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**TEMPERATURES GENERATED BY UNDERGROUND
STORAGE OF DEFENSE WASTE CANISTERS**

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INTRODUCTION

The plan for long-term management of Savannah River high-level liquid waste is that it will be calcined, combined with glass frit at high temperatures, and allowed to solidify in cylindrical steel canisters (2 feet in diameter, about 9 feet tall). The sealed canisters would then be inserted into cylindrical steel storage containers. After interim storage, the storage containers would be placed in an underground federal repository for long-term storage.

Although specifications for repository storage have not been established, it is assumed that a series of 15 to 50-foot-wide shafts would be mined at depths ranging from 1000 to 3000 feet. Storage containers would be placed in holes drilled in the shaft floors.

After container emplacement, the radioactive decay heat would be dissipated by conduction through the surrounding geologic formations to the earth's surface. From earth's surface, the energy would be transferred by convection to the atmosphere and ultimately to deep space by radiation.

To ensure safe storage, the design selected for an underground repository must take into account temperature restrictions placed on the defense waste glass, containers, and surrounding geology. Studies are planned at Savannah River Laboratory, in

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conjunction with Office of Nuclear Waste Isolation, to set temperature restrictions based on leach rates and canister compatibility with salt, water, and salt brine. However, determination of the limiting thermal restriction will require consideration of other phenomena such as devitrification, decrepitation, salt brine migration, and mine stability.

CONCLUSIONS

1. For conditions conducive to leaching, i.e., moisture in contact with glass, the glass surface temperature would essentially be the canister cavity temperature because temperature rises across wet annuli are small. In turn, canister cavity temperatures are dominated by canister spacing for a given canister power and decay curve. Actual canister powers may be as much as 40% less than those used for these calculations.
2. For dry salt in contact with the storage container, the temperature rises across the annulus may be large. The container temperature would tend to peak earlier for dry annuli than for wet annuli.
3. When canister cavity temperatures peak, salt temperatures would be increased over normal approximately 500 feet in any direction extending from the repository.

DISCUSSION

Methodology

Three models were used in this study. The models are classified as far-field, near-field, and very near-field. Far-field refers to the geologic region extending hundreds of feet from the repository, where the thermal response is sensitive to areal power densities, geologic properties, and stratigraphy. Near-field refers to the geologic region within tens of feet of the cavity in which the canister is placed, where the thermal response is sensitive to the overlying mine shaft, shielding plugs, liners, and local material properties. Very near-field refers to that region in the immediate vicinity of the canister, where the thermal response is sensitive to the size and content of any annuli between the canister cavity and waste glass.

All three models aid in repository design. Far-field models can be used to determine geologic temperatures affecting overlying aquifers, mine stability, uplift, and salt brine migration. Near-field models can be used to determine temperatures affecting reconsolidation and retrievability in the vicinity of the canister cavity. Very near-field models can be used to determine waste glass and container temperatures affecting waste glass devitrification and leaching as well as canister compatibility.

The relationship between the three models is shown in Figure 1. The far-field model assumes a thin cylindrical 833-acre repository* buried 2000 feet below the earth's surface. The repository itself is represented as a uniformly distributed heat source. The near-field model considers a narrow cylindrical slice from the center of the repository. It contains a single canister. Finally, the very near-field model considers the radial temperature rises across insulating annuli.

General Assumptions

1. Repository Conditions:

The entire repository was assumed to be simultaneously loaded with defense waste canisters having the thermal power and decay rates consistent with Figure 2. Five-year-old waste represents the freshest waste that might be processed. Most of the waste will be as much as 35 years old. No attempt was made to model mine shafts, shield plugs, liners, overlying aquifers, salt brine migration, ground water movements, reconsolidation, or any conditions pertaining to a retrievable period. Moisture was considered only in the annulus surrounding a canister.

Fig. 1. Relationship Between Models

* Proposed size of a national repository. All Savannah River waste will probably require less than 150 acres.

Fig. 2. Defense Waste Power Decay

2. Initial Conditions:

At the time of burial, the temperature of the geology was assumed to be 16°C at the earth's surface and to increase 11°C for every 1000 feet below the earth's surface. Geothermal fluxes in the continental United States range from 53 to 350 Btu/yr-ft^2 resulting in geothermal gradients ranging from 3°C to 33°C per 1000 feet depth.^{1,2}

3. Boundary Conditions:

The axial boundary conditions (Figure 1) were fixed by a temperature of 60°C at a depth of 4000 feet and convection (convective heat transfer coefficient of $1.0 \text{ Btu/hr-ft}^2\text{-}^{\circ}\text{F}$) to a 16°C environment at the earth's surface. Radially the far- and near-field models required adiabatic boundary conditions at 6000 feet and half the canister spacing, respectively. The canister cavity temperature, required as a radial boundary condition for the very near-field model, was determined from the near-field calculation.

4. Stratigraphy:

The stratigraphy assumed for the salt repository is shown in Table 1. Stratigraphy at a given site may vary markedly from that assumed.

5. Thermal Properties:

The temperature dependent thermal properties used are given in Table 1. These properties are typical, but may be significantly different from the properties at a given site.

Table 1. Material Properties

Salt				
Temperature, °F	Thermal Conductivity (K_g), BTU/hr-ft-°F			
32	3.47			
122	2.85			
212	2.39			
302	2.05			
392	1.77			

Repository				
Layer	Depth, ft	Density, lbm/ft ³	Specific Heat, BTU/lbm-°F	Thermal Conductivity, BTU/hr-ft-°F
1	0-1000	512	0.22	0.4 K_g
2	1000-1825	471	0.22	0.57 K_g
3	1825-2165	430	0.22	K_g
4	2165-3000	471	0.22	0.57 K_g
5	3000-4000	512	0.22	0.4 K_g

Backfill, 30% free volume		Thermal Conductivity BTU/hr-ft-°F
Dry Crushed Salt	0.15	
Wet Crushed Salt	1.20	

Solution Techniques

A cylindrical implicit transient version of the HEATING5 conduction code was used to calculate the temperatures for the far- and near-field models. Simple one-dimensional conduction calculations were used for the very near-field calculations.

Results

Far-Field:

After burial the temperature of the surrounding geology rises as the repository dissipates heat. As the repository temperature peaks, all the geology within 500 feet of the repository is affected. As time continues, the repository temperature will fall and the volume of geology affected will slowly grow.

Near-Field:

Figures 3 and 4 show the near-field results. Figure 3 shows that canister cavity temperatures tend to peak earlier with increased spacing. Figure 4 shows a sharp decline in peak canister cavity temperatures as the spacing is increased from 10 to approximately 30 feet. After that, increased spacing does not appreciably lower peak canister cavity temperatures.

Very-Near Field:

Figure 5 shows the temperature rise across crushed salt back-filled annuli for five-year-old waste. Dry annuli result in nearly 10 times higher temperature rises than do wet annuli. For 35-year-old waste, temperature rises across the annuli would only be ~40% of the values given in Figure 5.

Fig. 3. Canister Cavity Temperature in a Salt Repository — 5-Year-Old Waste

Fig. 4. Peak Canister Cavity Temperature in a Salt Repository

Fig. 5. Temperature Rises Across Dry and Wet Crushed Salt Backfill for 5-Year-Old Waste

Fig. 5 (Cont'd)

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