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GLASS TEMPERATURES IN FREE-STANDING CANISTERS (U)

by

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SAVANNAH RIVER TECHNOLOGY CENTER**

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SUBJECT: Glass Temperatures in Free Standing Canisters

TECHNICAL REVIEWERS:

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INTRODUCTION

The waste-forms produced by the Defense Waste Processing Facility (DWPF) are subject to the requirements of the Waste Acceptance Product Specifications (WAPS). The WAPS sets the maximum post cooldown temperature of the waste-form glass at 400°C.¹ This criterion must be satisfied for the ambient conditions and heat generation rates expected for the waste-forms.

As part of the work described in task plan, WSRC-RP-93-1177, Rev. 0, a computer model was used to calculate the maximum glass temperatures in free standing waste-forms for a variety of ambient temperatures and heat generation rates.

MODEL DESCRIPTION

Canister Model

The heat conduction code P/THERMAL² was used to model waste-form heat transfer in two dimensional cylindrical coordinates, r and z . The heat transfer at the surface of the canister was assumed to result from natural convection alone, as would be expected for a free standing canister. The natural convection boundary conditions were applied to the sides of the canister and the top and bottom were conservatively assumed to be insulated. The Nusselt number correlation used was³

$$Nu = 0.21 Ra^{0.4}$$

The canisters were filled to 85% of the total height with glass (100 in. measured from the bottom). The void between the top of the glass and the upper part of the canister is filled with air and water vapor. The nominal dimensions and geometry of a DWPF waste-form were used to build the model. The steel canisters were modeled with the thermal properties of 304 stainless steel, which was 3/8 in. thick in the cylindrical portion adjacent to the glass and 1/2 in. thick at the top and bottom. The thermal properties of TDS glass were used and are listed in Table 1.⁴ It should be noted that the glass thermal conductivity used in all calculations was that of high iron glass, which was conservatively assumed to have ~2/3 of the thermal conductivity obtained from Table 1. The properties of the 304 stainless steel were obtained from the P/THERMAL materials library and the canister dimensions are given in Reference 5.

P/THERMAL does not calculate convection processes, rather it only uses supplied convection boundary conditions. Therefore, heat transfer through the gas space at the top of the canister was by conduction only.

As the isotopes contained in the glass undergo radioactive decay, some of the emitted radiation interacts with the atoms in the waste-form and is transformed into heat. The attenuation of radiation thus results in a volumetric heat (or energy) source. The principal radiation emitted by isotopic decay is gamma radiation. Gamma radiation has a relatively long mean free path and is best attenuated by materials of high atomic weight. Therefore, the fraction of gamma radiation attenuated in the steel canister is a matter of concern. Rather than calculate the distribution of gamma radiation between the glass and the steel canister, scoping calculations were performed. The energy deposition due to radioactive decay was assumed to be uniform and to take place either in the glass or in the cylindrical part of the steel canister adjacent to the glass. That is, when heat generation is assumed to occur in the steel, it takes place in the steel wall from the bottom of the canister up to 100 in. A total canister heat generation rate of 460 watts per canister was assumed in the GWSB design basis. The maximum glass temperatures obtained from these calculations will be representative of the most conservative case.

Additional details of these calculations are available in Reference 6.

RESULTS AND CONCLUSIONS

The results of the P/THERMAL calculations are presented in Table 2. In these calculations the energy was assumed to be uniformly deposited in one of two regions, the glass or the steel cylinder adjacent to the glass. In Table 2 the location of energy deposition is specified according to the region in which the energy is deposited. The maximum glass temperatures are the maximum temperatures occurring at any location in the glass. Ambient temperatures of 100, 50 and 0°F (37.78, -17.78 and 10°C) were used in the calculations.

From Table 2 it can be seen that in all cases the deposition of energy in the glass yields higher maximum glass temperatures than energy deposition in the steel. Conservatively assuming energy deposition only in the glass and the ambient temperature to be 37.78 °C (100°F), the glass temperature limit of 400°C is not exceeded for heat generation rates which are three times the 460 watts per canister used as the design basis for the GWSB. Also, the glass temperature profile is flatter if the energy is deposited in the steel than if the energy is deposited in the glass

REFERENCES

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5. R. G. Baxter. *Defense Waste Processing Facility Wasteform and Canister Description*. E. I. Du Pont de Nemours & Co. document, DP-1606, Rev. 2 (1988).
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TABLE 1
Assumed Glass Thermal Properties (TDS Glass) ⁴

Property	Value
Density	$2.43 \frac{\text{g}}{\text{cm}^3}$ at 23°C
Thermal Diffusivity	$0.0031 \frac{\text{cm}^2}{\text{sec}}$ at 150°C
Specific Heat Capacity	$0.20 \frac{\text{cal}}{\text{g}^\circ\text{C}}$ at 100°C

TABLE 2
P/THERMAL Calculations for Glass and Canister Air Temperatures

Case No.	Location of Energy Deposition	Ambient Temp. (°C)	Total Power (Watts)	Max. Glass Temp (°C)*	Location of Max. Glass Temperature (°C)
1	Glass	37.78	460	132	CL48 in. from bottom
2	Glass	37.78	1280	301	CL48 in. from bottom
4	Steel	37.78	460	64	Outer edge of glass below energy deposition region in steel
5	Steel	-17.78	460	5	Outer edge of glass below energy deposition region in steel
6	Steel	-17.78	153.3	-8	Outer edge of glass below energy deposition region in steel
7	Glass	-17.78	460	73	CL50 in. from bottom
8	Glass	-17.78	153.3	15	CL46 in. from bottom
9	Glass	10	460	111	CL46 in. from bottom
10	Steel	10	460	43	Outer edge of glass below energy deposition region in steel

* temperature rounded to most conservative integer value

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