Influence of Non-Radioactive Payload Parameters on Radioactive Shipping Packages

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INTRODUCTION

The transport of radioactive waste materials in radioactive material (RAM) packages involves two components: the packaging used for transportation, and the waste which forms the payload. The payload is usually comprised of non-radioactive materials contaminated with radionuclides. The non-radionuclide payload characteristics can often be a controlling factor in determining the restrictions imposed on the certification of the package. This paper describes these package/payload interactions and the limiting parameters for the Transuranic Package Transporter-II (TRUPACT-II), designed for the transportation of Contact Handled Transuranic (CH-TRU) waste. The parameters discussed include the physical and chemical form of the payload, the configuration of the waste, and resulting gas generation and gas release phenomena. Brief descriptions of the TRUPACT-II package and its payload are presented initially.

The TRUPACT-II Package and Payload

TRUPACT-II is the shipping package developed by Nuclear Packaging, Inc., for the transportation of CH-TRU waste materials. Transuranic (TRU) waste is defined as waste contaminated to greater than 100 nanocuries per gram with predominantly alpha-emitting radionuclides of atomic numbers greater than 92 and half lives greater than 20 years (U.S. Department of Energy, 1988). CH-TRU waste is TRU waste with an external dose rate less than 200 mrem/hr at the waste container's surface. The TRUPACT-II package will transport CH-TRU waste to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, and among the Department of Energy (DOE) sites. The underground repository at the WIPP site is designed to be a storage facility for TRU waste from different DOE sites. The WIPP facility is described in detail elsewhere (U.S. Department of Energy, 1980, 1981, 1988). The TRUPACT-II is double-containment packaging, designed to carry either fourteen 55-gallon drums, or two Standard Waste Boxes (SWBs) of CH-TRU waste as payload. The primary material of construction for the packaging is 304 stainless steel. In meeting the U.S. Department of Transportation (DOT) requirements for Type B packages (49 CFR 173, 1986), the TRUPACT-II package is designed to satisfy a number of other stringent criteria (leak tightness under hypothetical accident conditions in a fire, drops, etc.), in order to meet certification requirements of the U.S. Nuclear Regulatory Commission (NRC) (10 CFR 71, 1983).

CH-TRU waste is characterized by the presence of a variety of organic and inorganic materials as part of the non-radionuclide inventory. For the transport of these CH-TRU materials in TRUPACT-II, the non-radioactive materials, to a large extent, determine the allowable payload per shipment. These payload parameters are discussed in subsequent sections.

PAYLOAD PARAMETERS

CH-TRU waste from the DOE sites is generated as either solid or solidified material. Examples of solid materials are glass, metal, plastics, paper, etc. Examples of solidified materials are dewatered sludges, or other liquids, immobilized in cement. These wastes are typically packaged in one or more layers of plastic bags (primarily polyethylene or polyvinyl chloride), which are then twisted and taped at the top to form a closure. (At the present time, bags that are heat sealed or clamped shut are not allowed in the TRUPACT-II payload, for reasons that will be discussed subsequently). These plastic bags are then placed inside a 55-gallon drum, or an SWB, which serves as a payload container for the TRUPACT-II package. The drums are sometimes lined with a 90-mil plastic, rigid liner, which is punctured to facilitate the release of gases. All the payload containers have carbon composite filters installed which allow the release of gases from the payload container, while retaining particulates within the container. Parameters that govern the allowable payload materials for the TRUPACT-II package are discussed below.

Physical Form of the Payload

CH-TRU waste materials at the DOE sites are present in one of the following four forms, and are classified as such into different waste types:

- Solidified Inorganics
- Solid Inorganics
- Solid Organics
- Solidified Organics

The immobilized and bulk nature of the waste makes the contents of the payload containers relatively inert. However, the physical form of the waste is additionally constrained to meet transportation requirements for safety. Restrictions have been placed on the following items:

- Compressed gases are prohibited.
- Sharp objects are prohibited unless suitably packaged to prevent possible damage to the payload containers and the Inner Containment Vessel of the TRUPACT-II packaging.
- Sealed containers with volumes greater than one gallon are prohibited.

While these restrictions are not a direct consequence of the radioactive nature of the waste, they relate to the safety of the integrity of the TRUPACT-II packaging. Conversely, CH-TRU waste not satisfying the above restrictions cannot be shipped in the TRUPACT-II package, regardless of its radionuclide content or properties.

Chemical Properties of the Payload

The chemical properties of the payload are governed by the constituents present in the different waste types. Restrictions on the chemical constituents of the waste are primarily of two types:

- The first restriction is on specific chemical forms that include explosives, non-radionuclide pyrophorics, and corrosives (49 CFR 173, 1986, 40 CFR 261, 1988). These are prohibited from being a part of the payload unless they are passivated, inerted, or immobilized prior to placement in a payload container.

- The second restriction is on the allowable materials that can be present within each waste type in the payload containers. This restriction is necessary for two purposes:

  1) To ensure chemical compatibility between the different chemical or material constituents in the payload containers, and chemical compatibility with the Inner Containment Vessel and closure seals of the TRUPACT-II packaging. The chemical compatibility evaluation is based on the method outlined in the document by Hatayama et al (1980). Compatible waste forms do not result in any adverse chemical reactions.

  2) To bound the maximum amount of potentially flammable and total gases that might be generated by the radiolysis of the non-radionuclide inventory of the waste. This restriction is required in order to limit the pressure that can build up within the TRUPACT-II package, and restrict the concentration of potentially flammable gases within different layers of the payload and in the Inner Containment Vessel. The impact of this restriction on the allowable contents of the payload is considerable, and is discussed in detail in the next section.

Radiolytic Gas Generation

The potential for radiolytic gas generation for a given compound is quantified by its "G value". The G value is defined as the number of molecules of gas generated per 100 electron volts of energy absorbed by the gas producing material. Radiolysis of water, for example, can result in the generation of hydrogen and oxygen. Radiolysis of waste materials or associated plastic bagging is the primary mechanism by which gases can potentially be generated in the TRUPACT-II payload. Given the nature of the payload and the TRUPACT-II shipping conditions, gas generation due to thermal, chemical or biological means will be insignificant. The different waste types that can be present in the CH-TRU waste are determined by bounding G values for the flammable gases (predominantly hydrogen), and the total gas. Materials that have G values that exceed these bounding G values cannot be present in the waste in amounts greater than one percent. The gas generation rate of the waste during transport is then a function of the bounding G value for the waste type, and the decay heat of the radionuclides within the payload container.

Once again, these restrictions are a result of the non-radionuclide inventory in the payload, and yet determine the type of radioactive waste that can be transported in the TRUPACT-II package.

Waste Configuration and Gas Distribution

As described earlier, CH-TRU waste at the DOE sites is usually placed in plastic bags within the payload containers. A typical drum configuraton is shown in Figure 1. Hydrogen can be generated inside or from the plastic bags by radiolysis, as described above. The release of hydrogen from within the plastic bags occurs by diffusion through the twist and tape closure, and by permeation through the bag material. Hydrogen release from the payload container occurs by diffusion through the filter. Hydrogen generation and release rates across the confinement layers determine the concentration of the hydrogen within the various layers of the payload container and in the Inner Containment Vessel.

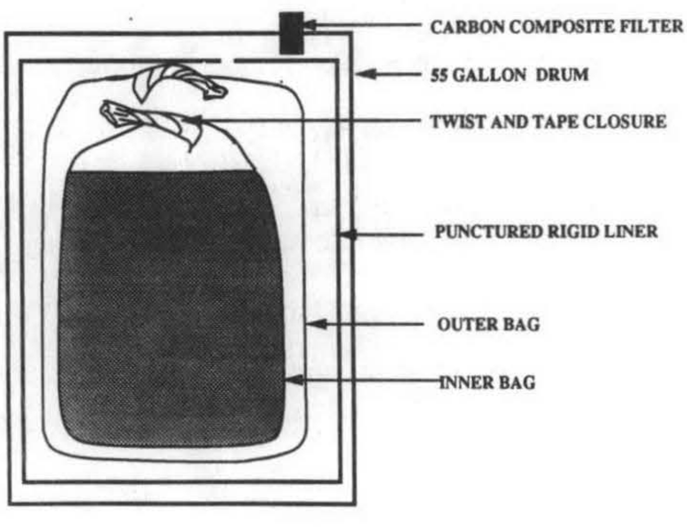

FIGURE 1. Typical Bagging Configuration for a 55-Gallon Drum

Approval of the TRUPACT-II package for transport is based on a requirement that the concentration of hydrogen within the payload container and the Inner Containment Vessel be restricted to a concentration not greater than 5% by volume. For a given payload configuration, the hydrogen release rates are determined by the waste type and the maximum number of bag layers. Hence the limit on the hydrogen concentration limits the decay heat (amount of radioactive material in the waste) that can be present per payload container in a TRUPACT-II. A qualitative model to describe these dependencies between the non-radionuclide parameters and the radionuclide content of the payload is presented below.

Decay Heat Limits for Payload Containers

To assemble a TRUPACT-II payload, prior knowledge of the transportation parameters is necessary to qualify each payload container for transport. In order to calculate the decay heat limits for the different waste types, literature surveys and experimental programs were conducted to obtain conservative estimates of the following parameters:

- Bounding G values
- Hydrogen release rates from plastic bags
- Hydrogen release rates from the filters in payload containers

The time profile of the hydrogen concentration in a payload container (a drum with two bag layers, a punctured liner and fitted with a filter) from the time of initiation of the waste filling process, to the end of the shipping period, is shown in Figure 2. The following assumptions are made in evaluating these concentrations:

1. Temperature and pressure are at 294° K and 1 atmosphere.

2. The shipping period for the TRUPACT-II package is 60 days.

3. All payload containers (14 drums) in a given TRUPACT-II shipment belong to the same waste type and have the same number of bag layers.

4. The void volume in the Inner Containment Vessel of a TRUPACT-II package with the payload is 2450 liters.

5. The sources of hydrogen generation (the radionuclides) are all present in the innermost bag.

Figure 2 shows the increase in the concentration of hydrogen in each of the different layers in the payload container from the time of waste generation (time, t=0). A maximum steady state concentration is reached in all layers (time, t=t1) after which the hydrogen release rates from all layers are the same, and equal to the generation rate. At time t2, the payload container is loaded into the TRUPACT-II (along with the other payload containers). Since the TRUPACT-II is a closed system, the concentration of hydrogen increases in all of the confinement layers until the end of the 60-day shipping period (time, t=t3).

The 5% upper limit on the hydrogen concentration restricts the amount of radionuclides (quantified by the decay heat or wattage) that can be present per payload container in a TRUPACT-II shipment. (The hydrogen generation rate is proportional to the bounding G value and the decay heat). In other words, the gas generation potential of the non-radionuclide inventory controls the amount of radioactive material that can be shipped in the TRUPACT-II package, regardless of package design.

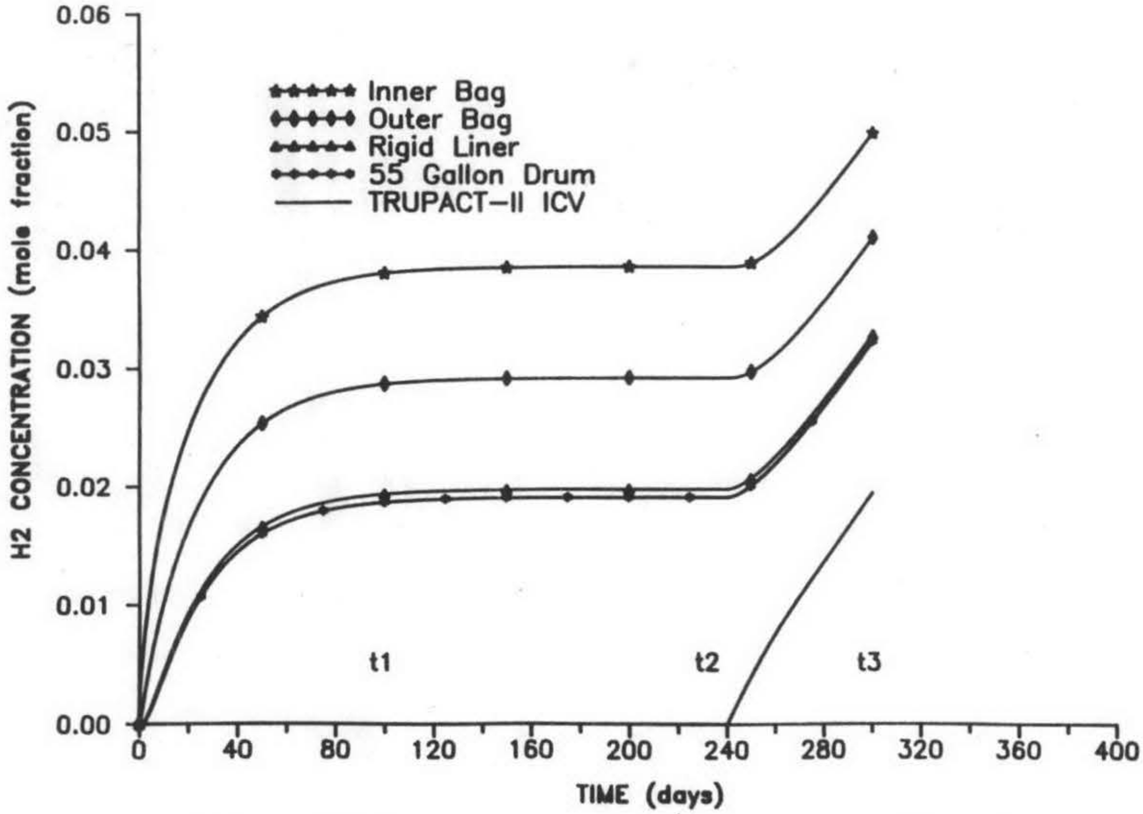

FIGURE 2. HYDROGEN CONCENTRATION PROFILES IN PAYLOAD CONTAINER LAYERS

SUMMARY AND CONCLUSIONS

The non-radionuclide properties of the TRUPACT-II payload control, to a large extent, the allowable contents of the TRUPACT-II package. Restrictions imposed on the physical and chemical form of the payload have a large impact on qualifying the radioactive waste materials as payload. For the TRUPACT-II package, these restrictions are the limiting factors for the payload contents, without consideration of the package design.

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