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18. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 12. Enter the affected document number in Block 19.

SDD/DD	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
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Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
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Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
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None applicable.		

20. Approvals

Signature	Date	Signature	Date
OPERATIONS AND ENGINEERING		ARCHITECT-ENGINEER	
Cog. Eng. G. W. Reddick (signature)	5/10/95	PE	
Cog. Mgr. J. P. Sloughter (signature)	5/10/95	QA	
QA		Safety	
Safety		Design	
Environ.		Environ.	
Other		Other	
		DEPARTMENT OF ENERGY	
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1	1	Cog.Eng. G. W. Reddick	[signature]	5/8/95	H5-49	K. A. Gasper	[signature]		G3-21	1	/
1	/	Cog. Mgr. J. P. Sloughter	[signature]	5-8-95	H5-27	D. J. Washenfelder	[signature]		H5-27	1	/
		QA									
		Safety									
		Env.									

18.	19.	20.	21. DOE APPROVAL (if required)
G. W. Reddick [signature] 5/8/95 Signature of EDT Originator Date	J. O. Honeyman [signature] 2/9/95 Authorized Representative for Receiving Organization Date	J. P. Sloughter [signature] 5-5-95 Cognizant Manager Date	Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

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APPROVED FOR PUBLIC RELEASE

WHC Information Release Administration Specialist:

V.L. Birkland (signature) — May 10, 1995

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7. Abstract

This document provides a strategy for performing radioactive (hot) and nonradioactive testing to support processing tank waste. It evaluates the need for hot pilot plant(s) to support pretreatment and other processing functions and presents a strategy for performing hot test work. A strategy also is provided for nonradioactive process and equipment testing. The testing strategy supports design, construction, startup, and operation of Tank Waste Remediation System (TWRS) facilities.

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TESTING AND DEVELOPMENT STRATEGY FOR THE TANK WASTE REMEDIATION SYSTEM

May 1995

G. W. Reddick

Westinghouse Hanford Company
Richland, Washington

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LIST OF TERMS

CC	Complexant concentrate
CPU	Compact Processing Unit
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy - Richland Field Office
DQO	Data Quality Objectives
DSSF	Double-shell slurry feed
DST	Double-shell tank
DWPF	Defense Waste Processing Facility
FMEF	Fuels and Materials Examination Facility
FY	Fiscal Year
HLW	High-level waste
HWVP	Hanford Waste Vitrification Project
IPM	Initial Pretreatment Module
LANL	Los Alamos National Laboratory
LLW	Low-level waste
NCAW	Neutralized Current Acid Waste
PFP	Plutonium Finishing Plant
PNL	Pacific Northwest Laboratory
SAR	Safety Analysis Report
SRS	Savannah River Site
SST	Single-shell tank
THORP	Thermal oxide reprocessing plant
TRU	Transuranic
TRUEX	Transuranic extraction
TWRS	Tank Waste Remediation System
WESF	Waste Encapsulation and Storage Facility
WHC	Westinghouse Hanford Company

TESTING AND DEVELOPMENT STRATEGY FOR THE TANK WASTE REMEDIATION SYSTEM

1.0 INTRODUCTION

This document provides a strategy for performing radioactive (hot) and nonradioactive testing and related activities to support processing tank waste. The testing strategy confirms the process flowsheet and supports optimization of the flowsheet. The testing strategy supports permitting, safety and environmental assessments, design, construction, startup, and operation of Tank Waste Remediation System (TWRS) facilities.

The strategy for testing and development consists of a description of what testing needs to be done and why. The strategy also addresses when the test results are needed to support the schedule for the project and startup. When the tests must be done also affects where and how the tests may be done. Examples are given of existing facilities that provide testing capabilities to meet testing needs. The strategy builds on other studies and other ongoing work (Howden et al. 1994, Howden et al. 1995).

Section 3.0 discusses the background of tank waste disposal programs. Section 4.0 discusses the overall strategy of testing to support design and operation. Section 5.0 describes the proposed testing strategy. The appendixes contain additional background information and experiences at the Hanford Site and other sites.

The handling and disposal of cesium and strontium capsules is outside the scope of the strategy in this report.

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2.0 SUMMARY

The proposed testing strategy includes both radioactive and nonradioactive testing. The strategy is designed to meet testing and schedule requirements for design, startup, and operation. The smallest feasible scale of testing is used to resolve technical issues for each candidate technology. Tests with radioactive material and actual tank waste are used only when required because of the relatively high costs associated with radioactive testing.

The strategy consists of using existing laboratory and hot cell capabilities at the Hanford Site and other sites for radioactive testing. Laboratory and bench-scale hot tests are conducted as needed to confirm the process flowsheet and to support optimization of the flowsheet. Emphasis is placed on doing laboratory tests with actual tank waste to confirm the viability of the chemical processes. Hot tests are started on a small laboratory scale. Results from the laboratory tests are incorporated into the test plans (both the amount of testing and the scale) for additional hot testing.

Results from radioactive laboratory tests are used to define and provide data for each unit operation. Data are provided for permitting, safety and environmental assessments, design, construction, startup, and operation of TWRS facilities. Laboratory tests also supply the data needed to develop simulants for larger scale tests.

Radioactive bench-scale tests are used as required to develop the processes and define parameters for unit operations.

Some radioactive tests are conducted at a scale that could be called large bench-scale or pilot-scale. Specifically, testing of solids/liquid separation in a hot cell is needed to confirm equipment scaleup. No other pilot-scale hot tests were identified.

Nonradioactive testing is used to develop and test equipment and instrumentation. The nonradioactive tests are conducted on a laboratory, bench, and pilot-scale. Full-scale mockups of equipment are used to confirm design configurations. Vendor testing capability is used when available.

Simulants are used for both process and equipment tests. To do meaningful tests with simulants, the simulant properties must match the properties of interest in the actual tank waste.

Vendor tests are used to make preliminary melter selections. Melter tests with simulants in large-scale and near full-scale equipment are used as needed for final design of equipment. The size of the equipment used is dependent on melter selection and scaleup considerations. As with other programs, the smallest feasible scale is used to obtain data when radioactive testing is required.

Full-scale hot demonstrations are conducted in TWRS facilities before hot start of facilities and as part of startup activities. Demonstration of retrieval equipment and other in-tank processes are done before the start of general retrieval operations. Retrieval tests use actual tank waste since they are conducted in-tank. Tests in new facilities start with cold functional tests and lead to hot demonstrations and hot startup.

Laboratory and bench-scale radioactive testing can be conducted in existing facilities. Use of existing facilities is also instrumental in adding assurance that data will be available in a timely manner to meet design, construction, and startup schedules.

A cost benefit analyses of proposed testing scenarios confirms that the cost of expanding the scope of testing beyond the strategy proposed in this report, especially larger scale tests in new facilities, is not cost effective and does not substantially reduce startup risk.

The testing for TWRS is an ongoing process. The TWRS testing strategy is implemented by test implementation plans, such as the Test Implementation Plan for the Initial Pretreatment Module (IPM). The test implementation plans are periodically updated to reflect results from testing and to define test plans. Characterization and testing may raise additional questions that require additional testing to resolve. Characterization may resolve issues such as the need for technetium and transuranic (TRU) separation and eliminate or limit some testing requirements.

3.0 BACKGROUND

The tank waste disposal program was redefined in 1991 (Grygiel 1991). TWRS came into being in January 1992. The effects of these activities were the inclusion of single-shell tanks (SSTs) in the disposal programs and abandonment of B Plant as a processing facility. The redefinition program evolved into renegotiation of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1994) and a new agreement. The new Tri-Party Agreement resulted in the cancellation of the Hanford Waste Vitrification Project (HWVP) and the termination of grout disposal for LLW and an agreement to design, construct, and operate facilities to vitrify both LLW and HLW.

The TWRS technical strategy (Alumkal 1994a, Wodrich 1994) describes the activities to implement the new Tri-Party Agreement. The new technical strategy consists of solution, salt cake, and sludge retrieval, removal of cesium from solution and dissolved salt cake, and vitrification of the LLW. The sludge is washed to remove the soluble salts, combined with the separated cesium, and vitrified. These activities are shown schematically in Figure 3-1. Other pretreatment processes may be used to remove radionuclides and other constituents from the feed to LLW and HLW vitrification. These additional processes may be necessary if solids dissolution is used and produces feed with LLW characteristics. The shaded blocks in the diagram indicate technology development activities.

The schedule for the major TWRS activities is shown in Figure 3-2. Definitive design for the LLW pretreatment facility begins December 1996 (M-50-01-T02). The evaluation of enhanced sludge washing and the determination of the need for advance separations will be completed March 1998 (M-50-03). Construction of the LLW pretreatment facility starts November 1998 (M-50-01). Construction of the LLW pretreatment facility will be completed December 2003 (M-50-02-T01). Hot startup of the LLW pretreatment facility will be December 2004 (M-50-02).

The reference melter for the LLW vitrification is selected June 1996 (M-60-02). Construction of the LLW vitrification facility starts December 1997 (M-60-04). Construction of the LLW vitrification facility is completed December 2003 (M-60-05-T01). Hot startup of the LLW vitrification facility is June 5, 2005 (M-60-05).

The current baseline includes a HLW pretreatment facility for those sludge treatment processes not performed in-tank. Definitive design of the HLW pretreatment facility will be started in November 1998 (M-50-04-T02). Construction of the HLW pretreatment facility starts June 2001 (M-50-04-T03). The reference melter for HLW vitrification will be selected September 1998 (M-51-02). Definitive design for HLW vitrification facility is initiated November 1998 (M-51-03-T02). Construction of the HLW vitrification facility starts June 2002 (M-51-03-T03). Hot startup of the HLW pretreatment facility will be June 2008 (M-50-04). Hot startup of the HLW vitrification facility will be December 2009 (M-51-03).

Figure 3-1. Hanford Site Tank Waste Remediation System Strategy.

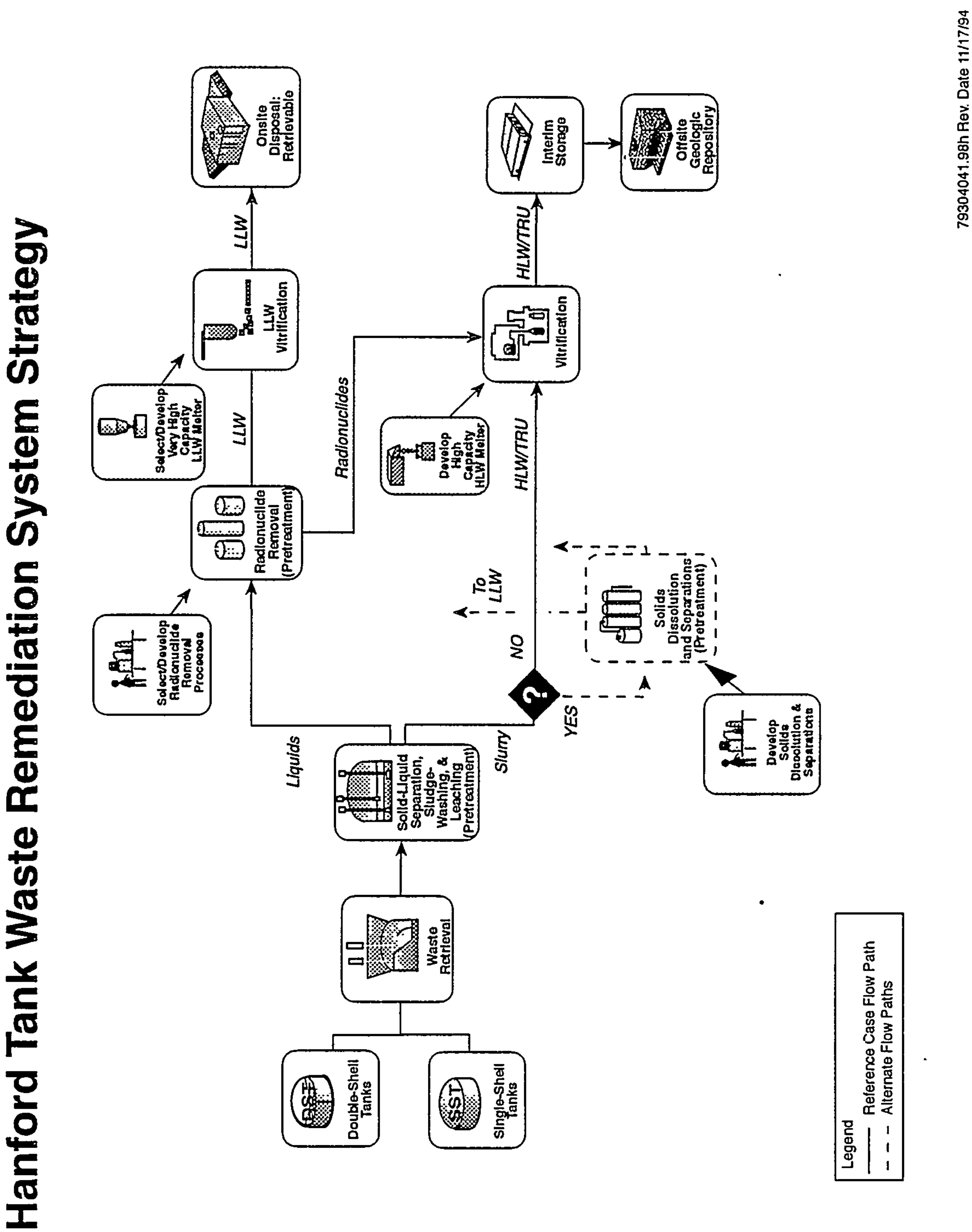
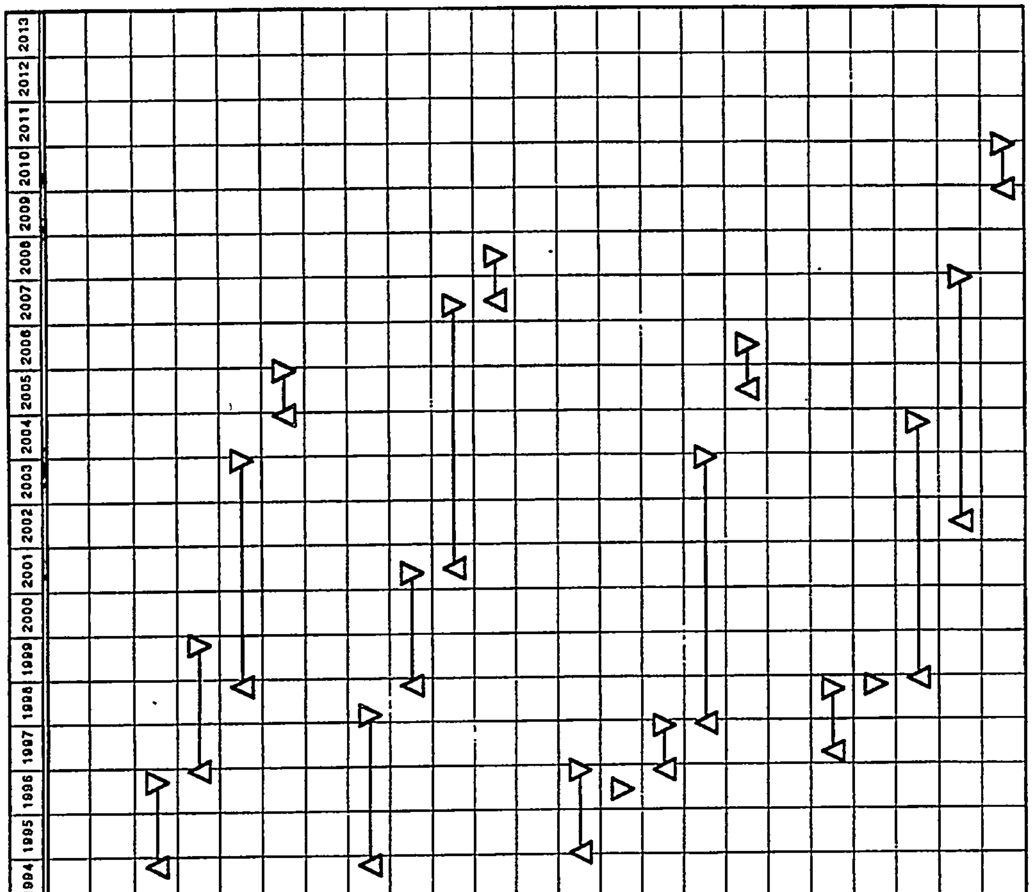


Figure 3-2. Schedule for Major Tank Waste Remediation System Activities.

MAJOR TANK WASTE REMEDIATION SYSTEM ACTIVITIES

04/04/95

Activities	Start Date	Finish Date
PRETREATMENT - LLW		
Conceptual Design	10/01/94	09/01/96
Definitive Design	12/01/96	10/01/99
Construction	11/01/98	12/01/03
Hot Startup	12/01/04	12/01/05
PRETREATMENT - HLW ADDITION		
Conceptual Design	10/01/94	03/01/98
Definitive Design	11/01/98	05/01/01
Construction	06/01/01	05/01/07
Hot Startup	06/01/07	06/01/08
LLW - VITRIFICATION		
Conceptual Design	01/01/95	11/01/96
Select Reference Melter		06/01/96
Definitive Design	11/01/96	11/01/97
Construction	12/01/97	12/01/03
Hot Startup	06/01/05	06/01/06
HLW - VITRIFICATION		
Conceptual Design	04/01/97	09/01/98
Select Reference Melter		09/30/98
Definitive Design	12/01/98	09/01/04
Construction	06/01/02	12/01/07
Hot Startup	12/01/09	12/01/10



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4.0 OVERALL STRATEGY OF DESIGN, OPERATION, AND TESTING

The overall strategy is to perform the tests that are needed to support permitting, environmental and safety assessments, design, construction, startup, and operation. The purpose of some of the earliest testing is to decide what processes to design into the plant. Hot testing is done when essential for process and product validation and when no reliable and suitable simulant is available. Hot testing may be necessary to identify the specific issues that testing is needed to resolve. The scale of hot testing is on the smallest scale possible to provide the needed data. Emphasis is placed on doing early hot tests to prove process viability. Nonradioactive simulants are used when feasible and when test objectives can be reasonably expected to be supported. This strategy matches historic Hanford Site successes and matches the general approach for other major facility starts.

Hot testing is required when process feeds cannot be reliably characterized and accurately simulated with cold chemicals (Place 1994). Simulants provide a means of finding process limitations and sensitivities. Hot testing is also used to confirm the results of tests with simulants. Two reasons for using simulants are (1) lack of availability of actual waste materials for testing and (2) cost. Supernatants (liquids) and salt cake are much easier to reliably characterize than sludges. Inorganic chemicals are typically easier to characterize than organic compounds. Cases where wastes cannot be effectively simulated include investigating effects of unknown minor constituents on newer high performance ion exchange resins. Simulation of the behavior of sludges and gels in solids/liquid separations equipment may not be effective. Retrieval and blending may change the characteristics of the waste. Minor constituents can have a large cumulative effect on the pretreatment processes and vitrification.

This overall strategy is consistent with the lessons learned at the Savannah River Site (SRS) with the Defense Waste Processing Facility (DWPF) (Schwallie 1993). The lessons learned from SRS include the following:

- Tank waste should be thoroughly characterized.
- The facility should be designed for maximum flexibility to handle future changes.
- Tests of equipment should be conducted with full-scale equipment or large-scale prototypes.
- Preparation should be made for the full range of tank waste compositions if blending may be precluded by tank space capabilities or process restrictions.
- Demonstrations should be used with actual tank waste where possible.
- The processes should be simplified where possible.

- Problems are expected to be uncovered during cold testing of the plant; that should be one of the testing purposes.

- Modifications to the plant should be expeditiously made by having methods to effectively and rapidly recover from uncovered problems.

Another suggestion expressed as a result of SRS experience is that development and verification testing to be judged sufficient must use actual waste.

Personnel used to perform pilot plant and development tests should be used to support the plant startup. This will be planned by using the plant engineers and operators to assist pilot plant and development activities. Startup engineers are stationed at the SRS to get hands on experience during the startup of those facilities. Support activities will be provided, such as waste handling and analytical support. The best available technologies will be used for process control and alarm management systems. The test program also will be geared to support the Safety Analysis Report (SAR) and other high-level design, safety, and operating documentation.

Testing emphasis will be placed on retrieval, pretreatment, and vitrification functions. LLW feed pretreatment consists of preparing solutions for disposal in LLW glass. The following are major parts of pretreatment:

1. Sludge washing/leaching
2. Solids/liquid separations
3. Blending
4. Cesium ion exchange.

Sludge washing consists of selective leaching of soluble constituents in the solids, such as aluminum, phosphate, and chromium, followed by washing of the leached solids. Concentrated and dilute caustic solutions are used for leaching. The solutions are fed to LLW pretreatment.

Solids/liquids separation provides the liquid to be processed by LLW pretreatment. Solids/liquid separation is required to prevent solids from plugging and coating process equipment designed for handling solutions. Particles can impact cesium ion exchange operations and on recycle streams. In addition, small particles may contain TRU elements that may result in exceeding the allowable TRU concentration in the LLW glass. Solids/liquid separation in the flowsheet (Orme 1994) for cesium ion exchange feed consists of two stages of settling in tanks. The solution is decanted and concentrated. The concentrated solution is filtered before being fed to the ion exchange column.

Solutions are blended as needed before ion exchange. Blending may be achieved as part of retrieval and sludge washing activities before reaching pretreatment facilities. Solutions may be blended after ion exchange to meet the feed requirements for LLW vitrification.

Ion exchange is used to remove cesium from the solutions. The separated cesium is concentrated and stored for blending with feed to HLW vitrification. The solution, depleted of cesium, is fed to LLW vitrification. If other radionuclides need to be removed from the solution (such as technetium or strontium), then processes will be included as necessary in the LLW pretreatment facility.

LLW vitrification receives pretreated solutions that are concentrated and melted with glass making material to produce a waste form suitable for onsite storage and disposal.

Concentrated cesium solutions are blended with solids to provide the feed to HLW vitrification. The HLW melter produces containers of glass for onsite storage and eventual repository disposal.

4.1 STARTUP AND OPERATION

All equipment and instrumentation will be thoroughly tested before and after installation in the pretreatment and vitrification facilities. Installation of the equipment and acceptance testing completes construction activities. Equipment and instrumentation will be thoroughly tested in the plant before hot startup. Operability testing will be conducted for all equipment. Simulants will be used for startup testing as required to test the functionality of equipment and instrumentation. The startup testing must be thorough and designed to resolve problems with equipment and instrumentation before going hot.

Cold and hot startup testing will be an integral part of qualifying the plant process as part of the waste form qualification.

Hot startup for each production facility will be conducted in a process testing/demonstration mode. A deliberately short campaign or series of campaigns will be thoroughly planned using predetermined feeds. A successful demonstration of the flowsheet and equipment results in continuing operations. The feed used for the startup of pretreatment is expected to be double-shell slurry feed (DSSF) or an equivalent material. This feed matches the desire for a predictable feed for startup and the values that supported the Tri-Party Agreement to have the emphasis placed on the early retrieval of the low-level fraction of the Hanford Site tank waste.

Eventually, the preparation of feed for the HLW vitrification system will begin. This operation will include blending a solution containing concentrated cesium and sludges. Hot startup for the HLW related processes uses the same approach as the earlier processes: process tests and process demonstrations. The HLW feeds are relatively well characterized since they are products or by-products of earlier cesium separation processes or sludge washing processes.

4.2 TESTING AND DEVELOPMENT

The amount of testing and development to support a project through startup and operation is determined by the needs of permitting, safety and environmental assessments, design, startup, and operation. Processes for each unit operation are validated as required by testing. The amount of testing needed is established through the close coordination of process engineers, designer, and technology developers. The amount of larger scale testing is determined by issues associated with process scaleup. Thorough testing will assure that the processes and equipment function as needed in the full-scale plant. The approach should be thorough when (1) technical needs are not well defined, (2) feed characteristics are not well understood, and (3) the capability of the processes is not well understood. Testing to support a flexible design approach may be less than the amount of testing required to support a more restrictive design because the flexible design will ease the difficulty of making future changes. A flexible design refers to the ease of making process and equipment changes in the processing facilities.

Testing and development emphasize the behavior of the waste in the unit operations described in the flowsheet (Orme 1994). These are the unit operations expected to be needed for startup and operations during the first three or more years. The individual processes and pieces of equipment are analyzed to determine testing needs.

The material in the waste tanks is heterogeneous, from tank to tank, and within tanks, from layer to layer and radially. No characterization or sampling program guarantees that all waste will be examined before retrieval. Knowledge of tank contents results from sampling and characterization combined with historical transfer records for tanks. This knowledge allows a reasonable estimate of the extremes in the waste to be retrieved from the tanks. The characterization strategy is designed to meet development needs in addition to the characterization needs (Schulz and Kupfer 1994).

The key tenet of the characterization strategy is that process testing with actual tank waste is necessary to design processes and measure their effectiveness. Tanks are grouped based on similarities in the waste streams that entered the tanks. Samples of waste from key tanks will provide the material representative of the major waste types and of bounding waste types that will prove limiting for the processes. The characterization strategy provides the criteria for selection of the tanks to be sampled. The characterization strategy also uses the results of selective sampling and process testing to confirm the historical information used in tank groupings.

Hot testing examines both the process compositions for typical waste types and blended feed expected in the facilities and the extremes possible based on the knowledge of tank waste characteristics. Simulants are prepared based on the characteristics of the actual tank waste. Simulants are used to find processing limits. Hot testing verifies that the simulants bracket the extremes of the waste properties.

Hot laboratory work will be used to thoroughly understand the waste composition and characteristics, the behavior during process, and to define the composition and characteristics of the simulants used in cold testing. The behavior of waste in the proposed unit operations will be thoroughly tested using actual tank waste in the laboratory. Larger laboratory and bench-scale testing will be used to confirm laboratory results and resolve potential concerns and problems.

Relevant information and experiences from the Savannah River Site and West Valley will be used. Hanford Site personnel will maintain contact with the progress of projects and programs at these U.S. Department of Energy (DOE) sites because their activities most nearly match the planned activities at the Hanford Site.

Judgment based on experience with similar processes will be applied to determine when the point of diminishing returns is reached with tests. No amount of testing will remove all risk and concern with hot startup and operation of major facilities. The time and cost associated with increased risk reduction beyond a reasonable level is not effective. Cost/benefit analyses can be used to assess the value of specific tests versus the potential impact to design, startup, and operation if the tests are not run. The impacts of potential plant failures must be understood, and testing decisions made based on that understanding.

Laboratory and bench-scale tests are conducted with actual tank waste. Because of problems in producing good simulants for solids/liquid separations, some testing with actual waste will be performed using the smallest size commercial equipment available. This is a common practice to assure acceptable operations in actual equipment.

The strategy of testing for pretreatment is that the program has knowledge of the tank waste composition and characteristics. Additional knowledge will be obtained during the characterization and testing programs. The processes proposed for pretreatment are relatively mature and based on processes previously used at the Hanford Site and other DOE sites. Unique waste material and unique applications of the processes will be thoroughly tested. Tests performed with actual tank waste are crucial and are expected to provide most of the process data needed to support design and startup activities.

The strategy of testing for LLW vitrification is that the large size and unique design required for radioactive service requires pilot-scale and near full-scale testing of the melter operation. Because the composition of LLW vitrification feed consists largely of sodium salts, tests with nonradioactive simulants provide needed design and operating data. Small-scale tests with real tank waste are needed primarily to confirm the product performance achieved with the vitrified simulants.

The strategy of testing for HLW vitrification is that the large size and unique design required for remote operation and maintenance requires pilot-scale and full-scale testing of the melter operation. In the future, the composition of HLW vitrification feed is expected to be known well enough to support tests with nonradioactive simulants to provide needed design and operating data. Small-scale tests with real tank waste are needed primarily to confirm the process and product performance achieved with the vitrified simulants. Full-scale testing with simulants and perhaps radioactive waste may be required at plant startup to qualify the product and the product control system.

If a high temperature melter is used, offgas problems may be produced that have not been observed before. Using actual tank waste and accurate simulates will be crucial to understanding potential offgas problems.

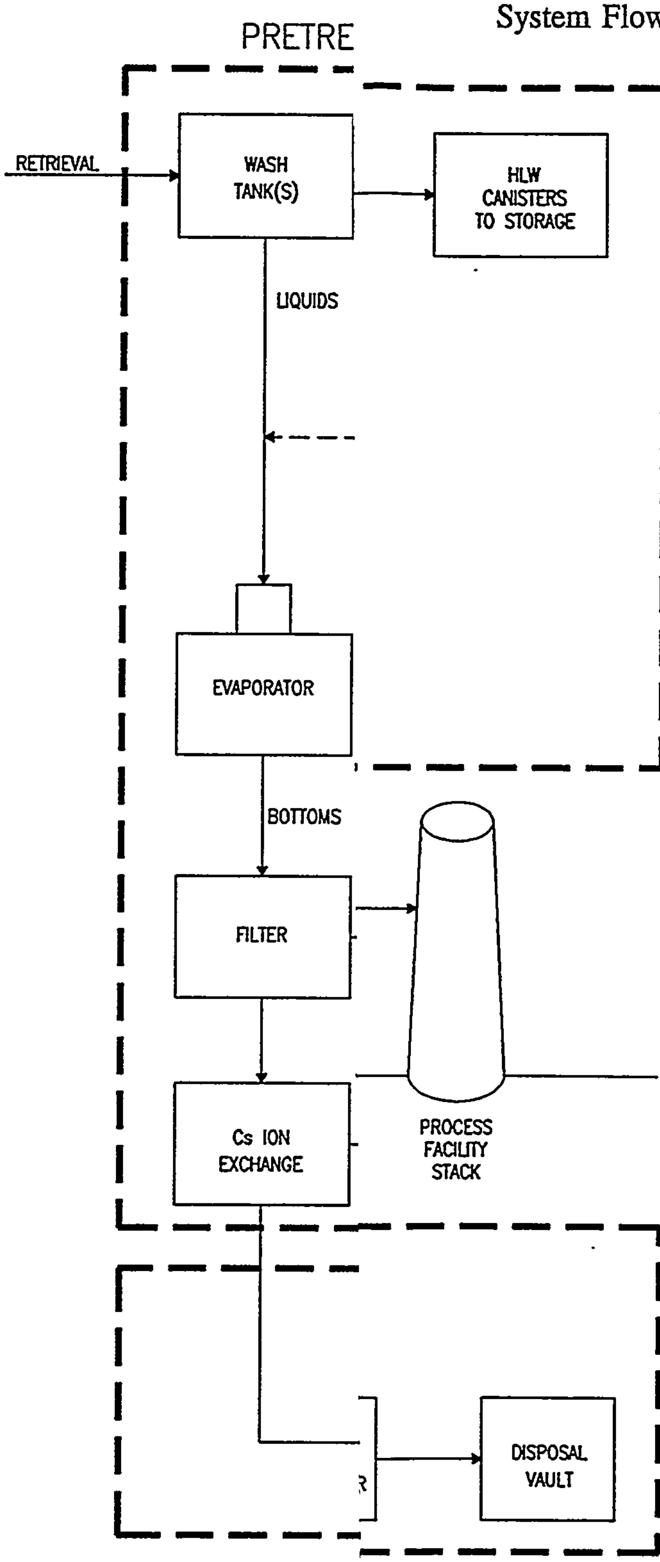
4.2.1 Chemistry/Process/Flowsheet

For TWRS processes, the several varieties of heterogeneous feed streams are a major concern. The strategy for characterizing the tank wastes (Schulz and Kupfer 1994) addresses this concern and provides the chemistry data needed to develop flowsheets. Westinghouse Hanford Company recently formed the Characterization Project to concentrate sampling and analytical activities.

The characterization strategy supports testing with actual tank waste. Obtaining and testing samples from all of the tanks is not cost effective. Tanks are grouped based on the similarities in the waste streams that entered the tanks. Samples of waste materials from key tanks will provide material representative of the major waste types and representative of bounding waste types that will be limiting for the processes. The results from selective sampling and process testing will be used to confirm the historical information used in tank grouping. Details of the planned analyses will be in the Pretreatment and Disposal Data Quality Objectives document.

The process flowsheet (Figure 4-1) (Orme 1994) will evolve with time based on the development program results. The existing flowsheet assumes average values and perfect blending for the material balances. In FY 1995, the first flowsheet with a tank retrieval sequence, blending, and pretreatment operating scenario will be prepared. Eventually, flowsheets for each type of waste, or each planned blend, will be produced. Hot laboratory testing of all process steps is used to confirm flowsheet parameters and support testing using simulants. Laboratory tests will use types of waste from individual tanks and examine the effects of blending.

Figure 4-1. Tank Waste Remediation System Flowsheet Schematic.



In addition, engineering evaluation is used to determine the risk of not doing specific tests compared to the value of doing tests. Engineering evaluations include trade studies, engineering studies, cost/benefit analyses, risk assessments, and safety analyses.

Scaleup needs are driven primarily by equipment requirements as discussed below. Bench-scale hot tests and pilot-scale hot tests are used very selectively to validate the effects of scale.

Nonradioactive simulants are used in both laboratory tests and larger scale tests. Simulants are simpler to prepare, easier to use, minimize personnel exposures, allow more repetitions due to reduced costs and ease of use, and thus are more effective in examining specific parameters. Simulants also are useful to examine boundary or worst case conditions. Simulants may not be satisfactory in measuring effects of some complex solutions found in the waste tanks and confirmation is provided with actual tank waste on the smallest practical scale. Simulants cannot duplicate some of the organics expected in the ion exchange feed. Organics also influence other properties that may affect solids/liquid separations.

Full-scale tests are needed to support retrieval operations and washing and decanting operations. Process tests and demonstration testing are used for retrieval, mixing, washing, settling, and decanting operations. These demonstrations are based on laboratory work with actual tank wastes.

Hot laboratory and bench-scale tests are used to establish waste characteristics and process parameters for solids/liquid separation. These tests include filtration and other methods as required to acquire the selected data. Separations methods such as centrifugation and filtration are tested with simulants in laboratory, bench-scale, and pilot-scale equipment.

4.2.2 Equipment and Instrumentation

Many of the startup problems with major facilities in the DOE complex are associated with equipment and instrumentation problems (as an example, in heating, ventilating, and air conditioning systems).. The problems result from a wrong decision in design, an error in equipment selection, and improper installation. The problems are not associated with the composition of the material being processed and are strictly mechanical and electrical. Equipment not previously employed in these or similar applications must be thoroughly developed and tested to confirm adequacy of performance.

All full-scale functional equipment and instrumentation are thoroughly tested before installation and after installation in the TWRS plant. Operation of all equipment with moving parts before installation is essential. These tests exercise control loops, demonstrate inherent stability, and confirm maintenance viability. Mockup and operational testing will be in a nonradioactive environment.

Testing components of equipment and instrumentation in a radioactive environment, with actual tank contents, is essential when problems such as corrosion, erosion, durability, or inability to downsize (as in the TRU monitor) are a concern. Generally, the equipment and instrumentation are tested with simulants.

Simulants will be used to test operations of pilot-scale or full-scale equipment when testing needs exceed simple operability. As described above, simulants are easier to use and can provide for thorough testing by controlling simulant characteristics to examine the limits of the processes. Simulants have proven to be effective for developing ion exchange processes at the Hanford Site and West Valley (Bray 1994).

4.2.3 Process Modeling and Simulation

Computer-based process modeling and simulation are modern tools that have come into everyday usage (Glasscock and Hale 1994). Properly used, modeling and simulation are effective in pinpointing testing and development needs, reducing the time for process development, improving the logic of process control, improving operator training, and supporting startup and operation activities (see the discussion in Appendix H). Modeling helps identify data needs that must be satisfied by testing. Modeling and simulation are used by TWRS to establish the mass balance and process logic. Process throughput, equipment sizing, and control systems are essential information easily obtained through modeling.

Effectively used, modeling reduces the total amount of actual testing and development needed. Modeling is used to examine a wide range of options and alternatives. Processes are compared and optimized. Modeling also is used to examine the effects of novel separations and helps identify where testing emphasis will be placed. Modeling results must be confirmed by actual data from testing.

5.0 PROPOSED TEST STRATEGY

The proposed test strategy meets the process development needs of the TWRS program; reduces risks to acceptable levels for startup and operation; supports the schedule for design, construction, and startup; and provides long term testing to support operations.

The strategy is designed to provide the technical data needed by the project and plant operations as shown in Figure 5-1. Testing is one of the activities that supplies technical data to the permitting, safety and environmental assessments, process flowsheet, process design, startup, and plant operation. Other technical information is supplied by characterization activities, by trade studies, simulation and modeling, and from literature. Testing also supplies data to the trade studies. The trade studies also will identify testing needs. Completed trade studies are identified in Appendix F.

Logically (Figure 5-1), both the process flowsheet and process design are ongoing and iterative processes. Feedback from the conceptual design is used to update and revise the process flowsheet. The revised flowsheet feeds into Title I design, which provides feedback for flowsheet revisions. This feedback process continues through construction and startup. Safety and operating documents also are affected and evolve in a similar fashion.

The proposed strategy integrates the normal systems engineering top-down approach (Swanson et al. 1994, Orme 1994, Slaathaag and Orme 1994) with the bottom-up work that has assessed the requirements for process development testing (Eager 1993, Howden et al. 1994, PNL 1994, Orme and Slaathaag 1994, Reynolds 1994a, Roal 1994, Waters 1994).

The process waste functions as defined by Systems Engineering consist of retrieve/transfer waste, store in-process waste, pretreat waste, immobilize/dispose of LLW, and immobilize/store/ship HLW (Swanson et al. 1994). These functions also are the high-level functions of the flowsheet as shown in Figure 5-2. Testing and development provide the data needed for process definition, equipment design, and process control. The testing and development requirements and data needs determine the scale and type of testing, including whether the testing is done with radioactive (hot) or nonradioactive material. After the type of testing and scale are determined, a location for the testing is identified. The testing and development schedule must support the design and construction schedule.

5.1 DESCRIPTION OF THE PROPOSED TESTING STRATEGY

The testing strategy includes both radioactive (hot) testing and nonradioactive testing. The proposed strategy for testing and development for TWRS is shown logically in Figure 5-3. The strategy is designed to meet the testing needs for permitting, safety and environmental assessments, design, startup, and operation. The strategy consists of using existing laboratory and hot cell capabilities at the Hanford Site and other sites to develop and

Figure 5-1. Implementation Steps of a Process Plant Project.

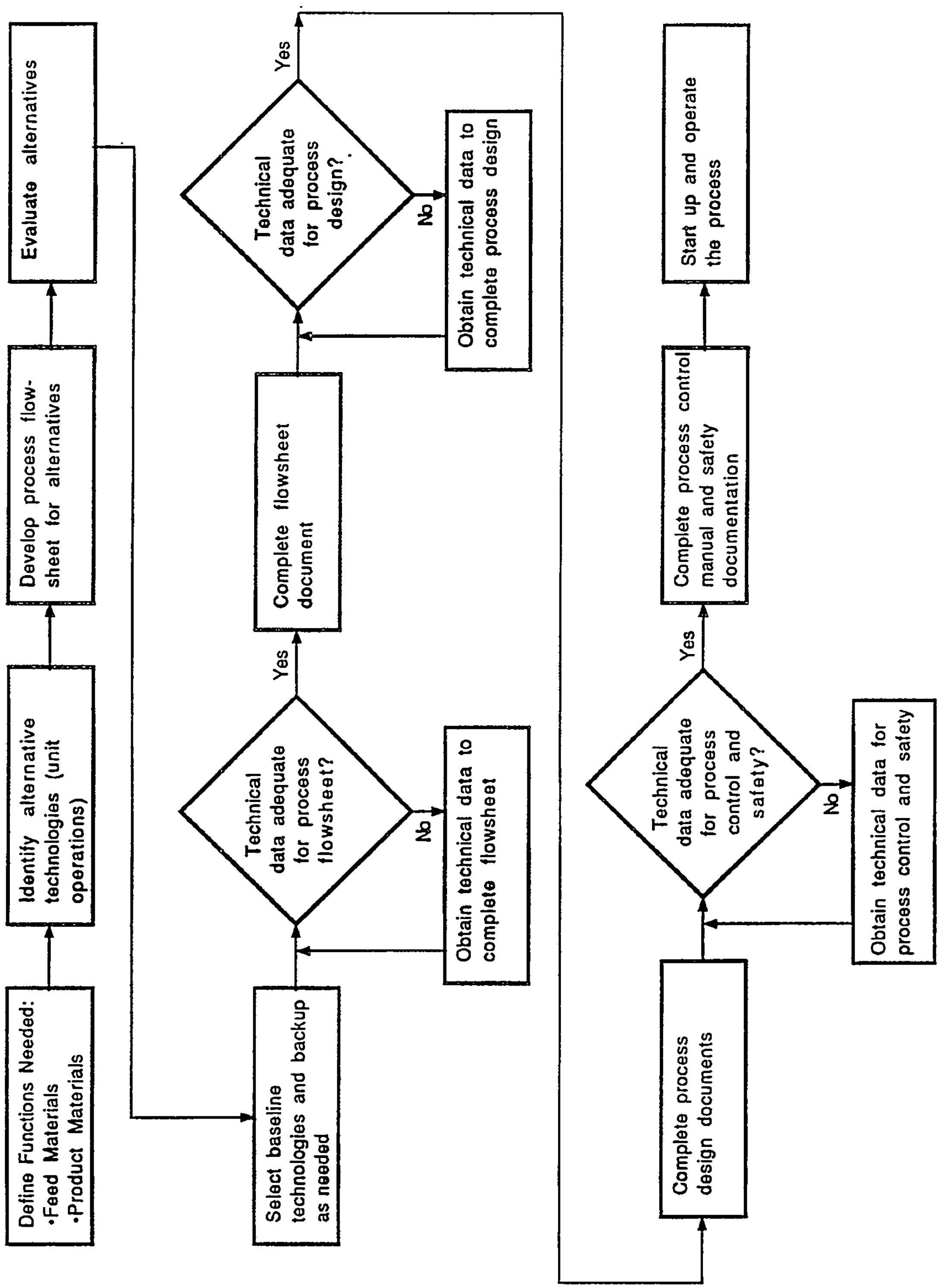
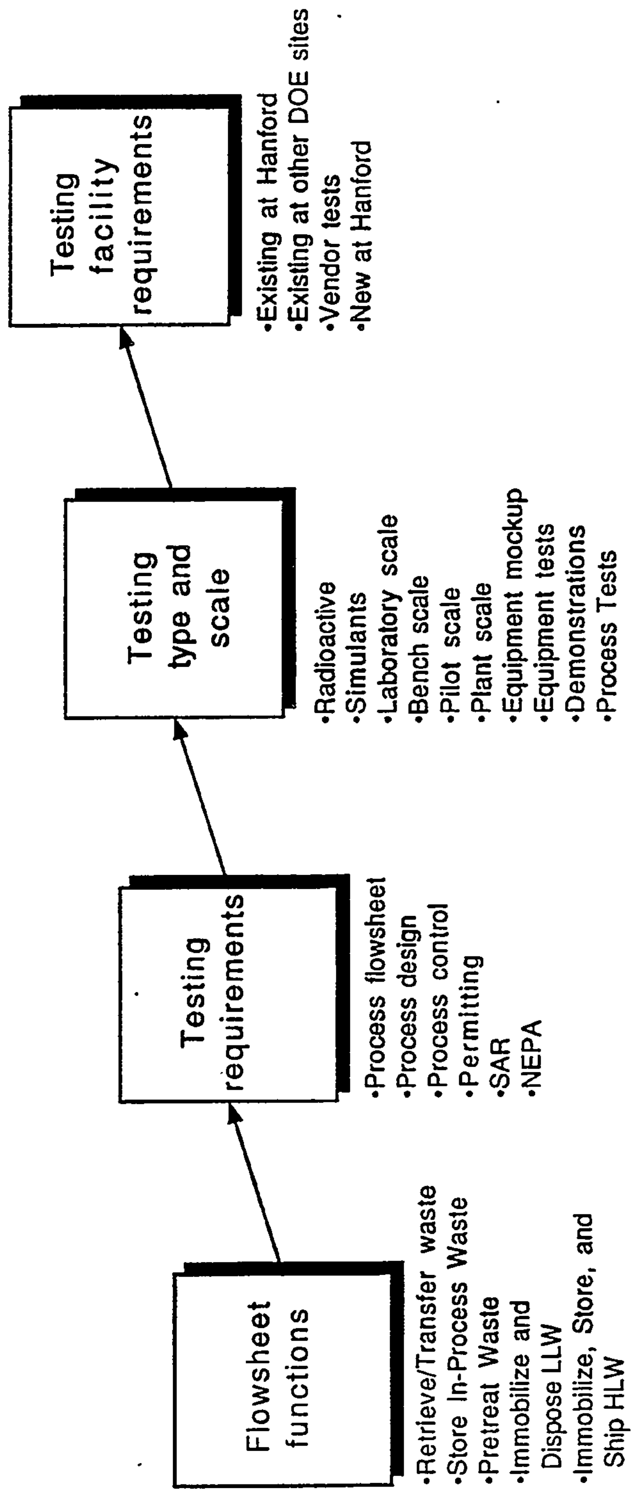


Figure 5-2. Tank Waste Remediation System Development/Testing for Processing of Tank Waste.



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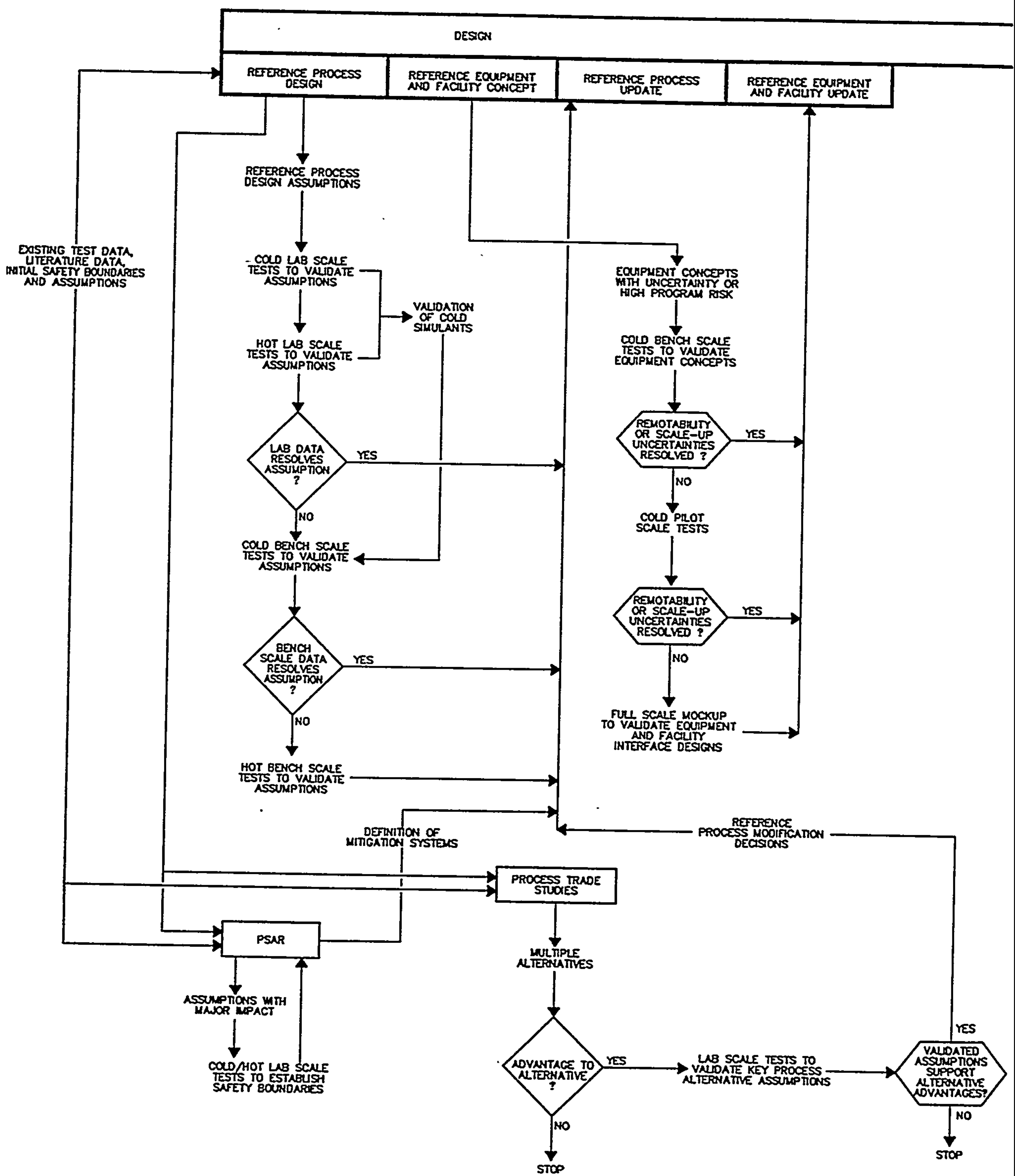
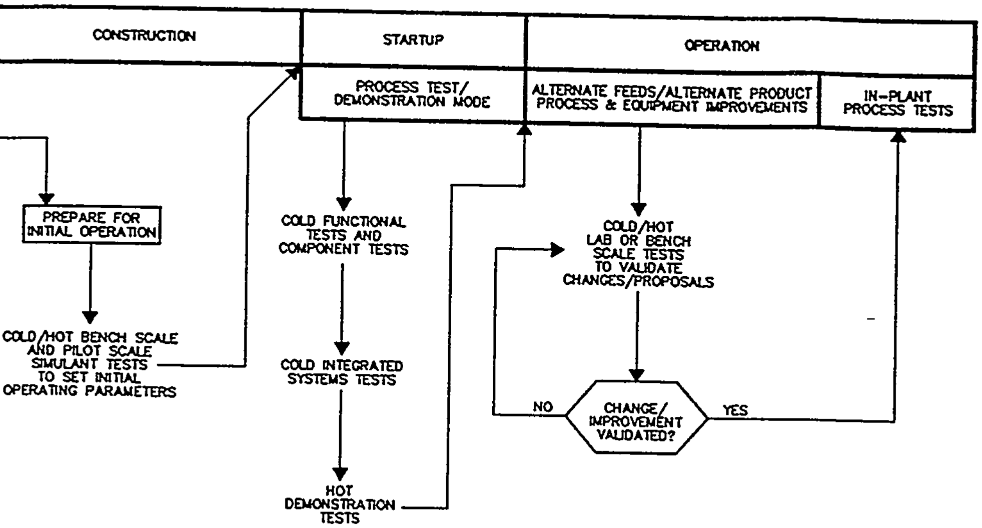

DESIGN
REFERENCE PROCESS DESIGN
REFERENCE EQUIPMENT AND FACILITY CONCEPT
REFERENCE PROCESS UPDATE
REFERENCE EQUIPMENT AND FACILITY UPDATE
EXISTING TEST DATA, LITERATURE DATA, INITIAL SAFETY BOUNDARIES AND ASSUMPTIONS
REFERENCE PROCESS DESIGN ASSUMPTIONS
COLD LAB SCALE TESTS TO VALIDATE ASSUMPTIONS
VALIDATION OF COLD SIMULANTS
HOT LAB SCALE TESTS TO VALIDATE ASSUMPTIONS
LAB DATA RESOLVES ASSUMPTION ?
YES
NO
COLD BENCH SCALE TESTS TO VALIDATE ASSUMPTIONS
BENCH SCALE DATA RESOLVES ASSUMPTION ?
YES
NO
HOT BENCH SCALE TESTS TO VALIDATE ASSUMPTIONS
DEFINITION OF MITIGATION SYSTEMS
EQUIPMENT CONCEPTS WITH UNCERTAINTY OR HIGH PROGRAM RISK
COLD BENCH SCALE TESTS TO VALIDATE EQUIPMENT CONCEPTS
REMOTABILITY OR SCALE-UP UNCERTAINTIES RESOLVED ?
YES
NO
COLD PILOT SCALE TESTS
REMOTABILITY OR SCALE-UP UNCERTAINTIES RESOLVED ?
YES
NO
FULL SCALE MOCKUP TO VALIDATE EQUIPMENT AND FACILITY INTERFACE DESIGNS
REFERENCE PROCESS MODIFICATION DECISIONS
PROCESS TRADE STUDIES
PSAR
ASSUMPTIONS WITH MAJOR IMPACT
COLD/HOT LAB SCALE TESTS TO ESTABLISH SAFETY BOUNDARIES
MULTIPLE ALTERNATIVES
ADVANTAGE TO ALTERNATIVE ?
YES
NO
STOP
LAB SCALE TESTS TO VALIDATE KEY PROCESS ALTERNATIVE ASSUMPTIONS
VALIDATED ASSUMPTIONS SUPPORT ALTERNATIVE ADVANTAGES?
YES
NO
STOP

Figure 5-3. Proposed Strategy for Testing and Development.



confirm flowsheet parameters, conducting nonradioactive bench testing for the process and equipment, and performing equipment tests.

The proposed testing strategy is shown in tabular form in Table 5-1. The strategy is described in more detail in the rest of this section.

Demonstration tests using actual tank waste for retrieval, sludge washing, and settling will be used as needed to confirm flowsheet parameters. Demonstration tests will be used for the startup of new facilities and processes.

The laboratory and bench-scale work with actual tank waste is used to characterize the various waste feeds for pretreatment and vitrification. The characterization work is used to determine the separations required in pretreatment. The emphasis of the testing is to prepare the processes in the flowsheet (Orme 1994) for implementation in TWRS facilities.

The need for other pretreatment processes, for strontium, technetium, and TRU separation and organic destruction, is determined by the results from characterization combined with the results from performance assessment of the LLW glass and negotiations with regulatory agencies, such as the NRC. The LLW Pretreatment Project will continue to include these separations processes and the program will continue to develop the processes until a definitive decision is made. High priority should be given to determination of the need for these processes. The performance assessment for LLW glass is planned for completion in 1998, which keeps the decision on processes open at least that long.

A flexible design of TWRS facilities provides for recovery from startup and operating problems. The flexible design is combined with equipment and instrumentation testing to avoid catastrophic problems during startup and operation.

Personnel should be assigned early in the project design phase to represent the needs of plant operations and TWRS engineering. These TWRS personnel will directly support the project personnel during design and construction of facilities, and provide overview of the architect-engineer in determining design points to ensure flexibility to accommodate expected feed variability. TWRS personnel participate in determining the flowsheet, defining development requirements, preparing test requirements, operating cold test facilities, and performing equipment tests. The TWRS personnel are incorporated into the facility operating organization at startup.

Computer-based process modeling is used to evaluate feed variability ranges for each unit operation, the design points and operating ranges, and impacts on interrelated systems to assure operability at design capacity.

Table 5-1. Proposed Testing Strategy for Tank Waste Remediation System.

Approximate scale of testing / Unit operation	Hot laboratory-scale (such as 222-S, 325 Building, and LANL)	Laboratory-scale simulants and tracers (such as 222-S and 325 Building)	Hot bench-scale (such as 222-S, 325 Building, and 324 Building)	Bench-scale simulant and tracers (such as 222-S, 325 Building, and 324 Building)	Pilot-scale simulant tests (Vendors and Cold Test Facility)	Large-scale and full-scale equipment tests, nonradioactive (Fabrication Shop, Cold Test Facility)	Full-scale hot demonstration and process tests (in-tank and in TWRS processing facilities)
Retrieval	Determine solution and solids characteristics (density, solubility, size reduction) (ml size samples)	Develop simulants with the parameters needed for larger scale tests	Conduct confirmatory laboratory tests, if needed (250 ml size samples)		Develop and test equipment and instrumentati on	Test full-scale equipment before installation	Perform selected hot demonstrations in the waste tanks
Sludge washing	Perform scoping tests to establish sludge washing parameters for typical sludge waste (ml size samples)		Test sludge washing flowsheet in hot cell tests with large samples (Liter(s) of sludge)				Perform hot demonstrations of sludge washing in-tank; verify mixing efficiency and process control
Solids/liquid separation	Work with priority tank wastes to determine solution/solids characteristics and validate properties of simulants (ml size samples)	Develop simulants with the parameters needed for larger scale tests	Test settling, filtration, and centrifugation of tank solutions; effect of solution chemistry on separations (about 10 L of tank waste for filter, approximately 1/100 scale)	Prepare and test simulants that represent the characteristics of actual tank waste (Liters of material)	Test at vendors to provide initial equipment screening and support to conceptual design (up to 1000 L)	Test solids/liquid separations equipment to expand testing envelope to waste types to support Initial Pretreatment Module conceptual design, Title I, and Title II design	Demonstrate solids settling in-tank. Use process test mode to demo solids/liquid separation at startup

Table 5-1. Proposed Testing Strategy for Tank Waste Remediation System.

Approximate scale of testing / Unit operation	Hot laboratory-scale (such as 222-S, 325 Building, and LANL)	Laboratory-scale simulants and tracers (such as 222-S and 325 Building)	Hot bench-scale (such as 222-S, 325 Building, and 324 Building)	Bench-scale simulant and tracers (such as 222-S, 325 Building, and 324 Building)	Pilot-scale simulant tests (Vendors and Cold Test Facility)	Large-scale and full-scale equipment tests, nonradioactive (Fabrication Shop, Cold Test Facility)	Full-scale hot demonstration and process tests (in-tank and in TWRS processing facilities)
Cesium ion exchange	Analyze selected tank solutions, including sludge wash streams, to determine the range of feed composition (ml size samples got small batch tests)	Optimize ion exchange column flowsheet using simulant with tracer (lab and bench-scale as needed) (2 ml size column tests)	Perform ion exchange column tests in conjunction with sludge wash tests; verify simulant tests (liter size samples) (2 ml to 10 ml column tests)	Verify continuous performance, determine column size for hot tests; support resin optimization (2 ml to 200 ml size column tests)		Perform resin tests to determine effects in normal column cycles. Test resin removal.	
Low-level waste melter	Perform vitrification tests (crucible melt, feed preparation) for selected low-level waste feed solutions (ml size samples)	Prepare and test simulants that represent project feeds and the bounding conditions for actual tank waste	Perform short term continuous process evaluation (liter size samples)	Material and features testing, feed sensitivity, glass former effects (up to 8 kg/h)	Perform pilot-scale melter and process system tests with simulants	Perform operability and performance tests with a large melter, offgas system, and offgas control system, as needed	Use cold plant process tests to demonstrate the operation of melter process systems at startup
High-level waste melter	Perform vitrification tests (crucible melt, feed preparation) for selected high-level waste feed solutions (ml size samples)	Prepare and test simulants that represent the bounding conditions for actual tank waste	Perform short term continuous process evaluation (liter size samples)	Material and features testing, feed sensitivity, glass former effects (up to 8 kg/h)	Perform pilot-scale melter and process system tests with simulants	Perform operability and performance tests with a large melter, offgas system, and offgas control system, as needed	Use cold plant process tests to demonstrate the operation of melter process systems at startup

Table 5-1. Proposed Testing Strategy for Tank Waste Remediation System.

Approximate scale of testing / Unit operation	Hot laboratory-scale (such as 222-S, 325 Building, and LANL)	Laboratory-scale simulants and tracers (such as 222-S and 325 Building)	Hot bench-scale (such as 222-S, 325 Building, and 324 Building)	Bench-scale simulant and tracers (such as 222-S, 325 Building, and 324 Building)	Pilot-scale simulant tests (Vendors and Cold Test Facility)	Large-scale and full-scale equipment tests, nonradioactive (Fabrication Shop, Cold Test Facility)	Full-scale hot demonstration and process tests (in-tank and in TWRS processing facilities)
Organic destruction	Determine the need for organic destruction using analyses and perform tests with actual tank waste; low temperature digest/expand kinetic information (ml size samples)		Confirm the performance of low temperature digest for organic destruction (liter size samples)				Perform demonstration in waste tanks as required
Transuranic separation	Determine the need for transuranic separation from solutions with work with actual tank waste (ml size samples)	Scoping tests for candidate processes if additional testing is necessary	Confirmation tests with actual tank waste, if necessary	Use miniature centrifugal contactors for process optimization	Perform equipment tests with simulants	Perform operability tests	Perform process tests with hot feed
Technetium separation	Determine the need for technetium separation with analyses of actual tank waste (ml size samples)	Scoping tests for candidate processes if additional testing is necessary	Confirmation tests with actual tank waste, if necessary	If required, tests are performed to optimize the process	Perform equipment tests with simulants	Perform operability tests	Perform process tests with hot feed

Table 5-1. Proposed Testing Strategy for Tank Waste Remediation System.

Approximate scale of testing / Unit operation	Hot laboratory-scale (such as 222-S, 325 Building, and LANL)	Laboratory-scale simulants and tracers (such as 222-S and 325 Building)	Hot bench-scale (such as 222-S, 325 Building, and 324 Building)	Bench-scale simulant and tracers (such as 222-S, 325 Building, and 324 Building)	Pilot-scale simulant tests (Vendors and Cold Test Facility)	Large-scale and full-scale equipment tests, nonradioactive (Fabrication Shop, Cold Test Facility)	Full-scale hot demonstration and process tests (in-tank and in TWRS processing facilities)
Strontium separation	Determine the need for strontium separations with analyses of actual tank waste, scoping tests for candidate processes (ml size samples)	Scoping tests for candidate processes if additional testing is necessary	Confirmation tests with actual tank waste	If required, tests are performed to optimize the process	Perform equipment tests with simulants	Perform operability tests	Perform process tests with hot feed
Other separations	Determine the need for other separations with analyses of actual tank waste, scoping tests for candidate processes (ml size samples)	Scoping tests for candidate processes if additional testing is necessary	Confirmation tests with actual tank waste	If required, tests are performed to optimize the process	Perform equipment tests with simulants	Perform operability tests	Perform process tests with hot feed
Offgas and effluent treatment	Characterize the expected offgas streams and effluents with tests using actual tank waste	Prepare and test simulants which represent bounding conditions				Test with other equipment during low-level waste melter tests	Use process tests to demonstrate operation at startup

5.1.1 Related Information and Activities

Several recent parallel activities produced reports that discuss testing needs and testing strategy. The testing requirements assessment (Howden 1994) examined testing needs through workshops and preparation of data sheets. The results of this work are shown in the table in Appendix C. A development priority table was prepared based on requirements determined by a review of the flowsheet (Slaathaug and Orme 1994). This table is shown in Appendix D.

Column size considerations for cesium ion exchange are discussed in other documents (Brooks 1994, Kurath 1994). A theoretical foundation is developed for using very small columns for obtaining process design data. This theoretical assessment confirms actual development and implementation experience (Bray 1984, Bray 1994).

Several other documents examine pretreatment testing and development needs and testing capability (PNL 1994, Reynolds 1994a, Reynolds 1994b). The technologies examined include settling, enhanced sludge washing, sludge washing, filtration, centrifugation, flocculation, organic destruction, caustic recycle, cesium removal, removal of other radionuclides, and electrochemical processes (PNL 1994). Status of the technology is identified. Issues with the technology are described. The need dates to the project design schedule are identified. The testing strategy for each technology is proposed which includes the scale of testing, the evaluation criteria, testing space needs, and potential sites. The risk associated with each issue is identified. Use of actual tank waste versus simulants also is discussed. Actual tank waste is used to define design parameters and to validate simulant performance.

A preliminary study, supporting the IPM Project, determined six groups of unit operations need testing with actual tank waste (Reynolds 1994a). The groups are ion exchange, sludge washing, centrifugation, filtration, settling, and organic destruction. The testing scale for each work task supporting each unit operations group is identified (Reynolds 1994b). Each work task identifies the need date for the architect-engineer. For ion exchange, hot laboratory and bench-scale tasks are identified. For sludge washing, hot laboratory and complementary characterization tasks are identified. In-tank testing for sludge washing also is identified to supply data by January 1998.

For organic destruction, hot laboratory and bench-scale tests are identified. For settling, hot laboratory and bench-scale tests are identified. For filtration, hot laboratory and bench-scale tests are identified. Functional pilot-scale tests are identified for filter efficiency, filtration system design issues, solids formation during processing, filter pluggage, and filter cake properties. Functional pilot-scale tests can be designed to use bench-scale quantities of process material as discussed in Section 5.1.5.

The scale of testing needed to support LLW vitrification also was examined (Morrissey and Whitney 1994). The testing recommended includes small-scale systems, one with radioactive material and one with simulants. A non-radioactive pilot plant that can be operated for extended periods also was recommended.

The testing needed to support HLW vitrification is to be defined in FY 1995. The HLW vitrification program uses actual tank waste in laboratory-scale tests and simulants in progressively larger tests.

5.1.2 Test Facilities

5.1.2.1 New Facilities. The new facilities needed to support this strategy are equipment test facilities to provide capability for testing all remote equipment and instrumentation. A mock-up of the TWRS facility will be needed to test equipment configuration, and train maintenance and operating personnel. Mock-up capabilities are needed to support the new TWRS processing facilities.

A mock-up of a waste tank will be provided to test equipment to be installed in tanks. The equipment test facilities and waste tank mock-up provide capabilities similar to that provided by canceled Project B-227 (Appendix E).

5.1.2.2 Vendor Facilities. Vendor test equipment should be used to the extent possible, particularly in the early scoping phase of equipment selection and design. As equipment is designed and fabricated for onsite tests, the testing is moved to the onsite locations.

5.1.2.3 Hot Cell Facilities. The Hot Test Siting Report (Howden 1995) provides recommendations for siting radioactive work with actual tank waste. The report's recommendations are based on technical and scheduling considerations. The report recommends making use of the existing facilities at Hanford, 222-S, 325 Building, and 324 Building. Some sludge washing tests are already underway at the Los Alamos National Laboratory (LANL). This test work will continue.

The siting report discusses the need for improved sampling and sample handling. The Hanford Site facilities are recommended for use for radioactive sample receiving and for transshipment, where required.

5.1.3 Retrieval

Retrieval testing is performed by using demonstrations and process tests in waste tanks. The strategy for retrieval testing is being prepared in FY 1995 as part of the program activities.

Retrieval affects both the solids characteristics and the solution conditions. These effects are investigated in the laboratory with actual tank waste.

The retrieval testing strategy will verify technologies capable of meeting the functional requirements of retrieving tank waste. Performance is evaluated through analysis and scale testing to establish operational parameters and validate design of referenced technologies. Technology performance is demonstrated with process tests. Alternate retrieval methods are evaluated as a fallback in the event that the reference technology cannot meet the functional requirements of retrieving tank waste. Alternate methods also are evaluated and tested when significant improvements over the reference methods for safety, performance, cost, and schedule are possible.

Equipment to be used in retrieval operations will be tested in the waste tank mockup and the other equipment test facilities. Demonstration of the reference technologies begins with process tests as early as September 1996, with the past-practice sluicing of SST 241-C-106. Mixer pump sludge mobilization is performed by a process test in 1997. Process test demonstration of an alternate retrieval technology, a long-reach manipulator system, takes place in 2003. The initial tank farm retrieval, necessary to feed and meet the requirements for pretreatment and LLW vitrification, begins about 2003.

5.1.4 Sludge Washing

Sludge washing testing is conducted in the 222-S Laboratory at the Pacific Northwest Laboratory (PNL) and LANL with actual tank wastes. Larger scale sludge washing tests are conducted in hot cells, such as 324 Building. Larger scale testing with simulants is conducted in the pilot plant and equipment test facilities as required before process demonstrations and startup of new TWRS facilities. The larger scale tests are primarily to test and run in equipment and instrumentation, not to optimize process parameters such as dissolution efficiency. The scale of testing is based on the assessment of needs for this process (Howden 1994, Reynolds 1994b).

A plan supporting the evaluation of enhanced sludge washing has been prepared (Jensen 1994). This plan was developed to complete the Tri-Party Agreement milestone to evaluate enhanced sludge washing, M-50-03 (Alumkal 1994a). The plan discusses the technical work that is underway, planned, and proposed to address the decision on the adequacy of enhanced sludge washing. The plan describes laboratory and bench-scale testing using actual tank waste. The plan also includes the Tank 241-AZ-101 sludge washing process test, which is conducted in-tank, and trade studies. The laboratory testing with actual tank waste includes sludge washing with water and sludge leaching using sodium hydroxide, selective sludge leaching with other solutions, settling tests, extending sludge washing science, and reconstituting sludges.

5.1.5 Solids/Liquid Separation

A classical chemical engineering approach is being used to select and design the solids/liquid separations equipment for TWRS (Perry 1984, Ernst 1994). The physical and chemical properties of material to be processed are determined as part of characterization (Kupfer et al. 1994). The properties determined include sedimentation velocity, mass of solids per solution volume, solution and solids densities, particle size distribution, and mean particle size.

Laboratory analyses are conducted to characterize representative tank sludge samples. Laboratory and bench-scale tests are performed to determine the effectiveness of selected solids/liquid separation methods. Due to properties of the tank waste and expected LLW product requirements, filtration is likely to be needed to achieve the desired separations and clarification of liquids before cesium ion exchange. Solids may appear in solutions that have been clarified. This effect is investigated using actual tank waste.

Equipment tests are conducted by vendors with simulants to support selection of equipment for solids/liquid separation. The simulants are selected based on the worst case or boundary conditions for such variables as solution density, solids loading, particle size, and particle size distribution.

Simulants may not be effective for some equipment tests. Selective tests with actual tank waste in small-scale equipment may be required. The equipment consists of the smallest commercial equipment available that represents operations that can be scaled to the plant-scale equipment.

The trade studies (Appendix F) are an integral part of the equipment selection process for filtration. Three kinds of filters are under consideration: cross-flow, frit (Orme 1994), and hydropulse. Tests with about 10 L of actual tank waste are used to confirm filtration effectiveness and to aid scaleup. Small-scale tests are recommended to aid selection of the proper filter and to determine sizing (Perry 1984). Tests with actual tank waste are required to confirm the relative effectiveness of the filters under consideration. The results of small-scale tests are determined as dry weight of solids or volume of filtrate per unit area. Vendors that manufacture solid-liquid separation equipment will be utilized and play a key role in establishing the testing needs for selected equipment.

Testing of a cross-flow filter will consist of both radioactive and nonradioactive tests. Nonradioactive tests are initiated with one to four filter tubes. Tests with actual tank waste start with single tubes. Confirmation tests may require the use of four to six filter tubes. These tests are done at the equivalent of a small pilot-scale with an amount (less than 25 L) of tank waste for testing that could be considered bench-scale. A plant-scale filter contains about 300 to 400 tubes.

5.1.6 Cesium Ion Exchange

The cesium ion exchange process is tested in the laboratory with actual tank waste. The laboratory tests are used to lead parallel testing done with simulants and tracers. Cesium ion exchange processes are largely developed using simulants with performance verification using actual tank waste. Tests with simulants containing trace amounts of ^{137}Cs for analytical purposes are performed with batch contacts and bench-scale columns with volumes up to 200 ml. Planned testing with actual wastes includes batch contacts and small columns (5 to 20 ml).

Tests will use simulants to determine the correct column size for conducting tests (Brooks 1994). These tests verify the validity of the columns used in tests with simulants and actual tank wastes. Columns less than 200 ml have been successfully used to scaleup ion exchange processes to full-scale and are expected to be valid for TWRS needs (Bray 1994, Kurath et al. 1994).

Ion exchange tests are conducted to evaluate and select ion exchange materials for plant-scale use (Kurath et al. 1994). Tests are used to determine and evaluate equilibrium behavior, including such variables as concentration, temperature, and pH. Tests are used to evaluate column loading data, including flow rate, residence time, temperature, and concentration.

The ionic equilibrium of cesium is determined for the tank wastes (Kurath et al. 1994). The equilibrium data are correlated to provide design relevant information. The correlations provide a method of predicting cesium column distribution ratio at specified temperatures and cesium and sodium concentration. Batch equilibrium experiments and column experiments are used to collect data. The number of bed volumes can be scaled directly from laboratory to full-sized columns.

The kinetics of the ion exchange system are determined. If diffusion in the ion exchange particle limits the ion exchange process, scaleup is done directly from laboratory to full-scale columns. The West Valley Demonstration Project successfully used such a scaleup approach.

The equilibrium and kinetic data gathered in the laboratory are used to develop thermodynamic models and analyses that provide the fundamental parameters for accurate scaleup.

CS-100 is the reference resin for cesium ion exchange; alternates being considered include resorcinol-formaldehyde and crystalline silico titanate resins. Resin optimization and flowsheet optimization occur in laboratory-scale columns with simulants and simulants with tracers. Results are confirmed with laboratory-scale tests with actual tank waste. Work is proposed to be conducted in columns with resin volumes as small as 10 ml. Simulants are used in small columns and larger columns up to 200 ml. This approach is consistent with past practice and successes at Hanford and West Valley (Popovich 1964, Bray 1984, Bray 1994). The Hanford scaleup studies for cesium ion exchange demonstrated the successful use of tracer data over a wide range of operating parameters (Popovich 1964).

Nonradioactive tests similar to the near full-scale column tests conducted for the West Valley Project also will be performed (Carrell 1984). These tests match the preliminary needs identified for TWRS (Eager 1993). The tests include resin changeout, bed pressure drop, elution and channelling effects, upflow and downflow effects, and alternate design configurations. Column design features, such as solution distributors, resin screens, and distributor nozzles, also are tested.

In work completed to date, simulants have been used to examine kinetic behavior, equilibrium behavior, elution behavior, radiation stability of the resin, chemical stability of the resin, and resin fouling (Kurath et al. 1994).

5.1.7 Low-Level Waste Vitrification

The preliminary hot test strategy for LLW vitrification is to perform laboratory tests with actual tank waste. These tests are compared to laboratory-scale tests with simulants to confirm simulant validity. Bench-scale and pilot-scale tests with simulant are used to confirm process scaleup (Morrissey and Whitney 1994). The LLW vitrification strategy is preliminary. The strategy will be further refined by program activities in FY 1995.

Vendor tests with simulant will be used to perform scoping tests for melter selection.

Pilot-scale and full-scale testing of the vitrification and product handling equipment in a nonradioactive environment will be used to identify potential design and operating problems and familiarize TWRS personnel with the operating characteristics.

5.1.8 High-Level Waste Vitrification

Laboratory and bench-scale tests will be performed with actual tank waste. These tests are compared to laboratory and bench-scale tests with simulants to confirm simulant validity, process chemistry, and product properties/composition. Pilot-scale melter system tests with simulant will be used to confirm process and equipment scaleup.

Vendor tests with simulant will be used to perform scoping tests for melter system selection.

Pilot-scale and large-scale testing of the vitrification equipment in a nonradioactive environment will be used to identify potential design operating problems and familiarize TWRS personnel with the operating characteristics.

As with the LLW vitrification tests above, the HLW vitrification testing strategy is preliminary. The strategy will be prepared by program activities during FY 1995. The strategy will implement the recommendation by WHC to DOE-RL on October 18, 1994, and accepted by DOE-RL on November 3, 1994. The recommendation focuses on testing of the joule-heated melter system, with an induction melter as the backup technology. The purpose of the melter testing is to select the HLW melter technology to meet the Tri-Party Agreement milestone, M-51-02, in September 1998.

As with other programs, the smallest feasible scale of testing is used to resolve technical issues for each candidate technology. The HLW program strategy is to resolve as many of the issues as possible with relatively inexpensive nonradioactive simulants and perform tests with radioactive feeds only when required to confirm simulant behavior.

Four phases of testing, from laboratory through pilot-scale, have tentatively been identified to select the HLW melter. The testing progresses from laboratory (crucible) tests to the larger equipment. Due to cost escalation as the test size increases, tests with larger scale equipment are generally limited to verifying scaleup behavior at a relatively small number of conditions.

Integration of pretreatment testing with vitrification testing is an issue with both LLW vitrification and HLW vitrification. Recommendations made before TWRS program redefinition had decoupled hot pretreatment testing from hot vitrification testing (Kupfer 1993). The testing strategy as described in this document does not identify any specific need to close-couple pretreatment hot testing with vitrification hot testing. The solids used for HLW vitrification testing should go through the normal process steps before being fed to the melter.

5.1.9 Other Testing Needs

Several other pretreatment and treatment unit operations may be required to meet product specifications for LLW glass and HLW glass and meet regulatory requirements for effluents. The need for separations processes for strontium, technetium, and TRU and for organic destruction will be determined by an assessment that will include the use of data obtained from testing and characterization. The LLW Pretreatment Project will continue to include these separations processes and the program will continue to develop the processes until a definitive decision is made about the need for these processes.

5.1.9.1 Strontium Separation. Characterization work prioritizes the analyses that determine the amount of strontium in tank waste solutions versus solids. As indicated by the performance assessment and regulatory requirements, strontium and cesium in LLW glass are a concern until sufficient radioactive decay has occurred. If strontium is contained in the tank waste solutions, pretreatment separation may be required. Characterization of tank waste combined with performance assessment and regulatory requirements will determine whether this separation is required. Organic destruction (see below) is one of the proposed processes used to remove strontium from the tank waste solutions. Solvent extraction, precipitation, and ion exchange are other proposed methods.

If strontium separation is required, laboratory tests with actual tank waste are used to scope the required processing. Laboratory work is underway with actual tank waste to determine the effectiveness of low temperature digestion. Destroying all or part of the complexant does not assure that all of the strontium will be removed from the solution because strontium may be somewhat soluble under some processing conditions. The laboratory work and follow on work will continue as long as the possible need for strontium separation continues.

5.1.9.2 Technetium Separation. Characterization work prioritizes the analyses that determine the amount of technetium in tank waste solutions. Technetium in solution is a possible concern for LLW performance assessment. Until a definite decision is made that technetium separation is not needed, laboratory and bench-scale tests with simulant and tracers, and with actual tank waste, will be used to define a separations method, such as ion exchange, precipitation, or solvent extraction.

If technetium is separated from the tank waste, a disposition strategy must be established. Disposal of separated technetium in HLW glass is one alternative. Technetium behavior during vitrification is a concern because of technetium volatility and possible accumulation in offgas equipment. Testing may be required to identify and confirm alternatives for technetium disposal.

5.1.9.3 Transuranic Separation. TRU may be complexed with organic compounds in waste tank solutions. TRU also may have limited solubility under some of the solution conditions for the stored waste and during pretreatment processes. TRU concentrations in the tank waste may be determined by the characterization program. The solubility of TRU during pretreatment processes will be determined using actual tank waste and simulants with tracers. If TRU is contained in the tank waste solutions, pretreatment separation may be required. Characterization of tank waste combined with performance assessment and regulatory requirements will determine whether this separation is required. Organic destruction (see below) is one of the proposed processes used to remove TRU from the tank waste solutions. TRU may be insoluble, even if complexants are present, under the right conditions. Solvent extraction, precipitation, and ion exchange are other methods. Bench-scale solvent extraction equipment is available for use with simulants and tracers (Geeting 1994).

5.1.9.4 Organic Destruction. The need for organic destruction will be determined by the results from the characterization program coupled with evaluation of removal requirements. In addition to the impacts of organics on strontium and TRU, organics in solution also may impact the cesium ion exchange process and the LLW melter operation. Preliminary work with the cesium ion exchange process does not show a problem with soluble organics. Additional tests in the laboratory with actual tank waste will be used to confirm these results. Impacts of organics on melter operation will be determined in laboratory and bench-scale melter tests.

5.1.9.5 Colloid Testing. Specific activities are planned to provide the needed solids property data to support solids/liquid separation (5.1.5). These activities will include work with actual tank waste to determine properties under a variety of processing conditions. In parallel, nonradioactive studies will be used to develop and validate computational models to predict behavior of solids for a wide range of sludge types.

5.1.9.6 Offgas and Effluent Treatment. Offgas and effluent treatment systems will be tested with simulants in bench-scale and pilot-scale equipment. The validity of the simulants will be established in laboratory and bench-scale tests using actual tank waste. Tests with actual tank waste are essential to identify minor constituents that may have longer term effects in the offgas systems.

Nonradioactive testing will be used to establish design and operating parameters and to thoroughly test equipment before plant startup. Equipment will be tested in the mockup facility and in the TWRS facilities during cold testing before hot startup.

5.1.9.7 Secondary Wastes. Testing, both radioactive and nonradioactive, will generate secondary waste such as ion exchange resin, filter media, and other solid waste. Wastes identified during tests will be used to establish disposal methods for the operating plants.

5.1.10 Startup and Operation

Testing of equipment and instrumentation will be performed in the nonradioactive mockup facilities before installation in the TWRS facilities to the extent necessary to validate computer based simulation. Nonradioactive testing of equipment and instrumentation will be performed in the TWRS facilities before hot startup. Water, dilute solutions, and simulants will be used as needed to confirm the operability of every process system.

Hot startup will be performed on a demonstration basis using process tests to confirm equipment operability and that product specifications are met.

5.1.11 Simulation and Modeling

Simulation and modeling perform a key role in supporting a project for a chemical process as discussed in Appendix H. Simulation and modeling are analogous to testing in supplying the needed data to the flowsheet, design, and startup and operation as shown in Figure 5-1.

5.2 MATCHING TESTING WITH THE PROJECT SCHEDULE

Enough information exists to start conceptual design of pretreatment processes. The characteristics of the early feed for TWRS facilities are known. TWRS has a process flowsheet and is continuing to refine the flowsheet based on individual tank waste characteristics and developing blending strategies. The unit operations and the desired throughput rate are defined based on the current assumptions. Test plans must be set up to beat the need dates for the project to allow for more tests if the data from the first round of tests are not sufficient to support design.

5.2.1 Retrieval

Retrieval of waste from tanks with safety issues could begin as early as 1996. Retrieval for pretreatment and disposal starts about 2003. The retrieval of waste from single-shell tanks containing salt will be followed by the retrieval of waste from TX Farm beginning about 2007. Solution retrieval and salt cake retrieval are established processes (past-practice sluicing). Equipment is available. Testing for the early retrieval operations to support pretreatment and LLW vitrification hot startup is not a schedule risk.

Retrieval of waste from some tanks, stabilized single-shell tanks or tanks with potential safety issues, may require the development of specific equipment and methods. The development of the specialized equipment and methods is not expected to be a schedule risk.

5.2.2 Pretreatment

Detailed design (Title I) of the Initial Pretreatment Module begins in fiscal year 1997. Some of the early decisions for the project/design process will be the determination of the method(s) for solids/liquid separation and the need for separations processes in addition to cesium ion exchange. These decisions will be made based primarily on the data generated by characterization activities, solids/liquid separations tests, and the feed requirements for LLW vitrification. Unfortunately, because the LLW glass performance assessment is not expected to be completed until 1998, radionuclide separations beyond cesium separation will need to be developed. The TWRS program is beginning to investigate regulatory requirements and political realities for radionuclide separations. This evaluation will include evaluation of past DOE practices at West Valley and SRS, and the impact of the 1993 Nuclear Regulatory Commission decision. The final determination of separations requirements by TWRS is expected to be complete, including Nuclear Regulatory Commission concurrence, before the start of the LLW Pretreatment Facility Title I design.

Sludge washing and cesium ion exchange testing on a laboratory-scale with actual tank waste is underway. Cesium ion exchange testing is using CS-100 as the reference resin, with tests underway to examine other resins.

Sludge washing and cesium ion exchange testing on a bench-scale with actual tank waste is expected to begin within two years. Sludge washing tests will be crucial to HLW vitrification. Sludge washing tests will not be crucial for early processing needs for LLW pretreatment, since the early feed is likely to be supernatant. Cesium ion exchange testing will be met by laboratory and bench-scale testing with hot wastes to verify previous simulant testing and to determine effects of minor constituents on performance of new high-efficiency resins such as candidate resorcinol-formaldehyde resin. Pilot-scale testing with simulated wastes over numerous processing cycles will be needed to demonstrate resin physical performance.

The performance assessment and negotiations with regulatory agencies for LLW glass disposal will be parts of the mechanism for determining an acceptable feed to LLW vitrification. Work with actual tank waste, other than characterization, is **not** expected to play a big role in this determination. The potential concern with LLW disposal and its impact on vitrification feed is the need to remove radionuclides in addition to those removed by feed clarification and cesium ion exchange (and potential organic destruction). Additional development may be needed to provide more extensive pretreatment.

Initial performance assessment evaluations indicate technetium may be a radionuclide issue. Work is underway to better estimate technetium concentrations in the tanks as opposed to the baseline flowsheet basis that conservatively used the technetium as discharged from the reactors based on ORIGEN calculations. Better estimates may eliminate technetium as a pretreatment issue. Alternatives to deal with technetium include the waste product form, chemical barriers, and removal using ion exchange or other methods. An aggressive pursuit of the LLW glass performance, with completion before 1998, should resolve the issue of other separations requirements before completion of Title 1 design.

Nonradioactive testing of solids/liquid separation processes should continue. Vendor testing with simulants may be the best way to expedite selection of the appropriate equipment. As noted in Section 5.1.5, tests with small commercial-scale equipment using actual tank waste may be required if concerns persist after vendor tests and other simulant testing. Concerns in the area of solid/liquid separations involve past problems with solid/liquid separations during tests at B Plant in 1989, and in the difficulty of finding a single separation method to address the various waste types. Without perfect blending, many feeds with differing solids loading and other characteristics are expected. Process and equipment changes are expected to be needed to respond to feed changes. Processes and equipment must be tested and installed for the various feeds.

5.2.3 Low-Level Waste Vitrification

Melter selection is the biggest testing concern for the support of LLW vitrification, design through startup. Vendor testing is underway. Other development and testing needs for the LLW vitrification program are being defined by the program this fiscal year (Morrissey and Whitney 1994).

Early melter fabrication and nonradioactive testing is recommended for the LLW vitrification system. The test melter must be actual plant size or easily scalable. Test plans and schedules must support the facility design and construction schedule.

5.2.4 High-Level Waste Vitrification

Melter selection also is a concern for the support of HLW vitrification design through startup. Vendor testing is recommended for melter selection that is to be completed in 1998. Other development and testing needs for the HLW vitrification program are being defined by the program this fiscal year.

Early melter fabrication and nonradioactive pilot-scale testing is recommended for the HLW vitrification system after melter selection. The test melter must be actual plant size or easily scalable (probably greater than 30 percent of plant size). These testing activities must support the facility design and construction schedule.

The melter design and process conditions will help establish the feed composition. The expected feed compositions also will impact the HLW vitrification system design. The sludge characterization program and the sludge washing tests with actual tank waste will be used to confirm the feed composition. The HLW pretreatment operations are scheduled to begin in 2008. Construction will begin in 2001. Definitive design is scheduled to begin in

November 1998. These schedules are supported by the characterization and technology development schedules.

5.2.5 Other Schedule Considerations

One alternative to meet testing needs is to build an integrated hot pilot plant. An integrated hot pilot plant is either a large integrated hot pilot plant or a small-scale hot pilot plant. For either size, by definition in Appendix A, the equipment in the pilot plant is directly scalable to plant-scale.

Two considerations are particularly important relative to schedule when considering a hot integrated pilot plant. First, since the equipment in the pilot plant is directly scalable to plant-scale, the same design data must be available to design the pilot-scale equipment that is needed to design the plant-scale equipment. Second, an integrated hot pilot plant will require a project schedule roughly equivalent to a schedule for a full-scale processing plant. Some schedule savings may be expected for the construction of a pilot plant since a greater risk of failure is acceptable for processes and equipment in a pilot plant. The completeness of design data for the pilot plant is expected to be somewhat less than for a full-scale production facility.

Data from operation of the hot pilot plant is fed into the Title I design of the full-scale plant. The design, quality assurance, and safety analysis requirements for any radioactive plant and therefore, the schedule will be very similar. Assuming one year is removed from the typical DOE project schedule, as shown in Figure 5-4, the first data generated by the hot pilot plant will be available about 2005. The year 2005 is one year after the LLW pretreatment facility is scheduled to go hot. Obviously, this approach is not practical because a delay of the Tri-Party Agreement milestones would be required.

5.3 COST

The sampling and characterization program, which is a cornerstone needed to support process development and testing, is an integral part of TWRS programs. The characterization program in the multiyear work plan (WHC 1994) supports disposal needs. Currently, characterization budgets and priority are being reduced corresponding to a reduction in core sampling required to support safe storage of waste in tanks. The characterization program still will need to be continued to support hot testing by providing the needed tank materials.

Figure 5-4. Project Schedule--Pilot Plant Data for Plant Design.

PILOT PLANT DESIGN FOR CURRENT PLANT DESIGN W/ NEW FACILITY 04/04/95

Activities	Start Date	Finish Date
PILOT PLANT		
Engineering Study	05/31/95	11/30/95
Conceptual Design	12/01/95	11/30/96
Definitive Design	12/01/95	05/31/01
Construction	12/01/00	08/31/04
Start-up	09/01/04	06/30/05
Data for Plant Design	07/01/05	03/31/07
UNIT TESTING	03/31/95	12/31/04
PLANT		
PRETREATMENT		
Conceptual Design	06/01/95	03/01/98
Definitive Design	12/01/96	05/01/01
Construction	11/01/98	05/01/07
Hot Startup (LLW)	12/01/04	12/01/05
Hot Startup (HLW)	06/01/07	06/01/08
VITRIFICATION		
Conceptual Design	06/01/95	09/01/98
Definitive Design	11/01/96	09/01/04
Construction	12/01/97	09/01/07
Hot Startup (LLW)	06/01/05	06/01/06
Hot Startup (HLW)	12/01/09	12/01/10

The activities in the multiyear work plan and the multiyear program plan for development and testing do not support all aspects of the proposed strategy for plant startup. Work is underway to perform hot laboratory tests and to renovate and use hot cells for bench-scale tests. Funding is not identified to support ongoing operation of large-scale mockup test facilities through plant startup. In the next update of the program plan, a correction is expected of this oversight.

The costs for a nonradioactive pilot plant and the equipment testing facility for pretreatment are not specifically included in the funding described in the multiyear work plan. The vitrification programs have not specifically identified this need in the years beyond FY 1998.

5.3.1 Other Cost Considerations

Costs are not included in the work plan or program plan to support an integrated hot pilot plant. This facility is envisioned to be have close-coupled unit operations that represent all of the processes supporting TWRS disposal. The instantaneous processing throughput would be between 2 percent and 10 percent of the throughput planned for the TWRS facilities. Even a small integrated hot pilot plant is expected to cost between $200 million and $500 million to build (Appendix E). Annual operating costs for an integrated hot pilot plant are expected to range from $75 million to greater than $100 million. Costs for obtaining feed materials are not specifically included. Both the capital and operating costs of a hot pilot plant are large due in part to its mission, which is to collect a broad spectrum of process and design data and to be directly scalable to full size. Extensive monitoring and sampling of the process is required to collect the needed data.

Expansion of hot testing beyond the bench-scale testing proposed in this document is not expected to be cost beneficial in reducing startup and operation problems (Merrow 1981, Schwallie 1993). The cost of building and operating a hot pilot plant capable of obtaining process data is expected to cost hundreds of millions of dollars and delay scheduled startup of the TWRS facilities (see 5.2.5). The startup reviews, permitting, FSAR, and cold and hot startup problems are not significantly reduced from a full size plant. The data obtained are not expected to substantially reduce startup risk because the specific testing needs are being met with laboratory and bench-scale testing (WHC 1995).

5.4 FACILITY AND EQUIPMENT DESIGN UNCERTAINTIES

The testing strategy must meet the reality of the facility design and equipment design approach (Figure 5-5). The maintenance and operating philosophy also must be matched with the design approach. Generally, the major equipment pieces in radioactive service in the TWRS facilities are expected to be designed for remote replacement. In addition, the cost of equipment and time required for replacement are expected to be small in comparison to the total estimated cost for TWRS facilities.

Flexibility is an important part of the approach to the TWRS facilities (Boomer et al. 1994). "Design flexibility means the ability to change the process and mechanical configuration of the facility after hot operation has begun. Some features lend themselves to flexibility, such as short lived equipment that must be designed for remote replacement anyway" (Boomer et al. 1994). This does not mean that extending equipment life is not important. Some equipment due to the inherent characteristics of the material being handled or the conditions under which processing occurs will result in predictable failures. Equipment exposed to a corrosive atmosphere and high temperatures and equipment with moving parts are subject to failure. Any process that involves solids handling may plug and break down.

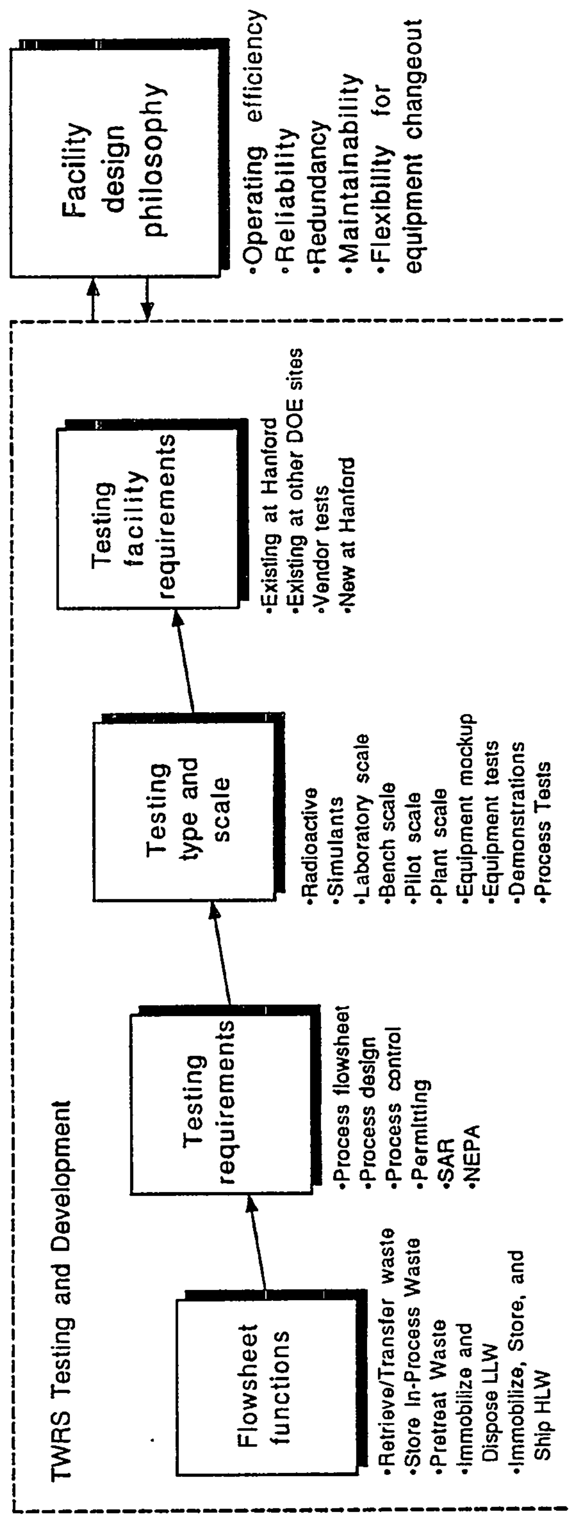
The active fuel reprocessing industry, which is outside of the United States, has gone more and more to remote operations and maintenance. In other countries, as here, the major motivation for remote processes, versus contact maintained processes, is tightening of requirements for personnel exposure.

The ability of the plant to recover from equipment failures will be crucial to continuity of operation. Reliability, redundancy, and maintenance will all be important for continuity of operation. In TWRS facilities, several areas will be likely to have equipment failures due the inherent characteristics of the processes. Equipment subject to erosion and corrosion, such as evaporators and filters, will be subject to replacement maintenance. High temperature processes such as melters and offgas heaters also will be failure prone. Equipment with moving parts, such as centrifuges, pumps, and valves also will be subject to failure.

The above process areas, which may be subject to failure, also will be key unit operations receiving most of the attention during development and testing. For the TWRS facilities these processes will be designed conservatively to not only handle the worst case process conditions such as throughput and solids loading but also to handle the conditions that may cause failure such as corrosion and high temperature.

In addition to failures, the TWRS facilities will be designed to accommodate potential process and equipment modifications. Modifications may be dictated by the desire to make process and technology improvements, by changes in regulatory requirements, and by changes in feed or product requirements.

Figure 5-5. Interaction of Design and Testing.



Testing will be used to provide the best processes and equipment for the beginning of hot operations. Testing capability will be available to support ongoing operations, to troubleshoot process problems, and to develop improved processes. Laboratory testing will be fundamental to the support of the chemical processes. Substantial nonradioactive testing capability for equipment and instrumentation will be crucial for maintaining continuity of operations and is provided by the testing strategy.

From a cost/benefit standpoint, the cost of building hot testing capability must be weighed versus the benefit of perfecting equipment that is failure prone and expected to be replaced frequently. The replacement frequency for some of the major equipment, such as melters, can be in the range of two years to five years. In order to maintain the long term operating efficiency of a facility requiring major equipment changes, the changes must be made quickly or the throughput during operation must exceed the "design basis."

The amount of testing needed to design for permanent installation of equipment for radioactive service must be broad and comprehensive. If "permanently" installed equipment fails and must be replaced, years may be required for replacement. At annual costs of about $500 million for each year of delay in operation, two or three years for an equipment change outage costs more than $1 billion. Spending hundreds of millions of dollars or even a billion dollars to be able to quickly replace equipment would be justified to prevent such an outage (WHC 1995).

With the flexibility to change out major equipment pieces within weeks or even days or hours, the amount of lost time due to failed equipment is significantly reduced. In addition, the cost justification for additional testing to remove all potential and unidentified concerns and problems becomes very small.

Scaleup issues also become important when trying to justify a pilot plant or semi-works. The Rand studies (Merrow et al. 1981, Myers et al. 1986) clearly show that unique facilities and processes are difficult to scale from pilot plants and semi-works. For TWRS facilities, solids/liquid separations and ion exchange systems are key areas of concern for the process design and startup. Fortunately, these also are processes with considerable experience, commercially and within DOE sites, which allow reasonable design approaches to be defined with small risk to startup and operation. The design data needs that define testing requirements are easily identified. The design data can be acquired using laboratory and bench-scale tests.

The unique processes such as melter operations will require testing with large-scale and near full-scale equipment. Since the crucial issues with melter operations and product handling are largely independent of the radionuclide content in the melt, melter tests for equipment development can be conducted with simulants. This approach will meet the needs of the facility design philosophy.

The TWRS processes are a series of unit operations that do not have extensive interactions and recycle streams. The interfaces between unit operations are easy to model and understand, consisting primarily of batch transfers or streams that are primarily water. No specific needs have been identified that require integration of pretreatment and vitrification processes during testing. As a consequence, hot testing of unit operations can be decoupled during hot testing as in actual plant operation. Issues and concerns with melter performance that can be affected by minor constituents and recycle streams are evaluated with actual tank waste on a small scale. Hot tests are coordinated to make maximum utilization of process material. As an example, waste that has carried through the pretreatment process is used when possible to feed radioactive vitrification tests.

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APPENDIX A

DISCUSSION OF SCALEUP

A1.0 DEFINITIONS

The following are definitions used for sizes of test equipment. The definitions in this appendix closely match the definitions in Howden (1994).

Pilot-Plant Scale

Pilot-scale equipment is generally one-tenth to one-thousandth size of full-scale equipment. The size of the pilot plant equipment is determined by the ability to scaleup to full size. Pilot-scale equipment can be scaled up to full size equipment directly or with known correlations. Larger scale equipment is used for pilot plant testing when scaleup correlations are not well known or are unknown. The scale of the equipment generally refers to the throughput and not the physical dimensions. As an example, pilot-scale equipment may have the same height of full-scale equipment while providing only one-tenth of the throughput.

Bench Scale

Bench-scale tests use laboratory-scale equipment and very small scale process equipment to simulate process conditions. Bench-scale tests are conducted in fume hoods, glove boxes, and small hot to large hot cells depending on the scale of process represented. Bench-scale testing is used to establish process parameters.

Laboratory Scale

Laboratory-scale tests are conducted in very small laboratory-scale columns, beakers, test tubes, and crucibles. Tests are conducted with very small amounts of material. The laboratory-scale tests establish basic process conditions. The analytical work that is part of the characterization program is considered part of the laboratory-scale tests.

A2.0 SCALEUP

The scaleup requirements for equipment vary from process to process. Generally, a theoretical model or an empirical model is used (Hamilton et al. 1962). The theoretical model allows scaleup of the process from first principles. Scaleup from very small size to full scale is possible using the theoretical model approach. Scaleup from very small to full scale requires a knowledge of the relative significance of variables. Likeness and similitude are essential for the geometric, mechanical, chemical, and thermal design factors. An example of a process that can be scaled from small scale to full scale is ion exchange chemistry. The geometric and mechanical aspects of operating an ion exchange bed must be tested at a larger scale.

The empirical model uses data collected through development and testing. Scaleup is not possible without knowledge of the impact on the process variables. High temperature processes such as melter operations are particularly difficult to scaleup due to effects on both heat transfer and mass transfer. The effectiveness of mixing, forced or natural convection, is a major concern in large melters. The design of the melter must be tested at near full scale to confirm mixing conditions and production rates.

The fluidized bed calciners at Idaho Falls are an example of scaleup of high temperature operations. Pilot plant operations were conducted with 6-in., 12-in., and 24-in. diameter test units to design a 48-in. plant-scale calciner (Cooper et al. 1965). The 6-in. unit was used to collect design data and basic operating conditions. The 24-in. unit was used to test the heat transfer and recirculating system and full-scale feed nozzles. The 12-in. unit was being maintained as a facility to test future changes. The plant calciner (48-in. diameter) had 750 hours of nonradioactive operation before starting hot feed. "Operation of the plant-scale unit with radioactive feed has remained essentially identical with earlier operation using simulated radioactive feed. Thus, the introduction of waste containing radioactive nuclides has had no perceptible effect..." The report didn't specifically state that all of the pilot units were run with nonradioactive simulants, but that was the inference.

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APPENDIX B

STARTUP AND OPERATING EXPERIENCE

A review of DOE failures, and successes, was conducted to determine what effects testing or lack of testing may have on successful and unsuccessful startups (Brooks, 1994; Bray et al. 1984; Bray 1994; Carrell 1984; Cline et al. 1989; Hanford 1956 a, b, c; Schwallie 1993). Other factors that affect startup and operation also were reviewed. Other experience with development and testing also was reviewed (Phillips 1989). Rand Corporation studies commissioned by DOE (Merrow et al. 1981, Myers et al. 1986) were reviewed.

Several general conclusions can be drawn from this experience base. Many of the startup problems within the DOE complex are **not** related to the chemical processes. A large percentage (probably a majority) of startup problems with new facilities is related to administrative, management, and regulatory issues. The Rand studies discussed below did not attach a significant impact to regulatory issues. Since the completion of the Rand study, regulatory agencies have expanded their authority and DOE activities are scrutinized by both Federal and State agencies that often have conflicting requirements. Many issues are related to fundamental equipment and instrumentation problems and failures that do not relate directly to the chemical process or the material being processed. More development of equipment and instrumentation would have resolved many of these problems. Resolution does not generally require hot testing.

Other problems relate to the use of new methods and technology to replace established and proven processes. In many cases, the new methods did not match established practice and were impractical in the planned application. In other cases, the new technology was not an improvement. In most cases, the new technology did not work or was misapplied. Technology application points to another problem with large DOE projects - lack of active participation on the part of the knowledgeable operations and engineering personnel, the plant people who will startup and operate the facility. Another problem that affects DOE projects is the inability to maintain the technical baseline in the face of intense cost and schedule pressure.

The Rand studies confirmed these conclusions and added some additional insight. The Rand studies examined cost growth, schedule slippages, and performance shortfalls (Myers et al. 1986, Merrow et al. 1981). "Construction schedule slippage is strongly associated with poor project definition at the start of detailed engineering... Startup costs as a percentage of total costs are closely related to the number of new process steps, the extent of difficulty with materials handling issues...encountered during process development, and whether the plant processes are unrefined solid feed stock." Total startup time is closely related by the number of commercially unproven steps. "Most of the variation in plant performance is explained by the measures of new technology and whether or not a plant processes solid materials. ...(R)outinely high performance assumed for pioneer process plants when financial analyses are done is unrealistic. Over 50 percent of the plants in our sample failed to achieve their production goals in the second six months after start-up." "...(C)onventional estimating techniques will routinely overstate any advantages of advanced technologies..."

"In addition, placing responsibility for the project in a team composed of representatives from each of the corporate divisions, rather than dispersing project responsibility across these divisions, appears to result in better communication and shorter startups."

Extensive testing does not resolve all of the concerns with a new technology or first-of-a-kind facility. "...(I)t is commercial use that distinguishes known from unknown technology. Having constructed pilot or other facilities to prove the technology at smaller scale does not alter this conclusion....So-called "semi-works" plants probably do not provide a basis for cost estimation and performance for the commercial units" (Merrow 1981).

APPENDIX C

TESTING REQUIREMENTS SUMMARY (HOWDEN 1994)

The x's in the table indicate that the testing is recommended.

Table C-1. Testing Requirements Summary.

Tank Waste Remediation System Tank Waste Requirements Summary for Pretreatment, Low-Level Waste, and High-Level Waste Vitrification.

Function	Technology	Testing											
		1	2	3	4	5	6	7	8	9	10	11	12
		Cold lab	Cold bench	Small cold pilot plant	Waste character-ization	Hot lab	Large cold pilot plant	Testing using existing DSTs	Functional pilot plant	Hot bench scale	Full-scale cold pilot	Small hot pilot	Large hot pilot
1. Solids Processing	Settling	--	--	--	--	X	--	X	--	--	--	--	--
	Enhanced Sludge Washing	X	--	--	X	X	--	X	--	--	--	--	--
	Sludge Washing	X	--	--	X	X	--	X	--	--	--	--	--
	Filtration	X	X	--	--	X	--	X	X H	X	--	--	--
	Centrifugation	X	--	--	X	X	X	X	--	--	--	--	--
2. Pretreatment Processes	Cs, Removal, IX	X	X	--	--	X	X	--	--	X	--	--	--
	TRU, Tc, Sr, IX	X	X	--	X	X	X	--	--	X	--	--	--
	Sr Precipitation	--	--	--	X	X	--	--	--	--	--	--	--
3. Organic Destruction	Calcination	X	X	--	--	X	X	--	--	--	--	--	--
	Steam Reforming	X	X	X	X	--	X	--	--	X	--	X	--
	High-Temp Hydrothermal	--	X	X	--	X	--	--	X C	X	--	--	--
	Low-Temp Hydrothermal	X	X	X	--	X	--	--	X C	X	--	--	--
	In Tank Organic Destruction	--	--	--	--	X	--	--	--	--	--	--	--
4. Low-Level Waste Vitrification	Joule-Heated Melter	X	X	X	X	X	X	--	#	X	--	X*	--
	All Melters	X	X	X	X	X	X	--	#	X	--	X*	--
5. High-Level Waste Vitrification	Joule-Heated Melter	X	X	X	X	X	X	--	#	X	--	X	--
	All Melters	X	X	X	X	X	X	--	#	X	--	X	--

*C denotes cold test.
H denotes hot test.

*Not required but highly desirable
#Not evaluated in sufficient detail to determine need

DST = Double-shell tank
IX = Ion exchange
Sr = Strontium
Tc = Technetium
TRU = Transuranic

APPENDIX D

SLAATHAUG/ORME DEVELOPMENT PRIORITY TABLE

The development priority table (Slaathaug and Orme 1994), Table D-1, gives the impact level (priority) and technical maturity of processes within the flowsheet. The purpose of the table was to identify and prioritize information deficiencies to define needed development testing. Development testing is used to provide information when engineering analysis cannot provide validation of flow sheet assumptions.

The approach used to prepare the priority list included an examination of each flowsheet function, including low-level waste vitrification offgas and high-level waste vitrification offgas. Within each flowsheet function, the systems and unit operations were examined. The scope of each unit operation was defined: the purpose of each operation was identified. The need, timing, and justification of information to support each operation was identified. The impact of the need on the flowsheet was stated.

An approach to resolution of each need was recommended. When the recommended approach included development testing, that need was prioritized and placed in the development table. The priority was determined by the impact on the flowsheet. Highest impact, and thus highest priority, is shown in the table as a 3. Lowest impact is shown as a 1. The technical maturity levels were ranked for each priority. Highest technical maturity is shown as A. Lowest technical maturity is C.

Table D-1. Development Priority Table.

Priority (3 high)	Technical Maturity	Description	Major Areas of Concern
3	C	High-Level Waste Loading	Verify high-level waste loading in glass which is a major factor in reducing glass volume.
3	C	Process Feed Characteristics and Composition	Physical properties, viscosity, particle size, solids loading variability, etc... Reliability of inventory, solubility data, and tank retrieval order.
3	C	Rapid and on-line analysis for process control	Large volumes require process control analyses to be quick and satisfy hazardous waste requirements.
3	C	Enhanced Wash Efficiency	Verify washing assumptions, efficiency and rates.
3	C	LLW Melter	Melter reactions, melt retention, and offgas composition (especially volatiles - iodine, chlorine, fluorine, Tc).
3	C	Sulfur Cement	Operation and vault decant. Waste form qualification.
3	B	Operation of Frit Filter	Filter type, filter media, and efficiency. Filter aids and filter rejuvenation.
3	B	Settle/Decant Operation	Flocculent impact on settling efficiency and DST requirements. Control and extent of solids carryover.
3	B	Disposition of Secondary Wastes	Spent ion exchangers, non-vitrifiable waste components, miscellaneous solid wastes.
3	B	HLW Melter	Melter reactions, melt retention, offgas composition, feed pretreatment, and glass product constraints.
3	B	HLW Centrifuge	Efficiency (data could be used for implementation of centrifuges in pretreatment).
2	C	Tank Integrity	Corrosion, erosion, temperature cycling, mechanical fatigue, cold brittle fracture, etc.
2	C	Other Pretreatment Steps	Organic destruction, Tc removal, Sr removal, additional solid/liquid separation steps, etc...
2	B	LLW Roll Crusher	Impacts amount of recycled fines.
2	B	Cesium Ion Exchange	Characteristics of media chosen and secondary waste streams. Efficiency, stability of resin.
2	B	LLW Quench Operation	Fairly mature process in industry.
2	A	LLW Feed Evaporator	Composition of overheads. Characteristics of bottoms.
2	A	HLW Evaporator	Composition of overheads.
2	A	Supernatant Evaporator	Composition of overheads.
1	B	Feed Adjustment Reactors	Additional components in waste not found in NCAW.
1	A	Cesium Ion Exchange Evaporator	Composition of overheads. Not as important because overheads are recycled directly back to process.
1	A	LLW Cullet Screen	Mature process in industry.
1	A	LLW Bin Air	Check for validity of pneumatic transfer.
1	A	Cyclone Operation	Mature process in industry.
1	A	Sulfur Cement Formulation	Composition specifications are robust.
1	A	Offgas Solids Removal	Simple, robust process.

Table D-1. Development Priority Table.

Priority (3 high)	Technical Maturity	Description	Major Areas of Concern
1	A	SO2 Removal	Mature process in industry.
1	A	NOx Destruction	Mature process in industry.
1	A	Claus Reactor	Mature process in industry
1	A	Solids Blending	Mature process in industry.
1	A	Process Condensate Handling	Provided by existing facility.
1	A	Pressure Swing Adsorption Unit	Mature process in industry.

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APPENDIX E

DESCRIPTIONS AND ESTIMATED COSTS OF TEST FACILITIES

This appendix contains the descriptions and costs of proposals for facilities for hot and nonradioactive testing. Some of the proposals were completed through advanced conceptual design. None of the facilities have been constructed. These proposals are useful to provide estimates of costs for similar test facilities.

Some nontesting facilities such as the Space Isotopic Project (SIP) were scoped and designed for installation into the Fuels and Materials Examination Facility (FMEF). Most of these concepts would match the level of complexity of an integrated hot pilot plant. The costs for these concepts in 1995 dollars would be in the range of $200 million to prepare FMEF for operation.

E1.0 PROJECT B-226 - HOT CELL FACILITY

The purpose of Project B-226 was to construct a hot cell facility to support waste management activities (Buehler 1979, Buehler 1980). The project was terminated. The facility was intended to support major waste characterization studies, laboratory research, process development and optimization, and flowsheet demonstration. The facility included four hot cells for radioactive development.

The project included a three level structure to house the hot cells and support systems. The structure was about 48 m by 24 m (156 ft by 80 ft). The hot cells were each about 2.8 m by 3 m and 3.7 m high (9 ft by 10 ft and 12 ft high).

The project also included a single level structure for support personnel. This structure was 21 m by 14 m (70 ft by 44 ft).

The total estimated cost was $40.5 million (Buehler 1979). This cost would be about $100 million in 1995.

E2.0 PROJECT B-227 - ENGINEERING TEST FACILITY

The purpose of Project B-227 was to construct a nonradioactive engineering test facility (Rockwell 1980). The project was terminated. The facilities included three bays for equipment, an office facility, a storage building, and a mockup of a waste tank. The engineering test facility was to support (1) in situ storage and disposal, (2) waste retrieval, (3) separation and concentration operations, (4) waste fixation (immobilization), (5) packaging, and (6) decontamination and decommissioning.

The facilities were intended for equipment development, testing, and modification for remote operation and testing. Thorough testing and checkout was provided. Large-scale, special purpose equipment could be assembled, tested, modified, and performance experience gained. The facilities were to be located in the 200 East Area and activities were to be closely coordinated with the technical personnel and operational facilities to be served.

The facility was to have a 30-year design life (Cowley 1979). The total cost was about $20 million (Rockwell 1980). This cost would be approximately $50 million in 1995.

E3.0 TRUEX PILOT PLANT - WESF

Project W-153 was to place a transuranic extraction (TRUEX) pilot plant into the Waste Encapsulation and Storage Facility (WESF). This project was not funded. The estimated cost for this facility is $25 million (Kaiser 1991). This cost would be about $30 million in 1995.

E4.0 CESIUM COMPACT PROCESSING UNIT DEMONSTRATION

The Cesium Compact Processing Unit (CPU) Demonstration project was to place a facility in or near the tank farms to demonstrate cesium separation (Hirschi 1992). This project was canceled. The facility would have been an approximate 4.58-m (15-ft) cube weighing less than 500 tonnes. The CPU would process about 3,800 m^3 (1 Mgal) of waste in one year. The project would have been completed in FY 2000. The total estimated cost was about $78 million.

E5.0 ORGANIC DESTRUCTION PILOT PLANT - WESF

The cost for using the WESF as a pilot plant and hot test facility for organic destruction and other process testing was made in 1993 (Howden 1993). This project was not funded. The proposed project included about $86 million in capital and $41 million in expense funding. The project modified and added to WESF capabilities to provide testing and support capabilities. The project drained and modified eleven WESF pool cells and the transfer aisle to provide windowless hot cells to provide storage and processing space to compliment the existing WESF hot cells.

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APPENDIX F

RELATED TRADE STUDIES

The following is a list of trade studies identified to support the functions and requirements for the Initial Pretreatment Module.

1A. Tank Utilization (E/B-SD-W236B-RPT-016)

2. In-Tank versus Out-of-Tank Pretreatment (E/B-SD-W236B-RPT-017)

3. In-Tank Radionuclide Separation (E/B-SD-W236B-RPT-018)

4. Solid/Liquid Separation (E/B-SD-W236B-RPT-019)

5. Sludge Washing (WHC-SD-W236B-TI-006)

6A. Evaporation and Water Reuse (E/B-SD-W236B-RPT-022)

7. Out-of-Tank Radionuclide Separation (E/B-SD-W236B-RPT-023)

8. Caustic Recycle (E/B-SD-W236B-RPT-024)

9. (not used)

10. Ion Exchange Material Disposal (E/B-SD-W236B-RPT-025)

11. Engineering Study Basis to Support Second Tier Trades (E/B-SD-W236B-RPT-026).

Pretreatment decisions are made using the studies. The decision from study #5 determines if sludge washing is performed in-tank or out-of-tank, and if performed out-of-tank, should the function be allocated to LLW pretreatment, HLW pretreatment, or HLW vitrification. The decisions from studies #3 and #7 determine strontium separation from the LLW stream is not required, determine cesium removal by ion exchange out-of-tank, and determine the strategy for providing contingency for TRU and Tc separations processes in the LLW pretreatment facility. The decisions from studies #3, #5, #7 determine if out-of-tank scope goes with LLW pretreatment facility, HLW pretreatment, or HLW vitrification facility. Study #2 summarizes the decisions from Studies #3, #5, and #7.

The decision from study #1A determines if existing DSTs can be utilized to support Pretreatment needs and do existing upgrade projects adequately address pretreatment requirements. The decisions from studies #4A and #4B determine the appropriate solid/liquid separation system to support radionuclide removal and ion exchange. The decision from study #6A determines the appropriate evaporation related recommendations to be implemented. The decision from study #8 determines if caustic recycle is implemented. The decision from study #10 determines the appropriate disposal system for the ion exchange resin, CST, CS-100, and R-F.

After these decisions are made, the functions and requirements are converted into a design requirements document in accordance with system engineering requirements.

APPENDIX G

TEST OPTIONS

G1.0 IDENTIFICATION OF REPRESENTATIVE HOT TEST PLATFORM OPTIONS

The discussion that follows in this section describes representative hot testing options for equipment and facilities. Each of the test "platforms" must be combined with other platforms to produce a comprehensive hot testing approach. The combined, comprehensive options are described in Section G2.0.

G1.1 FULL-SCALE INTEGRATED HOT PILOT PLANT

A full-scale integrated hot pilot plant is practically equivalent in construction and operating costs to a Tank Waste Remediation System (TWRS) processing facility containing pretreatment, low-level waste (LLW) vitrification, and high-level waste (HLW) vitrification processes. A difference between a pilot plant and a processing facility is the continuity of operation. The processing facility is built for continuous processing and 60 percent total operating efficiency (TOE). The pilot plant would generally not operate continuously on a feed batch for more than a few days. The schedule for development and testing of a full-scale hot plant is about the same whether called a pilot facility or a processing facility.

G1.2 FULL-SCALE FUNCTIONAL HOT PILOT PLANT

A full-scale functional hot pilot plant tests specific unit operations that require full-scale tests. The pilot plant tests one system such as cesium ion exchange. Unit operations for other processes are generally not provided. Some provision may exist for testing one unit operation, changing out and replacing equipment, and then testing another unit operation. Pilot plants are to test equipment and instrumentation as well as the chemical processes.

G1.3 SMALL-SCALE INTEGRATED HOT PILOT PLANT

A small-scale integrated hot pilot plant contains all of the unit operations in the flowsheet that normally operate in a close-coupled fashion and have direct interfaces. The integrated pilot plant tests all of the unit operations and the supporting functions.

G1.4 SMALL-SCALE FUNCTIONAL HOT PILOT PLANT

A small-scale functional hot pilot plant tests individual unit operations on the smallest size that be effectively scaled to the full plant size. The tests are conducted with actual tank waste or simulants with tracers. Tests of sludge washing and cesium ion exchange processes in the 324 Building hot cells are considered a small functional pilot test if scaleup of equipment is practical.

A pilot-scale melter operation is probably 1/10 to 1/50 of the actual plant scale. A minimum throughput for the pilot-scale LLW melter is 2 tons of glass per day. Two tons per day is the throughput rate of the melter in DWPF. A new dedicated facility is required to support this option.

G1.5 BENCH-SCALE HOT TESTS

Bench-scale hot tests are used to test the chemical processes at a larger scale than laboratory scale to confirm kinetic and mass transfer data. The tests are conducted with actual plant waste or simulants with tracers. Bench-scale tests are coordinated with hot laboratory tests and tests with simulants.

G1.6 LABORATORY-SCALE HOT TESTS

Laboratory-scale hot tests are conducted in facilities such as 222-S and 325 Building using actual tank waste and simulants with radioactive tracers. The amount and scope of laboratory tests is about the same to support all testing approaches. Laboratory tests are used to determine waste characteristics, to scope out potential processing problems, and to develop processes and resolve identified problems.

G1.7 NON-RADIOACTIVE AND TRACER TESTS

Tests in a nonradioactive environment and with simulants are required to test processes and equipment. Tests with simulants and tracers at the bench and pilot scale are used in conjunction with hot laboratory and bench-scale tests. Tests with simulants in the laboratory are used to establish the value of the simulant versus hot tests with actual tank waste.

Nonradioactive testing and mockup also are used for personnel training.

G2.0 EVALUATION OF TEST ALTERNATIVES

Hot laboratory and bench-scale testing is required to support the design and operation of a hot pilot plant. Equipment development is required to support equipment design for the pilot plant and for the TWRS processing facilities. The use of hot bench and pilot testing does not reduce the amount of hot laboratory testing.

None of the testing options in G1.0 are standalone options. All of the platform options are shown in Table G-1. The equipment size and throughput capacity of each platform are matched in each column with facilities that provide the needed scale. As an example, laboratory hot tests are conducted in 222-S and the 325 Building. These facility examples for each platform are to provide examples for the purposes of illustration and to indicate existing capability when available.

G2.1 DESCRIPTION OF SELECTED ALTERNATIVES

From the options in Table G-1, four combined alternatives for testing are selected for comparison. These alternatives are representative of the possible methods of implementing testing. Alternative 1 (Table G-2) includes the use of a large hot functional pilot plant combined with hot laboratory and bench-scale tests and cold pilot plant and equipment tests. Shading in the alternative tables is used to show the options deleted from each alternative. Alternative 2 (Table G-3) combines a small hot integrated pilot plant with hot laboratory and bench-scale tests and cold pilot plant and equipment tests. Alternative 3 (Table G-4) combines a small hot functional pilot plant with hot laboratory and bench-scale tests and cold pilot plant and equipment tests. Alternative 4 (Table G-5) combines hot laboratory and bench-scale tests with cold plant and equipment tests. Full-scale demonstrations and process tests are common to all testing alternatives.

G2.1.1 Alternative 1

Alternative 1 provides large-scale functional testing for each of the major unit operations in the TWRS facilities. The large throughput for this equipment requires feed and waste handling capability for large volumes. To support these operations, the pilot plant is tied directly to the tank farms. An example of this platform is the CPU for cesium ion exchange (see Appendix D4.0). Use of the CPU concept for functional testing requires a CPU for each of the major unit operations. A CPU is built for each of sludge washing, solids/liquids separation, and HLW melter operations. A CPU also is built for LLW melter operations. Due to the large size of the LLW melter, the CPU size melter is equivalent to a small functional pilot scale as shown in the table.

Table G-1. Testing Options for Tank Waste Remediation System.

PILOT PLANT DESIGN FOR CURRENT PLANT DESIGN W/ NEW FACILITY 04/04/95

Activities	Start Date	Finish Date
PILOT PLANT		
Engineering Study	05/31/95	11/30/95
Conceptual Design	12/01/95	11/30/96
Definitive Design	12/01/95	05/31/01
Construction	12/01/00	08/31/04
Start-up	09/01/04	06/30/05
Data for Plant Design	07/01/05	03/31/07
UNIT TESTING	03/31/95	12/31/04
PLANT		
PRETREATMENT		
Conceptual Design	06/01/95	03/01/98
Definitive Design	12/01/96	05/01/01
Construction	11/01/98	05/01/07
Hot Startup (LLW)	12/01/04	12/01/05
Hot Startup (HLW)	06/01/07	06/01/08
VITRIFICATION		
Conceptual Design	06/01/95	09/01/98
Definitive Design	11/01/96	09/01/04
Construction	12/01/97	09/01/07
Hot Startup (LLW)	06/01/05	06/01/06
Hot Startup (HLW)	12/01/09	12/01/10

Table G-2. Alternative 1--Large-Scale Functional Pilot Plant.

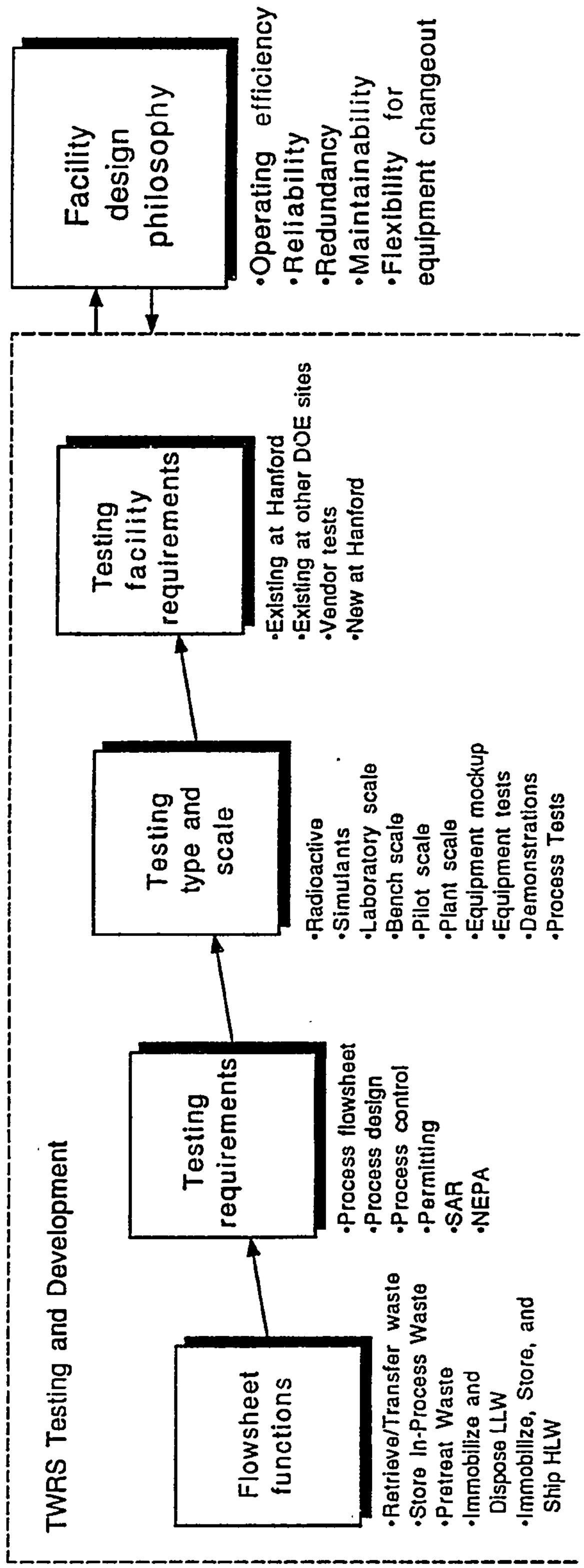

Table G-3. Alternative 2--Small-Scale Integrated Pilot Plant.

Large pilot plant for hot functional testing	Small scale integrated pilot plant	Small scale functional hot pilot plant	Bench scale hot tests	Lab scale hot tests	Bench scale simulants and tracers	Lab scale simulants and tracers	Pilot scale simulant tests	Large scale and full scale equipment tests	Full scale hot demonstration or process test
Retrieval	Retrieval	Retrieval	Retrieval	Retrieval	Retrieval	Retrieval	Retrieval	Retrieval	Retrieval
Sludge washing	Sludge washing	Sludge washing	Sludge washing	Sludge washing	Sludge washing	Sludge washing	Sludge washing	Sludge washing	Sludge washing
Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation
Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX
LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter
HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter
New facility tied directly to the tank farms	New facility tied directly to the tank farms	WESF, FMEF, 324 Bldg.	222-S, 325 Bldg., 324 Bldg.	222-S, 325 Bldg.	222-S, 325 Bldg., 324 Bldg.	222-S, 325 Bldg.	Chem. Engr. Lab. 200E, 300 Area	New facility in 200E	IN-Tank and In-Facility

Table G-4. Alternative 3--Small-Scale Functional Hot Pilot Plant.

Alternative 1 - Large Scale Functional Pilot Plant

Large pilot plant for hot functional testing	Small scale integrated pilot plant	Small scale functional hot pilot plant	Bench scale hot tests	Lab scale hot tests	Bench scale simulants and tracers	Lab scale simulants and tracers	Pilot scale simulant tests	Large scale and full scale equipment tests	Full scale hot demonstration or process test
[illegible]	[illegible]	Retrieval	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Retrieval	Retrieval
Sludge washing	[illegible]	[illegible]	Sludge washing	Sludge washing	[illegible]	[illegible]	Sludge washing	Sludge washing	Sludge washing
Solids/liquid separation	[illegible]	[illegible]	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation
Cs IX	[illegible]	[illegible]	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX
LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter
HLW melter	[illegible]	[illegible]	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter
New facility tied directly to the tank farms	[illegible]	[illegible]	222-S, 325 Bldg., 324 Bldg.	222-S, 325 Bldg.	222-S, 325 Bldg., 324 Bldg.	222-S, 325 Bldg.	Chem. Engr. Lab. 200E, 300 Area	New facility in 200E	IN-Tank and In-Facility

Table G-5. Alternative 4--Bench-Scale/Laboratory Hot Testing.

Alternative 2 - Small Scale Integrated Pilot Plant

Large pilot plant for hot functional testing	Small scale integrated pilot plant	Small scale functional hot pilot plant	Bench scale hot tests	Lab scale hot tests	Bench scale simulants and tracers	Lab scale simulants and tracers	Pilot scale simulant tests	Large scale and full scale equipment tests	Full scale hot demonstration or process test
								Retrieval	Retrieval
	Sludge washing		Sludge washing	Sludge washing			Sludge washing	Sludge washing	Sludge washing
	Solids/liquid separation		Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation
	Cs IX		Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX
			LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter
	HLW melter		HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter
	New facility tied directly to the tank farms		222-S, 325 Bldg., 324 Bldg.	222-S, 325 Bldg.	222-S, 325 Bldg., 324 Bldg.	222-S, 325 Bldg.	Chem. Engr. Lab. 200E, 300 Area	New facility in 200E	In-Tank and In-Facility

An option to using the CPU approach is to build a new permanent facility with the capability to change out and replace the equipment for each of the various operations tests.

The other tests for this alternative are the approximately the same as the complementary tests used in Alternatives 2, 3, and 4. Hot and radioactive laboratory and bench tests are used to characterize tank waste and develop processes. Equipment is tested with simulants in a cold pilot plant. Full-scale equipment is mocked up and tested before installation in the TWRS facilities. Full-scale demonstrations are used for retrieval and sludge washing in the waste tanks. Hot demonstrations of the other unit operations are conducted in the TWRS facilities.

G2.1.2 Alternative 2

Alternative 2 provides a small integrated hot pilot plant for testing TWRS process unit operations. To operate the integrated pilot plant, large volumes of feed and waste are handled. The facility is directly tied to tank farms. This platform is a new facility because no other existing facility meets location and size needs. A pilot-scale LLW melter is not operated hot with this alternative due to size considerations. Hot bench-scale melter operations are combined with pilot-scale simulant testing for the LLW melter development.

The other hot and cold testing needs are approximately the same as for Alternative 1, as well as Alternatives 3 and 4.

G2.1.3 Alternative 3

Alternative 3 provides a small hot-scale functional pilot plant for each of the major unit operations except the LLW melter. Typically one of the unit operations is operated independently from the other unit operations. Changeout of equipment and replacement of equipment may be required between the tests for each unit operation. Serial development as used in this approach extends the testing schedule more than parallel testing approaches.

Due the size of the pilot-scale LLW melter, hot bench-scale tests and pilot-scale testing with simulants are used for the melter tests. The facility requirements for this alternative are equivalent to the use of WESF or FMEF.

The other tests are approximately the same as for the other alternatives.

G2.1.4 Alternative 4

Alternative 4 uses hot laboratory and bench-scale tests combined with nonradioactive and simulant testing of pilot-scale and full-scale equipment. These tests are equivalent to the complimentary testing used in each of the other alternatives. Existing laboratory and hot cell capability in facilities such as 222-S, 325 Building, and 324 Building, and chemical engineering laboratory (CEL, 200E) are combined with new pilot-scale and full-scale test facilities. The new facilities are equivalent to those described by Project B-227 (Appendix D.2).

G2.2 COSTS

Costs are evaluated on an incremental and a total basis. Alternative 4 is considered the base case for costs as the tests required in Alternative 4 are required by the other alternatives. The costs estimates are very preliminary and are intended to provide an order of magnitude value for comparison purposes. An effort was made to show the costs as operating/expense, capital equipment not related to construction, and project. These categories of expenditures will change depending on programmatic decisions about length of facility life and the availability of the needed funds.

The differences in costs among the alternatives are large. Over the long period of testing to support design, startup and operation, the expense/operating cost for each alternative is the largest percentage of the total cost. The operating costs are about 60 percent of the cost for Alternative 4 and range up to 75 percent for Alternative 3. Changing the length of time for operation of test equipment and changing the mode of operation will significantly impact the cost estimates.

G2.2.1 Alternative 1

Alternative 1 requires the equivalent of 5 CPU facilities, one each for sludge washing, solids/liquid separation, cesium ion exchange, HLW melter, and LLW melter. One CPU costs about $80 million for a total cost of $400 million for five. Some savings is expected from preparing multiple units. The total cost is assumed to be $250 million. This estimate assumes that logistical support for staging feed and waste is provided by the tanks in the tank farms. If the movement of tank material is restricted, additional CPUs may need to be built to have access to the desired feed material. Costs associated with operating each CPU are estimated to be at least $15 million per year, or a total of about $60 per year for five CPUs, assuming some economy in numbers. This cost is based on the annual operating cost of the 242-A.

The incremental cost of Alternative 1 is about $850 million. The total cost of Alternative 1 including the testing in Alternative 4 is about $1.08 billion.

A specific cost estimate was not obtained for the Alternative 1 option of building a new permanent facility. A permanent facility with one unit operation installed is expected to cost about $200 million to build and about $50 million per year to operate.

G2.2.2 Alternative 2

Alternative 2 requires the construction of a new facility. This integrated facility has all of the major unit operations except the LLW melter. This facility is similar to placing SIP (Appendix D) capability in the 200 East Area. The cost for the bare facility is expected to be about $100 million. Fully outfitting the facility with equipment, instrumentation, and support systems costs another $200 million. This cost is similar to SIP (see Appendix E). Annual operating costs are expected to be about $75 million per year.

The incremental cost of Alternative 2 is about $1.1 billion. The total cost of Alternative 2 including the testing in Alternative 4 is about $1.32 billion.

G2.2.3 Alternative 3

Alternative 3 uses existing facilities such as WESF or FMEF and outfits them for functional pilot testing except LLW melter operations, which are too large for a small pilot facility. The cost for outfitting the small functional pilot plant is about $100 million based on estimates to prepare WESF. The annual operating costs are estimated to be $35 million per year.

The incremental cost of Alternative 3 is about $535 million. The total cost of Alternative 3 including the testing in Alternative 4 is about $760 million.

G2.2.4 Alternative 4

Alternative 4 costs, which are included in each alternative, include the cost for nonradioactive test capability in the 200 East Area equivalent to Project B-227. These costs were about $20 million in 1979. Escalated to today's costs and adjusted for the increase in the regulatory and oversite requirements, the cost of this capability is expected to be at least $50 million. Annual operating costs are about $10 million per year.

G2.2.5 Comparison to TWRS Facility Costs

The total cost for a combined pretreatment and LLW vitrification facility is about $1.7 billion. Of this cost about 29 percent, or $490 million, is assigned to process equipment. The total cost for the HLW vitrification facility is $1.36 billion. Of this cost about 20 percent, or $260 million, is assigned to process equipment. The total equipment cost for the TWRS facilities is about $750 million.

The annual operating cost of the TWRS facilities is about $300 million.

If hot pilot plant testing saved one year of startup delay, the savings are $300 million plus any equipment costs. As much as $400 million, total, is saved if major equipment changes are avoided. The estimated cost of hot testing incrementally for each alternative through HLW vitrification startup in 2009 is Alternative 1, $850 million; Alternative 2, $1.1 billion; Alternative 3, $535 million. The cost for the cold pilot plant and equipment testing in Alternative 4 is about $225 million. This cost also is added to the incremental cost for each of the other alternatives.

To justify the cost of the testing in Alternative 4, saving about one year of startup delay is needed. To justify Alternative 3, saving about two years of startup delay is needed. To justify Alternative 1 and Alternative 2, saving about three years and four years of startup delay, respectively, is needed (WHC 1995).

G2.3 SCHEDULE

The schedule as a spreadsheet with the incremental costs of testing is shown in Table G-6. The new cold pilot plant and other nonradioactive testing capability, in all of the alternatives, is complete in about 1997. This facility continues to operate indefinitely to support equipment design and facility startup and operation.

The large capacity hot capability for Alternative 1 becomes available in the year 1999 and later. This schedule assumes the use of facilities similar to the CPU. Some of the tests such as the HLW melter are not needed for the startup of the first TWRS facilities and are conducted later. The high capacity functional testing is primarily used to support hot startup and will have reduced utilization after start of the applicable TWRS facilities. Table G-6 shows a schedule for the permanent facility used as the facility option for Alternative 1. This facility is available for use in 2001 and is available to support startup and operational activities for the TWRS facilities.

The small hot integrated pilot plant in Alternative 2 is completed in about 2002. The pilot plant is operated to support the TWRS facilities startup and on going operations.

The small hot functional pilot plant in Alternative 3 is available for operation in about 1998. The pilot plant continues operation through the start of the HLW vitrification plant in 2009.

Table G-6. Estimated Expenditures for Testing Alternatives (Millions of 1995 Dollars).

Alternative 3 - Small Scale Functional Hot Pilot Plant

Large pilot plant for hot functional testing	Small scale integrated pilot plant	Small scale functional hot pilot plant	Bench scale hot tests	Lab scale hot tests	Bench scale simulants and tracers	Lab scale simulants and tracers	Pilot scale simulant tests	Large scale and full scale equipment tests	Full scale hot demonstration or process test
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Retrieval	Retrieval
[illegible]	[illegible]	Sludge washing	Sludge washing	Sludge washing	[illegible]	[illegible]	Sludge washing	Sludge washing	Sludge washing
[illegible]	[illegible]	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation
[illegible]	[illegible]	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX
[illegible]	[illegible]	[illegible]	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter
[illegible]	[illegible]	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter
[illegible]	[illegible]	WESF, FMEF, 324 Bldg.	222-S, 325 Bldg., 324 Bldg.	222-S, 325 Bldg.	222-S, 325 Bldg., 324 Bldg.	222-S, 325 Bldg.	Chem. Engr. Lab. 200E, 300 Area	New facility in 200E	In-Tank or In-Facility

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APPENDIX H

PROCESS SIMULATION AND MODELING

"...process simulation has fundamentally changed not only how engineering is practiced on the plant floor, but what is expected of today's design and operation teams" (Glasscock and Hale 1994). The preceding statement is a good description of the impact of process simulation and modeling impacts in industry and also at Hanford. Modeling and its cousin, electronic automation, are now large ingredients in project logic shown in Figure 5-1. A very similar diagram is given in Glasscock and Hale and is reproduced in Figure I-1. The life cycle of a chemical process flows from the early evaluations through process design, control system design, plant startup, and plant operation. The capabilities for modeling very complex, highly interrelated chemical processes have increased significantly in recent years and modeling is generally available to all organizations and modeling is now a part of everyday tasks for engineers.

Processing modeling helps reduce the cycle time for new process development. In the design phase, modeling can reduce costs through optimization that simplifies the process systems, evaluated alternate control strategies, and examines separations alternatives and the effects on products and waste (effluent and recycle).

The effectiveness of modeling depends on the complexity of the process and the availability of applicable data. For simpler processes with few major unit operations, the model becomes a material balance problem dependent on accurate feed compositions. TWRS separations are examples of simple processes involving few chemical reactions and potential side reactions that can occur in more complicated chemical processes in the petrochemical and chemical industry. The recycle and effluent streams within TWRS will be predominantly water with trace quantities of other constituents.

Models for TWRS processes are highly dependent on the laboratory work that defines the effectiveness of sludge washing, the solids characteristics for solids/liquid separation, and the efficiency of cesium ion exchange.

The TWRS Process Flowsheet is being modelled using the Aspen Plus software package. Aspen Plus, a commercially available program, is a steady state flowsheet simulator. Material flow calculations are made for the process flow diagram in the flowsheet document (Orme 1994). Other process simulation packages are being reviewed for possible use by TWRS. Both static and dynamic models are available and will be used as needed to support TWRS programs.

Figure H-1. Life-Cycle of a Chemical Process.

Alternative 4 - Bench Scale/Laboratory Hot Testing

Large pilot plant for hot functional testing	Small scale integrated pilot plant	Small scale functional hot pilot plant	Bench scale hot tests	Lab scale hot tests	Bench scale simulants and tracers	Lab scale simulant and tracers	Pilot scale simulant tests	Large scale and full scale equipment tests	Full scale hot demonstration or process test
								Retrieval	Retrieval
			Sludge washing	Sludge washing			Sludge washing	Sludge washing	Sludge washing
			Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation	Solids/liquid separation
			Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX	Cs IX
			LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter	LLW melter
			HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter	HLW melter
			222-S, 325 Bldg., 324 Bldg.	222-S, 325 Bldg.	222-S, 325 Bldg., 324 Bldg.	222-S, 325 Bldg.	Chem. Engr. Lab. 200E, 300 Area	New facility in 200E	In-Tank and In-Facility