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1	1	Cog.Eng. G. E. Stegen	[signature]	1/16/96	H5-27						
1	1	Cog. Mgr. D. J. Washenfelder	[signature]	2/13/96	H5-27						
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		Env.									

18.	19.	20.	21. DOE APPROVAL (if required)
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High-Level Waste Process and Product Data Annotated Bibliography

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Abstract: The objective of this document is to provide information on available issued documents that will assist interested parties in finding available data on high-level waste and transuranic waste feed compositions, properties, behavior in candidate processing operations, and behavior on candidate product glasses made from those wastes. This initial compilation is only a partial list of available references.

Approved for Public Release

HIGH-LEVEL WASTE PROCESS AND PRODUCT DATA ANNOTATED BIBLIOGRAPHY

G. E. Stegen

February 1996

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HIGH-LEVEL WASTE PROCESS AND PRODUCT DATA ANNOTATED BIBLIOGRAPHY

1.0 INTRODUCTION

A processing plant is planned to immobilize the high-level waste (HLW) and transuranic (TRU) fraction of tank wastes produced by defense activities at the Hanford Site. Tank wastes were generated over an extended period beginning the mid-1940s, and are currently stored in underground tanks. Before processing for HLW immobilization, the wastes will be processed (pretreated) to remove most of the inert components to reduce final volume of immobilized HLW to be produced. High-level and TRU residues from pretreatment will be immobilized by melting them together with additives, to form a durable vitreous waste form (glass).

A two-phase program has been proposed to immobilize the waste. Phase I is a proof of principal phase expected to immobilize only a few percent of the currently stored HLW and TRU waste. Four tanks currently are designated as source tanks for HLW to be immobilized in Phase I (241-AZ-101, 241-AZ-102, 241-AY-102, and 241-C-106). There also is a possibility that other waste sources could be considered as substitutes or supplements to waste from these four tanks during Phase I. In Phase II, the balance of the HLW and TRU tank waste will be processed at a substantially higher rate.

Historical production records and limited sampling of the underground waste storage tanks provide some information on composition and characteristics of the stored waste. However, there is uncertainty as to some characteristics of the wastes, particularly in regard to the older single-shell tank (SST) wastes.

2.0 SCOPE AND OBJECTIVE

A substantial amount of technical information has been developed over the years on composition and characteristics of tank wastes, behavior of HLW feeds in candidate waste treatment processes, and properties of candidate product glass waste forms. A large fraction of this information is a product of U.S. Department of Energy (DOE) sponsored work, including work at the Hanford Site, Savannah River Site, and the West Valley Demonstration Project (WVDP). Some of the information has been published in open literature, while a substantial fraction is in internal documentation. Some information is unpublished, such as data recorded only in laboratory notebooks or unissued draft reports.

The objective of this document is to provide a bibliography of issued, publicly available documents that will assist interested parties in finding available data on HLW and TRU waste feed compositions, properties, behavior in candidate processing operations, and behavior on candidate product glasses made from those wastes. This initial compilation is only a partial list of available references. A separate companion bibliography is being prepared by Pacific Northwest National Laboratory (PNNL) to cover potentially useful PNNL references from the relatively large amount of work performed for the Hanford Waste Vitrification Project (HWVP) (Larson 1996). In future updates, it is planned to merge the bibliography herein with the PNNL developed bibliography and to expand the bibliography both in terms of references and annotations.

The bibliography is focused primarily on results of DOE sponsored work at the Hanford Site. However, some references from other DOE sites and a limited number of additional outside references are included that have been found in past work to provide some valuable information in this subject. For selected references, annotations have been included to assist in identifying contents and applicability.

The references are organized into four major groupings. References included in Section 3.0 are primarily related to Phase I and Phase II tank waste composition, waste quantity, waste sludge behavior during water washing or caustic digestion pretreatment processes, and effect of blending HLW feeds. References in Section 4.0 are primarily related to feed behavior in candidate immobilization processes, properties and behavior of immobilized waste forms, process and equipment performance, and process technology evaluations. References in Section 5.0 are related to processes for removal of radionuclides from liquid tank waste. The high activity product from these processes may represent a portion of the feed to the HLW immobilization process. References in Section 6.0 include: integrated Hanford Site waste management system studies, process facility options studies, process system studies and flowsheets, process and facility design requirements documents, policy type documents, and miscellaneous supporting documents.

A large fraction of available data has been developed using non-radioactive simulants intended to mimic the behavior and properties of actual waste. The reader needs to be aware that the simulants do not always accurately mimic actual waste properties and behavior.

3.0 TANK WASTE COMPOSITION, QUANTITY, AND SLUDGE PRETREATMENT

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Anderson, J. D., 1990, *A History of the 200 Area Tank Farms*, WHC-MR-0132, Westinghouse Hanford Company, Richland, Washington.

Certa, P. J., 1995, *Preliminary Retrieval Sequence and Blending Strategy*, WHC-SD-WM-RPT-167, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Notes: Evaluates effects of alternate Hanford Site tank waste retrieval and blending scenarios, including effect on estimated achievable volume of HLW glass produced.

Colton, N. G., 1995, *Sludge Pretreatment Chemistry Evaluation: Enhanced Sludge Washing Separation Factors*, PNL-10512, Pacific Northwest Laboratory, Richland, Washington.

Notes: Review of FY 1994 test data on pretreatment of Hanford Site tank waste solids samples.

Geeting, J. G. H., and D. E. Kurath, 1993, *Preliminary Assessment of Blending Hanford Tank Wastes*, PNL-8589, Pacific Northwest Laboratory, Richland, Washington.

Hanlon, B. M., 1994, *Tank Farm Surveillance and Waste Status Summary Report for October 1993*, WHC-EP-0182-67, Westinghouse Hanford Company, Richland, Washington.

Notes: Provides a summary of current Hanford Site double-shell tank (DST) and SST waste volume estimates by tank in categories of supernate, sludge, salt cake, and drainable liquid.

Hara, F. T., J. H. Kaye, R. T. Steele, R. W. Stromalt, D. L. Thoman, and M. W. Urie, 1990, *SST Sample Characterization Analysis of Archive Samples 102-C, 105-C, and 106-C*, PNL-7258, Pacific Northwest Laboratories, Richland, Washington.

Notes: Report of chemical and radioisotope analyses of a waste sample from waste tanks including 241-C-106. The sample is from the same core as the Weiss report and the McCown report, however, the exact history of the sample is not determined. Some additional unpublished data are available on this sample analysis.

Hill, J. G., and B. C. Simpson, 1994, *The Sort on Radioactive Waste Type Model: A Method to Sort Single-Shell Tanks into Characteristic Groups*, PNL-9814, Pacific Northwest Laboratory, Richland, Washington.

Hodgson, K. M. and T. T. Tran, 1995, *Tank Characterization Report for Double-Shell Tank 241-AZ-101, WHC-SD-WM-ER-410*, Rev. 0-A, Westinghouse Hanford Company.

Jungfleisch, F. M., 1984, *TRAC: A Preliminary Estimation of the Waste Inventories in Hanford Tanks Through 1980*, SD-WM-TI-057, Rockwell Hanford Operations, Richland, Washington.

Lambert, S. L., and D. S. Kim, 1994, *Tank Waste Remediation System High-Level Waste Feed Processability Assessment Report*, WHC-SP-1143, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Notes: Study evaluates effect of feed composition on performance of the HLW vitrification process, primarily focussing on glass quantity. Includes evaluation of effect of feed blending and melter temperature on glass quantity.

Lumetta, G. J., M. J. Wagner, R. J. Barrington, B. M. Rapko, and C. D. Carlson, 1994, *Sludge Treatment and Extraction Technology Development: Results of FY 1993 Studies*, PNL-9387, Pacific Northwest Laboratory, Richland, Washington.

Manuel, A. F., J. D. Galbraith, S. L. Lambert, and G. E. Stegen, 1996 *Phase 1 High-Level Waste Pretreatment and Feed Staging Plan*, WHC-SD-WM-ES-370, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Peterson, M. E., R. D. Sheele, and J. M. Tingey, 1989, *Characterization of the First Core Sample of Neutralized Current Acid Waste from Double-Shell Tank 101-AZ*, PNL-7758, Pacific Northwest Laboratory, Richland, Washington.

Notes: Report of analysis of a core sample of sludge from tank 241-AZ-101 taken in 1989. Report includes chemical composition, radioisotope composition, physical properties, rheology, solids settling rates. Results of water washing the sludge are also reported.

Rapko, B. M., G. J. Lumetta, and M. J. Wagner, 1995, *Washing and Caustic Leaching of Hanford Tank Sludges: Results of FY 1995 Studies*, PNL-10712, Pacific Northwest National Laboratory, Richland, Washington.

Notes: Report the results of water washing and caustic digestion tests on a number of different types of tank waste sludges. Includes chemical and radiochemical analyses on the sludges and leach or wash solutions.

Ryan, G. W. and T. T. Tran, 1995, *Tank Characterization Report for Double-Shell Tank 241-AZ-102*, WHC-SD-WM-ER-411, Rev. 0-A, Westinghouse Hanford Company, Richland, Washington.

Ryan, G. W., 1995, *Tank Characterization Report for Double-Shell Tank 241-AY-102*, WHC-SD-WM-ER-454, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Weiss, R. L. and K. E. Schull, 1991, *Data Transmittal Package for 241-C-106 Waste Tank Characterization*, WHC-SD-RE-TI-205, Rev. 0, 1988, modified by ECN 164206, September 28, 1991, approved for Public Release August 11, 1992, Westinghouse Hanford Company, Richland, Washington.

Notes: Contains information on core sampling of Tank 241-C-106 performed in 1986, physical description of core sample material, and results of laboratory analysis of a blended composite of the core sample. Additional analysis on the same core sample are reported in PNL-7258 (Hara et al. 1990).

WHC, 1995a, *Historical Tank Waste Content Estimate for the Southeast Quadrant of the Hanford 200 West Area*, WHC-SD-WM-ER-350, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995b, *Historical Tank Waste Content Estimate for the Northwest Quadrant of the Hanford 200 West Area*, WHC-SD-WM-ER-351, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995c, *Historical Tank Waste Content Estimate for the Southeast Quadrant of the Hanford 200 East Area*, WHC-SD-WM-ER-352, Rev. 0-A, Westinghouse Hanford Company, Richland, Washington.

WHC, 1995d, *Historical Tank Waste Content Estimate for the Northeast Quadrant of the Hanford 200 West Area*, WHC-SD-WM-ER-349, Rev. 0-A, Westinghouse Hanford Company, Richland, Washington.

4.0 IMMOBILIZATION PROCESS, SUPERNATE PRETREATMENT PROCESS, AND IMMOBILIZED PRODUCT BEHAVIOR REFERENCES

Andrews, M. K. and N. E. Bibler, 1992, *Radioactive Demonstration of DWPF Product Control Strategy*, Ceramic Transactions, Vol. 39, pp. 205-211, American Ceramic Society, Westerville, Ohio.

Notes: Summary of the results of glass production from washed tank 51 waste. About 31 kg of glass was produced from 10 kg (dry basis) actual tank sludge. Paper gives chemical composition, and Product Consistency Test durability results and also gives information on use of the Product Composition Control System models to formulate feed.

Andrews, M. K., et al., 1991, *Initial Demonstration of the DWPF Vitrification Process and Product Control Strategy Using Actual Radioactive Waste*, Nuclear Waste Management IV, pp. 569-576, American Ceramic Society, Westerville, Ohio.

Notes: 25 kg of glass was made from 12.5 kg actual radioactive waste sludge from tanks 8 and 12 using an 8-in. diameter by 6-in. deep Joule heated melter at 1150 °C. Predicted and measured composition and PCT leach rate data are presented, measured leach rate was 2 to 3 times the predicted values based on the prediction model in use at that time, a trace (<1 percent) of spinel crystals were also detected in the glass.

Barnes, S. M., 1980, *High-Temperature Vitrification of Hanford Residual-Liquid Waste in a Continuous Melter*, PNL-3343, Pacific Northwest Laboratory, Richland, Washington.

Notes: Testing with a high temperature melter with tin oxide electrodes, high sodium feed, 1250 to 1300 °C operating temperature, measured cesium loss to offgas (<1 percent).

Barnes, S. M., and D. E. Larson, 1981, *Materials and Design Experience in a Slurry-Fed Electric Glass Melter*, PNL-3959, Pacific Northwest Laboratory, Richland, Washington.

Bibler, N. E., 1983, *Characterization of Borosilicate Glass Containing Savannah River Plant Radioactive Waste. II. Microstructure and Durability*, DP-MS-82-111, Savannah River Laboratory, Aiken, South Carolina.

Bickford, D. F., and C. M. Jantzen, 1986, "Devitrification of Defense Nuclear Waste Glasses: Role of Insolubles," *Journal of Non-Crystalline Solids*, Vol. 84, No. 1-3, pp. 299-307.

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Notes: Discusses redox effects in glass melting, formation and precipitation of nickel sulfide including estimated oxygen potential at point of incipient sulfide formation and corresponding H2/H2O and CO/CO2 and Fe+2/Fe+3 ratios, concludes reasonable limit is to keep pO2 > E-8 and Fe+2/Fe+3 < 1.

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Blair, H. T., and J. M. Luckacs, 1980, *Investigating of Foaming During Nuclear Defense-Waste Solidification by Electric Melting*, PNL-3552, Pacific Northwest Laboratory, Richland, Washington.

Bradley, D. J., 1991, *Radioactive Waste Management in the USSR: A Review of Unclassified Sources*, Vol. II, PNL-7645, Pacific Northwest Laboratory, Richland, Washington.

Bunnel, L. R., 1988, *Laboratory Work in Support of West Valley Glass Development*, PNL-6539, Pacific Northwest Laboratory, Richland, Washington.

Notes: This report describes results of melter and glass testing for the WVDP. Provides information on glass product durability, glass melt foaming and the effect of sugar addition on foaming. Includes foam measurement in crucible melts using a variable pressure technique. Data indicates sugar addition has a negative effect on glass melting rate. Report includes some discussion of redox measurement methods and formation of secondary phases in the melt (calcium phosphate, rare earth phosphates, CrFe spinels, etc. Data indicates the phosphorus solubility limit in glass varies with concentration of calcium, rare earths, and possibly other components.

Burkholder, H. C., and J. H. Jarrett, 1986, *Nuclear Waste Treatment Program Annual Report for FY 1985*, PNL-5787, Rev. 0, Pacific Northwest Laboratory, Richland, Washington.

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Calmus, R. B., 1995, *High-Level Waste Melter Alternatives Assessment Report*, WHC-EP-0847, Westinghouse Hanford Company, Richland, Washington.

Chapman, C. C., 1983, *Comparison of the Rotary Calciner-Metallic Melter and the Slurry-Fed Ceramic Melter Technologies for Vitrifying West Valley High-Level Wastes*, DOE/NE/44139-6 (DOE86010532), West Valley Nuclear Services Company, West Valley, New York.

Chick, L. A., J. L. Swanson, and D. S. Goldman, 1984, "Nuclear Waste Glass Composition Limitations," *Proceedings of Fuel Reprocessing and Waste Management*, Vol. 1, pp. 371-385, American Nuclear Society, Inc., LaGrange Park, Illinois.

Cooper, M. F., M. L. Elliott, L. L. Eyler, C. J. Freeman, J. J. Higginson, L. A. Mahoney, and M. R. Powell, 1994, *Research-Scale Melter Test Report*, PNL-9428, Pacific Northwest Laboratory, Richland, Washington.

Crow, K. R., A. F. Weisman, P. D. Guidotti, A. M. Wehner, and G. A. Griffin, 1987, *Summary of Campaigns SGM-4 and SGM-5 of the Defense Waste Processing Facility Scale Glass Melter*, DPST-87-247, Savannah River Laboratory, Aiken, South Carolina.

Dierks, R. D., 1980, *Investigation of Corrosion Experience in a Spray Calciner/Ceramic Melter Vitrification System*, PNL-3406, Pacific Northwest Laboratory, Richland, Washington.

DOE, 1981, *The Evaluation and Review of Alternative Waste Forms for Immobilization of High-Level Radioactive Waste*, DOE/TIC-11472, U.S. Department of Energy-Office of Nuclear Waste Management, Germantown, Maryland.

DOE, 1990, *Evaluation and Selection of Borosilicate Glass as the Waste Form for Hanford High-Level Radioactive Waste*, DOE/RL-90-27, Rev. 1, U.S. Department of Energy Project Technical Support Office, Washington, D.C.

DOE, 1994, *High-Level Waste Borosilicate Glass A Compendium of Corrosion Characteristics*, Volumes 1, 2 and 3, DOE-EM-0177, U. S. Department of Energy, Office of Waste Management, Washington D. C.

Eaton, W. C., 1995a, *Test Plan: Phase I Hanford LLW Melter Tests, GTS Duratek, Inc.*, WHC-SD-WM-VI-020, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Eaton, W. C., 1995b, *Test Plan: Phase I Demonstration of 3 Phase Electric Arch Melting Furnace Technology for Vitrifying High-Sodium Content Low-Level Radioactive Liquid Wastes*, WHC-SD-WM-VI-021, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Eaton, W. C., 1995c, *GTS Duratek, Phase I Hanford Low-Level Waste Melter Tests: Final Report*, WHC-SD-WM-VI-027, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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Elliott, M. L., L. L. Eyler, L. A. Mahoney, M. F. Cooper, L. D. Whitney, and P. J. Shafer, 1994, *Preliminary Melter Performance Assessment Report*, PNL-9822, Pacific Northwest Laboratory, Richland, Washington.

Elmore, M. R., and G. A. Jensen, 1991, *Materials Selection for Process Equipment in the Hanford Waste Vitrification Plant*, PNL-7729, Pacific Northwest Laboratory, Richland, Washington.

Goldman, D. S., and D. W. Brite, 1986, "Redox Characterization of Simulated Nuclear Waste Glass," *Journal of the American Ceramic Society*, Volume 69 No. 5, May 1986.

Notes: Provides data on Fe+2/Fe+3 on simulated HLW borosilicate glass melts as a function of temperature and oxygen pressure, data for commercial alkali borosilicate glasses is also provided for comparison.

Goldman, D. S., D. W. Brite, and W. C. Richey, 1986, "Investigation of Foaming in Liquid Fed Melting of Simulated Nuclear Waste Glass" *Journal of the American Ceramic Society*, Volume 69 No. 5 pp 413-417.

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Goles, R. W., and C. M. Anderson, 1986, "LFCM Emission and Off-Gas System Performance for Feed Component Cesium," *American Nuclear Society Meeting-Spectrum '86*, Richland, Washington.

Goles, R. W., and R. K. Nakaoka, 1990, *Hanford Waste Vitrification Program Pilot-Scale Ceramic Melter Test 23*, PNL-7142, Pacific Northwest Laboratory, Richland, Washington.

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Guidotti, P. D., K. R. Crow, A. F. Weisman, M. R. Baron, and A. M. Wehner, 1987, *Summary of Campaigns SGM-6 and SGM-7 of the DWPF Scale Glass Melter*, DPST-87-532, Savannah River Laboratory, Aiken, South Carolina.

Notes: Describes results of two test runs with the Scale Glass Melter (about 0.4 scale with full scale melter feed and glass pour mechanical features). Besides basic melter operating performance, report includes significant information on the glass pour system, melter feed system, pump and valve performance in slurry service, and melter offgas.

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Notes: Reports results of rheology testing on actual waste from three tanks and also for three simulants. Yield stress and consistency versus suspended solids content is given based on a Bingham plastic model. The high aluminum waste and simulant are found to have much higher yield stress. Tanks 15 and 42 Yield stress ranged up to 260 dyne/cm2 at 14 wt% insoluble solids with a rapid increase above about 10 wt%. Tank 8F ranged up to 350 dyne/cm2 at 30 wt% insoluble solids with a rapid increase above about 20 wt%.

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Higley, B. A., 1995b, *Glass Melter System Technologies for Vitrification of High-Sodium-Content Low-Level Radioactive Liquid Wastes--Phase I: SBS Demonstration With Simulated Low-Level Waste--Final Test Report*, WHC-SD-WM-VI-024, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Hrma, P. R., and A. W. Bailey, 1995, "Waste Loading Maximization for Vitrified Hanford HLW Blend," *Proceedings of the Fifth International Conference on Radioactive Waste Management and Environmental Remediation*, American Society of Mechanical Engineers, New York, New York.

Hrma, P. R., and W. T. Cobb, 1991, *Behavior of RuO_2 in a Glass Melt*, PNL-SA-19544, Pacific Northwest Laboratory, Richland, Washington.

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Notes: Report summarizes results of test work performed by PNL from 1989 to 1994 on properties of 120 glass compositions that may be produced from Hanford Site HLW. Data correlations and models are presented together with statistical analysis of the data and models. Glass compositions studied were targeted for melters operating at approximately 1150 °C melting temperatures. Glass properties studied were primarily those related to processability in resistance electric heated melters, and those related to immobilized HLW product quality, i.e., Viscosity, electrical conductivity, crystal formation behavior, thermal expansion coefficient, and durability (leach rate).

Hutson, N. D., 1994, *Integrated DWPF Melter System (IDMS) Campaign Report: Hanford Waste Vitrification Plant (HWVP) Process Demonstration*, WSRC-TR-92-0403, Rev. 1, Westinghouse Savannah River Company, Savannah River Technology Center, Aiken, South Carolina.

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[1]Inconel and Inconel 690 are trademarks of International Nickel Company.

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5.0 SEPARATION OF RADIONUCLIDES FROM LIQUID TANK WASTES

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[2]SuperLig 644 is a registered trademark of ICB Technologies, Inc., Provo, Utah.

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Notes: This report provides technetium batch distribution coefficients, laboratory scale breakthrough and elution profiles for partitioning from synthetic and actual Hanford Site wastes.

6.0 INTEGRATED SYSTEMS STUDIES, FLOWSHEETS, AND MISCELLANEOUS SUPPORTING DOCUMENTS

Boomer, K. D., S. K. Baker, A. L. Boldt, J. D. Galbraith, J. S. Garfield, C. E. Golberg, B. A. Higley, L. J. Johnson, M. J. Kupfer, R. M. Marusich, R. J. Parazin, A. N. Praga, G. W. Reddick, J. A. Reddick, E. J. Slaathaug, L. M. Swanson, T. L. Waldo, and C. E. Worcester, 1993, *Tank Waste Technical Options Report*, WHC-EP-0616, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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Notes: This report provides a summary of an engineering study to evaluate feasibility of substantial increasing capacity of HWVP with minimal design impacts to the fixed facility. This report indicates capacity increase up to about four times the baseline capacity can likely be achieved through use of advanced melters. Limited changes were identified to the remote process building and more extensive changes to external support facilities were identified to allow the required capacity increase.

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