Shipment of Solidified Resins in the RT-100 Cask

Public Meeting

November 17, 2015

Topic

- Robatel is gathering requirements to assess the possibility of shipping solidified resins in the RT-100 Type B transportation cask.
- The solidified resin density is typically less than 1.3 g/cm^3.
- The certificate of compliance (Revision 1) limits the contents to:
  - dewatered and grossly dewatered resins and filters,
  - with a maximum content bulk density is limited to a maximum of 1.0 g/cm^3.

Presentation Outline

1. **Solidification Process**
   General description of the solidification process
2. **Shielding Evaluation**
   Discussion about the Content Density limits
3. **Containment Evaluation**
   Discussion of the Hydrogen Gas Generation as applied to solidified resins
4. **Summary**

Resin Solidification Process

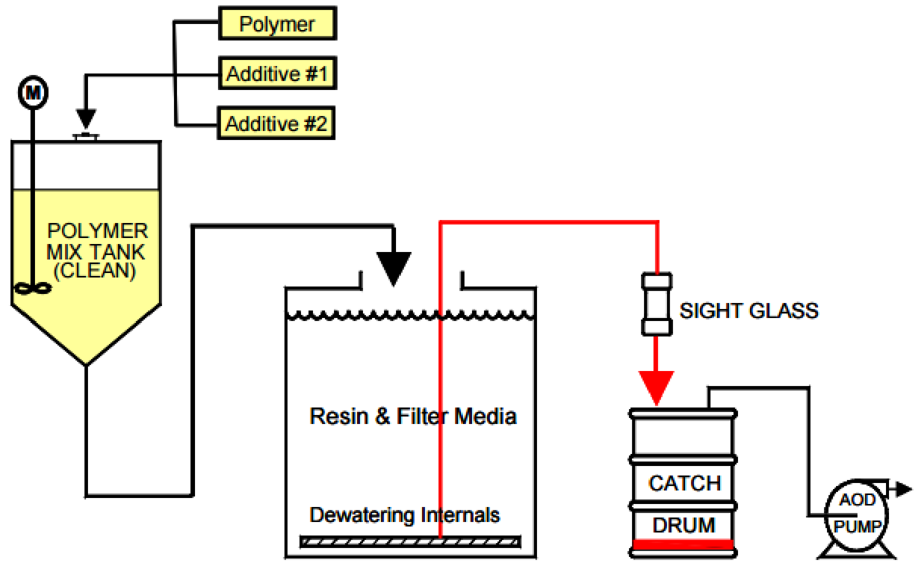
- Diversified Technologies APS™ (Advanced Polymer Solidification) process
- Used to solidify resins in a rock hard, stable monolith
- Result is a form of stable class B and C wastes
- The only water/moisture remaining in the solidified monolith is the chemically bound water within the ion exchange beads.
- The APS™ process involves a chemical formulation similar to that described in NRC-approved Topical Report DTI-VERI-100-NP-A: "Vinyl Ester Resin In Situ Solidification Process for Low-Level Radioactive Waste, Rev 1."
- APS™ uses the same in situ solidification process, but a different proprietary modified polymer formulation, referred to as the Advanced Polymer (AP). The AP formulation, like the Vinyl Ester Styrene (VES) binder, results in a rock hard, stable monolith.

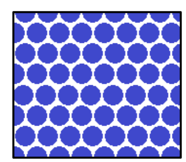
Reference: Jensen, Charles. *The Role of Advanced Polymer Solidification in a Comprehensive Plan for Handling, Storing and Disposing of Class B & C Resins and Filters.* 2008.

Resin Solidification Process

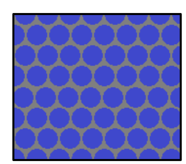
1. Binder and curing agents are combined in a mix tank.
2. The mix tank is pressurized allowing the Advanced Polymer (AP) to flow into a liner containing dewatered resin and filter media.
3. Once the AP has formed a cap on the top of the waste media, the AOD pump used during dewatering is activated, and a combination of vacuum and gravity draws the AP through the waste media.
4. The AP is hydrophobic, and drives remaining interstitial water from the media as it flows down through the liner.
5. When the AOD pump begins drawing the AP, it is detected by a sight glass, and the process is complete.
6. The polymer cures over 24 hours.

   Note: Steps 1 and 2 may be combined using a "tankless" system option with a metering pump.





Liner contents prior to addition of polymer binder:
–Radioactive contents with interstitial space filled with void or residual water.



Liner contents after addition of polymer binder:
–Same radioactive contents with interstitial space filled entirely with polymer binder.

Reference: Jensen, Charles. *The Role of Advanced Polymer Solidification in a Comprehensive Plan for Handling, Storing and Disposing of Class B & C Resins and Filters.* 2008.

Content Density Details

- The RT-100 Certificate of Compliance, Certificate No. 9365, Revision 1, includes the following restrictions:

  (b) Contents

  (1) Type and form of material: dispersible solids, in the form of both dewatered and grossly dewatered resins and filters, contained within secondary containers.

  (2) Maximum quantity of material per package

  (i) Activity not to exceed 3,000 times a Type A quantity, along with the following limits:

  (1) As prescribed by the procedure in Section No. 7.6 of the application, for beta and gamma emitting radionuclides.

Content Density Details

- Section 7.6 of the application, RT-100 Safety Analysis Report, Revision 6, includes the following restriction:

  The following appendices are included for Chapter 7 instruction and information. Additional steps and conditions of use for the RT-100 are as follows:

  1. *The maximum content density is 1.0 g/cm^3. The weight of free water must be excluded in this determination. The source strength density must be ensured at any point of the content. Average density by dividing the total activity by total weight is not acceptable.*

  9. *The radioactive content is not to exceed 1.0 g/cm^3 and the nuclear physical characteristics, i.e., the gamma attenuation coefficient of the content must not be smaller than that of the carbon material resin.*

RT-100 SAR Rev. 6
Shielding Method

Shielding Analysis

1. MCNP Shielding Analysis Models–
   a. For the eight most significant radionuclides: 1 g/cm^3 of radioactive contents that is the least effective from a shielding perspective (Carbon) entirely filling the RT-100 cavity, taking credit for shielding provided by the radioactive contents.
   b. For energy line method radionuclides: Entire cavity is modeled as void.
2. Calculated maximum allowable activities are divided by the maximum possible mass of radioactive contents in the cavity at a density of 1 g/cm^3 to give the maximum allowable source strength density.

Demonstrating Compliance

1. Samples of the resin/filter media are taken from the respective liner. The maximum measured specific activity in the liner is considered representative of the specific activity distributed uniformly throughout the liner.
2. Limits required to remain in compliance based on the shielding analysis are:
   a. Density less than 1 g/cm^3 of **radioactive contents** inside the cask.
   b. Measured specific activity of the radioactive contents in the liner is less than the calculated maximum allowable specific activity limit, or, the the specific activity fractions in the loading table sum to a value less than 1.

Note: Non-radioactive materials inside the cask cavity, such as the liner itself and any residual water, are neglected in the shielding analysis.

RT-100 Shielding Analysis

Points to consider:

1. A higher density is only more restrictive when the mass added to the fixed volume is radioactive.
2. If additional non-radioactive material is added and the radioactive content of a liner stays constant, external dose rates will remain constant or decrease due to the additional shielding provided by the added non-radioactive material.
3. For the solidified resin liners, the overall density of the contents may increase to >1 g/cm^3 due to the polymer material filling all voids between the resin/filter media, but the density of the radioactive contents will remain constant.
4. Source strength densities for a given liner must be entered into the loading table with data measured **prior to** the pouring of the solidifying polymer material (i.e. not taking credit for added mass of the polymer).
5. No changes required for the SAR shielding analysis. Only changes to wording in sections 1, 5, and 7 to restrict the radioactive content density to 1 g/cm^3, but allow for the overall content density to exceed 1 g/cm^3.

RT-100 Shielding Analysis

ROBATEL technologies

Operational changes for shipments of solidified resins:

SAR CH 7.6 provides additional information for the operation of the cask. Minor revisions to this section may be required to provide clarity and ensure compliance with the dose rate regulations. Revised steps below with changes marked:

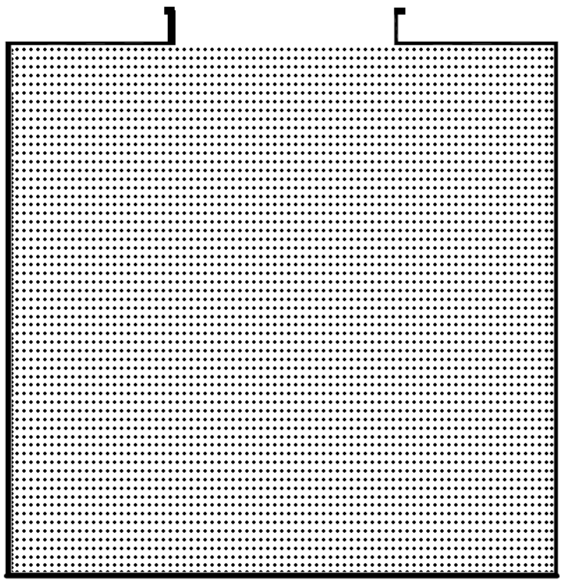
1. The maximum radioactive content density is 1.0 g/cm³. The weight of free water and any polymer binding material must be excluded in this determination. The source strength density, prior to the addition of any polymer binding agent, must be ensured at any point of the content. Average density by dividing the total activity by total weight is not acceptable.

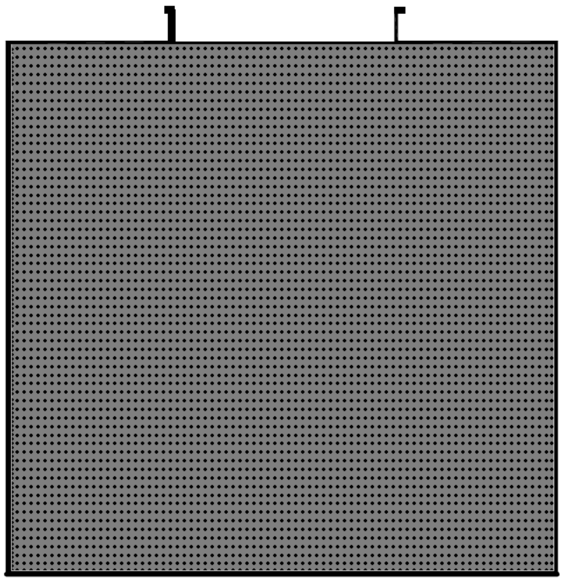
3. The weight of water and any solidifying polymer material must be excluded when determining the Ci/gram of content limit.

9. The radioactive content, prior to the addition of any solidifying polymer binding agent, is not to exceed 1.0 g/cm³ and the nuclear physical characteristics, i.e., the gamma attenuation coefficient of the content must not be smaller than that of the carbon material resin. An increase in the overall content density to a value greater than 1.0 g/cm³ solely due to the addition of non-radioactive polymer binding material is acceptable.

Shielding Analysis Example

Example: Consider a hypothetical liner before and after adding the polymer binder





Prior to pouring polymer binder (Current Model):
Co-60 Source strength Density: 2.5006E-04 Ci/g
Radioactive Content Density: 1 g/cm^3 Carbon
Overall Content Density: 1 g/cm^3 Carbon
Estimated 2m Dose rate: 9.5 mrem/hr

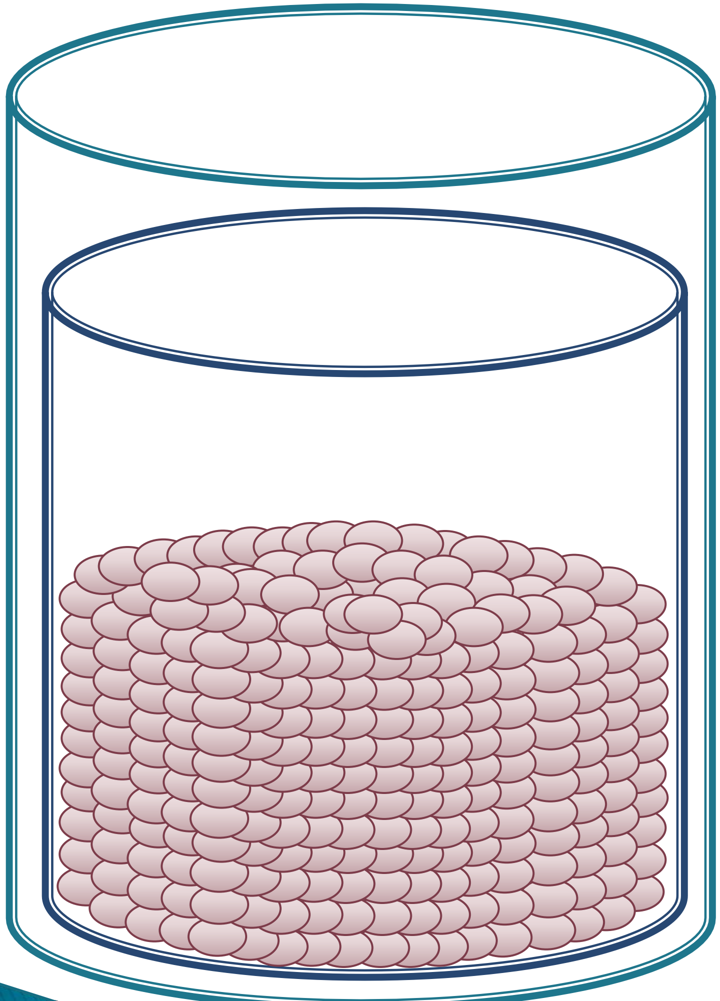
After pouring polymer binder:
Co-60 Source strength Density: 2.5006E-04 Ci/g
Radioactive Content Density: 1 g/cm^3 Carbon
Overall Content Density: 1.3 g/cm^3 Carbon + Polymer
Estimated 2m Dose rate: 9.5 mrem/hr

Note: Estimated 2-meter dose rates based on the SAR shielding analysis. No credit taken for the polymer binder material for the source strength density or the estimated external dose rate.

Current Containment Analysis

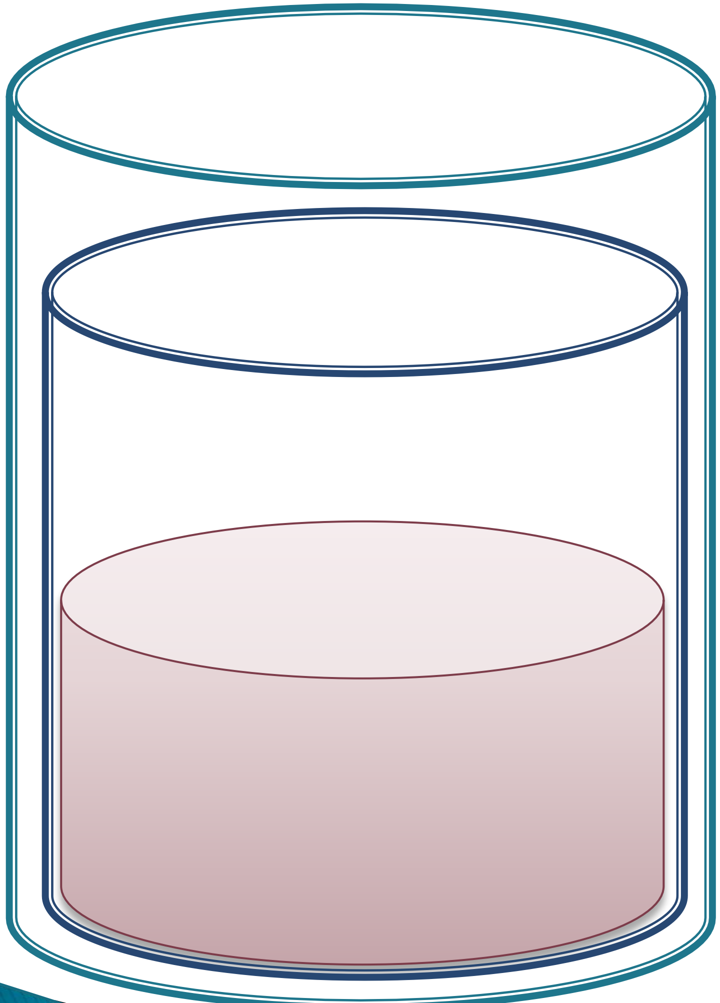
- The hydrogen gas generation analysis is described in Section 4.4 of the SAR.
- The methodology is described as follows
  - Determination of G-values for the contents
    - Calculate effective G-values based on typical decay heat energy
    - Adjust G-values for NCT temperature
  - Establish volume ratios for the contents, and determine the fraction of decay heat energy absorbed by each content type.
  - Establish the free gas volume
  - Calculate maximum allowable decay heat (D_H) as a function of waste volume (V_{WASTE})
  - Develop a loading curve based on $D_H = f(V_{WASTE})$

Model for Dewatered Resins (Current)



- RT-100 Inner Cavity Capacity
  - 162.37 ft^3
- Volume occupied by Liner & Shoring
  - 30.10 ft^3
- Remaining volume
  - 132.27 ft^3
- Waste Volume (V_{WASTE})
  - 63.36% Ionic Resin ($G_T = 1.59$)
  - 25.75% Water ($G_T = 0.68$)
  - 10.89% Air
- Liner Type
  - Limited to liners listed in SAR Table 4.4.3-6
  - May be polyethylene ($G_T = 5.06$) or steel (not radiolytic)
  - When using the simplified loading curve, waste volume is limited to 130 ft^3

Model for Solidified Resins (Proposed)



- RT-100 Inner Cavity Capacity
  - 162.37 ft^3
- Volume occupied by Liner & Shoring
  - 4 ft^3 Liner
  - 6 ft^3 Shoring (approximate)
- Remaining volume
  - 152.37 ft^3
- Waste Volume (V_{WASTE})
  - 63.36% Ionic Resin (G_T = 1.59)
  - 01.00% Water (G_T = 0.68)
  - 35.64% AP (G_T = 0.59)
  - 00.00% Air
- Liner Type
  - Typically L-92 (steel)
  - Maximum waste volume = 92 ft^3

Model Differences

- Solidified resins are stored in a smaller container
  - More air volume for hydrogen gas to expand into
- Solidified resins are stored in a steel container
  - Steel is not radiolytic, like polyethylene
- Water is replaced by Advanced Polymer
  - Advanced Polymer has a lower G-value than water

Summary

- Robatel plans to request a letter of authorization to ship solidified resins prepared with the Diversified Technologies APS™ process.
- Since the density of radioactive content is not changed, we believe we can justify that the current shielding analysis for this type of contents.
- The current containment model is based on up to 130 ft^3 of grossly dewatered resins packaged in a polyethylene liner. We believe a reduced volume of waste packaged in a steel liner is a less restrictive model.