WSRC-TR-98-00013

CONF-980712--

Compliance with Waste Acceptance Criteria of WIPP and NTS for Vitrified Low-Level and TRU Waste Forms

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A document prepared for THE 18TH INTERNATIONAL CONGRESS ON GLASS at San Francisco, CA, USA from 7/5/98 - 7/10/98.

DOE Contract No. DE-AC09-96SR18500

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A paper proposed for presentation and publication in the Proceedings of the Eighteenth International Congress on Glass, San Francisco, CA, July 5-10, 1998

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ABSTRACT

A joint project between the Oak Ridge National Laboratory (ORNL) and the Savannah River Technology Center (SRTC) has been established to evaluate vitrification as an option for the immobilization of waste within ORNL tank farms. The radioactive waste is from the Gunite and Associated Tanks, the Melton Valley Storage Tanks , the Bethel Valley Evaporater Service Tanks and the Old Hydrofracture tanks. An ORNL demonstration passed supernate from tank W-29 through a column containing the ion exchange material, Crystalline Silicotitanate (CST). This project demonstrated effective removal of Cs-137 from the supernate. In parallel, SRTC developed a glass formulation which readily incorporated the CST into glass. Glass formulation efforts for incorporating the sludge from the tanks has led to waste loadings of 40 wt% on an oxide basis. The glass waste forms produced from both waste streams must meet the Waste Acceptance Criteria (WAC) of either the Waste Isolation Pilot Plant (WIPP) for TRU waste or the Nevada Test Site (NTS) for low-level waste. This paper presents details of calculations based on current best available analyses of the Oak Ridge Tanks on the limits for waste loadings imposed by the WAC's. It turns out that glass formulation efforts at SRTC have led to waste loadings greater than allowed by the waste acceptance criteria of the NTS and WIPP. Attainment of the maximum achievable waste loading for the Oak Ridge waste streams is critical since the cost savings associated with reducing waste form volume is tremendous.

INTRODUCTION

As part of the privatization initiative, Oak Ridge has issued a request for proposal for treatment of their transuranic and low-level wastes. A major part of this proposal addresses the treatment and immobilization of the sludge and supernate from the four Oak Ridge Tank Farms:

Melton Valley Storage Tanks (MVST)
Bethel Valley Evaporator Service Tanks (BVEST)
Gunite and Associated Tanks (GAAT)
Old Hydrofracture Tanks (OHF)

The immobilized waste forms produced as part of this process must comply with the Waste Acceptance Criteria (WAC) for the Waste Isolation Pilot Plant (WIPP)[1] or the Nevada Test Site (NTS)[2] depending upon which site is appropriate for disposal of the waste forms. The Tanks

Focus Area of the DOE's Office of Science and Technology (EM-50) has funded the Savannah River Technology Center (SRTC) to develop glass formulations which can incorporate (1) sludges from Oak Ridge Tank Farms and (2) Cs-137 loaded Crystalline Silicotitanates (CST) generated from treatment of the tank supernate. Radionuclide concentrations and waste loadings in the glass are the major factors in determining whether the waste forms will be sent to WIPP or NTS, and whether the waste forms will require remote-handling (RH).

The goal of SRTC's glass formulation development is to (1) increase waste loading in the glass in order to reduce the total volume of waste form produced, (2) decrease the time and cost for immobilization operations, and (3) reduce costs associated with transportation of the waste forms to and disposal within the WIPP or NTS. The criteria imposed by the WIPP and NTS WAC's must also be considered in this effort to maximize waste loadings.

This paper presents the results of calculations based on the best available analyses[3-6] of the Oak Ridge Tanks for potential waste loading limitations imposed by the WIPP and NTS WAC's. The Waste Acceptance Criteria, rather than the glass formulations, actually limit waste loadings. For NTS, the Class C requirement is the limiting factor for maximum CST loading (and consequently Cs-137 loading) in glass. For WIPP, the fissile gram equivalent requirement (325 g per canister) limits the maximum sludge loading in glass for some of the tanks.

TREATMENT AND IMMOBILIZATION OF THE TANK SUPERNATE

Oak Ridge[7] has successfully demonstrated that the Cs-137 in the supernate from Tank W-29 can be effieciently removed when passed through a column containing CST. In parallel, SRTC[8] developed a glass formulation which can incorporate high levels of the Cs-137 loaded CST into borosilicate waste forms. As a confirmation of this glass formulation, SRTC, using a melter within the SRTC Shielded Cells Facility, successfully vitrified Cs-137 loaded CST obtained from Oak Ridge.

The intent is to send the vitrified CST waste forms to NTS since they are not TRU waste forms. The two significant criteria of the NTS WAC for these waste forms are (1) the waste form can not be hazardous and (2) the radionuclide content must not exceed the Class C limit. It is well known that vitrification significantly limits leaching of the waste form. The glasses produced in this study, even at the highest waste loading, readily met the Product Consistency Test (PCT) specification for High Level Waste. This essentially confirms that the glass will not be characteristically hazardous. However, TCLP tests must currently be performed to verify this requirement. Efforts are underway by SRTC to gain credit for glass waste forms in meeting the RCRA hazardous metal requirements.

The Class C limit (less than 4,600 Curies (Ci) per cubic meter for Cs-137) reduces the waste loadings which have been demonstrated for vitrification. This limit is currently in place due to exposure concerns to employees at NTS. At 8 Ci of Cs-137 per kg of CST, the CST loading in glass is limited to ~20 wt%. Glass formulations have been produced which can incorporate up to 60 wt% CST. Therefore, in this case, the Class C requirement in the NTS WAC significantly limits the loadings which are technically achievable and thereby increases the volume of waste produced. NTS is considering a relaxation of this requirement relative to a safety/cost analysis for handling and disposal operations.

TREATMENT AND IMMOBILIZATION OF THE TANK SLUDGE

The chemical and radionuclide content of the Oak Ridge sludge waste varies significantly from tank to tank. In fact, there may be significant in-tank variability as well. Analyses have been performed from samples taken from most of the tanks and these best available values will be used in the discussions that follow. It is important to understand that the radial and height variations in composition have not been measured for these tanks.

TRU Limits in Glass. The WIPP WAC defines TRU waste as waste that contains alpha-emitting radionuclides with atomic numbers greater than that of Uranium (92) and which have a combined alpha activity level greater than 100 nCi/g. Furthermore, the half life of the TRU radionuclides must be greater than 20 years to be included in the total alpha activity level. Calculations of the activity levels include only the mass of the waste form and can not include the mass of any containers. Calculations show that vitrified sludge from these tanks will be TRU at loadings of 10 wt% sludge oxides and above. In fact, most of the tanks will lead to TRU waste forms at loadings significantly less than 10 wt%. Current glass formulation efforts[9] have shown that the sludge can be incorporated at oxide levels of ~ 40 wt% and efforts are ongoing to increase this value. This implies that the vitrified waste forms will be TRU and consequently, must be disposed of at the WIPP.

There is an upper limit of 23 Ci of TRU radionuclides per canister. The maximum TRU level is found in Tank W-23 from the BVEST tank farm, and it contains 2.7 E-06 Ci/g of wet sludge. Even at a 70 wt% loading of sludge oxides in glass, the TRU content per canister (at 2000 kg of glass per canister) would be 14.4 Ci. The average value of TRU content from the other tanks is approximately one fourth of this value, and therefore, the upper limit of 23 Ci, even considering the uncertainities in measurement, will most likely not be bounding for achievable waste loadings in glass.

Remote Handling. The WIPP defines remote handled waste as waste that has a dose rate greater than 200 mrem/hr at the canister surface. Calculations show that the vitrified waste forms will exceed the limit of 200 mrem/hr at the surface of the container on average at waste loadings less than 1 wt%. This will define the waste forms as remote handled (RH) waste for any reasonable sludge loading. The RH canister is 3 meters tall by 0.64 meters in diameter and is similar in design to the DWPF canister. Only one canister per shipment is allowed to the WIPP. The costs for handling and disposal of RH waste forms are greater than $20K for each canister. Although it would reduce costs to produce a waste form which could be contact handled (CH), the increase in waste form volume would exceed 50 times that which is currently achievable. Therefore, the goal is to produce as high a waste loading as possible to reduce the number of RH canisters produced.

RCRA LDR Limits. Although the WIPP will accept mixed TRU waste and has no leaching limits, the Oak Ridge Request for Proposal specifies that the waste form also meet the RCRA LDR limits for hazardous metals. As discussed above for the NTS requirements, the use of vitrification for immobilization normally generates a waste form which will meet the LDR limits. It is therefore not expected that this requirement will limit the loadings achievable in glass.

Thermal Power Limit. For RH waste forms, the WIPP limit is 300 watts/canister. Previous calculations have shown that on average, the wattage is in the single digit regime and far from the 300 watt limit. Therefore, the waste loading will not be limited by the WIPP WAC wattage requirement of less than 300 watts/canister. It is interesting to note that the DWPF canisters which contain HLW have a design basis thermal power of 700 watts/canister which is driven mainly by the cesium and strontium radioisotopes.

Pu-239 Fissile Gram Equivalent (FGE). The fissile or fissionable radionuclide content of RH-TRU waste is limited to 325 g Pu-239 FGE per RH-TRU 72B Cask. The major radionuclides in the Oak Ridge sludges which contribute to the FGE are U-233, U-235, and Pu-239. Table I provides the total FGE for each tank at loadings of 40, 50, and 60 wt% sludge oxides. At the currently achievable 40 wt% loading of sludge in glass, Tank W-31 of the MVST and several of the GAAT Tanks would produce waste forms which exceed the 325 g limit. As the waste loading is increased to 50 wt%, the glass produced from nine of the tanks will exceed the FGE limit.

Table I. Calculated values for FGE for waste loadings of 40, 50, and 60 wt% on an oxide basis.

TANK #	TOTAL FGE (g) per canister at 40 wt%	TOTAL FGE (g) per canister at 50 wt%	TOTAL FGE (g) per canister at 60 wt%
BVEST			
W-21	289	361	433
W-22	288	360	432
W-23	171	213	256
MVST			
W-24	146	182	219
W-25	172	216	259
W-26	270	338	405
W-27	139	173	208
W-28	221	276	331
W-31	465	581	697
OHF			
OHF-1	110	137	165
OHF-2	99	123	148
OHF-3	160	200	241
OHF-4	307	383	460
OHF-9	94	118	141
GAAT			
W-5	28	35	42
W-6	209	261	313
W-7	1794	2242	2691
W-8	304	380	456
W-9	915	1144	1373
W-10	375	468	562

The waste in the tanks will be mixed in a manner which is convenient for transfer operations at OR. It is expected that all of the sludge will eventually be transferred to the MVST Tanks. Therefore, the final contents of each of the MVST tanks will be an unknown combination of several tanks. To complicate matters further, it is not clear whether complete mixing within a tank will occur after transfer. Therefore, the feed to the melter may be variable from a single MVST tank.

The results of the calculations for FGE show that the 325 g limit may be a problem at high waste loadings for some of the sludges. It will therefore be important that frequent sampling of the feed stream be conducted in order to ensure that the limit is not exceeded.

Pu-239 Equivalent Activity: The requirement for the Pu-239 equivalent (PE) activity for RH TRU waste in the WIPP WAC is less than 1000 PE-Ci/canister. This requirement is based on inhalation of fine particulates contaminated with radionuclides. It is interesting to note that the limit has been relaxed to 1800 PE Ci for a 55 gallon drum for contact handled TRU waste if the waste has been vitrified. This is due to the fact that the glass waste contains less fines and consequently, inhalation of particulate fines is not as great a concern. The preliminary requirements for the RH waste have not yet relaxed this requirement for vitrified waste. However, calculations have shown that the values for the Pu-239 PE are less than 10 for these waste loadings. Therefore, this requirement is readily met and does not limit the loading of waste into the glass.

CONCLUSIONS

The glass development activities for both Oak Ridge sludge and Cs-137 loaded CST have led to significant waste loadings. In fact, the achievable waste loading will not be limited by the glass formulation, but rather by the limits imposed by the WIPP and NTS WAC's. For the Cs-137 loaded CST, the Class C limit for radionuclides imposed by NTS limits the loading to ~ 20 wt%, whereas glass formulations developed at SRTC reached 60 wt%. For the WIPP, several tanks contain sludge which, if incorporated solely into glass, will exceed the Pu-239 FGE limit of 325 g per cask for RH waste forms at waste loadings of ~ 40 wt%. Current efforts on glass formulation development are directed at increasing the waste loading above this 40 wt% value. Due to the uncertainties in tank transfers and mixing, and inhomogeneities within tanks, the actual values of FGE radionuclides will not be known until the time of vitrification. It is important to continue efforts at increasing the waste loadings of sludge in glass due to the tremendous cost benefits which arise from reducing the amount of waste form shipped to and disposed of at WIPP. This may lead to a variable waste loading for each feed batch.

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