**Westinghouse
Hanford Company**

**Internal
Memo**

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Date: February 9, 1995
Subject: TANK WASTE REMEDIATION SYSTEM HIGH-LEVEL WASTE VITRIFICATION
SYSTEM DEVELOPMENT AND TESTING STRATEGY DOCUMENT WHC-SD-WM-SD-020
REVISION 0

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Attached is the Tank Waste Remediation System High-Level Waste Vitrification System Development and Testing Strategy document, WHC-SD-WM-SD-020, Revision 0. Transmittal of this approved document completes performance of Key Milestone Control No. T3C-95-161, "Issue Final Vitrification System Development Strategy".

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Attachment

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7. Abstract

This document provides the general strategy for developing and testing the performance of candidate high-level waste melter systems and establishing the basis for selecting the preferred melter system for the high-level waste vitrification plant.

8. RELEASE STAMP

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TANK WASTE REMEDIATION SYSTEM HIGH-LEVEL WASTE VITRIFICATION SYSTEM DEVELOPMENT AND TESTING STRATEGY

1.0 INTRODUCTION AND BACKGROUND

A Tank Waste Remediation System (TWRS) High-Level Waste (HLW) Program (hereafter called HLW Program) melter assessment activity was initiated in fiscal year (FY) 1994 to develop a recommendation of the most viable vitrification technologies for immobilization of Hanford Site HLW. The assessment was performed during two workshops, which were attended by Hanford Site technical staff and external experts. The external, non-Hanford Site participants included a Technical Advisory Committee (TAC), consisting of experts from U.S. Department of Energy (DOE) vitrification sites, academia, and commercial glass-making industry. Other participants included technical expert staff with broad-based melter system expertise in HLW vitrification and specific expertise in the candidate vitrification technologies.

During the first workshop, participants used general evaluation criteria to assess 15 potential vitrification technologies. Six technologies were selected for further detailed assessment. During the second workshop, participants used more detailed evaluation criteria to assess the remaining technologies. The assessment culminated in a recommendation of two vitrification technologies and specific technology features/variations that could provide significant benefits relative to total life-cycle cost or system performance. These technologies were also considered to have a high probability of being successfully developed within HLW Program constraints. These constraints include cost, schedule, and the programmatic risk of pursuing immature technologies or technologies with significant, fundamental, unresolved technical issues.

Westinghouse Hanford Company (WHC) used the TAC recommendation to develop a recommendation (Honeyman 1994) to the U.S. Department of Energy, Richland Operations Office regarding the direction of the HLW Program's melter testing program leading to HLW vitrification plant melter selection. The WHC recommendation was subsequently approved (Erickson 1994) and provides the basis for multi-year work planning of melter testing activities through FY 1998.

This strategy document provides the HLW vitrification melter system testing strategy that must be followed to implement the recommendation and meet the schedule commitments in the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1994). The overall strategy is based on general testing activities used to develop melter systems at the DOE Savannah River Site (for high-, low-, and mixed-waste immobilization) and other international melter system development programs for radioactive waste immobilization. The general approach is to test melter systems in a phased program. The smallest, most cost-effective test systems are needed in the initial phases to resolve key technical issues generally associated with process chemistry, process performance, feed processability, and glass product behavior with HLW feed simulants. In the later phases, large-scale test systems are needed to confirm small-scale test results and

demonstrate plant-scale performance and operability. In addition, testing with radioactive waste feeds is limited to small-scale system testing to develop the necessary correlation between HLW simulants and actual radioactive waste feeds relative to process chemistry and feed processability behavior, and glass product performance.

The key elements of the HLW vitrification melter system testing strategy are as follows.

- Establish the type, size, and extent of vitrification system testing necessary to select the HLW plant melter and confirm plant-scale system performance.
- Provide direction for development and testing (D&T) of new or modified melter system process and design features, which may provide significant benefits relative to plant life-cycle costs, ease of operation, system/component reliability, and overall system performance.
- Establish the type and extent of testing necessary to derive correlations between nonradioactive test simulants and actual HLW to validate projected performance of plant systems and products.
- Define HLW Program decision points, which allow for adjustments and refinements to the direction of vitrification system development activities and integration of test activity results with the balance-of-plant and process flowsheet studies.
- Establish testing activities and testing sequences within expected TWRS Program constraints, namely, cost, schedule, and technical risk.

These key elements are discussed in more detail in Section 3.0.

A TWRS HLW melter system testing requirements document will be prepared for FY 1995 test activities and updated periodically in accordance with selected HLW Program decision-making activities. The document will define specific D&T activities, expected test results, deliverables, and time phasing of key testing activities. The current HLW Program's baseline planning was established in April 1994 (RL 1994) and further delineated for FYs 1995 through 1997 in September 1994 (Jordan 1994). This baseline will be modified to implement the revised melter system testing strategy. This strategy document provides the basis for defining and implementing the necessary changes.

2.0 RECOMMENDED TECHNOLOGIES

The Hanford Site HLW Program is presently focusing on development of melter system technologies and features identified in the WHC melter testing recommendation (Honeyman 1994; Erickson 1994). This section describes the recommended vitrification systems to be tested.

2.1 CANDIDATE VITRIFICATION SYSTEMS

The two technologies selected for in-depth D&T are (1) the high-temperature (>1200 °C), ceramic-lined, joule-heated melter system (referred to as the HTCM); and (2) the high-frequency, cold-wall, induction-heated melter system, referred to as the cold-crucible melter (CCM). The low-temperature, ceramic-lined, joule-heated melter (referred to as the LTCM), which operates at 1150 °C, is currently the reference technology for the HLW Program. Westinghouse Hanford Company will continue to evaluate the feasibility of other (high-risk) melter technologies that could provide substantial benefit over the baseline technologies, but these evaluations will not be included in the scope of the present HLW Program's melter development activities.

The FY 1994 recommendation provides for testing of the HTCM and CCM based on the maturity of these technologies for HLW. The focus is on developing high-temperature operation, which allows for increased waste oxide loading and increased feed composition processing flexibility. Additional focus is on assessing the volatility effects caused by operating at higher temperatures and developing system features to increase glass processing rates, such as melt agitation and melter configurations, which allow for remediation of accumulated sludge.

2.1.1 LTCM

The LTCM is the reference technology for HLW immobilization based on the significant domestic and international experience with this technology for vitrification of HLW. Limited testing may be necessary to bridge between the extensive testing base that already exists for the LTCM and new data being generated for the HTCM. Additional testing might be required to evaluate the broad range of HLW feed compositions and the performance of scaled plant systems and melter or system enhancement features. The development of this technology could be enhanced by evaluating materials and integrated system performance with double-/single-shell tank waste types, and by verifying full-scale performance based on pilot- or larger-scale system tests.

2.1.2 HTCM

Development of the HTCM could produce significant cost benefits. High-temperature operations may provide higher waste oxide loading leading to a substantial reduction in the volume of glass or number of glass canisters for permanent disposal in a geologic repository. This decrease in glass volume is expected to produce significant cost savings primarily from a commensurate

decrease in plant operational and HLW disposal costs. To confirm the feasibility of high-temperature operation, high-temperature electrode and refractory materials must be tested to demonstrate acceptable performance under realistic operating conditions. In addition, the impact of high-temperature operation, such as the impact of melter offgas rates and amount of volatiles, must also be assessed. Therefore, the near-term development of the HTCMT will focus on (1) assessing the feasibility of operation with high-temperature materials in contact with molten glass, and (2) characterizing the technical issues associated with high-temperature operation with Hanford Site HLW feed types. Emphasis will be placed on determining the type and scale of testing required to adequately resolve identified issues, especially those which may require large-scale testing.

2.1.3 CCM

Cold-crucible melter technology is the recommended backup technology for HLW melter system D&T. This technology is considered to involve higher technical risk than HTCMTs, based on the relative immaturity of this technology for Hanford Site HLW feed types. The CCM technology has the significant benefit of high operating temperatures (up to 1550 °C) coupled with limited melter materials concerns because electrode materials are absent and because the melter operates in a cold-wall environment where a layer of frozen glass protects the melter wall. Initial development of the CCM technology will focus on (1) obtaining data from pilot-scale tests (15 to 30 kg/h of glass) to determine the feasibility of integrated feed drying and melter system operation with Hanford Site simulated HLW feed types, and (2) conducting tests that may be required to establish the basis for predicting plant-scale system performance.

2.1.4 Metal Pot Stirred Melter (SM)

The metal pot SM is a derivative of the joule-heated melter. Unlike the ceramic-lined melters, which rely on stationary electrodes to heat the melt, the SM technology provides heating by passing a current between an Inconel* agitator assembly and an Inconel melter pot. This technology is limited by the use of Inconel as the electrode material to a low-temperature range of operation (1050 to 1100 °C).

The temperature limitation of SM technology reduces the flexibility of the system to process a wide range of Hanford Site HLW feed compositions and may limit the waste oxide loading of the glass product. However, SM technology has the potential advantage of providing (1) high glass processing rates, (2) low propensity for sludge buildup, and (3) melter component disposal incentives due to its small, modular design. While this technology provides benefits in key areas, a lower priority was placed on the development of this technology because of the current temperature limitation and immature system development and performance testing with Hanford Site feed types. Limited laboratory- and bench-scale testing of the SM technology may be performed to characterize effects and potential benefits of agitation using

*Inconel is a trademark of International Nickel Company.

Hanford Site feeds; however, no significant development or testing of this technology will be pursued during the first phase of the HLW Program. The need and benefit of testing will be reconsidered after the performance of the HTCM is assessed during the first quarter of FY 1996.

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3.0 D&T STRATEGY

This section discusses the strategies for the following areas: progression from small- to large-scale testing (phased testing approach), radioactive testing and integration with melter system testing using nonradioactive simulants, and key program decision points and impacts on overall melter system testing strategy.

3.1 PHASED TESTING APPROACH

The HLW Program is separated into four testing phases. Phase I involves feasibility testing of the HTCM system technologies at laboratory (crucible size or 100 to 200 g of glass) and bench scale (1 to 15 kg/h) using the master blend waste feed simulant. Phase II provides for laboratory- and bench-scale testing of a wider range of feeds and operating conditions. Melter feed compositions will be defined by retrieval and blending scenarios being developed for the Hanford Site. Phase III includes testing of pilot-scale systems (15 to 80 kg/h) with limited laboratory- and bench-scale testing as required. Phase III overlaps Phase II primarily because of the long lead time required to establish pilot-scale test capabilities. Phase IV focuses on testing required to resolve issues related to scaleup of the plant reference system for definitive plant design. Phase IV may include continued pilot- or large-scale testing (200 kg/h to full scale) depending on a program decision to be made during FY 1996 regarding the size of the system necessary to resolve high-risk technical issues.

Figure 3-1 presents the general strategy for progressing from laboratory- to larger-scale testing to support the selection of the reference melter system for the plant. Figure 3-1 also includes melter assessment activities and key decision-making activities. Results of the vitrification system D&T activities will be coupled with planned engineering trade studies and melter system feature evaluations to provide the basis for periodic assessment of the HLW melters and key decision points. The activities to be performed in the testing phases are addressed in the following paragraphs and are discussed by the type of tests involved or the evaluations that will be performed.

Phase I

- Laboratory- and bench-scale melters will be installed and tested in FY 1995 for the high-temperature technologies, namely the HTCM and CCM technologies. These tests will be used to determine (1) the technologies to be carried forward for larger-scale testing, and (2) the implementation strategy for pilot-scale integrated system design and system component testing.
- Evaluations will be performed on melter-specific and supporting equipment features for candidate technologies. During these evaluations, technical surveys will be performed and technical options will be evaluated. In addition, recommendations will be made relative to types of equipment, scale of testing, equipment operation, test facilities, and configurations for implementation.

Figure 3-1. High-Level Waste Melter System Development and Testing Assessment and Decision-Making Activities.

The evaluations will study melter systems with features that offer significant benefits if developed and implemented. Viable options must have a high probability of being developed within TWRs Program constraints. Key features to be evaluated are melter feed drying technologies to improve waste processing capacity; alternate melter/offgas system designs to reduce offgas rate/volume, system size, and complexity; and alternate melter designs for mitigation of refractory sludge buildup within the melter cavity.

- Melter modeling capabilities for the joule-heated, ceramic-lined melter systems will be assessed.

Phase II

- Laboratory- and bench-scale testing will continue through Phase II to obtain process chemistry data for a wide range of potential Hanford Site feed types and to assess the performance of certain enhancement features (feed drying, alternative offgas systems/melter designs). This testing will also provide support data for pilot-scale tests and property data for melter modeling, primarily to define scaleup factors for prediction of plant-scale system performance.
- Modeling of the joule-heated, ceramic-lined melter systems will be initiated. This modeling will only be initiated if modeling capabilities are determined (in Phase I) to be adequately sophisticated to provide reasonable basis for assessing the performance of the large-scale system.

Modeling of the CCM process will be initiated to provide information for larger-scale integrated system design and to characterize the behavior and capacity of the CCM system. Modeling activities for the baseline HLW Program technologies will receive more emphasis in Phase III to correlate small- and large-scale test results and to provide the basis for more quantitative prediction of large- and/or plant-scale systems and components.

Phase III

- Phase III testing activities will focus on testing of pilot-scale system(s), supporting systems, and associated melter components to resolve key equipment and process issues and to identify any new issues that may affect system performance and scaleup. Limited laboratory- and bench-scale testing will be performed to support pilot-scale testing and to further define composition limits for the candidate melter technologies. Current planning includes testing of two pilot-scale melter systems. The pilot-scale system for the HTCM technology will be Pacific Northwest Laboratory's (PNL) operational HTCM test system. It is expected that a pilot- or large-scale system will be needed to evaluate CCM technology. In addition to PNL's HTCM system, other available, high-temperature, ceramic-lined system designs will be assessed and an alternate system tested, if necessary, to evaluate the impact of different designs on HTCM system performance.

Phase IV

- Phase IV testing activities will focus on pilot- or large-scale system testing and independent feature testing to assess system operating and performance limits, confirm laboratory- and bench-scale test data with process-limiting feed types, provide data for predicting plant operation and performance, confirm materials performance, provide data to establish predictions of plant-scale system performance, and identify any key issues associated with plant scaleup.

The planning basis assumes that only one large-scale system, the system selected as the reference plant melter system during Phase III, will be tested. The need for large-scale testing, specific system size and configuration, and type and duration of testing required will be determined based on the results of Phase II and III testing activities. If it is determined that large-scale testing is unnecessary to resolve key technical issues, or that resources are unavailable to support this scale of effort, pilot-scale tests will be continued, as necessary, with existing or modified test equipment.

3.2 MELTER SYSTEM TESTING

Historically, melter system D&T activities have progressed from small- to large-scale tests, as successfully demonstrated by the DOE's Savannah River Site. For the Hanford Site HLW vitrification plant, this progression will proceed primarily from laboratory scale (crucible size, 100 to 200 g) to bench scale (1 and 15 kg/h) to pilot scale (15 to 80 kg/h) to large scale (expected to be from 200 kg/h to full scale). The Hanford Site HLW vitrification plant will require a glass production capacity between 400 and 800 kg/h.

Laboratory- and bench-scale testing generally focuses on materials or process chemistry and effects of changes in variables over a relatively wide range and is generally performed throughout the HLW Program. Pilot- and large-scale testing typically investigates scaleup considerations and identifies process- and equipment-related problems. Because the capital and operating costs escalate with an increase in size, large-scale tests are generally used only to verify scaleup of laboratory-/bench-scale results for a limited number of conditions. These development stages are incorporated into the HLW Program melter development strategy for the baseline technologies using nonradioactive feed simulants.

Existing test systems and equipment will be used when available and/or practical. For example, emphasis will be placed on operating the existing bench- and pilot-scale high-temperature (up to 1550 °C) HTCMTs developed by PNL for the Hanford Site. These systems will be operated to resolve system feasibility issues generic to this and similar melter technologies. Melter systems at other locations may also warrant testing if significant benefits can be realized from alternative system designs.

Vitrification system components and features will be evaluated as part of the melter system assessment task. Respective evaluations will include

recommendations regarding the most appropriate test scale, test conditions, and requirements. For components and features for which full-scale performance can be predicted from bench- and pilot-scale testing, an effort will be made to incorporate these features into integrated melter test systems. However, vendor testing may be performed in lieu of integrated system testing or before installation if a cost and schedule benefit is apparent.

Melter feed drying technologies will be assessed for the HTCM and CCM technologies. For the CCM technology, testing of the recommended drying technology (e.g., horizontal wiped film evaporators or inclined rotary calciner systems) may require pilot-scale confirmation testing. An assessment will be conducted to determine whether drying equipment can be tested at the vendor facility or as part of an integrated melter system. If an integrated system test is needed, a pilot-scale CCM system may be designed to include the equipment or the equipment may be retrofitted to an existing CCM pilot-scale system and the equipment tested during scheduled integrated system performance testing.

Where costly or extensive large- or full-scale system testing is required, considerable emphasis will be placed on performing independent tests of components or features. It is expected that large-scale integrated system testing will only be required if there are high-risk melter performance issues that must be resolved. If large-scale testing is necessary, individual component feature testing will be assessed for cost versus risk reduction on a case-by-case basis.

3.3 RADIOACTIVE TESTING

The overall logic of the melter D&T activities is to confirm that laboratory-, bench-, pilot-, and large-scale tests performed with nonradioactive HLW simulants can be used to predict the performance characteristics of the full-scale plant. Once this is demonstrated, the range of HLW feed compositions need only be tested on small scale to predict plant system performance. The validity of using information from nonradioactive simulant testing will be established by comparing the performance of laboratory- and bench-scale tests conducted with actual waste to the same scale tests performed with nonradioactive simulants. Given these comparisons, small-scale tests with actual waste can then be extrapolated with reasonable confidence to the full-scale HLW vitrification plant.

Testing with radioactive feeds is performed on small scale primarily because such tests are extremely expensive and require extensive facility support. Laboratory- and bench-scale radioactive testing of baseline TWRS HLW melter system technologies with Hanford Site HLW feed is expected to yield good correlation to plant-scale system performance, relative to process chemistry, melting, and product performance behavior. In addition, this testing will highlight differences between simulants and actual waste process and product performance, which may lead to refinement of nonradioactive feed simulants for large-scale testing.

The expectation that reasonable correlations will be established for the HLW baseline technologies is based on experience with laboratory- and bench-

scale (1 kg/h) tests with radioactive HLW feeds and pilot-scale tests with nonradioactive simulants performed in support of the Defense Waste Processing Facility and Hanford Waste Vitrification Plant projects. The TWRS HLW D&T strategy is to conduct laboratory- and bench-scale melter system tests with pretreated radioactive tank waste. These results will be correlated with simulant tests performed at the same scale using similar test systems. The specific melter size required for bench-scale testing will be determined after the reference HLW vitrification plant melter system is selected in FY 1997. However, scoping studies that evaluate bench-scale testing needs and possible options for scale system tests will be estimated starting in FY 1995. These studies will support the development of an integrated testing strategy and a facility planning strategy for radioactive wastes. Sizing of the bench-scale system will primarily depend on tank sampling and retrieval capabilities, results of laboratory-scale tests with simulants, perceived impact of technical issues, radioactive facility availability, and cost/schedule impacts.

Radioactive pilot- or larger-scale system or component tests should not be necessary for the prediction of system performance capabilities, or to confirm glass property models and glass product performance characteristics. Once it is established that the nonradioactive simulant is representative of actual tank waste at crucible and bench scale, scaling factors and overall plant system performance could be predicted from large-scale simulant tests. Plans have not been made to accommodate pilot-scale radioactive system testing for the plant reference melter technology. If testing of this scale is determined to be necessary, a radioactive melter system (including remote operating features and feed availability) would most likely be unavailable until the scheduled plant detailed design is completed.

4.0 MELTER SELECTION DECISION POINTS

Selection of the HLW vitrification plant melter technology and key system features is scheduled for September 1998 (Tri-Party Agreement Milestone M-51-02). Two interim decision points are identified in the new HLW baseline program to allow for adjustments to melter system testing activities. These decision points were established to ensure that sufficient information is available to select an HLW vitrification plant melter system and meet the Tri-Party Agreement commitment.

The first decision point is at the end of calendar year 1995. This decision will assess FY 1995 melter system D&T results to determine whether testing of candidate HTCM system technologies should continue as scheduled, be eliminated, or be redirected. A determination will be made regarding overall feasibility and probability of successful development of high-temperature technologies within expected TWRS Program constraints. Melter system assessment and decision-making activities are presented in Figure 3-1. If either, or both, high-temperature technologies are determined to have unacceptable risk, the resource allocation will shift from development of high-temperature technologies to development and engineering testing of lower temperature technologies. The decision will consider extent of laboratory-, bench-, or pilot-scale integrated melter system testing needed to resolve key performance and design issues.

The second decision point, which is in mid-FY 1997, assesses small- (laboratory- and bench-scale) and large- (pilot-scale, integrated pilot-scale, and pilot- and large-scale feature) scale test results to determine which technology is best suited to be the primary and backup plant melter system technology. This decision will consider the need to continue pilot-scale testing of the primary and backup technologies and for large-scale testing of the primary reference technology to support conceptual and definitive plant design.

The configuration needed for melter system testing of radioactive wastes will be determined at the mid-FY 1997 decision point corresponding to selection of the preferred reference plant vitrification system. Detailed planning and implementation of radioactive bench-scale test system design, procurement, installation, and operation will be initiated after the FY 1997 decision and will be coordinated with other TWRS Program element (e.g., retrieval and pretreatment) activities.

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5.0 STRATEGY IMPLEMENTATION

Melter test results will be used in conjunction with melter system-related engineering and technology studies to reassess the melter system D&T approach at key decision points in the program. In addition, operating experience gained at the Savannah River Site and the West Valley Demonstration Project will be used to judge the operability of current designs. Outside experts will be sought, as necessary, from the commercial glass-making industry, academia, and internationally to independently review test plans, test results, and related material of intrinsic value. These periodic assessments will guide future development of melter system technologies and melter system designs.

Development and testing requirements will be established to provide the basis of detailed work scope definitions. Detailed baseline planning will be performed by the identified responsible organizations. The Hanford Site's Research and Development (R&D) Contractor, PNL, will be responsible for R&D testing activities. The Hanford Site Management and Operations contractor, WHC, will be responsible for engineering and confirmation testing activities and oversight of R&D contractor work. For R&D and engineering testing activities, significant emphasis will be placed on performing tests at the lowest possible cost within TWRS Program schedule constraints. Alternative testing options will be evaluated in Phases I and II to provide more cost-effective and timely test results. Alternative tests may be performed, as required, at various DOE vitrification sites or by commercial or academic contractors.

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7.0 GLOSSARY

ABBREVIATIONS AND ACRONYMS

CCM	cold-crucible melter
CDR	conceptual design report
D&T	development and testing
DOE	U.S. Department of Energy
FY	fiscal year
HLW	high-level waste
HTCM	high-temperature, ceramic-lined melter
LTCM	low-temperature, ceramic-lined melter
MSA	melter system assessment
PNL	Pacific Northwest Laboratory
R&D	research and development
SM	stirred melter
TAC	Technical Advisory Committee
TPA	Tri-Party Agreement
TWRS	Tank Waste Remediation System
WHC	Westinghouse Hanford Company

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