LOW-LEVEL LIQUID WASTE TREATMENT SYSTEM START-UP

Topical Report

By
Merritt N. Baker
Ralph F. Gessner

July 1989

Work Performed Under Contract No. DE-AC07-81NE44139

Prepared for
U.S. Department of Energy
Assistant Secretary for Nuclear Energy

Prepared by
West Valley Nuclear Services Co., Inc.
P. O. Box 191
West Valley, New York 14171-0191

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
LIST OF FIGURES	v
LIST OF TABLES	vi
ABSTRACT	vii
ACKNOWLEDGMENTS	viii
EXECUTIVE SUMMARY	ix
1.0 INTRODUCTION	1
2.0 LIQUID WASTE TREATMENT SYSTEM (LWTS)	5
2.1 Principle Subsystems of the LWTS	5
2.1.1 Waste Transfer Subsystem	5
2.1.2 Evaporator Subsystem	6
2.1.3 Distillate Ion Exchange Subsystem	7
2.1.4 Concentrates Cooler Subsystem	8
2.1.5 Concentrates Storage and Transfer System	9
2.1.6 Evaporator Waste Feed Subsystem	10
2.1.7 Zeolite Loading Subsystem	11
2.1.8 Spent Zeolite Unload/Unloading/Storage Subsystem	12
2.1.9 Spent Zeolite Transfer Subsystem	13
2.1.10 Cement Solidification System	14
2.1.11 Sampling Subsystem	15
2.2 Process Requirements	16
2.2.1 Function	16
2.2.2 Capacity	16
2.2.3 Product	16
2.2.4 Special Environmental and Facility Constraints	16
2.2.5 Process Ventilation	17
2.2.6 Sampling	17
2.2.7 Other Process Features	17
3.0 SYSTEM DESIGN, CONSTRUCTION & TESTING EVOLUTION	18
3.1 Construction Test Phase	18
3.2 Start-up Phase	18
3.3 Radioactive Test Phase	19

TABLE OF CONTENTS (continued)

<u>Section</u>	<u>Page</u>
4.0 TEST RESULTS	24
4.1 Verification of System Performance vs. Design Criteria	24
4.2 Checkout of Pump and Valve Interlocks and Sequencing (Software)	24
4.3 Performance Testing of the Evaporator and Distillate Ion Exchange Subsystem Using Simulated Supernatant	25
5.0 CONTROLLED START-UP	27
6.0 CONCLUSIONS	29
7.0 REFERENCES	30
APPENDIX A: CHARTS	32

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1-1 HLW Processing Logic Diagram	2
1-2 Conceptual HLW Process Flow Diagram	3
3-1 Construction Test Phase	20
3-2 Principal Components	21
3-3 Nonradioactive Test Phase	22
3-4 Radioactive Test Phase	23
A-1 Chart 1 - Steady-state Operation, Evaporator 31017, 6/10/88	33
A-2 Chart 2 - Steady-state Operation, Tank 5D-15A1, 6/10/88	34
A-3 Chart 3 - Steady-state Operation, Evaporator 31017, 8/18/88	35
A-4 Chart 4 - Unsteady Operation, Tank 5D15A1, 8/18/88	36

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1-1 8D-2 Supernatant Chemical Composition	4
4-1 Performance Summary of HTDS System During Testing	24
4-2 Simulated Supernatant Composition (Simlated Waste Preparation for SIP 87-49)	25
5-1 Campaign Results vs. Design Criteria	27

ABSTRACT

Following removal of Cs-137 by ion exchange in the Supernatant Treatment System immediately upstream, the radioactive liquid waste is volume-reduced by evaporation. Trace amounts of Cs-137 in the resulting distillate are removed by ion exchange, then the distillate is discharged to the existing plant water treatment system. The concentrated product, 37 to 41 percent solids (by weight), is encapsulated in cement, producing a stable low-level waste form.

This report provides a summary of work performed to test the Liquid Waste Treatment System following construction turnover and prior to radioactive operation.

All mechanical and electrical components, piping, valves, pumps, tanks, controls, and instrumentation required to operate the system were tested; first with water, then with simulated waste. Subsystems (individual tanks, pumps, and control loops) were tested individually, then as a complete system. Finally, the system began a controlled start-up phase, which included the first four months of radioactive operation.

Components were tested for operability then for performance data to verify the system's ability to produce an acceptable waste form at design feed rates.

ACKNOWLEDGMENTS

Appreciation is expressed to Ms. Lori E. Domes and Ms. Sharon R. Stephan for patient cooperation in preparing this report from the original manuscript.

EXECUTIVE SUMMARY

This report provides a summary of work performed to test the Liquid Waste Treatment System (LWTS) following construction turnover, nonradioactive testing, and the first four months of radioactive operation. The system is designed to concentrate decontaminated high-level waste liquid produced as a by-product of Plutonium Uranium Reduction Extraction (PUREX) spent fuel reprocessing.

The volume reduction, which results from evaporating water from the liquid waste, appears as a direct cost savings in downstream cement solidification operations by reducing the number of drums produced. The distillate which is evaporated and then condensed contains 1/10,000 of the radioactive material contained in the waste feed stream.

Spent fuel reprocessing facilities were decommissioned and new equipment was installed in the former extraction cells. Some existing storage tanks were flushed and reutilized.

All mechanical and electrical components, piping, valves, pumps, tanks, controls, and instrumentation required to operate the system were tested; first with water, then with simulated waste. Subsystems (individual tanks, pumps, and control loops) were tested individually, then as a complete system.

Components were tested for operability then for performance data to verify the system's ability to produce an acceptable waste form at design feed rates.

Temporary valving and hoses were used at first to bypass existing contaminated or potentially contaminated piping. Finally, the entire Integrated Radwaste Treatment System (IRTS) was tested using all of the actual system interfaces, beginning with simulated raw waste fed to the Supernatant Treatment System (STS), processing by LWTS, encapsulation in the Cement Solidification System (CSS), and finally storage at the Drum Storage Facility (Drum Cell).

The Western New York Nuclear Services Center was extensively decontaminated in order to install the components of the Liquid Waste Treatment System. Structures, vessels, piping, and support systems already in place were cleaned to the maximum extent practical.

1.0 INTRODUCTION

The West Valley Demonstration Project Act of October 1, 1980 (Public Law 96-368) directs the Department of Energy (DOE) to carry out a high-level, radioactive waste (HLW) management demonstration project at the former Western New York Nuclear Services Center site located in West Valley, New York. Under the Act, the Department is responsible for removing HLW from underground storage tanks and solidifying it into a form suitable for ultimate transportation to a federal repository for final disposal. The facility at West Valley, New York was formerly operated by Nuclear Fuel Services, Inc. (NFS) as a commercial nuclear fuel reprocessing plant. West Valley Nuclear Services, Co., Inc. (WVNS), a subsidiary of Westinghouse Electric Corporation, was selected to be the prime contractor for site operations and assumed control of the site in February of 1982.

The West Valley site was the location of the only operating commercial nuclear fuel reprocessing plant in the United States. NFS operated this facility from 1966 to 1972, processing 640 metric tons of commercial and defense fuels using the PUREX (Plutonium Uranium Reduction Extraction) process. Approximately 2.1 million litres of liquid fuel reprocessing waste resulted from this operation. These wastes are stored in an underground storage tank, designated 8D-2. The bulk of the tank's contents was formed by adding excess caustic (NaOH) to a nitric acid-based stream originating from essentially the first solvent extraction cycle (although other additions of decontamination and cleanup waste have been made). Concentration of the neutralized solution has resulted in the formation of a sludge layer at the bottom of the waste tank.

Early in the project, two decisions were made that determined the major thrust of the high-level waste solidification effort:

- 1) The HLW alkaline supernatant would be separated from the sludge and the radioactive components in the supernatant would be chemically separated and combined with the sludge into a terminal HLW form. The treated (or decontaminated) supernatant would be processed into a suitable low-level waste (LLW) for the separated salt/sludge option of the Final Environmental Impact Statement. Reference: Carl and Leonard, 1987.
- 2) The terminal HLW form would be borosilicate glass.

The decision on the processing scheme was based on chemical, radiochemical, and physical properties characterizations performed on samples of the PUREX high-level waste.

The steps to be performed prior to high-level waste processing are listed in the High-level Waste Process Logic Diagram, figure 1-1. Reference: Rykken, 1986.

Two reasons for supernatant treatment are:

- 1) The large quantity of sodium (Na^+) salts, which are incompatible with glass recipes, must be removed and encapsulated in cement, the low-level waste form.
- 2) The major radioactive constituent, Cs-137, was to be removed by ion exchange, resulting in the highest possible radionuclide content in the high-level waste product (borosilicate glass) and, correspondingly, low radionuclide content in the cement (low-level waste) product.

Reuse of existing facilities to the maximum extent required decontamination of former reprocessing cells and equipment, and reactivation of the cells for containment of new treatment equipment. Reference: Gessner and Tundo, 1989. Refer to figure 1-2 for a graphic representation of the high- and low-level waste treatment processes.

Figure 1-1. HLW Processing Logic Diagram

Low-Level Waste Processing Cycle

High-Level Waste Processing Cycle

Figure 1-2. Conceptual HLW Process Flow Diagram

Table 1-1. 8D-2 Supernatant Chemical Composition

<u>Wt. % Compound</u>	<u>Wt. % Wet Basis</u>	<u>Total Kg in Dry Basis</u>	<u>Supernatant</u>
NaNO ₃	21.10000	53.3800	602,659
NaNO ₂	10.90000	27.5700	311,326
Na ₂ SO ₄	2.67000	6.7600	76,261
NaHCO ₃	1.49000	3.7700	42,557
KNO ₃	1.27000	3.2100	36,274
Na ₂ CO ₃	0.88400	2.2400	25,249
NaOH	0.61400	1.5500	17,537
K ₂ CrO ₄	0.17900	0.4500	5,113
NaCl	0.16400	0.4200	4,684
Na ₃ PO ₄	0.13300	0.3400	3,799
Na ₂ MoO ₄	0.02420	0.0600	691
Na ₃ BO ₃	0.02090	0.0500	597
CsNO ₃	0.01870	0.0500	534
NaF	0.01760	0.0400	503
Sn(NO ₃) ₄	0.00859	0.0200	245
Na ₂ U ₂ O ₇	0.00808	0.0200	231
Si(NO ₃) ₄	0.00806	0.0200	230
NaTcO ₄	0.00620	0.0200	177
RbNO ₃	0.00416	0.0100	119
Na ₂ TeO ₄	0.00287	0.0070	82
AlF ₃	0.00271	0.0070	77
Fe(NO ₃) ₃	0.00152	0.0040	43
Na ₂ SeO ₄	0.00054	0.0010	15
LiNO ₃	0.00048	0.0010	14
H ₂ CO ₃	0.00032	0.0008	9
Cu(NO ₃) ₂	0.00022	0.0005	6
Sr(NO ₃) ₂	0.00013	0.0004	4
Mg(NO ₃) ₂	0.00008	0.0002	2
Total	39.53000	100.0000	1,129,038
H ₂ O (by difference)	60.47		1,727,164

2.0 LIQUID WASTE TREATMENT SYSTEM (LWTS)

The Liquid Waste Treatment System (LWTS) is required to process decontaminated supernatant by evaporation into a minimum volume ready for encapsulation in the CSS and to decontaminate the water removed by ion exchange to allow it to be either recycled or released to the environment.

The LWTS process uses both new and existing tanks and equipment and existing cells, aisles, and containment systems.

2.1 Principle Subsystems of the LWTS

2.1.1 Waste Transfer Subsystem

Tank 35104 (Existing)
Transfer Pump 71-P-01

The Supernatant Treatment System (STS) (Reference: Ploetz and Leonard, 1988) is equipped with a storage tank and pump. Decontaminated supernatant is pumped to Evaporator Feed Tank 5D15B or Plant Drain Tank 35104 (both existing). Transfer Pump 71-P-01 is used to withdraw liquid from 35104 or acts as a booster pump if 35104 is bypassed.

Performance and run-in testing of Transfer Pump 71-P-01 and verification of inter-tank flow paths from 35104 to the evaporator and from 35104 to 5D15B were completed by Special Instruction Procedure, SIP 87-01.

2.1.2 Evaporator Subsystem

Evaporator 31017 (Existing) including: vapor body, reboiler, condenser

Control Valves 71-LCV-100 (Level Control Valve)

71-FCV-111 (Steam Flow Control Valve)

71-TCV-160 (Cooling Water Flow Control Valve)

Evaporator 31017 is used to concentrate supernatant by boiling off excess water. Steam and feed flow rates are balanced so that the level can be kept constant while withdrawing product from the bottom and allowing distillate to flow out through the condenser.

Process controls, interlocks, and boil-off rates were checked using SIP 87-2. Samples were taken of both concentrates and distillates during SIP 87-49 to obtain other performance data: decontamination factors, total dissolved solids vs density, etc. Process control loops for density, level, and temperature control were fine-tuned during SIP 87-49.

2.1.3 Distillate Ion Exchange Subsystem

Distillate Surge Tank 71-D-005

Zeolite Ion Exchange Column 71-D-003

Distillate Pump 71-P-15

Control Valve 71-LCV-103 (IX Column Level and Flow)

The distillate ion exchange subsystem completes the decontamination of the waste liquid begun in the evaporator. Overheads produced in the evaporator flow out of the condenser and are held in the distillate surge tank then pumped through the zeolite ion exchange column. Flow is modulated by a control valve located downstream of the column, ensuring that the column is always flowing full.

Performed concurrently with SIP 87-2, Zeolite Ion Exchange Column bed hydraulics were tested by SIP 87-3. Performance of the zeolite ion exchange column for sodium, potassium, cesium, and strontium removal was tested during SIPs 87-49, 87-59, and 87-69.

2.1.4 Concentrates Cooler Subsystem

Concentrates Cooler 71-E-005

Concentrates Pump 71-P-16

Valve 71-FCV-157

The concentrated waste produced in the evaporator is reduced to a temperature below its critical temperature in the concentrates cooler. Concentrates are transferred to either of the concentrates storage tanks by Concentrates Pump 71-P-16. The flow of concentrates is modulated by Flow Control Valve 71-FCV-157 to maintain the evaporator pool at the desired density.

Cold testing of subsystem hydraulics, including valves and interlocks, was performed during SIP 87-4. Performance testing of the concentrates cooler was performed during evaporator testing of SIP 87-49.

2.1.5 Concentrates Storage and Transfer System

Concentrates Storage Tank 5D-15A1 (Existing)

Concentrates Storage Tank 5D15A2 (Existing)

Concentrates Transfer Pump 71-P-05

Concentrates Transfer Pump 71-P-05

Decontaminated supernatant, which was concentrated in the evaporator and then cooled, is routed to either of the two concentrates storage tanks, 5D15A1 or 5D15A2. These existing tanks are actually a single tank divided into two sections. Each is furnished with inlet and outlet piping, level and density instruments, and transfer pumps. Concentrated decontaminated supernatant is the final product of the LWTS and is pumped to the Solidification System for encapsulation.

It is possible to transfer concentrates from one tank to the other, if required for any reason. Isolation valves are interlocked so the concentrates will be routed to the other tank if one reaches high level.

Checkout of subsystem interlocks, signal simulation of process variables (level and flow), automatic actions of valves and pumps, and run-in testing of transfer pumps were performed during SIP 87-5.

2.1.6 Evaporator Waste Feed Subsystem

Tank 5D-15B (Existing)
Waste Feed Pump 71-P-04

Dilute decontaminated supernatant is received from the Supernatant Treatment System and held in Evaporator Feed Tank 5D15B. Supernatant is transferred to the evaporator by Evaporator Feed Pump 71-P-04 in response to changing evaporator level.

Testing of valves and associated piping between tanks 5D15B, 5D15A1, 5D15A2 and pump 71-P-04 was performed during SIP 87-6. This procedure included run-in testing of 71-P-04.

2.1.7 Zeolite Loading Subsystem

Fill Hopper 71-D-004
Eductor

Fresh zeolite is loaded into Fill Hopper 71-D-004 and sluiced to Zeolite Ion Exchange Column 71-D-003. The entire fill cycle, using air and water eductors and associated piping, was tested during SIP 87-9.

2.1.8 Spent Zeolite Unload/Unloading/Storage Subsystem

Spent Zeolite Tank 71-D-007

Spent zeolite is sluiced from Zeolite Ion Exchange Column 71-D-003 to Spent Zeolite Tank 71-D-007. SIP 87-10 checked out all sluicing operations. Process parameters (air and water flow and pressure) were compared to design values. The ability to sluice all of the zeolite out of the Ion Exchange Column was verified.

2.1.9 Spent Zeolite Transfer Subsystem

Positive Displacement Pump 71-P-09

When the spent zeolite tank is full, the material may be resuspended and pumped to a settling or disposal system. Dewatering, resuspension, and sluicing of zeolite from Spent Zeolite Tank 71-D-007 to CSS Waste Dispensing Vessel 70-D-001, includes operation of the pumps, controls, instruments, and interlocks.

2.1.10 Cement Solidification System

Waste Dispensing Vessel 70-D-001

Concentrated decontaminated supernatant is transferred to the Cement Solidification System (CSS) from either of the Concentrates Storage Tanks, 5D15A1 or 5D15A2. Isolation valves are interlocked to prevent transfers when the waste dispensing vessel is at high level. Interlocks were verified in full-scale testing during SIPs 87-59 and 87-69.

2.1.11 Sampling Subsystem

Sample Point 71-L-004 (from 5D-15B)
Sample Point 71-L-001 (from 35104)
Sample Point 71-L-005 (from 5D-15A1)
Sample Point 71-L-006 (from 5D-15A2)

Existing sample stations permit sampling any of the feed or receiving tanks. The sample stations utilize an airlift or eductor-type system to draw the sample into a bottle. Sampling is performed in a glove box, which can be drained back to the tank. Controlled ventilation of the glove box and a bag-out port prevent the spread of contamination. A functional test of all LWTS sample points was performed during SIP 87-68.

2.2 Process Requirements

2.2.1 Function

Low-level liquid waste will be collected from two upstream sources: (1) decontaminated supernatant and (2) by-product from sludge washes.

These wastes are routed through new and existing piping to Evaporator Feed Tank 5D-15B. Evaporator concentrates are cooled and then held in Concentrates Storage Tanks 5D-15A1 and 5D-15A2 to be sent to the CSS for encapsulation.

2.2.2 Capacity

The evaporation subsystem has a capacity of 10 gallons per minute. The feed capacity of the evaporator is 20 gallons per minute.

2.2.3 Product

Concentrates produced by the evaporator subsystem are 37 to 41 weight percent solids (nominally 39 weight percent). Administrative controls required to ensure STS performance limit the Cs-137 concentration in the product to 3.3 uCi/mL.

Condensate (evaporator overheads) will be decontaminated to less than 3.0 uCi/mL gross beta.

A Modified State Pollutant Discharge and Elimination System (SPDES) Permit was issued by the New York State Department of Environmental Conservation (NYSDEC) to include condensate added to the existing plant wastewater treatment system.

2.2.4 Special Environmental and Facility Constraints

Pumps and mechanical equipment requiring routine maintenance are located in shielded rooms or niches so that they can be accessed for maintenance without exposure of personnel to other radioactive equipment such as vessels. Valves, actuators, pumps, and other parts requiring service or replacement are placed in areas of lower radiation such as pump niches, the valve gallery, and aisles.

Interconnecting lines between 01-14 Building and the Uranium Loadout Room, Uranium Purification Cell, Extraction Cell 3, and Upper Warm Aisle are encased in occupied areas by a shielded pipe chase. The pipe chase provides secondary containment for leaks and includes a leak detection system. The pipe chase is vented to the existing plant Vessel Off-gas System.

2.2.5 Process Ventilation

All process equipment vents are routed to the existing plant Vessel Off-gas System. Existing tanks were vented to the plant Off-gas System prior to construction.

2.2.6 Sampling

Existing tanks employ their existing vacuum jet-type samplers. New sample stream and return piping was installed from existing sample connections to a new sample station glove box. The tanks are thoroughly sparged prior to sampling in order to guarantee a homogeneous mix and, therefore, a representative sample.

2.2.7 Other Process Features

All instrumentation and operators for pump and valve starting and switching are controlled from the LWTS Control Panel, located in the 01-14 Building.

3.0 SYSTEM DESIGN, CONSTRUCTION & TESTING EVOLUTION

3.1 Construction Test Phase

Following installation and completion of associated contractual requirements, the subcontractor submitted a turnover package, including records and reports for the system or subsystems. The turnover package includes welding and pressure test results, as well as electrical continuity test results. A flow sheet of construction test results is included in figure 3-1. Reference: Reeves et. al., 1989.

3.2 Start-up Phase

A Test Plan (Reference: Denero, 1987) was developed that identified the components, systems, and subsystems that required testing to verify compliance with the specified design and performance requirements. The plan provided a description of the scope and acceptance criteria for each test.

The Test Plan was arranged so that each Special Instruction Procedure (SIP) tested individual tanks and pumps and their associated instruments and controls. In this manner, the subsystems were isolated for each test. Calibration and repair of other equipment continued throughout the test period. Similarly, deficiencies uncovered during a test could be corrected without interrupting other work. Subsystems are separated by SIP in figure 3-2.

Tests were performed concurrently whenever possible. All nonradioactive testing utilized plant water and nonradioactive commercial grade chemicals.

All testing was performed by trained operators using applicable Temporary Operating Procedures (TOPs) or Special Instruction Procedures (SIPs). Start-up crews included shift supervisors, shift engineers, and shift managers to direct testing.

The cognizant start-up shift engineer prepared a Test Results Report (TRR) on each system of subsystem test. The reports listed the actual test results against the desired test results and defined them as acceptable or unacceptable.

The test plan can be divided roughly into two phases: nonradioactive and radioactive. All construction checkout (pressure tests, electrical continuity testing, etc.) testing of subsystem hydraulics using water and performance testing of systems using "cold" chemicals were completed during the nonradioactive phase. Existing contaminated piping or tanks were eliminated from the nonradioactive phase by using temporary piping, hoses, and tanks.

A Failure Modes and Effects Criticality Analysis (FMECA) was completed early in the nonradioactive test phase, evaluating the Operability and Reliability of the Integrated Radwaste Treatment System. All actions resulting from observations were addressed and completed prior to the radioactive test phase.

3.3 Radioactive Test Phase

After all of the Integrated Radwaste Treatment System (STS, LWTS, CSS, and Drum Cell) completed nonradioactive testing, the final tie-ins were completed and all temporary piping removed. Radioactive testing began using simulated supernatant fed to the STS. The entire IRTS processed the supernatant through normal flow paths, including existing contaminated tanks and piping. All existing equipment that had been bypassed during nonradioactive testing was checked out during this integrated test. A flow sheet showing the test plan matrix for nonradioactive testing is included in figure 3-3. Radioactive testing is included in figure 3-4.

Figure 3-1. Construction Test Phase

Figure 3-2. Principal Components

Figure 3-3. Nonradioactive Test Phase

Figure 3-4. Radioactive Test Phase

4.0 TEST RESULTS

The results of each test step were documented in data sheets associated with the Special Instruction Procedure (SIP) for each test.

Unanticipated or unsatisfactory results were also recorded and were documented on Test Exceptions (TE) or Trouble Records in accordance with the appropriate engineering procedure. System deficiencies were corrected and the repairs were rechecked in subsequent tests.

The IRTS integrated test included the last reverifications and all steps that had been postponed from previous tests. At the conclusion of the IRTS integrated test, all steps had been completed satisfactorily.

Details and complete test results are given in the Test Results Reports, references 1 through 15.

4.1 Verification of System Performance vs. Design Criteria

A review of system performance is shown in table 4-1.

Table 4-1. Performance Summary of HTDS System During Testing

<u>Parameter</u>	<u>Design</u>	<u>Actual</u>
Decontamination Factor (CS+)	1.0E04	1.9E05
Decontamination Factor (Sr++)	1.0E04	>3.3E04
Volume Reduction Factor	3.0	3.0 - 3.3
Feed Flowrate (gpm)	10	11
Concentrates Flowrate (gpm)	N/A	4
Distillates Flowrate (gpm)	N/A	7

4.2 Checkout of Pump and Valve Interlocks and Sequencing (Software)

In the LWTS, all of the pneumatic valves and electric and pneumatic pumps are controlled by a Programmable Logic Controller (PLC). The software in the controller is the switchboard that determines the interlocking of the valves and pumps with other valves and process variables. The process variables are the fluid levels in tanks, the seal water flows, the radiation levels, the discharge fluids, and other analog variables in the process. The PLC measures the variable and determines the go, no-go level for each process variable interlock used in the system.

The hardware/software is designed to incorporate safety interlocks that cause the system to fail safe during sectionalized power or electrical equipment failures. This is done to assure a complete fail-safe condition when any part of the control fails.

The software test was a valve-by-valve and pump-by-pump check in which all the interlocks from other valves, level transmitters, radiation monitors, ion monitors, flow switches, and controllers were checked. In most cases, the actual device such as a valve, pump starter, or seal water flow switch was operated; however, certain valves and the process transmitter had to be simulated. The valves that were simulated were either part of the Recycle Water System or, if operated, could possibly cause contamination of the clean parts of the

system. The test was designed to be a dry test with no water flowing except for seal water. It was then necessary to simulate all analog levels in tanks to complete the software checkout. In all cases the simulators (relays or test boxes) were connected directly in place of the device. No software simulation (dummy software signals) were used during the test.

The checkout of the software compared actual equipment operation by observation of valves and valve and pump indicating lights and compared it with the expected operation. The software check confirmed that the software interlocking functions as described in the design criteria documents and sectionalized power or electrical equipment failures cause the entire system to fail to a safe condition.

4.3 Performance Testing of the Evaporator and Distillate Ion Exchange Subsystem Using Simulated Supernatant

Prior to this test, the thermalhydraulic and flow characteristics had been checked out. During this test, ion exchange column and evaporator decontamination factors (DFs) and set points for control instruments were established.

The composition of the simulated supernatant is given in table 4-2. Samples were taken throughout the test period and analyzed to obtain process performance data. These included decontamination factors, percent Total Dissolved Solids (TDS) vs. density, steam flow vs. boil-off rate, etc. All of the pertinent process control loops; for example, density level, distillate temperature, and steam flow were checked or calibrated and fine-tuned as applicable.

Table 4-2. Simulated Supernatant Composition (Simulated Waste Preparation for SIP 87-49)

Water H ₂ O	3,785 litres (1,000 gallons)
Cesium Nitrate CsNO ₃	6.6 kg
Strontium Nitrate Sr(NO ₃) ₂	10.87 kg
Sodium Nitrate NaNO ₃	383.30 kg
Sodium Nitrite NaNO ₂	197.72 kg
Sodium Sulfate Na ₂ SO ₄	48.53 kg
Sodium Bicarbonate NaHCO ₃	2.7 kg
Potassium Nitrate KNO ₃	23.0 kg
Sodium Carbonate Na ₂ CO ₃	16.0 kg
Sodium Hydroxide NaOH	11.23 kg
Potassium Chromate K ₂ CrO ₄	3.24 kg
Sodium Chloride NaCl	2.97 kg
Trisodium Phosphate Na ₃ PO ₄	2.43 kg

Forty-three thousand gallons of supernatant feed were processed through the evaporator and 14,000 gallons of concentrates were received in the final hold-up tank. Part of the concentrates were reused to make more feed so that the evaporator could run continuously.

The average feed concentration was ~13-15 w/o TDS, the average concentrates concentration was ~43-45 w/o TDS.

The average volume reduction factor [(volume of feed) ÷ (volume of concentrate)] for the entire test was 3.0 to 3.3.

The evaporator overall process performance matched or exceeded the design criteria. Evaporators with this thermosiphon design normally produce DFs in the range of $1E +04$. However, in this test the average DF for the most abundant cation, i.e., Na^+ , was $1E +05$ to $1E +06$. The major benefit of this very high DF is considerable reduction in the distillate ion-exchange requirement downstream of the evaporator resulting in a longer lasting zeolite ion-exchange bed.

The process control performance for this testing, however, was mixed because the evaporator was not running in a true continuous mode. After attaining stabilization, the evaporator operated on a "time-average continuous" basis (intermittent flow), which is not the design intention for the evaporator. The time averaging operation of the evaporator can be smoothed out with control modifications.

Operation of the Ion Exchange Column was not steady. The column was furnished with downstream piping in a gooseneck configuration intended to keep the column flooded. Since flow was from a higher elevation to a lower elevation, siphoning occurred. The column would alternately fill up and drain down. This resulted in nonlinear flow and reduced column performance, although cesium and strontium removal exceeded the design criteria requirements.

Siphoning was eliminated by moving the Distillate Level Control Valve LCV-103 to a location downstream of the ion exchange column. Other control loop modifications, such as the addition of valve position limiters so that control valves do not open and close completely, were also installed as a result of this test. The performance of these control loops following the modifications were verified during subsequent testing and found to be satisfactory.

5.0 CONTROLLED START-UP

A presentation was made to DOE-Idaho Operations Office personnel on the operational readiness of the West Valley Demonstration Project Integrated Radwaste Treatment System (IRTS) which includes the Supernatant Treatment System (STS), Liquid Waste Treatment System (LWTS), Cement Solidification System (CSS), and Drum Cell (DC). The presentations included reviews of system design, product quality, safety system analysis/operational safety requirements, training, staffing, start-up procedures, environmental monitoring, and permits and run plans. Final closeout of open items from the combined DOE/WVNS Operational Readiness Review Board (ORRB) that was held at West Valley was also presented.

Based upon the above presented information, approval was granted to proceed with controlled start-up of the Integrated Radwaste Treatment System for supernatant processing at the West Valley Demonstration Project, consistent with the approved Safety Analysis Requirements and Operational Safety Requirements documents.

Actual supernatant from HLW Tank 8D-2 was used and all systems were operated by qualified operators using approved standard operating procedures.

The results of each campaign, including volume processed, product density, flow rates, Cs-137 activity, radionuclide inventory, and problems encountered (if any), are summarized in a run report.

Operating data for the first four campaigns vs. design criteria are shown in table 5-1.

The initial operating runs of the LWTS were closely monitored by operators, supervisors, low-level waste treatment project engineers, and management personnel.

Chart recorders were used to obtain a graphic presentation of such parameters as evaporator level, static liquid pool (concentrates) density, and concentrates storage tank (cooled) density. Charts 1 and 2, found in Appendix A, depict actual results for a period of evaporator operation. Line A of chart 1 shows a fairly uniform, static liquid pool density for the evaporator operating in its design steady-state condition. Line A of chart 2 shows the density of the cooled concentrates in Concentrates Storage Tank 5D-15A1, with the product final density at the design density of 1.324 gm/mL and 39.7 percent solids. Note that as the concentrates cooled, the specific volume (mL/gm) decreased, resulting in an increased density.

Table 5-1. Campaign Results vs. Design Criteria

Parameter	Desired	Design Criteria for			
		Campaign 1	Campaign 2	Campaign 3	Campaign 4
Decontamination Factor (Cs-137)	1.0 E4	7.3E E4	6.21 E3	1.48 E4	2.1 E5
Feed Flow Rate (Weighted Average)	10 gpm	11.42 gpm	4.8 gpm	10.78 gpm	10.0 gpm
TDS in Concentrates	37-41%	40.13%	38.52%	39.29%	38.11%

Detailed discussion of evaporator boiling:

When a liquid is heated, vapor bubbles form at the liquid surface and because they are lighter, move upward by natural convection. This first stage of boiling is known as "convection boiling." As the temperature differential between the cold liquid and heating fluid increases, the second stage of boiling, called "nucleate boiling," is reached. In nucleate boiling, small nuclei of vapor bubbles form on the heat transfer surfaces (the reboiler tubes in this case) and the heat transfer coefficient in that zone increases.

The LWTS evaporator operates between convective boiling and nucleate boiling, providing the optimum overall heat transfer coefficient and thus the best thermal output. Further increases in temperature difference cause the heat transfer coefficient to **decrease**. Unstable evaporator level and density condition and the corresponding unsteady product density are shown in chart tracings in charts 3 and 4. Line A of chart 3 shows unstable density in the evaporator liquid pool. Line B of chart 3 shows the resulting variations in the evaporator level. Line A of chart 4 shows the corresponding variability in the concentrated product density. Line B of chart 4 shows the level increasing in the concentrates tank.

For this reason, a considerable effort was spent in tuning and adjusting the evaporator controls to achieve the most stable conditions of heat and mass flow. As an example, the level and density controllers modulate evaporator feed and concentrate removal, respectively. Software was revised so the level and density signals are received and **averaged** instead of changing instantaneously.

6.0 CONCLUSIONS

System performance during integrated (radioactive) testing and controlled start-up demonstrated that the system is capable of safe, efficient operation.

The Liquid Waste Treatment System yields products (evaporator concentrates and distillates) of a consistent quality.

Measureable system parameters such as throughput rates, decontamination factors, and volume reduction, meet or exceed the system design criteria.

7.0 REFERENCES

1. WVNS-TR-71-002, Test Results Report on Testing and Checkout of Concentrates Storage Tanks 5D-15A1, 5D-15A2, and Concentrates Pumps P-05 and P-06, M. N. Baker, released March 18, 1988.
2. WVNS-TR-71-004, Test Results Report on Checkout of Pump and Valve Interlocks and Sequencing - LWTS Software, W. E. Mateer, October 1987.
3. WVNS-TR-71-005, Test Results Report on Evaporator Testing with Simulated Supernatant, M. N. Baker, April 1988.
4. WVNS-TR-71-006, Test Results on Testing and Checkout for Unloading Ion-Exchange Media, M. N. Baker, March 1988.
5. WVNS-TR-71-007, Test Results on Testing and Checkout of Resin/Zeolite Addition System, M. N. Baker, March 1988.
6. WVNS-TR-71-008, Test Results Report on Evaporator System Thermal Hydraulics Checkout with Utility Water, M. N. Baker, April 1988.
7. WVNS-TR-71-009, Test Results Report on Testing and Checkout of Evaporation System Along with Distillate Ion-Exchange Column, M. N. Baker, April 1988.
8. WVNS-TR-71-010, Test Results Report on Testing and Checkout of Evaporator Concentrates Cooler 71-E-005 and Concentrates Pump 71-P-16, M. N. Baker, March 1988.
9. WVNS-TR-71-013, Test Results Report on Testing and Checkout for Dewatering and Transfer of Wet Solids from Tanks 71-D-006, 71-D-007, and 71-D-008, to CSS Waste Dispensing Vessel, M. N. Baker, April 1988.
10. WVNS-TR-71-014, Test Results Report on LWTS Sampling System Checkout, K. T. Cotter, April 1988.
11. WVNS-TR-71-015, Test Results Report on Testing and checkout of Tanks 5D-15B, 5D-15A1, 5D-15A2, 7D-13, and High TBD Storage Tank Pump 71-P-04, S. R. Reeves, April 1988.
12. WVNS-TR-70-012, Test Results Report on LWTS/CSS Integrated Test, M. N. Baker, March 1988.
13. WVNS-TR-70-013, Test Results Report on Integrated Testing of STS/LWTS/CSS/RTS, M. N. Baker and S. R. Reeves, April 1988.
14. DOE/NE/44139-14, High Level Waste Characterization at West Valley, L. E. Rykken, June 1986.
15. DOE/NE/44139-25, Selection of the Treatment Method for the West Valley Alkaline Supernatant, D. E. Carl and I. M. Leonard, February 1987.

16. DOE/NE/44139-47, Supernatant Treatment System Design Through Testing, D. K. Ploetz and I. M. Leonard, December 1988.
17. DOE/NE/44139-54, Lessons Learned at West Valley During Facility Decontamination for Reuse, R. F. Gessner, D. Tundo, and R. E. Lawrence, January 1989.
18. DOE/NE/44139-56, Low Level Liquid Waste Treatment System Design and Construction, S. R. Reeves et. al., 1989.
19. WVNS-TP-71-001, Test Plan for Operational Checkout of the LWTS, J. V. Denero, June 1987.
20. NYSDEC SPDES No. NY-0000973, Permit No. 90-87-1268.

APPENDIX A: CHARTS

Figure A-1. Chart 1 - Steady-state Operation, Evaporator 31017, 6/10/88

Figure A-2. Chart 2 - Steady-state Operation, Tank 5D-15A1, 6/10/88

Figure A-3. Chart 3 - Steady-state Operation, Evaporator 31017, 8/18/88