finalize recommendations and determine the path forward for each recommendation. A summary of this process for each of the final recommendations is provided in the following section.

RECOMMENDATIONS OF THE PANEL

Recommendation 1: Pressure Analysis Using Less Conservative Assumptions of Time Frame (Less Than One Year) and Total Gas Generation

The TRUPACT-II packaging has a design pressure limit of 50 pounds per square inch gauge [8]. As required by 10 CFR 71, compliance with this pressure limit is ensured by assuming a one-year time period and limiting the payload to control the total gas generation over this time period. The assumption of the one-year time frame and the assumption of bounding total G values limit the total gas generation allowed for Waste Type IV and other high-loaded test category wastes. The regulations in 10 CFR 71.41(c) state [2]:

> "Environmental and test conditions different from those specified in §§ 71.71 and 71.73 may be approved by the Commission if the controls proposed to be exercised by the shipper are demonstrated to be adequate to provide equivalent safety of the shipment."

This provision in 10 CFR 71.41(c) was used in Revision 19a of the TRUPACT-II SAR to justify a pressure analysis for a time period of 60 days for a specific population of waste from LANL. The TRUPACT-II SAR also shows that a 60-day time period bounds the expected shipping time by a large margin and is the basis for the hydrogen analysis.

Based on the analyses performed, the following are the benefits of implementing Recommendation 1:

- Waste Types I, II, and III can be shown by analysis to be compliant with the total gas generation limit with wattages up to 40 watts without the need for elevated temperature testing

- For Waste Type IV, the maximum allowable total gas generation rate increases from 6.51E-07 moles/second per drum to 3.72E-06 moles/second per drum, as shown in Fig. 1.

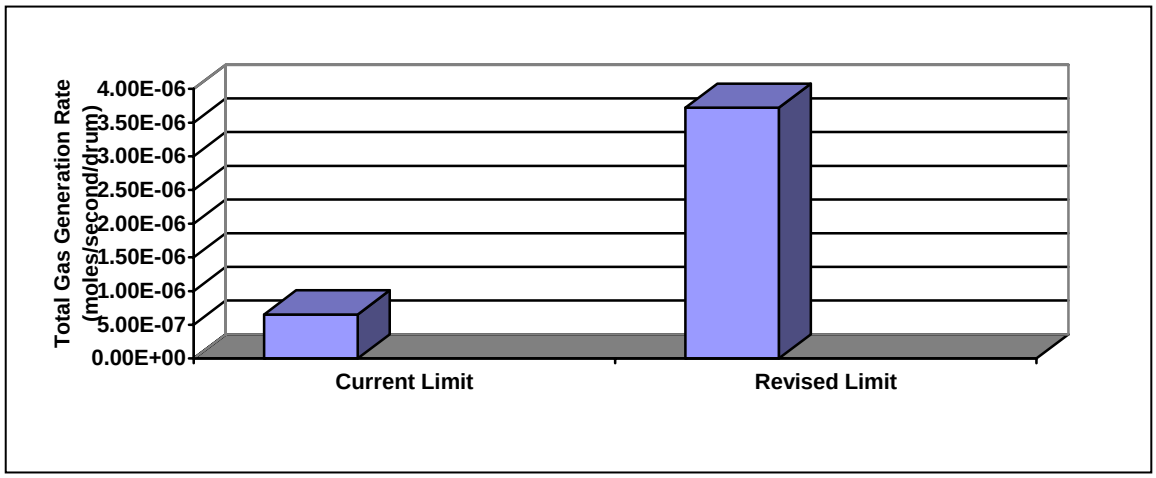

Fig. 1 Increase in maximum allowable gas generation rate limit based on 60-day pressure analysis

Based upon the data presented pertaining to waste at RFETS and the Panel discussions, the Panel concluded that Recommendation 1 was needed and should be included in the application for Revision 20. This recommendation was, therefore, included in the application for Revision 20 of the TRUPACT-II SAR and TRAMPAC (submitted to the NRC in October 2003 and currently under review).

Recommendation 2: Evaluate Impacts of Wattage Assumptions in the TRAMPAC that Determine Test Temperatures for Test Category Waste (Requirement for High-Temperature Tests)

Elevated temperature testing is currently required for all containers of Waste Type IV and Waste Type III containers with loadings greater than 7 watts. The required test temperatures are 146 degrees Fahrenheit (°F) for Waste Type III and 135°F for Waste Type IV. These temperatures were arrived at based on the TRUPACT-II thermal analysis and assuming a worst-case wattage loading of 20 watts for Waste Type III and 7 watts for Waste Type IV. In general, such high loadings are not expected, especially for Waste Type IV containers. For example, Waste Type IV is predominantly Pu-239, which is also subject to a 200 gram fissile gram equivalent limit per drum that translates to a decay heat of only 0.39 watt. As shown in the thermal analysis section of the TRUPACT-II SAR, the temperature profile for the TRUPACT-II is such that even with no decay heat loading, the temperature based on insolation and other initial conditions is 127°F. Therefore, there will be minimal benefit (in terms of reduction in the test temperature) by decreasing the maximum wattage assumption for test category waste.

Based on discussions during the Panel meeting, it was determined that Recommendation 2 would not result in any significant benefits (especially as Recommendation 1 would increase total gas generation rate limits for Waste Type IV and allow Waste Type III shipments without the need for elevated temperature testing). However, the Panel developed a new recommendation (Recommendation 2a) to review the thermal analysis assumptions that dictate the temperature for Waste Type IV testing. It was believed that if room temperature testing could be justified, shippability of this waste would significantly increase. Based on these discussions, the Panel recommended that an evaluation be performed on the thermal analysis assumptions for possible inclusion in the application for Revision 21.

Recommendation 3: Changes to Reduce Shipping Period for Flammable Gas Generation Analysis Based on Operational Experience to Date

The TRUPACT-II SAR currently assumes a maximum shipping time of 60 days. This time period impacts flammable gas generation limits in the SAR, as the hydrogen generated during transport is assumed to be accumulating in a sealed TRUPACT-II and the payload containers for a 60-day period. The derivation of this bounding time period assumes a series of simultaneous low-probability events (bad weather, trailer breakdown, driver illness, accident, maximum possible times for loading and unloading, etc.), with the resulting time of 31 days doubled to approximately 60 days. Experience with more than 2,200 shipments to date has shown that shipments can be consistently made within time frames much less than the 60 days. Figure 2 presents the results of the sensitivity analysis performed for different packaging configurations (i.e., 2 filtered liner bag layers and 6 layers [2 liner and 4 inner bag layers]). The higher the number of layers of confinement, the lesser the benefit from a reduced shipping time (the primary resistance to hydrogen release is from the bag layers, and shipping time has a minimal impact). Although the benefit for packaging configurations with six layers of confinement is low, for packaging configurations with only two layers of confinement, a 20-day shipping period provides a 72 percent increase in wattage limit, and a 5-day shipping period provides a 135 percent increase in wattage limit.

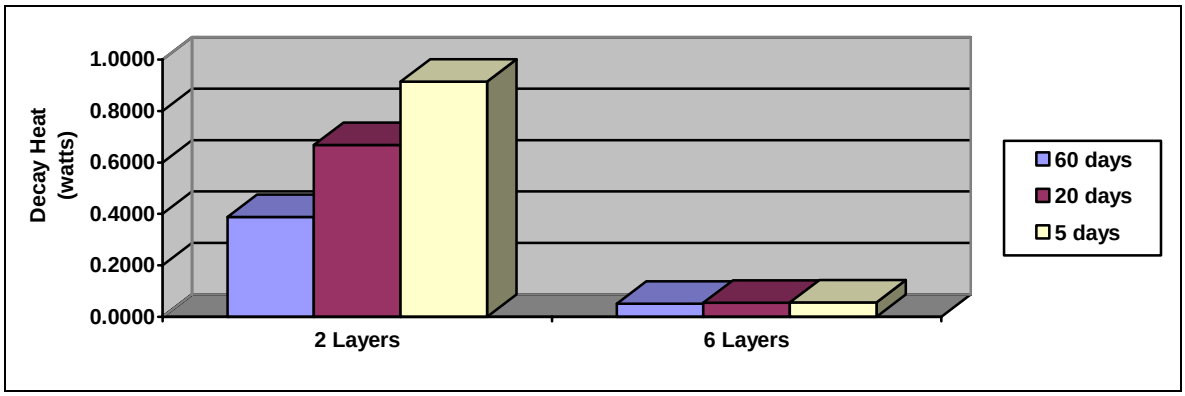

Fig. 2 Decay heat limits for various shipping times

The application for Revision 20 of the TRUPACT-II SAR (which was under preparation at the time of the Panel meeting) proposed the use of a 20-day shipping period (without requiring additional administrative controls) for sites in close proximity to the WIPP [i.e., LANL, the Nevada Test Site (NTS), and RFETS]. For these sites, implementation of this recommendation provides higher wattage limits for newly generated waste, which can be packaged with fewer confinement layers. The Panel recommended that the application for Revision 20 allow intra-site shipments within a radius of approximately 1,000 miles using a 20-day shipping period in addition to the shipments to WIPP.

Additional discussion among the Panel and other feedback led to a recommendation that, in addition to the 20-day shipping time (for near sites without administrative controls), the Revision 19a experience with a 5-day shipping time for LANL (with administrative controls) could be used to justify a 10-day shipping time for any site with similar administrative controls.

Based on the recommendations of the Panel, the application for Revision 20 contains a provision for shipments within a 1,000 mile radius. This would allow a large site to ship waste to another DOE site within a 1,000-mile radius using a 20-day shipping time. In addition, a 10-day shipping time with administrative controls was incorporated into the application for Revision 20 as part of this recommendation.

Recommendation 4: Evaluation of HalfPACT-Specific Limits Based on Actual Void Volumes in the HalfPACT

Currently, the HalfPACT (a shorter version of the TRUPACT-II) is a second packaging that is authorized for the shipment of CH-TRU waste. Individual decay heat and gas generation limits for the TRUPACT-II and HalfPACT packagings are the same for a given container of TRU waste. The safety analysis for the packagings showed that the TRUPACT-II limits are bounding for the HalfPACT, based on the larger void volume per container available within the HalfPACT packaging. The limits were chosen to be the same to facilitate compliance evaluations and certification at the sites, independent of the packaging used. The results of the sensitivity analyses showed that the benefit of implementing this recommendation is minimal and, as with Recommendation 3, the benefit for packaging configurations with 2 layers of confinement is greater (27%) than that for packaging configurations with 6 layers of confinement (3%). Implementation of Recommendation 4 would also require sites to have two decay heat limits for each container, one for shipment in the TRUPACT-II and one for shipment in the HalfPACT. Based on the Panel discussions, the Panel consensus was that Recommendation 4 is not needed.

Recommendations 5 and 6: Evaluation of a Transient Analysis Instead of a Pseudo Steady-State Analysis to Determine Decay Heat Limits and Analysis of Impacts of Container Void Volumes Based on Available Information

Note: Recommendations 5 and 6 were combined because Recommendation 6 (taking credit for container void volumes) does not apply unless a transient model is used.

In the current gas generation model in the TRUPACT-II SAR, pseudo steady-state conditions are assumed, and no credit is taken for void volumes within containers. The decay heat limits and gas generation limits in the TRUPACT-II SAR are currently based on this simple pseudo steady-state analysis for the concentration profile of hydrogen during the shipping period. This simplified analysis calculates a mole fraction of hydrogen in the TRUPACT-II inner containment vessel (ICV) based on the allowable gas generation rates and a 60-day shipping period (i.e., the allowed gas generation rate times the 60 days yields the number of moles that can be converted to a mole fraction based on the ICV void volume). This mole fraction is assumed to be instantaneously present in the ICV and is also added to the hydrogen concentration in the innermost confinement layer in a payload container, which is then restricted to 5 percent. Mass balance considerations show that the actual concentrations will always be lower than predicted by this method, as some of the hydrogen generated during the shipping period will be within the containers and the rest released into the ICV.

Figure 3 presents the results of the sensitivity analyses for two different packaging configurations (i.e., 2 and 6 layers of confinement). The benefit is greater for the packaging configuration with 2 layers of confinement (62%) as compared with the packaging configuration with 6 layers of confinement (9%), as more hydrogen is released into the TRUPACT-II ICV with fewer confinement layers.

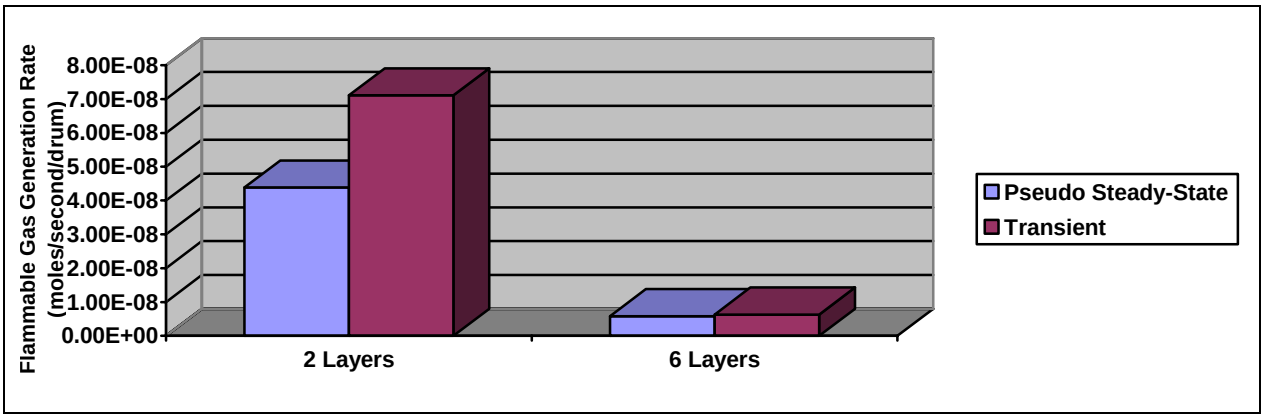

Fig. 3 Flammable Gas generation rate limits based on pseudo steady-state transient analysis

The Panel noted that extensive changes to the TRUPACT-II SAR and a complete revision of all decay heat limits would be needed to implement this recommendation. As the benefits are positive, it was recommended that these changes be targeted for a future TRUPACT-II SAR revision. Therefore, the Panel concluded that Recommendations 5/6 should be included in the application for Revision 21, due to the complexity of the revisions required.

Recommendation 7: Application of the Full-Drum Tests to Containers Other than 55-Gallon Drums

At the present time (under Revision 19c), full-drum testing (to evaluate compliance with gas generation rate limits for test category wastes) is limited to 55-gallon drums. However, 55-gallon drums overpacked

in 85-gallon drums and standard waste boxes that exceed limits also fall into the test category and may require testing.

Feedback from the sites indicated that this is a real need for a portion of the inventory, in particular for overpacked containers. Based on the Panel discussions, Recommendation 7 was incorporated into the application for Revision 20.

Recommendation 8: Analysis of the Mixing Methodology to Take Credit for Total Gas Generation Limits

The total gas generation rate limits in the TRUPACT-II SAR assume the shipment of a full payload of the same shipping category (e.g., 14 55-gallon drums) even in cases where dunnage containers are used or where different shipping categories are mixed. It may be possible to increase these limits by taking credit for dunnage and mixing of shipping categories, as is done for flammable gas generation.

Analyses were performed for Waste Type IV with 7 and 13 dunnage drums, and the results are shown in Figure 4. The increase in total gas generation rate limit is over a factor of 2 for a payload with 7 dunnage drums and a factor of 28 for a payload with 13 dunnage drums (lesser number of gas generators and increased void volume).

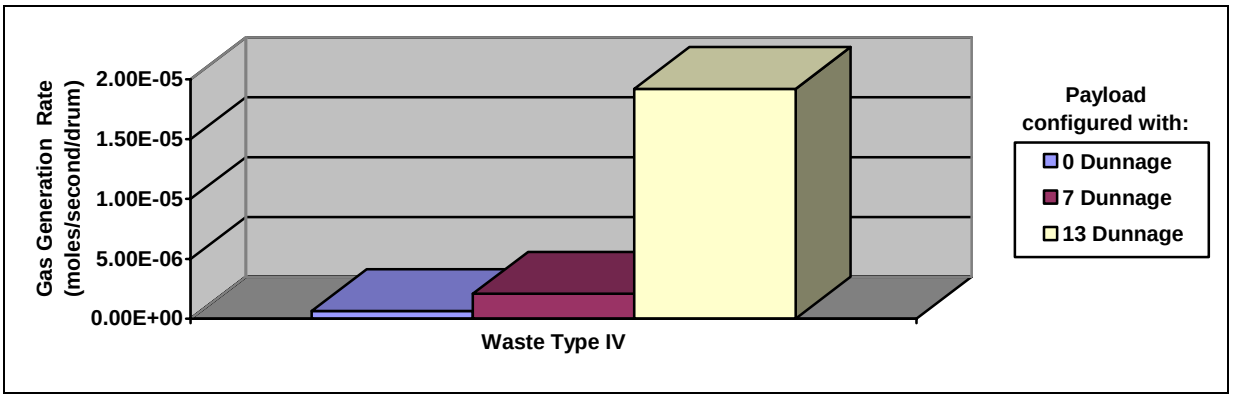

Fig. 4 Increase in gas generation rate limits based on use of dunnage

The Panel concluded that implementation of this recommendation in conjunction with Recommendation 1 would alleviate the total gas generation rate issues with Waste Type IV. As the use of larger number of dunnage containers is inefficient and not recommended, it is likely that mixing will consist of drums with low total gas generation with drums of higher total gas generation to ensure that the payload assembly will meet the limits.

CONCLUSIONS AND PATH FORWARD

The Panel considered a series of recommendations for changes to the TRUPACT-II Hydrogen and Gas Generation Model that would benefit the DOE sites in terms of TRU waste transportation. Based upon the information gathered during this project and the discussions of the Panel, Table I presents the final recommendations and corresponding proposed path forward for each recommendation.

Table I TRUPACT-II Gas Generation Model Review Team Final Recommendations and Corresponding Path Forward

No.	Description	Benefit	Path Forward
1	60-Day pressure analysis	• No elevated temperature testing for Waste Types I, II, and III • Waste Type IV total gas generation rate increases	Include in Revision 20
2	Reduce test temperatures	Minimal benefit	Not needed
2a	Review thermal analysis assumptions	Evaluate room temperature testing justification for Waste Type IV (Note: May require NRC exemption)	Evaluate feasibility for possible inclusion in Revision 21
3	Reduce shipping period for flammable gas generation analysis	• Increase for 2 layers of confinement is 72% for a 20-day shipping period • Minimal increase for 6 layers of confinement	Include in Revision 20 • Add SQ content code(s) with a 20-day shipping time • Add a 10-day shipping time with controls as needed
4	Credit for HalfPACT void volume	Minimal benefit	Not needed
5/6	Transient analysis and credit for void volume	Flammable gas generation rate increases 62% for 2 layers of confinement	Include in Revision 21
7	Full-"container" testing	Site input indicates this is needed	Include in Revision 20
8	Credit for total gas in mixed payloads	Significant benefit (2 to 28 times increase)	Include in Revision 20

As noted in Table I, Recommendations 2 and 4 were deemed to be of minimal benefit and were not considered for further evaluation. Recommendations 1, 3, 7, and 8 were incorporated into the application for Revision 20 of the TRUPACT-II SAR (currently under NRC review), and Recommendation 5/6 could be incorporated into a future application of the TRUPACT-II SAR. In addition, Recommendation 2a will be evaluated to determine the feasibility of its incorporation into a future application of the TRUPACT-II SAR.

REFERENCES

1 Public Law 102-579 (106 Stat. 4777), "Waste Isolation Pilot Plant Land Withdrawal Act," Washington, D.C., (1992) (as amended by Public Law 104 201, [1996]).

2 U.S. NRC, "Packaging and Transportation of Radioactive Material," Code of Federal Regulations, Title 10, Part 71, U.S. Nuclear Regulatory Commission, Washington, D.C.

3 U.S. NRC, "Standard Review Plan for Transportation Packages for Radioactive Material," NUREG-1609, U.S. Nuclear Regulatory Commission, Washington, D.C. (1999).

4 DOE, "Safety Analysis Report for the TRUPACT-II Shipping Package," Rev. 19c, U.S. Department of Energy, Carlsbad Field Office (2003).

5 DOE, "TRUPACT-II Authorized Methods for Payload Control (TRAMPAC)," Rev. 19c, U.S. Department of Energy, Carlsbad Field Office (2003)