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**Temperature History for
Canistered Fuel Lag Storage
Areas During the Loss of
Cooling Air at the Receiving
and Handling Building of
the MRS Facility**

D. Kim

April 1986

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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TEMPERATURE HISTORY FOR CANISTERED FUEL LAG
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OF THE MRS FACILITY

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April 1932

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Under the Act of March 3, 1909

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SUMMARY

The Pacific Northwest Laboratory has analyzed the temperature history at a canistered fuel lag storage area during a postulated failure of the cooling system. A two-dimensional analysis was performed using the GE2D computer code, which accounts for thermal radiation, conduction, and convective heat transfer.

The results indicate that the system may not reach a steady-state condition because heat transfer through the top and the bottom of the system is not enough to remove the energy generated in the canistered fuel. Although limits for abnormal operation have not been set, the temperatures do not reach limiting conditions for normal operation for 32 hours, which should be enough time to repair the cooling system.

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1.0 INTRODUCTION

The Monitored Retrievable Storage (MRS) Facility is designed to consolidate and package spent fuel from commercial reactors before shipment to a geologic repository. The MRS facility will also provide temporary storage for other nuclear waste. The consolidated spent fuel canisters are stored in an open cycle vault within the receiving and handling (R&H) building (Ralph M. Parsons Company 1985a).

In normal operation an air cooling system carries off the decay heat generated by the consolidated and canistered spent fuel rods. The design objective is for the cladding all fuel rods to be maintained below 375°C (707°F) in the inert atmosphere of the canister. For a 12.75-inch-O.D. canister, the surface temperature must be maintained below 285°C (545°F) to achieve this 375°C cladding temperature limit. Previous calculations (Ralph M. Parsons 1985b) have indicated that the canister surface temperature can be achieved, with reasonable accuracy, by an outside air temperature of 38°C (100°F) and an air flow of 1250 CFM. The above conditions result in a concrete vault wall surface temperature below the 94°C (200°F) high point maximum allowed by code requirements of the American Concrete Institute (1980).

This study focuses on the thermal analysis of the canistered fuel lag storage areas during a postulated failure of the air cooling system. It is important to understand the temperature history of the canistered fuel and the vault concrete wall to insure that the cooling system can be restored before the concrete gets hot enough to fail. Failure of the cooling system will shut off the air flow to the canistered fuel lag storage areas. The temperature of the canisters, the vault concrete, and the stainless steel walls will increase because the decay heat will not be removed from the system.

During the loss of cooling air, heat conduction is a main heat transfer mode in the concrete wall and the canister. Thermal radiation plays an important role in dissipating heat from the canistered fuel to the vault concrete wall. Natural convection that results from the temperature difference between the canistered fuel and ambient air should also be an important heat transfer mode in cooling the canistered fuel.

The thermal analysis was performed using the GE2D computer code^(a) to predict temperature distributions in the canister and the vault concrete wall. The GE2D code provides a transient finite-difference solution in Cartesian, polar, and axisymmetric coordinates to the equations governing the conservation of mass, momentum, and energy. The system was simulated using a two-dimensional approximation.

2.0 MODEL OF THE SYSTEM

Figure 1 shows the dimensions and materials of the system (Ralph M. Parsons Company 1985c). The 42-inch top wall contains several shield plug openings that reduce the effective thickness for heat transfer. Therefore, a top wall thickness of 20 inches was used to correctly model the overall thermal resistance. The thermophysical properties used in this study are listed in Table 1 (Incropera and DeWitt 1981). Convective heat transfer coefficients and the wall emissivity of the materials are indicated in Figure 1.

The physical model and the heat transfer data of the problem are illustrated in Figure 2. Since the system was modeled as a two-dimensional problem, a canister was assumed to be an infinite plate with a 7-in. thickness. The thermal analysis of the canisters assumed the worst conditions with all canisters being filled with the consolidated spent fuel generating 1650 watts.

Initially, the temperature of the system was assumed to be at a uniform temperature of 68°C (155°F) except for the canistered fuel (Ralph M. Parsons Company 1985a). The canistered fuel was considered to be at a uniform

(a) Song, T. H. and D. Kim, 1985. "General Elliptic Multidimensional Solver," unpublished, Purdue University.

temperature of 150°C (302°F) initially (Ralph M. Parsons 1985a). The boundary conditions of the two vertical walls are assumed to be insulated as shown in Figure 2. A constant temperature is specified at the bottom of the floor. However, the top of the system is exposed to ambient air at 60°C (140°F).

Radiation view factors between the wall and the stainless steel plates were evaluated. Several different heat transfer coefficients were used to estimate natural convective heat transfer in the system. Two-dimensional conduction equations were solved using the GE2D code by accounting for thermal radiation and convection at the surface of the canister, the vault concrete wall, and stainless steel wall.

3.0 RESULTS

The numerical calculations were performed with GE2D using a 34x19 nonuniform grid and a 10-minute time step. The temperatures of the four locations illustrated in Figure 2 are plotted as a function of time in Figure 3. The simulation indicates that it will take about 32 hours for the canister surface temperature to reach 285°C (545°F), which is the allowable limit for normal operation. The corresponding vault concrete wall temperature is 90°C (194°F) at 32 hours. This vault concrete wall temperature is very close to the maximum allowable limit (94°C) for the normal operation. The temperature difference between the center and the surface of the canister is small, since the canister was assumed to be one material. However, if the model were modified to account for thermal contact resistance between the consolidated fuel rods and the canisters, the temperature difference would be increased.

The vault concrete wall temperature increases slowly, as indicated in Figure 3. The temperature difference between the canister surface and the stainless steel wall also increases with time. This means that the main driving force to increase the vault wall temperature is thermal radiation rather than natural convection.

4.0 CONCLUSIONS

The results of this study give information on the temperature history during the loss of cooling air. The system does not reach steady-state temperatures because heat transfer through the top and the bottom of the system is not enough to remove the energy generated in the canistered fuel. Although limits for abnormal operation have not been set, the temperatures do not reach limiting conditions for normal operation for 32 hours, which should be enough time to repair the cooling system.

If the cooling system is not restored in the 32 hours, the temperatures of the canistered fuel and concrete vault walls will continue to rise. However, for the relatively short time (up to several days), no permanent detrimental effects are expected in the concrete, except a minor reduction in concrete compressive strength. This is analogous to the fire exposure tests performed on concrete specimens (Fimtel 1974). Although fuel cladding temperatures above 375°C in an inert atmosphere can be tolerated at the MRS, the repository fuel acceptance criteria will have to be considered in developing the final MRS limits on temperature excursions.

The results should strongly depend on the parameters such as heat generation rates, material properties, and natural convection heat transfer coefficients. Even though the two-dimensional model should predict conservative temperature distributions during the loss of cooling air in the vaults, a detailed three-dimensional analysis would give more realistic results. However, three-dimensional simulations would be very complicated and tedious problems because of the radiation view factor calculations between the canisters and the vault concrete walls. The two-dimensional model is sufficient to predict the worst temperature distributions in the vaults.

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FIGURE 1. Physical Dimensions and Materials of the System

*Data Points (1, 2, 3, 4) for Plotting

FIGURE 2. Physical Model of the Fuel Lag Storage Area

FIGURE 3. Temperature Distributions as a Function of Time

TABLE 1. Thermophysical Properties Used in the Analysis

	Density [kg/m ³]	Conductivity [w/m•k]	Specific Heat [j/kg•k]
Concrete	2,000	1.2	880
Canister	12,000	19.0	190
Stainless Steel	8,000	17.5	475
Air	0.58	0.05	1051

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