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ENGINEERING DATA TRANSMITTAL

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1	1	Design Authority MM Pereira [signature] S6-81	3	1	FN Simmons [signature] 7/31/98 S6-51
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1	1	Cog.Eng. SD Landsman EJB for SDL L1-02			Central Files B1-07
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1	1	QA DH Sandoz [signature] for 8/26/98 L1-06			
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[signature] EJB 9/9/98 Signature of EDT Originator Date	[signature] 9/9/98 Authorized Representative for Receiving Organization Date	[signature] 9/9/98 Design Authority/ Cognizant Manager Date	Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

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304L Stainless Steel Resistance to Cesium Chloride

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304L STAINLESS STEEL RESISTANCE TO CESIUM CHLORIDE

August 1998

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ABBREVIATIONS / ACRONYMS

ALARA	As Low As Reasonably Achievable
C	carbon
Cd	cadmium
Cl	chlorine
Cr	chromium
CsCl	cesium chloride
Fe	iron
H	hydrogen
in.	inch
μm	micron (10^{-6} m)
Mn	manganese
Mo	molybdenum
Ni	nickel
O	oxygen
ORNL	Oak Ridge National Laboratory (Oak Ridge, Tennessee)
P	phosphorus
PNNL	Pacific Northwest National Laboratory
SEM	Scanning Electron Microscopy
Si	silicon
SS	stainless steel
WESF	Waste Encapsulation and Storage Facility

304L STAINLESS STEEL RESISTANCE TO CESIUM CHLORIDE

1.0 INTRODUCTION

B&W Hanford Company have two Oak Ridge National Laboratory (ORNL) Type 4 canisters filled with cesium chloride (CsCl) originally produced at WESF (Waste Encapsulation and Storage Facility). These canisters are constructed of 304L stainless steel per drawing ORNL 970-294. Instead of removing the CsCl from the Type 4 canisters and repacking into an Inner Capsule, it is intended (for ALARA, schedule and cost purposes) that the Type 4 canisters be decontaminated (scrubbed) and placed [whole] inside a Type "W" overpack. The overpack is constructed from 316L stainless steel.

Several tests have been run by Pacific Northwest National Laboratory (PNNL) over the years documenting the corrosion compatibility of 316L SS with CsCl (Bryan 1989 and Fullam 1972). However, no information for 304L SS compatibility is readily available. This document estimates the corrosion resistance of 304L stainless steel in a WESF CsCl environment as it compares with that of 316L stainless steel.

2.0 316L SS CORROSION RESISTANCE TO CsCl

Fullam (1972) extrapolated his short-term compatibility data to indicate the attack of 316L SS by CsCl waste at 400 °C (750 °F) over a 600 year period should not exceed 635 μm (0.025 in.). Visual inspection of photomicrographs showed little evidence of intergranular penetration but some pitting and subsurface void formation was present. Carbide precipitation was evident near the sample surface and along grain boundaries. The extent of the carbide precipitation increased with time at temperature.[†]

Bryan (1989) conducted long term (6 year) tests with WESF canisters to try to obtain more reliable estimates on the long-term corrosion resistance of 316L SS to CsCl at 450 °C (840 °F). His examination of photomicrographs also showed subsurface void formation and carbide precipitation (again, the number of precipitates increased with time at temperature).

[†] The presence of carbide precipitates reduces the corrosion resistance of the stainless steel at the grain boundaries.

Thermodynamic calculations by Bryan (1989) indicate that pure CsCl should not react with 316L SS at the test temperatures, however, certain impurities in the CsCl could react with the 316L SS. Possible impurities that could react include the less stable chlorides, such as $FeCl_2$, $NiCl_2$, and $CdCl_2$, and the less stable oxides such as Fe_3O_4, NiO and H_2O. In trying to identify the reactions, samples were analyzed by SEM (scanning electron microscopy). Bryan concludes that the only reaction that could be identified with any certainty was the leaching of Mn from the 316L SS in the reaction zone.

If impurities in the CsCl are the principal cause of corrosion, the extent of reaction should be limited by the amount of impurities available to react with the 316L SS components. The corrosion rate would initially be high and then decrease with time as the impurities are consumed. The rate controlling step for each reaction is likely to be the diffusion of the impurity reactant from the bulk CsCl to the metal/CsCl interface (Bryan 1989). If a liquid phase is present, it could accelerate this diffusion.

Bryan tabulated the effect of impurities on the phase transition temperature and melting point of CsCl (1989, pg A.17). The impurity with the greatest effect is iron. For a CsCl + 3% $FeCl_3$ system the minimum melting point is 270 °C (520 °F); melting began before a phase transition temperature could be detected. This falls well below the test temperature, thus a liquid phase would be present.

When pure molten CsCl is poured into a 316L SS capsule and allowed to solidify, the solid mass does not adhere to the wall (void spaces are formed as the mixture cools and collapses). Bryan (1989) hypothesizes that impurities cause some of the CsCl to adhere to the capsule wall. Thus, corrosion in areas where there is no CsCl/steel contact should be much less than in contact areas. If samples were [inadvertently] taken in areas of no contact, this theory could help to explain some of the data scatter in previous studies.

3.0 DISCUSSION

304L and 316L SS are both austenitic stainless steels with similar compositions (see Table 1). The lower carbon values (versus 304 and 316) improve corrosion resistance in welded structures (ASM 1990). The addition of molybdenum in 316L SS increases the steel's resistance to the initiation of pitting and crevice corrosion (ASM 1990). Both of these alloys are used extensively in the nuclear industry.

Table 1: Stainless Steel Compositions (ASM 1990, pg 843)

Type	Composition, wt.% (Remainder is Fe)							
	C	Mn	Si	Cr	Ni	P	S	Mo
304L	0.03	2.00	1.00	18 - 20	8 - 12	0.045	0.03	---

316L	0.03	2.00	1.00	16 - 18	10 - 14	0.045	0.03	2.00 - 3.00

With the great similarity in composition between the 304L and 316L SS (equal amounts of Mn and Si, near equal amounts of Cr and Ni), the potential corrosion reactions with the CsCl would also be similar (leaching of manganese in the reaction area). As subsurface void formation and carbide precipitation are the predominate corrosion features observed, the addition of molybdenum to the 316L [to reduce pitting and crevice corrosion] does not seem to provide an extra advantage to corrosion resistance.

During its stay at ORNL, the CsCl was water-washed which lowered the impurity levels (Landsman 1998), thus lowering the amount of available corrosion reactants. The lowering of iron content by washing (to <0.005%) would also minimize the potential for any liquid phase to form and decrease impurity diffusion to the surface. Water storage of this WESF canister would greatly reduce the system (CsCl/steel) temperature, which in turn would further lower corrosion rates.

Corrosion on the exterior of the Type 4 canister due to any remaining CsCl after decontamination would be minimal, as any impurity would be quickly consumed. Lastly, as no water or moisture is expected between the Type 4 canister and the WESF overpack, any possible galvanic corrosion between the 304L and 316L SS is avoided. As these two alloys are only slightly separated on the galvanic series (ASM 1990, pg 557), galvanic corrosion would be unlikely even with water present.

4.0 CONCLUSIONS

With much lower impurity levels in the water-washed ORNL CsCl and a similar steel composition, the 304L stainless steel is expected to exhibit equal to or better corrosion resistance than the 316L stainless steel in this application. Thus, packing of the Type 4 canisters within the WESF overpack is judged acceptable.

5.0 REFERENCES

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DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	BWHC/324 Facility	Date 07/28/98
Project Title/Work Order		EDT No. 625234
304L Stainless Steel Resistance to Cesium Chloride HNF-3108, Rev. 0		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
TG Beam	S6-51				
EJ Bitten	L1-02				
SD Landsman	L1-02				
MM Pereira	S6-81				
DE Rasmussen	L1-04				
DH Sandoz	L1-06				
FN Simmons	S6-51				
Central Files	B1-07				