Questions Related to Hydrogen Generation

1.1 Clarify the statement that the free water may not exceed 1% by volume of the secondary container under package loading.

Section 1.2.2 of the application states, as one of the Model No. 3-60B package loading restrictions, that the free water may not exceed 1% by volume of the secondary container. Example 2 of Attachment 7.1 states that the swarf, contained in a sealed steel liner, is dewatered to 1% of the waste volume.

The application needs to clarify, or confirm, if the statement "the free water should not exceed 1% by volume of the secondary container under package loading" is applicable to either dewatered swarf, or powdered solids, or irradiated hardware, or to all the contents of the Model No. 3-60B package.

This information is required by the staff to determine compliance with 10 CFR 71.35, and 71.87.

RESPONSE

The water content of waste materials in the cask is dictated by the acceptance criteria of the site receiving the waste. A typical requirement, i.e., not more than 1% of the waste volume, was used in the hydrogen generation example calculation. Section 1.2.2 has been revised (see below) to state that the cask cavity is to be emptied of water to the extent practical and that wet solid waste, e.g., resins, in secondary containers is to be dewatered per ANSI/ANS-55.1-1992.

1.2.2 Contents

CASK CONTENTS

The type and form of permitted contents of the cask will consist of:

1) By-product, source, or special nuclear material, in the form of:
   - de-watered inorganic solids, including powdered or dispersible solids, or
   - inorganic solidified material, or
   - de-watered inorganic resins, or
   - activated and/or contaminated non-fuel-bearing reactor or accelerator components or segments of components

Maximum quantity of material per package.

1) Greater than Type A quantities of radioactive materials up to a maximum of 3000 A_2 or 1110 TBq (30,000 Ci), whichever is less.

2) Fissile material provided the mass limits of 10 CFR 71.15 are not exceeded

3) Decay heat of contents not to exceed 500 watts. For contents with residual water or that contain water, the decay heat may be further limited to ensure a flammable mixture of hydrogen will not result. The decay heat limit is determined per Chapter 7 Attachment 1.

4) The specific activity of radioactive powdered or dispersible solids (in units of A_2 per gram) shall not exceed 30.

5) Payload weight of 9,500 lbs, including contents, secondary containers, and shoring

Loading Restrictions

Contents shall be packaged in secondary containers. A typical secondary container is shown in Figure 1-2. Wet Solid Waste shall be dewatered per ANSI/ANS-55.1-1992. Except for close fitting contents, shoring must be placed between the secondary containers or activated components and the cask cavity to prevent movement during accident conditions of transport. Explosives, pyrophorics, and corrosives (pH less than 2 or greater than 12.5), are prohibited. For contents loaded underwater, the cavity shall be drained of water to the extent practicable.

1.2 Explain why the radiolysis of water is the only primary gas generation mechanism analyzed in the Model No. 3-60B package.

The applicant performs hydrogen generation calculations with the radiolysis of water as the primary mechanism for gas generation, and neglects other mechanisms such as chemical or thermal activity.

The application needs to:

(i) Refer to Table 3.1 of NUREG/CR-6673 “Hydrogen Generation in TRU Waste Transportation Packages” for bounding G values of the package contents which contribute to hydrogen generation, and

(ii) Document why gas generation from other mechanisms, such as chemical or thermal, is expected to be insignificant for the Model No. 3-60B package.

This information is required by the staff to determine compliance with 10 CFR 71.35 and 71.43(d).

RESPONSE

The contents of the 3-60B (see response above) are restricted to solid inorganic materials. As noted in NUREG/CR-6673, solid inorganic materials have a G value of zero, i.e., solid inorganic materials do not generate hydrogen through radiolysis. With the contents limited to inorganic materials, the radiolytic generation of hydrogen is limited to water, which may be retained in the cavity or contents.

In addition to radiolysis, the mechanisms that produce hydrogen are chemical reactions, thermal degradation, and biological activity. In accordance with 10 CFR 71.43(d), the contents of the package must not react with the packaging. The statement “Explosives, pyrophorics, and corrosives (pH less than 2 or greater than 12.5), are prohibited” has been added to the loading restrictions (see above). Also, an assurance of chemical compatibility using EPA's Chemical Compatibility Chart, EPA-600/2-80-076, has been included in the operating procedures of Chapter 7 as a required activity prior to loading. These restrictions preclude chemical reactions that might produce hydrogen. The restriction of the contents to inorganic materials eliminates the potential for flammable gas generation due to thermal degradation or biological activity.

1.3 Provide a detailed description of the characteristics of the contents and of their corresponding radioactive constituents which contribute to hydrogen generation due to radiolysis.

The application does not include a detailed description of the characteristics of the contents (as currently listed in Section 1.2.2 of the application) and of their corresponding radioactive constituents (e.g., radiation types) which are considered to contribute to radiolytic hydrogen generation.

This information is required by the staff to determine compliance with 10 CFR 71.35 and 71.43(d).

RESPONSE

The contents of the 3-60B are restricted to solid inorganic materials but may include a small amount of water after draining or dewatering. As discussed in the response to 1.2, water is the only constituent of the contents which may contribute to hydrogen generation due to radiolysis. The radioactive constituents may include byproduct, source, or SNM. These radionuclides may produce alpha, beta, and/or gamma radiation. The bounding G-value for water of 1.6, which is independent of radiation type, is used in the calculation of hydrogen generation. Also, the total decay energy is conservatively assumed to be absorbed by the contents. Thus, the type of radiation does not affect the calculated amount of hydrogen generated.

1.4 Justify if the contents consisting of solidified material and resin are considered either as a type of irradiated hardware or as a powdered solid for the evaluation of hydrogen generation.

Section 1.2.2 of the application identifies component segments (irradiated hardware), inorganic solids (powdered solids), inorganic solidified material, and inorganic resins as contents of the Model No. 3-60 B package. The application provides examples for characterizing hydrogen generation only for powered solids and irradiated hardware contents, but not for the other types of contents.

The application needs to clarify how the corresponding approach for the evaluation of hydrogen generation is applicable to resins and solidified material.

This information is required by the staff to determine compliance with 10 CFR 71.35 and 71.43(d).

RESPONSE

The calculational method detailed in Attachment 7.1 to Chapter 7 is not specific to a particular material. Examples of a calculation for resin and solidified material have been added to Attachment 7.1. The revised Chapter 7 is included with the RAI response.

1.5 Justify why the dewatered swarf may be considered as a type of powdered solids for the determination of hydrogen generation.

The package contents are categorized into irradiated hardware and powdered solids for the hydrogen generation analysis. Irradiated hardware and dewatered swarf (a type of powdered solids) are used as examples for the evaluation of hydrogen generation.

The application should provide a detailed description of the dewatered swarf, including photos or pictures, to help confirm that dewatered swarf is a type of powdered solids suitable for the evaluation of hydrogen generation.

This information is required by the staff to determine compliance with 10 CFR 71.35 and 71.43(d).

RESPONSE

The calculational method for determining hydrogen generation, detailed in Attachment 7.1 to Chapter 7, is not specific to a particular material or physical form. Two example calculations were provided, one for irradiated hardware and one for swarf; two additional examples have been added, for de-watered resin and solidified material.

Swarf is defined as: material (as metallic particles and abrasive fragments) removed by a cutting or grinding tool (Webster's New Collegiate Dictionary, G.& C. Merriam Co., 1980). Radioactive swarf is typically produced from the cutting or grinding of irradiated metal reactor components. Pictures of swarf are included with the response.

The hydrogen generation calculational process used in the 3-60B SAR conservatively assumes that all the radioactive decay energy is absorbed by the cask contents and the G value is independent of the type of decay. With these conservative assumptions, the physical form of the contents is not important so it is appropriate to consider swarf as a powdered solid for the determination of hydrogen generation.

3.1 Correct the mass fraction of water in the calculations of hydrogen generation for both irradiated hardware and dewatered swarf.

The applicant calculates the mass fraction of water F_w by excluding the water mass from the total mass in the cask, but includes the water volume in the calculation of void volume, VOID, for both irradiated hardware and dewatered swarf in Attachment 3B of the application. The applicant is required to correct the equation for the mass fraction of water from $F_w = M_w / (M_L + M_H)$ to $F_w = M_w / (M_L + M_H + M_w)$, to make both the mass fraction calculation and the void volume calculation consistent.

This information is required by the staff to determine compliance with 10 CFR 71.35 and 71.43(d).

RESPONSE

The corrections have been incorporated. The examples have been removed from Chapter 3 and are now found only in Chapter 7.

3.2 Provide the basis for the determination that 2 gallons of water remaining in the cask cavity, after the cask is drained, is a conservative assumption for the evaluation of hydrogen generation.

The applicant assumes that the grooves in the cask cavity base and the drain port have a combined volume of less than 0.02 gallons after the package is drained. The applicant estimates a volume of 2 gallons if any additional water remains on the base to a depth of 0.5 inch, and then uses a total of 4-gallon water for the determination of hydrogen generation in the package containing irradiated hardware waste form.

The applicant is required to (i) validate the assumption that there are 2 gallons of water remaining in the cask cavity for hydrogen generation after the package is drained, and (ii) demonstrate that such assumption is conservative for the analysis (see also RAI No. 7.1).

This information is required by the staff to determine compliance with 10 CFR 71.35. and 71.43(d).

RESPONSE

The cask is designed to minimize the retention of water in the cavity after draining. To ensure no more than 2 gallons of water is retained after draining, the following acceptance criterion is added to the acceptance requirements of Chapter 8:

> No more than 2 gallons of water may be retained in the cask cavity and drain port when the cask sits vertically on an essentially horizontal flat surface.

Meeting this acceptance criterion validates the assumption that no more than 2 gallons of water is retained in cask cavity outside of the secondary container.

The amount of water retained in the secondary container is assessed by the shipper based on the design of the secondary container and the contents. In the revised irradiated hardware example, the assessment has determined that no more than 2 gallons of water are retained in the secondary container. An amount of 4 gallons of water is used as the amount of water subject to radiolysis. Since the fabrication acceptance testing has demonstrated that the cask will retain no more than 2 gallons and the waste assessment has determined that the water retained will be no more than 2 gallons, the analysis amount of 4 gallons will not underestimate the amount of hydrogen generated.

7.2 Revise Attachment No. 7.1 to be a stand-alone procedure in Chapter 7.0 “Package Operations” for package users to determine the flammable gas concentration for the authorized contents.

The applicant develops a method for the determination of the hydrogen generation to ensure that the flammable gas concentration does not exceed a limit of 5%, and describes this method in Chapter 3.0 and Attachment No. 7.1 of the application.

The applicant is required to revise Attachment 7.1 as a stand-alone procedure for package users to determine the void fraction (Fv), the mass fraction of water (Fw), and the allowable decay heat load (Q) for the loaded contents.

The procedure should instruct users for categorizing the contents (irradiated hardware, powder solids, etc.), listing all parameters/values used in the calculations and applying the appropriate formulas for determining F_v, F_w and Q, as generally described in Section 3.3.2 and the current examples in Attachment No. 7.1 of the application.

This information is required by the staff to determine compliance with 10 CFR 71.33, 71.35, 71.43(d) and 71.87.

RESPONSE

Attachment 7.1 has been revised to include a step-wise process for determining the decay heat limit. The user of the package determines volumes and masses based on configurations of the packaged material and engineering evaluations, which would be performed under the users NRC authorized QA program. The process is invariant with the physical form of the contents of the secondary container, i.e., the process is the same for irradiated hardware, dewatered particulate material (swarf or ion-exchange resin) or solidified material. Additional examples, de-watered resin and solidified material, have been added. The examples are not intended to be all-inclusive but to provide the user guidance in applying the process provided in Attachment 7.1. See the revised Chapter 7 for these changes.

The results of calculations for various combinations of void fraction and water content have been plotted to show the interaction of these parameters and the relationship of the calculated decay heat limit to the cask limit. This plot is included with the response.

7.3 Clarify how the water content and density of the dewatered swarf are determined for the evaluation of hydrogen generation.

Attachment No. 7.1 of the application mentions that the swarf, contained in a sealed steel liner, is dewatered to 1% of the waste volume and has a density of 4.0 g/cc for the evaluation of hydrogen generation. The applicant is required to clarify how the water content and density of the swarf are determined for the calculations.

This information is required by the staff to determine compliance with 10 CFR 71.35 and 71.43(d).

RESPONSE:

The water content of waste materials like swarf and ion-exchange resin is governed by disposal site requirements in accordance with U.S. NRC Waste Form Technical Position, Rev.1, January 24, 1991 and determined in accordance with the generator’s Process Control Program (PCP), as described in ANSI/ANS-55.1-1992, Solid Radioactive Waste Processing System for Light-Water-Cooled Reactor Plants, Section 9. Operation and Maintenance.

The density of swarf can be determined by measurement or estimated by calculation. The text of the example is revised to indicate the density was determined by measurement.