PATH FORWARD TO SHIP ALL OF THE CH-TRU WASTE TO WIPP – SOLUTION TO THE FLAMMABLE GAS GENERATION ISSUE

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ABSTRACT

The Transuranic Package Transporter-II (TRUPACT-II) and the HalfPACT are packagings designed for the shipment of contact-handled transuranic (CH-TRU) wastes to the Waste Isolation Pilot Plant (WIPP). A Certificate of Compliance (C of C) for the TRUPACT-II package was originally granted by the U.S. Nuclear Regulatory Commission (NRC) in 1989. In November 2000, the NRC granted a C of C for the HalfPACT package. The C of Cs for the TRUPACT-II and HalfPACT packages specify the payload limits that need to be met in order to ensure safe transportation of the waste. With the opening of the WIPP in 1999, a path forward for the shipment of the entire CH-TRU waste inventory is needed to fill the WIPP pipeline and to ensure successful disposal of the U.S. Department of Energy (DOE) CH-TRU waste inventory. Expanding the allowable payload of the TRUPACT-II has been addressed in Safety Analysis Report (SAR) amendments, based upon testing and analysis performed to better characterize the properties of the CH-TRU waste under shipping conditions. The current approved version of the TRUPACT-II SAR is Revision 18. It is expected that the payload expansion needed to ship more than 90% of the CH-TRU waste inventory to the WIPP will be achieved upon approval of Revision 19 and future amendments to the TRUPACT-II SAR. Revision 19 of the SAR is currently under review by the NRC, with future revisions of the SAR to be submitted upon approval of Revision 19. The key initiatives in Revision 19 include credit for matrix depletion, use of headspace gas sampling to determine the potential flammability of gas/volatile organic compound mixtures, mixing of payload shipping categories, and the use of filters with higher hydrogen diffusivity properties. A future initiative will be to investigate the potential use of hydrogen gas getters in the TRUPACT-II inner containment vessel, which will minimize the accumulation of hydrogen during transportation.

Upon approval by the NRC, the proper use of the payload expansion initiatives to match the waste inventory is crucial to solving the CH-TRU waste shippability problem and filling the WIPP pipeline. For example, use of better filters in containers is ineffective in cases where multiple (three or more) bag layers exist because of the restriction to the release of hydrogen from the bags. Similarly, the use of hydrogen gas getters would be meaningful only if the hydrogen is released with minimal resistance from the container (for example, by using fewer layers of confinement that use high diffusivity bag filters, increasing the hole size in the liner, or using high diffusivity drum filters).

This paper will present an analysis to determine the optimal application of the payload expansion initiatives to facilitate the shipment of the entire CH-TRU waste inventory, with an end goal of minimizing testing and/or repackaging and overall system costs. Specific examples (plutonium [Pu]-238 wastes, residues, etc.) will be analyzed to show the benefit of various alternatives to the packaging and shipment of the wastes. This analysis can be used by the DOE sites to configure

existing payloads and determine packaging configurations for wastes to be generated in the future.

INTRODUCTION

The Transuranic Package Transporter-II (TRUPACT-II) and the HalfPACT are double-contained, Type B packagings, which were developed primarily for the shipment of contact-handled transuranic (CH-TRU) waste from the U.S. Department of Energy (DOE) generator/storage sites to the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico for permanent disposal. The WIPP Land Withdrawal Act (1) requires that all shipments to the WIPP be made in packagings certified by the U.S. Nuclear Regulatory Commission (NRC). Safety Analysis Reports (SARs) for both these packagings were submitted to the NRC demonstrating compliance with the Type B packaging requirements of Title 10, Code of Federal Regulations (CFR), Part 71 (10 CFR 71). Based on the safety analysis, the NRC has issued Certificates of Compliance (C of C) for both the TRUPACT-II (in August 1989) (2) and the HalfPACT (in November 2000) (3). These C of Cs and the SARs describe the conditions under which CH-TRU wastes may be shipped to WIPP and the limits to be met by the payloads shipped. Since the opening of WIPP in March 1999, over 100 TRUPACT-II shipments of waste have been made to date from four different DOE sites.

The current approved version of the TRUPACT-II SAR is Revision 18 (4). Since the issuance of the TRUPACT-II C of C in 1989, several successful applications for amendments to the TRUPACT-II SAR have been submitted to the NRC to expand the allowable payload that can be shipped. Revision 19 of the SAR is currently under review by the NRC, with later revisions of the SAR to be submitted upon approval of Revision 19. One of the key issues addressed by these amendments has been potential flammable gas generation during transportation and methods of demonstrating compliance with applicable limits for CH-TRU wastes. It is expected that the payload expansion needed to ship more than 90% of the CH-TRU waste inventory and resolve the flammable gas generation issue will be achieved upon approval of currently planned amendments to the TRUPACT-II SAR.

CH-TRU WASTE AND FLAMMABLE GAS GENERATION

The TRUPACT-II safety analysis included the evaluation of the following potential gas generation mechanisms with respect to the possible build up of pressure in the TRUPACT-II inner containment vessel (ICV) or generation of potentially flammable gases:

- Thermal
- Chemical
- Biological
- Radiolytic.

Analyses showed that the generation of flammable gas through the thermal degradation, chemical interaction, and biological activity of the CH-TRU waste forms will be negligible during the TRUPACT-II shipping period of 60 days. The primary gas generation mechanism during the transportation of CH-TRU wastes is the radiolysis of the waste materials or packaging materials. Therefore, hydrogen gas generation by radiolysis is a key issue in the TRUPACT-II safety analysis.

Hydrogen Concentration Limit

In 1984, the NRC released an information notice to clarify conditions for waste shipments subject to hydrogen gas generation (5). The notice stated that "[g]eneric requirements have recently been included in certain NRC Certificates of Compliance to preclude the possibility of significantly reducing packaging effectiveness in use." The information notice further states that "[f]or any package containing water and/or organic substances that could radiolytically generate combustible gases, it must be determined by tests and measurements of a representative package whether or not the following criteria are met over a period of time that is twice the expected shipment time: (a) The hydrogen generated must be limited to a molar quantity that would be no more than 5% by volume (or equivalent limits for other inflammable gases) of the secondary container gas void, if present, at STP (i.e., no more than 0.063 g-moles/ft3 at 14.7psia and 70°F), or (b) the secondary container and cask cavity must be inerted with a diluent to ensure that oxygen must be limited to 5% by volume in those portions of the package that could have hydrogen greater than 5%." In 1999, NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material," was finalized (6). This application review guide requires the NRC to "[c]onfirm that the application demonstrates that any combustible gases generated in the package during a period of one year do not exceed 5% (by volume) of the free gas volume in any confined region of the package." Shorter time periods have been approved based on detailed operating procedures to control and track the shipment of packages. In addition, the 5 volume percent hydrogen limit is used as the lower flammability limit for hydrogen in air in NUREG/CR-6673, "Hydrogen Generation in TRU Waste Transportation Packages" (7).

TRUPACT-II Limits Based on Flammable Gas Generation

The TRUPACT-II approach for ensuring compliance with the 5 volume percent hydrogen concentration limit in any confined region of the package involves the classification of the authorized payload. CH-TRU waste has been classified into "payload shipping categories" to evaluate and ensure compliance with the gas generation requirements (4). The decay heat per payload container is restricted such that the hydrogen generated during twice the expected shipment time results in a molar quantity of not more than 5 volume percent in any layer of confinement in the payload container. The compliance evaluation associated with the payload shipping category classification requires the following specific knowledge of the waste to be shipped:

- Chemical characteristics of the waste, which define its hydrogen gas generation potential
- Packaging configuration, which defines the resistance provided to hydrogen gas release.

The chemical composition of the waste determines its waste type. An assessment of the radiolytic gas generation potential from the chemical constituents of the waste resulted in the assignment of a "G value" quantifying the gas generation potential. Waste Types I (solidified inorganics), II (solid inorganics), and III (solid organics) have known G values, but the G value for Waste Type IV (solidified organics) is unknown. The resistance to gas release is based on the type and maximum number of layers of confinement used to package the waste. The balance between the gas generation potential of the waste and the resistance to hydrogen release determine a unique decay heat limit for each payload shipping category, or payload container, to demonstrate compliance with the 5 percent limit on hydrogen. These analytic limits preclude the shipment of payload containers that have a potential for the generation of significant amounts of flammable gases. Payload containers that exceed the decay heat limit and containers in Waste Type IV belong to the "test category" and must be tested to demonstrate that the actual rate of gas generation is less than the allowable rate. The assignment of a payload shipping category (and, therefore, an associated decay heat limit) is documented in TRUPACT-II content codes (8), which describe how site-specific wastes comply with the requirements of the TRUPACT-II SAR (4). The payload expansion initiatives in the TRUPACT-II SAR are aimed at increasing the shippable payload while demonstrating compliance with this governing limit of 5% hydrogen. The mathematical analyses to relate gas generation to decay heat limits are presented in the TRUPACT-II SAR (4).

PAYLOAD EXPANSION PLAN

Following the identification of the CH-TRU waste inventory at the DOE generator/storage sites that was restricted from TRUPACT-II shipment due to one or more of the limits in the TRUPACT-II C of C, the "TRUPACT-II Payload Expansion Plan" was developed and approved by the DOE in 1997 (9). The document describes an integrated plan to ensure TRUPACT-II payload expansion activities will support filling the WIPP pipeline. The plan also ensures that TRUPACT-II SAR revisions prepared to expand the TRUPACT-II authorized contents address key issues impacting CH-TRU waste shippability in the TRUPACT-II. The plan covers Revisions 18 and 19 and future revisions of the TRUPACT-II SAR.

The "TRUPACT-II Payload Expansion Plan" proposes solutions to each of the issues affecting CH-TRU waste shippability (9). Table I provides a comprehensive matrix of shippability solutions included in Revisions 18 and 19 in future revisions of the TRUPACT-II SAR. As shown, the TRUPACT-II SAR amendments, including Revision 19, have addressed most of the shippability issues. Table II summarizes the parameters governing the TRUPACT-II hydrogen gas generation limits.

The TRUPACT-II SAR amendments for payload expansion have focussed on addressing the hydrogen gas generation limits that restrict the efficient use of the TRUPACT-II by the DOE sites. The payload expansion initiatives included in the application for Revision 19 of the TRUPACT-II SAR and to be proposed in future revisions of the TRUPACT-II SAR will address all of these issues, as detailed below.

Table I. Shippability Solutions Achieved in Revisions 18 and 19 and Future Revision of the TRUPACT-II SAR.

	Through Revision 18 (currently approved)		**Revision 19 (currently under NRC review)**				**Future Revisions (to be submitted to NRC)**	**HalfPACT**
Shippability Issue	Additional TRUCON Codes	Pipe Overpack and Revised FGE Limit Analysis	Gas Generation Testing (Flammability Test Procedure)	MixCat	Use of Better Filters	Matrix Depletion Program	Gas Getters	
High concentrations of Pu-239 wastes		T	T		T	T	T	
Pu-238 wastes			T		T	T	T	
Waste Type IV wastes			T				T	
Payloads with >23 g average FGE in a 14-drum payload		T		T				
Payloads not part of authorized TRUCON codes	T							
Waste packaged in 85-gallon drums								T
Heavier payloads				T				T

FGE = Fissile gram equivalent.
g = Gram(s).
NRC = U.S. Nuclear Regulatory Commission.
Pu = Plutonium.
SAR = Safety Analysis Report.

Table II. Parameters Governing TRUPACT-II Hydrogen Gas Generation Limits

Components of Gas Generation Limits	Governing Parameters
• Hydrogen Gas Generation Potential	• G value[1]
• Hydrogen Gas Release	• Number and type of layers of confinement
• Hydrogen Accumulation in TRUPACT-II Inner Containment Vessel During Transportation	• TRUPACT-II void volume • Number of waste containers • TRUPACT-II shipping time

[1] Number of molecules of hydrogen produced per 100 electron volts of energy absorbed. The higher the G value, the greater potential for hydrogen generation.

Solutions to the Hydrogen Gas Generation Potential Issue

Revision 19 of the TRUPACT-II SAR includes credit for matrix depletion, or the reduction in hydrogen gas generation potential, with increasing dose. Tests done with CH-TRU waste materials under rigorous controlled conditions provide the basis for more realistic G values applicable to CH-TRU wastes. In addition, use of waste form-specific G values allows further subdivision of CH-TRU waste materials without the need for classifying several waste forms under a bounding G value. For example, Waste Material Type III.2 defines homogeneous mixed organic (10% by weight) and inorganic (90% by weight) materials in metal cans. This waste can be assigned a lower G value than Waste Material Type III.1, which can be comprised of solid organic materials only. Figure 1 presents the potential increases in decay heat limits for different waste types based on the application of more realistic G values. As seen, improvements up to a factor of 5.3 are achievable in terms of the amount of waste that can be shipped per container.

Solution to the Hydrogen Gas Release Issue

Revision 19 of the TRUPACT-II SAR allows the determination of hydrogen gas release rates from a container based on the specific packaging configuration used (e.g., number of plastic bags, etc.). In addition, Revision 19 allows for the use of improved bag and drum filters, as well as rigid drum liners with different hole sizes. Figure 2 shows the impact of these improvements on the shippability of plutonium [Pu]-239 wastes. As shown in Figure 2, for a drum of solid organic waste with four layers of packaging, 11 grams (g) of Pu-239 waste can be shipped. The limit can be raised to 242 g/drum by decreasing the number of packaging layers to two, credit for matrix depletion, use of better filters, and a larger hole in the liner. It should also be noted that the 200 g limit for Pu-239 based on criticality concerns will be more restrictive than the packaging configuration shown with 242 g shippable based on gas generation issues. Conversely, further payload expansion for Pu-239 wastes (beyond that shown in Figure 2 and covered by Revision 19) is most likely not needed.

Solution for the Issue of Hydrogen Accumulation in the ICV

Because the TRUPACT-II is assumed to remain in a leak-tight, sealed condition for a period of 60 days, the accumulation of hydrogen in the TRUPACT-II ICV impacts hydrogen concentrations and decay heat limits. The hydrogen accumulation can be reduced by one or more of the following methods:

- Increasing the void volume of the TRUPACT-II ICV by taking credit for available void volume in dunnage containers
- Reducing the shipping time
- Use of hydrogen gas getters that can scavenge any hydrogen released into the TRUPACT-II ICV.

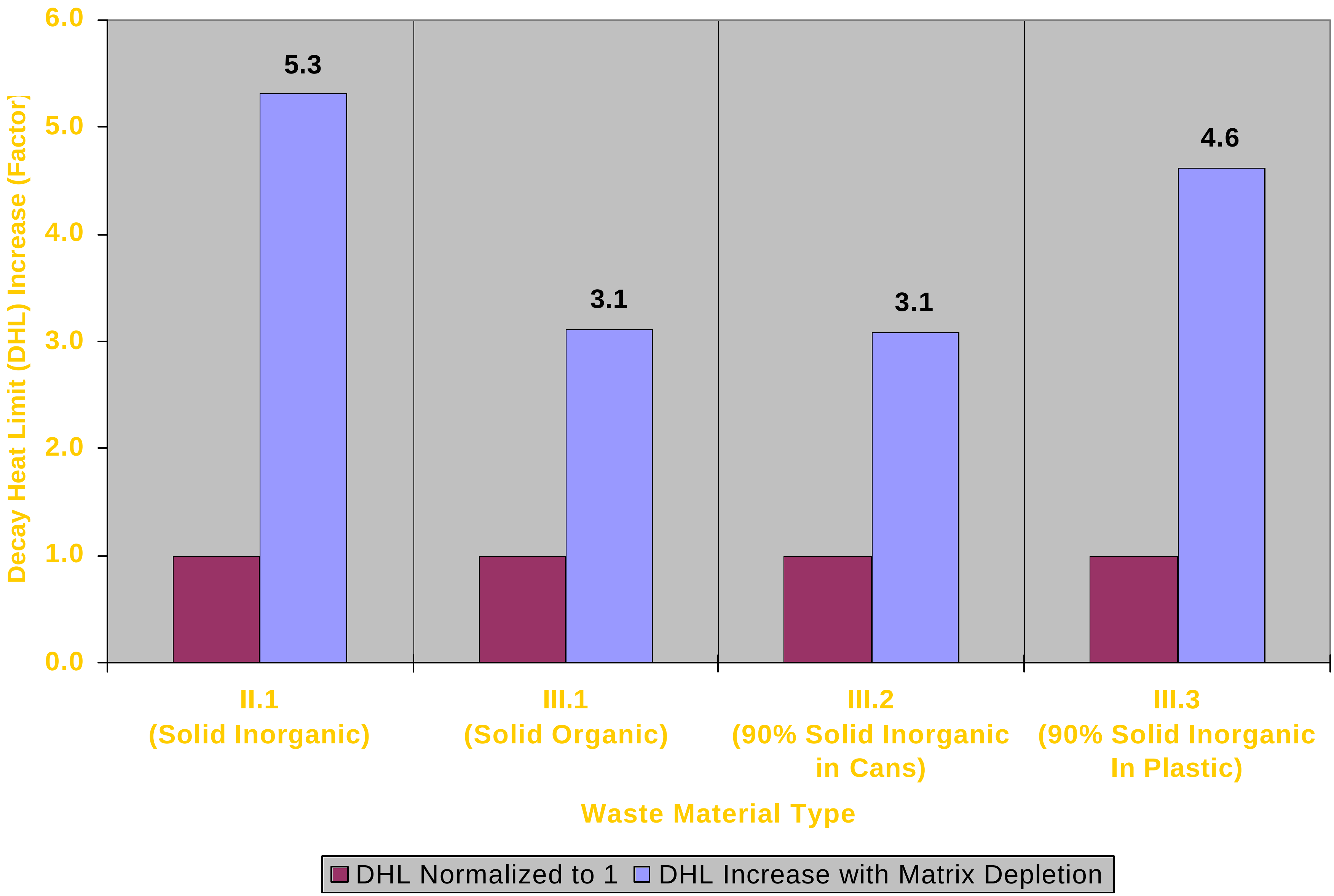

Fig. 1. Potential Increase in Decay Heat Limits Based on Matrix Depletion

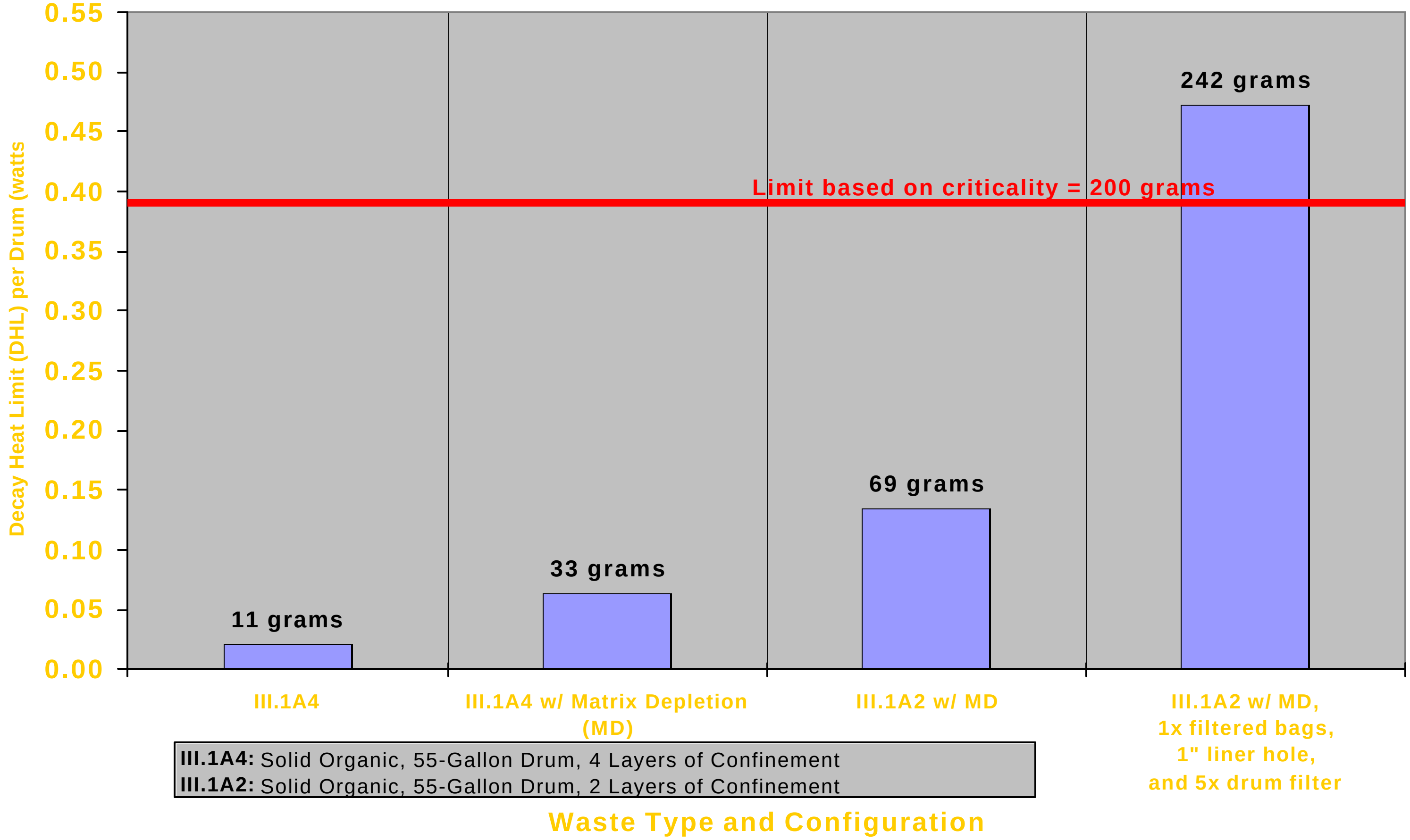

Fig. 2. Potential Decay Heat Limits Based on Different Packaging Configurations (Pu-239 Example)

Any benefit of reducing the hydrogen accumulation in the ICV is strongly dependent upon the potential for hydrogen gas release into the ICV, as illustrated in Figures 3 and 4. Figure 3 shows the potential increase in decay heat limits as a function of the number of drums being shipped (or available void volume) for two different packaging configurations. For a drum with four layers of confinement, the 5% limit on hydrogen means that very little hydrogen is released into the TRUPACT-II ICV (due to the higher resistance to gas release). In this case, increasing the available TRUPACT-II ICV void volume is of little or no benefit. For a packaging configuration with only one layer of confinement, resistance to hydrogen release from the container is smaller. Larger amounts of hydrogen can accumulate in the ICV, and increasing the void volume (by shipping a smaller number of drums per TRUPACT-II) offers more benefit. Similarly, Figure 4 shows that reducing the shipping time offers little benefit for containers with multiple bag layers, because the controlling parameter is the resistance to hydrogen release from the container itself.

Figure 5 shows the potential improvements from different payload expansion initiatives for the case of Pu-238 wastes. The first four bar graphs on Figure 5 are the same as those shown on Figure 2. The last two bar graphs show the impact of reducing the shipping time (from 60 to 20 days) and using hydrogen gas getters, respectively. The desired loading levels for Pu-238 wastes would be to be able to make shipments at the 40 watt TRUPACT-II limit, or an average of 2.85 watts per drum. These loadings are achievable with NRC approval of the initiatives in Revision 19 and future revisions of the TRUPACT-II SAR, as shown in Figure 5.

CONCLUSIONS

The "TRUPACT-II Payload Expansion Plan" (9) is being successfully implemented through the applications for Revisions 18, 19, and future revisions of the TRUPACT-II SAR. When successful, these applications will successfully resolve the flammable gas issues associated with CH-TRU wastes and facilitate optimum shipments in compliance with the 5% hydrogen limit. Fully loaded shipments, at 200 g per drum for Pu-239 wastes and at 2.85 watts per drum for Pu-238 wastes are feasible once the gas generation initiatives are successful. Knowledge of the waste and packaging will facilitate proper use and implementation of the SAR requirements and payload expansion initiatives.

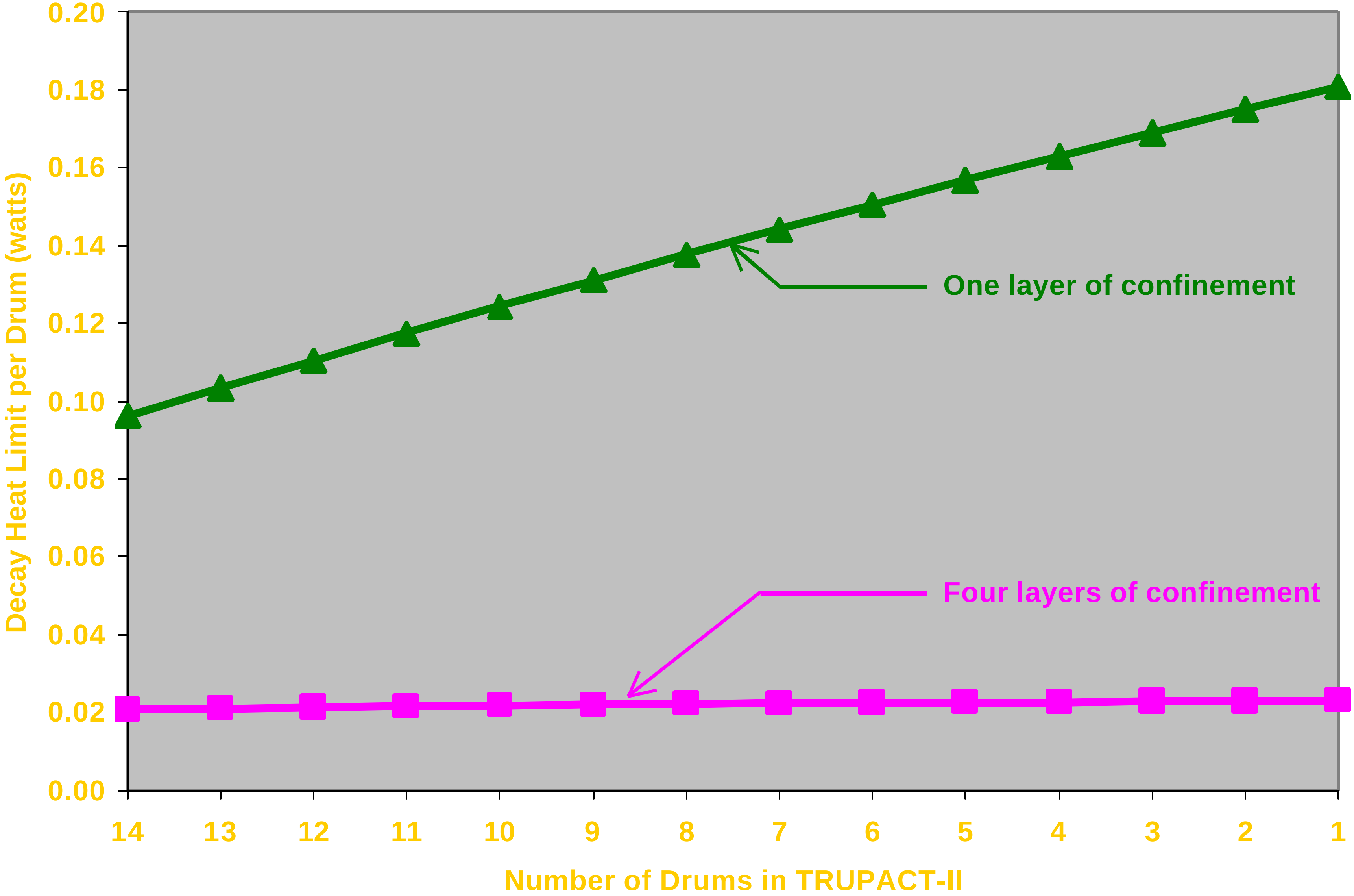

Fig. 3. Potential Decay Heat Limit as a Function of Number of Drums
(Void Volume in the TRUPACT-II Inner Containment Vessel)

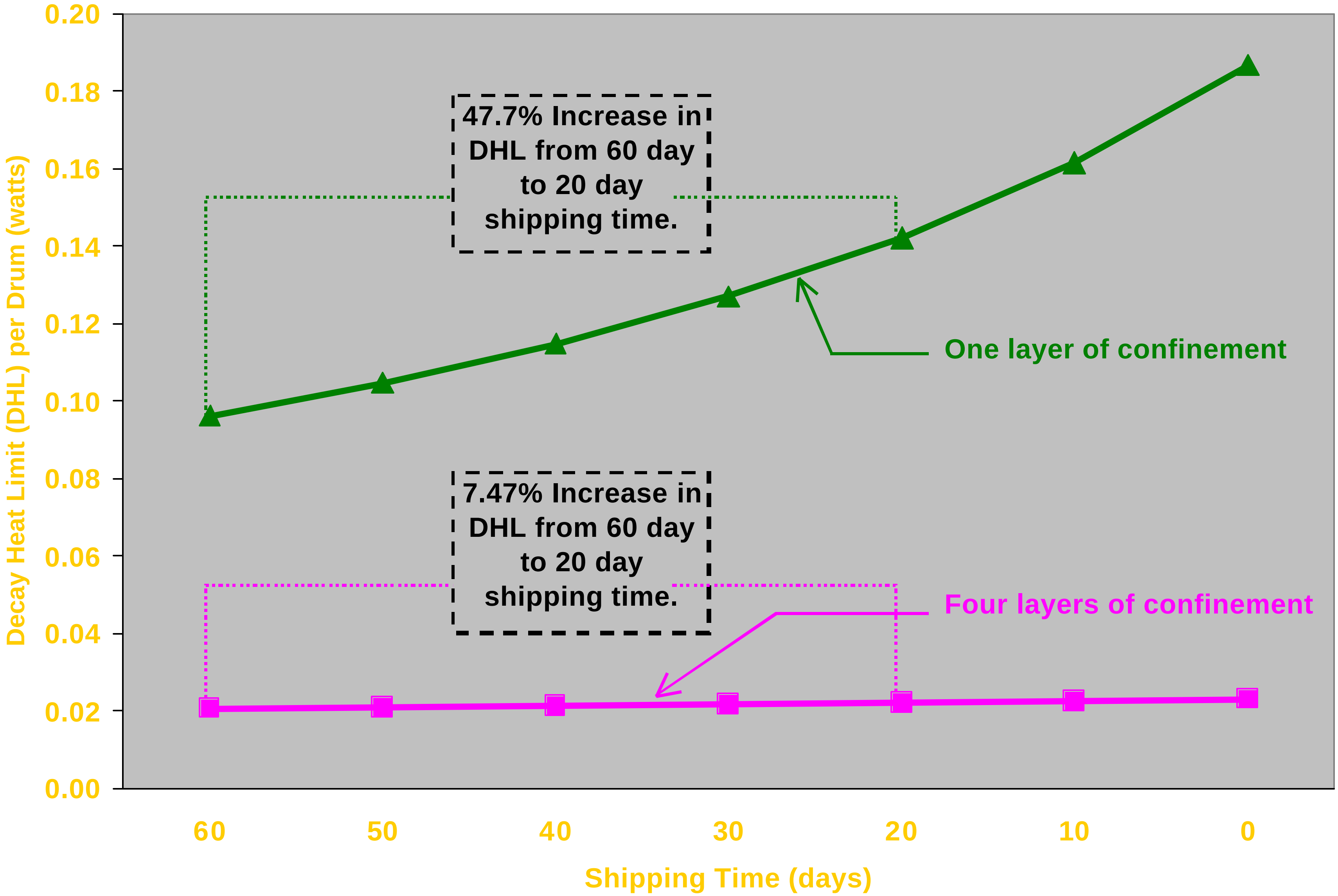

Fig. 4. Potential Decay Heat Limits as a Function of Shipping Time

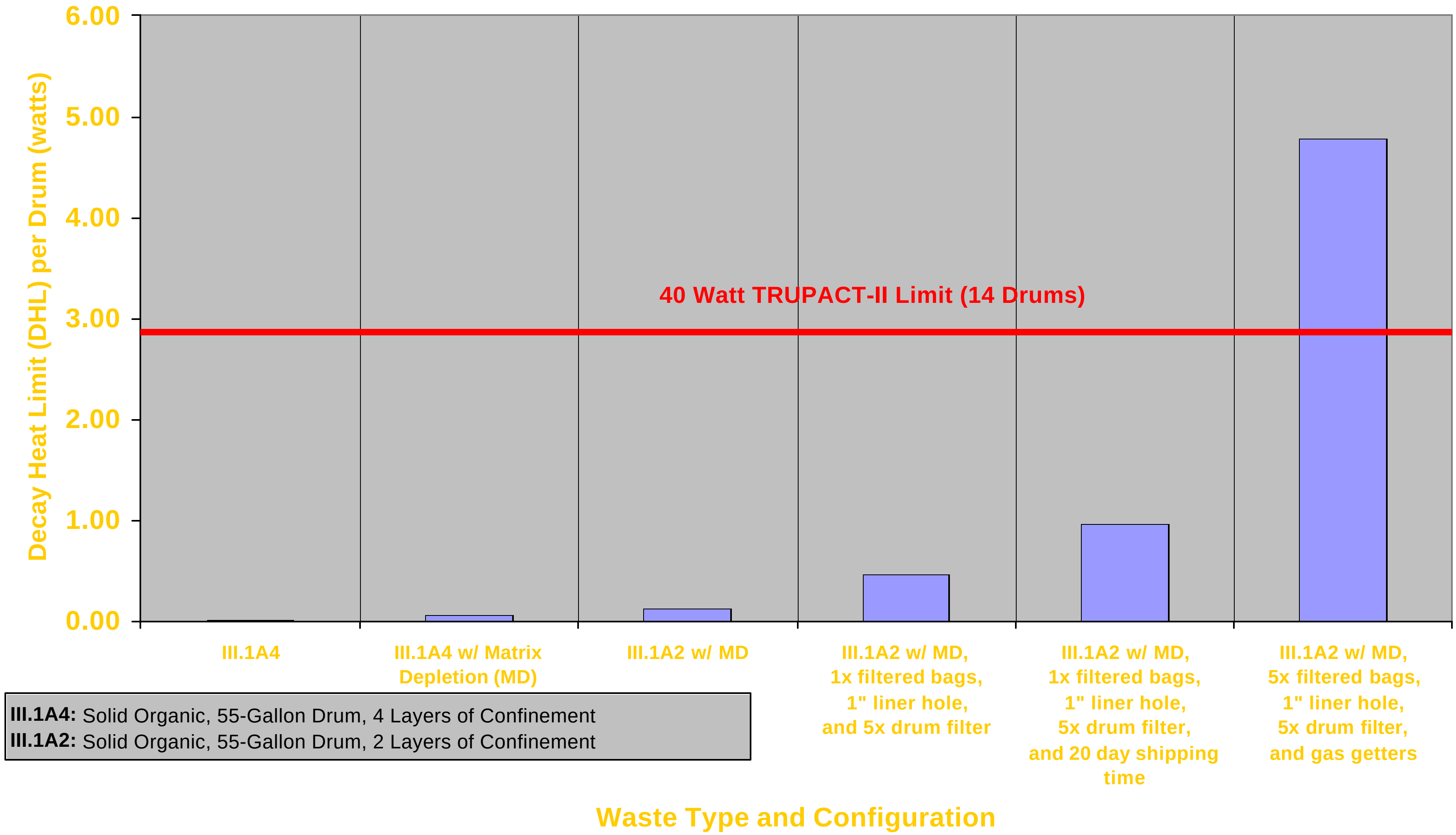

Fig. 5. Potential Decay Heat Limits Based on Different Packaging Configurations (Pu-238 Example)

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