PRELIMINARY EVALUATION OF PREDICTED PEAK RELEASE RATES FROM THE ENGINEERED BARRIER SYSTEM FOR A POTENTIAL REPOSITORY AT YUCCA MOUNTAIN, NEVADA

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I. INTRODUCTION

Any potential repository for the ultimate disposal of the nation's high-level radioactive wastes is subject to meeting post-closure regulatory requirements as specified by the NRC. Three NRC sub-system performance measures are relevant to the evaluation of the Yucca Mountain site and possible engineered barriers. These performance requirements are specified in 10 CFR 60. These include the substantially complete containment requirement, the engineered barrier system (EBS) release requirement, and the pre-waste emplacement ground-water travel time requirement. The present paper documents an initial evaluation of the peak EBS release rates. More detailed discussion is presented in M&O (1994).[1]

II. APPROACH AND ASSUMPTIONS

A number of key factors significantly impact the maximum release rate from the engineered barrier system. The first factor is the time and rate at which waste packages are breached. Simply and crudely stated, if the waste packages remain intact longer than the time period of concern, then the EBS release rate is zero. Similarly, if the waste packages are breached at a rate of less than one percent per 1,000 years (equivalent to one part in 100,000 years) then the EBS release rate criterion is also met, even if the entire contents of the waste package are immediately released to the geosphere (an extremely unlikely scenario). Therefore it is clear that delaying and spreading out the "failure" of the waste package outer and inner barriers and the breaching of the cladding would significantly reduce the maximum EBS release rates. We have conducted four simulations to approximate the effects of delaying and spreading out the failure distribution that are based on different thermal loads and criteria for the initiation of aqueous corrosion. Using an assumed outer barrier of 10 cm and an inner barrier of 0.95 cm and the Stahl model for aqueous pitting corrosion, we have analyzed the EBS release rates for thermal loads of 28.5, 57 and 83 kW/Ac using temperature as the corrosion limiting factor and at 57 kW/Ac for saturation limiting the initiation of corrosion. The later had the earliest failures and the most rapid failure rates observed in the TSPA-1993 [2] analyses so provides the upper bound on the release rates.

Once the waste packages have failed, the cladding must be breached, the waste form exposed and water brought into contact with the waste form prior to the initiation of aqueous phase alteration/dissolution. In TSPA-1993 it was assumed that the cladding was breached congruently with the inner waste package barrier, that the entire cladding surface was breached and the entire waste form surface exposed and wetted with a thin film (1.0 mm) of water. The impact of this conservative assumption has been investigated by reducing the percent of cladding surface area that has been degraded (equivalent to the percent of the waste form surface exposed or the percent of the waste form surface area wetted) from 100% (which is analogous to the TSPA-1993 assumption) to 10% to 1% and finally to 0.01%.

III. RESULTS AND DISCUSSION

Table 1 presents the peak 10,000 year EBS release rates for those radionuclides which exceed 0.1% of the total release limit (i.e., 1.28 Ci/yr); ^{14}C, ^{135}Cs, ^{59}Ni, ^{237}Np, ^{79}Se, and ^{99}Tc. [For these calculations, ^{14}C is considered to be released in the aqueous phase.] The peak release rates for each of these radionuclides occurs in less than

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10,000 years. ^{210}Pb and ^{226}Ra have peaks which occur beyond 10,000 years.

The results presented in Table 1 indicate the expected reduction in peak EBS release rate when the corrosion initiation criterion causes a delay and, more importantly, a spreading of the failure distribution. In general, the lower thermal load has a lower peak EBS release rate than the higher thermal loads. This is due to a combination of the fact that the lower thermal load causes a spreading of waste package failures[2] lower temperatures which result from the lower thermal loads cause lower alteration/dissolution rates from the waste form and lower solubilities of the radionuclides.

The result of reducing the percent of waste form surface area exposed and wetted from 100% (equivalent to the assumption made in TSPA-1993) to 0.01% for the "reference" design is tabulated in Table 2 for the 6 radionuclides of interest. These results are very illuminating into the significance of the rate at which waste packages "fail". For the solubility-limited radionuclides, there is an approximately linear reduction in the peak release rate with the percent of waste form surface area exposed and wetted. For the alteration-limited radionuclides, there is a slight reduction (about a factor of 2) in peak release rate when the percent of waste form surface exposed and wetted is reduced from 100% to about 1%, but below that value the peak release rate remains virtually unchanged (although the integral of the release over time would be significantly reduced). This is a direct result of the gap fraction for these radionuclides.

REFERENCES

1. Civilian Radioactive Waste Management Systems Management & Operating Contractor (CRWMS M&O). Additional Sensitivity Analyses Extending the Total System Performance Assessment (TSPA) - 1993 Results, B00000000-01717-0200-00122-Rev. 00, prepared for the U. S. Department of Energy, Yucca Mountain Site Characterization Project, Las Vegas, Nevada (1994).

2. Andrews, R. W., T. F. Dale, J. A. McNeish, Total System Performance Assessment - 1993: An Evaluation of the Potential Yucca Mountain Repository, B0000000-01717-2200-00099-Rev. 01, Civilian Radioactive Waste Management Systems Management & Operating Contractor (CRWMS M&O) prepared for the U. S. Department of Energy, Yucca Mountain Site Characterization Project, Las Vegas, Nevada (1994).

Table 1. Comparison of Maximum EBS Release Rates for Alternate Thermal Loads and Corrosion Initiation Criterion

	24/10/.95/S2 [1]		57/10/.95/S2 [2]		87/10/.95/S2 [3]		57/10/.95/S1 [4]	
	Release Rate (Ci/yr)	Release Rate/ NRC Limit	Release Rate (Ci/yr)	Release Rate/ NRC Limit	Release Rate (Ci/yr)	Release Rate/ NRC Limit	Release Rate (Ci/yr)	Release Rate/ NRC Limit
C-14	1.0	1.2	2.0	2.4	0.8	1.0	6.2	7.4
Cs-135	0.7	.13	1.2	.22	1.2	.22	1.9	5.4
Ni-59	2.6	.65	4.3	1.1	4.7	1.2	6.3	4.0
Np-237	1.7	.36	3.2	.68	2.3	.49	3.9	4.7
Se-79	0.5	1.7	0.9	3.0	0.9	3.0	1.6	5.2
Tc-99	18.0	1.9	31.0	3.3	31.0	3.3	49.9	5.3

All assume 100% of waste form surface is wet

(1) 24 kW/Ac, 10 cm. outer barrier, 0.95 cm inner barrier, Stahl corrosion, temperature initiation
(2) 57 kW/Ac, 10 cm. outer barrier, 0.95 cm inner barrier, Stahl corrosion, temperature initiation
(3) 87 kW/Ac, 10 cm. outer barrier, 0.95 cm inner barrier, Stahl corrosion, temperature initiation
(4) 57 kW/Ac, 10 cm. outer barrier, 0.95 cm inner barrier, Stahl corrosion, saturation initiation

Table 2. Comparison of NRC Release Rate Limit 100,000-year Simulation: Sensitivity to Percent of Waste Surface Wetted

Radio-nuclide	NRC Limit (Ci/yr)	Gap Fraction (%)	Percent of Waste Surface Wetted: 100% (Reference Case)		10%		1%		0.01%	
			Rate (Ci/yr)	Release/ NRC Limit	Rate (Ci/yr)	Release/ NRC Limit	Rate (Ci/yr)	Release/ NRC Limit	Rate (Ci/yr)	Release/ NRC Limit
C-14	0.83	3.5	6.18	7.4	4.91	5.9	4.78	5.8	4.77	5.7
Cs-135	0.36	2	1.94	5.4	0.97	2.7	0.58	1.6	0.53	1.5
Ni-59	1.57	0	6.33	4.0	0.68	0.43	0.075	0.048	0.00079	0.00050
Np-237	0.82	0	3.88	4.7	0.52	0.63	0.062	0.076	0.00049	0.00060
Se-79	0.30	2	1.57	5.2	0.92	3.1	0.56	1.9	0.55	1.8
Tc-99	9.5	2	49.91	5.3	29.21	3.1	17.9	1.9	17.7	1.9