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M E M O R A N D U M

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PREDICTION OF CANISTER LIFETIME

Introduction and Summary

The lifetime of vitrified waste and waste concrete canisters stored in air or in dry salt was predicted by extrapolating the thickness of reactions observed in long-term heating tests to estimate the time required for penetration of the reference design (3/8-inch-thick) canister.[1] Test specimens were heated for up to 20,000 hours at temperatures that bracket the temperature expected during waste-form storage.[2]

These results indicate that 304L stainless steel is a satisfactory canister material for storage in either air or dry salt, but that low carbon steel should no longer be considered as a candidate canister alloy for air storage. Oxidation would penetrate a 3/8" thick carbon steel canister in about 200 years of storage in a surface facility, and its strength would be reduced in a much shorter period. A 3/8" thick canister of 304L stainless steel would not be penetrated for more than 8000 years in either air or in dry salt.

Evaluation of more expensive canister alloys necessary to provide a long-term barrier in wet salt were not included in this program. If these alloys are necessary to insure canister integrity in wet salt, their high cost and limited availability would probably necessitate that waste form storage would be in another location.

Discussion

We carried out a series of long-term heating tests to evaluate compatibility of candidate canister alloys with both vitrified waste and waste concrete. The penetration of the canister alloy by oxidation was evaluated for both storage in air, and in dry salt from Carlsbad NM. In these tests, reactions were characterized by the destructive examination of replicate specimens periodically removed from the test. In this memorandum the lifetime of canisters is predicted from reaction thickness measurements made on specimens heated for up to 20,000 hours. The alloys tested, test specimens, test plan, test matrices, and the results of the examination of specimens previously removed from tests have been reported previously.[3-12]

Predicted canister lifetimes are given in Table 1. Lifetimes were predicted from the amount of penetration from the outside of the canister by reaction with the storage environment (air or dry salt) and by the amount of penetration from the inside of the canister by reaction with the solidified waste (vitrified waste or waste cement). Penetration was measured for both Type 304L stainless steel and low carbon steel canisters. Measured penetrations are given in Table 1 in units of mils of penetration/hours of testing.

Penetration Measurements

The depth of penetration of test specimens was determined from changes in specimen dimensions and thickness measurements of surface films (Table 1). Penetration is normally determined from changes in specimen dimensions. But, if the penetration is very small, as it was in most specimens, the experimental error of this technique is so large that a small amount of penetration cannot be seen. In these cases, the thickness of the oxide film on the surface of the specimen was assumed to be the depth of penetration (Figure 1).

Extrapolating Penetration Data

A standard method for extrapolating data from short-term oxidation tests to predict the results of long-term exposure is simply to plot penetration depth vs time.[13] From this plot the reaction rate and the dependence of the reaction rate on time can be determined (Figure 2). In the SRL tests, penetrations were so small that it was impossible to tell whether the reaction rate had a linear or a parabolic dependence on time even after 2.3 years of testing (20,000 hours). The reaction rate of metal oxidation normally has a parabolic dependence on time because the reaction is diffusion limited. However, the more conservative linear extrapolation was used to give predicted lifetimes in Table 1.

Extrapolation was normally made from the penetration of the replicate specimen heated for 20,000 hours, the longest time tested. However, extrapolation for the waste concrete/canister reaction was made from data from the specimen heated 10,000 hours. A small amount of selective penetration was found on this specimen, but not on the replicate specimen heated for 20,000 hours.

Effect of Radiation

Radiation is not expected to have a significant effect on reactions between the solidified waste and the inside of the canister. No difference was found in the waste concrete canister reaction in tests with simulated or actual sludge. Tests are planned with glass containing actual sludge.

Radiation can accelerate the penetration of the outside of the canister. In a radiation yield the oxidation of low carbon steel is accelerated because of nitric acid that is formed by radiolysis of N_2 in humid air.[14] The oxidation of Type 304L stainless steel under these conditions is not accelerated because this alloy is resistant to nitric acid. Penetration data for the outside of the canister in these tests was taken from capsules that were heated in the radiation field found in the High Level Caves.

Data for the penetration of the outside of the canister because of reaction with dry salt was from tests carried on outside of a radiation field. It is not expected that this reaction would be accelerated by a radiation field to the same degree as the oxidation in air of low carbon steel because canisters stored in salt will be exposed to air oxidation only a short time. There will be intimate contact between the dry salt and the canister (no air gap) because of creep of the salt (reconsolidation).[15]

Program

o Long-term heating tests to evaluate the compatibility between canister alloys and vitrified waste containing actual sludge are scheduled to begin in the HLC ∿1/80. Similar tests with glass containing simulated sludge will continue for comparison with the tests with actual sludge.

o Specimens of canister alloys will be included in M. D. Dukes' program to evaluate the effects of salt brines on vitrified waste.[16] Type 304L stainless steel cannot be expected to provide a long-term barrier in a wet salt environment.[17]

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Att

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TABLE 1: PREDICTED LIFETIME OF CANISTERS

STORAGE ENVIRONMENT	SOLIDIFICATION MATRIX	CANISTER ALLOY					
		TYPE 304L STAINLESS STEEL			LOW CARBON STEEL		
		MEASURED PENETRATION (mils / Hours of Test) ID	OD	PREDICTED LIFETIME (YEARS)	MEASURED PENETRATION (mils / Hours of Test) ID	OD	PREDICTED LIFETIME (YEARS)
AIR	CONCRETE	1.8/10,000	<0.1/20,000	>231	2.8/20,000	3.6/20,000	134
	GLASS	None/20,000	<0.1/20,000	>8562	None/20,000	3.6/20,000	238
DRY SALT	CONCRETE	1.8/10,000	<0.1/20,000	>231	2.8/20,000	<0.3/20,000	<276
	GLASS	None/20,000	<0.1/20,000	>8562	None/20,000	<0.3/20,000	>2854

FIGURE 1

ESTIMATING PENETRATION OF SPECIMENS HAVING NO SIGNIFICANT CHANGE IN OVERALL DIMENSIONS

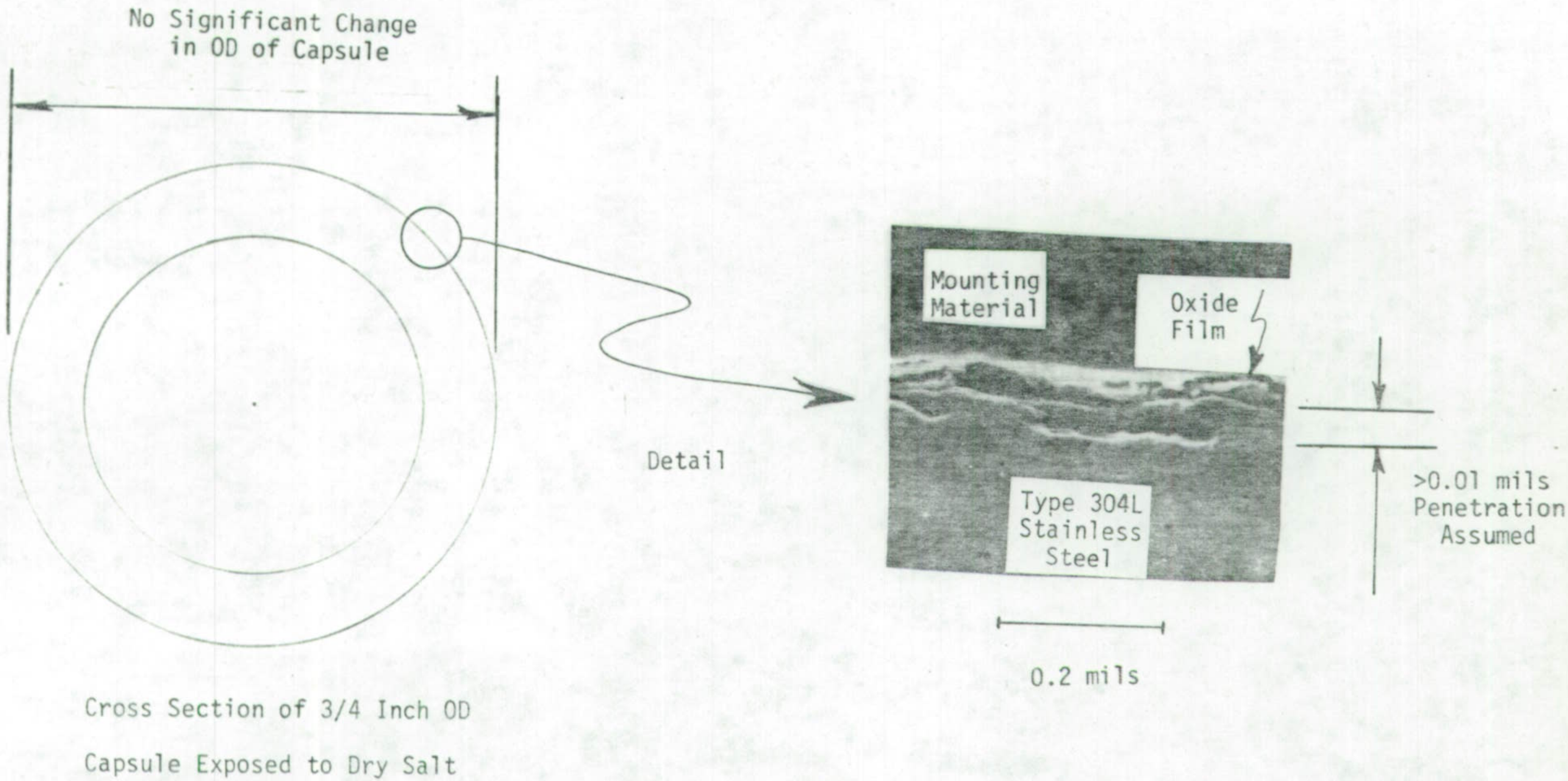

FIGURE 2

TYPICAL EXTRAPOLATION OF MEASURED PENETRATION TO DETERMINE CANISTER LIFETIME