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Document Number: WHC-SD-SNF-^{TRP}~~RPT~~-007, Rev. 0

Document Title: 105K West Isolation Barrier Acceptance Test Results

Release Date: May 18, 1995

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SUPPORTING DOCUMENT		1. Total Pages 58
2. Title 105K West Isolation Barrier Acceptance Test Results	3. Number WHC-SD-SNF-^{TRP}RPT-007	4. Rev No. 0
5. Key Words 105 K West Isolation Barrier Test Results Analysis	6. Author Name: K. J. McCracken <i>K. J. McCracken</i> Signature Organization/Charge Code 57400 / L1175	
7. Abstract This report displays the results and analysis of the 105K West Isolation Barrier Acceptance Test.		

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8. RELEASE STAMP
OFFICIAL RELEASE (21) BY WHC DATE MAY 18 1995 <i>Sta. 21</i>

105 K WEST ISOLATION BARRIER ACCEPTANCE ANALYSIS REPORT

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INDEPENDENT REVIEW

Document Reviewed 105K West Isolation Barrier Acceptance Analysis Report

Author K. J. McCracken Report No. WHC-SD-SNF-RPT-007 EDT No. 142772

The subject document has been reviewed by the undersigned. The reviewer reviewed and verified the following items as applicable [EP.4.1].

- Engineering Specification
- Design Input
- Basic Assumption
- Approach/Design Methodology
- Related Information
- Conclusion/Result Interpretation

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Reviewer

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5-17-85
Date

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed 105K West Isolation Barrier Acceptance Analysis ReportAuthor K. J. McCracken

<u>Yes</u>	<u>No</u>	<u>N/A</u>	
☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	<i>checked on TEST Plan</i> Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☒	☐	☐	Code run streams correct and consistent with analysis documentation.
☒	☐	☐	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

Software QA Log Number NAD. A. Wallace
Reviewer 5-17-95
Date

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1.0 INTRODUCTION

The objective of this document is to report and interpret the findings of the isolation barrier acceptance tests performed in 105KW/100K. The tests were performed in accordance with the test plan (McCracken 1995c) and acceptance test procedure (McCracken 1995a). The test report (McCracken 1995b) contains the test data. This document compares the test data (McCracken 1995b) against the criteria (McCracken 1995a, c). A discussion of the leak rate analytical characterization (Irwin 1995) describes how the flow characteristics flow rate will be determined using the test data from the test report (McCracken 1995b).

The barriers must adequately control the leakage from the main basin to the discharge chute to less than the 1,500 gph (5,680 lph) Safety Analysis Report (SAR) limit.

Two modes of water loss were considered; basin and/or discharge chute leakage, and evaporation. An initial test (Test 1, 11/18/94) established baseline leakage data and instrumentation performance. For the second test the results of test 1 are reported in Appendix A.

Test 2 evaluated the sealing performance of the isolation barrier by inducing an 11 in. (27.9 cm) level differential across the barrier. The leak rate at this 11 in. (27.9 cm) level is extrapolated to the 16 ft. (4.9 m) level differential postulated in the DBE post seismic event. If the leak rate, adjusted for evaporation and basin leakage (determined from Test 1), is less than the SAR limit of 1,500 gph (5,680 lph) at a 16 ft (4.9 m) level differential, the barriers pass the acceptance test.

2.0 DEFINITIONS

BASIN - That portion of 100-KW used for irradiated fuel storage; is hydraulically connected to the Weasel Pit, Filter/Viewing Pits, Dummy Elevator Pit, and South Loadout Pit; and is hydraulically separated from the Discharge Chute, by the isolation barrier and the North Loadout Pit (Sand Filter Backwash Pit) by a separate barrier.

DISCHARGE CHUTE - That portion of 100-KW that contains no irradiated fuel; is hydraulically separated from the basin by the isolation barriers; and is hydraulically connected to the Reactor Fuel Discharge Pit.

ISOLATION BARRIER - The two steel barriers and (McCracken 1995) the mounting brackets that were installed in the discharge chute openings, isolating the basin from the discharge chute.

- TEST 1 - The initial baseline test for basin leakage and instrumentation set-up. The basin and discharge chute levels were equal to measure evaporation and construction joint losses.
- TEST 2 - The isolation barrier leak test where a level differential was induced across the isolation barrier to determine leak tightness.

3.0 TEST SPECIFICATION REVIEW

As discussed in McCracken 1995c, the acceptance criteria of 1,500 gallons (5,680) per hour at a 16 ft. (4.9 m) corresponded to 358 gallons (1,360 l) per hour for a turbulent criteria and 86 gallons (326 l) per hour for a laminar criteria at an 11 in. (27.9 cm) level differential between the basin and discharge chute. These leak rate values corresponded to a turbulent 0.64 in. (16.2 mm) or a laminar 0.16 in. (4.1 mm) rise in the discharge chute in one hour provided no construction joint leakage.

McCracken 1995c and Irwin 1995 discussed the turbulent relationship between flow (Q) through the isolation barrier and differential water level (ΔH) across the isolation barrier as being:

$$Q \propto \sqrt{\Delta H} \quad (1)$$

and the laminar flow relationship as being:

$$Q \propto \Delta H. \quad (2)$$

Figure 1 depicts the acceptance criteria for the laminar and turbulent flow regimes relationship.

Figure 1. Revised Isolation Barrier Acceptance Criteria

4.0 ACCEPTANCE TEST PROCEDURE/ACCEPTANCE TEST REPORT

The leak test procedure was conducted in accordance with the acceptance test procedure (ATP) (McCracken 1995a). The acceptance test report (ATR) (McCracken 1995b), documents completion of all ATP steps.

5.0 ACCEPTANCE TEST RESULTS

Figure 2 shows the basin and discharge chute level data prior to and during the acceptance test. The ultra-sonic level detectors (USLDs) are set on different ranges to monitor the entire drawdown. With the basin and discharge chute levels equal, the USLDs were calibrated to read 2.0 in. (5.0 cm) and 12.0 (30.5 cm) in. respectively. Once the drawdown was initiated observations, indicated that as the discharge chute level was decreasing and the basin level was increasing as seen in Figure 2. Test 2 began at T_0 when the 11-in. (27.9 cm) level differential was obtained (discharge chute level down 10 in. (25.0 cm) and the basin level up 1 in. (2.5 cm)).

Figure 2. Acceptance Test Basin and Discharge Chute Level Data

There were no basin water additions during the 24 hour test, but less than 1 gallon (3.8 l) of water was sprayed on the discharge chute walls every four hours. This was performed to minimize airborne contamination from the exposed discharge chute walls.

6.1 RESULTS DISCUSSION

The discussion of the test results is in the following format.

- Field Isolation Barrier Leakage Estimate
- Discharge Chute Leakage and Additions, Evaporation, and Instrumentation Effects
- Adjusted Isolation Barrier Leakage Computation.

6.1.1 Field Isolation Barrier Leakage Estimate

Based on the 24 hour USLD test data, the flow through the isolation barrier at the 11 in. (27.9 cm) level differential was fully turbulent at a rate of 4.41 gpm (16.5 lpm). The following describes how these numbers were calculated.

The test data needed manipulation in accordance with Irwin 1995 to determine the leak rate and the flow exponent (0.5 for turbulent and 1 for laminar). The data was manipulated to obtain a leak rate in units of feet per hour. The leak rate is the difference between the basin and discharge chute water levels as it changed over time. Figure 3 displays the converted data. NOTE: The level differential did not exceed the expected 11 in. (29.7 cm).

Using these data conversions, the initial isolation barrier leakage was calculated from the counted data using three separate calculation methods: Grapher¹ for Windows² software; LEAK.EXE software; and TK!Solver³ software. The three separate methods and field calculations allowed a check to be performed verifying the results of each software package.

Grapher for Windows software (Golden Software) was used to establish the flow exponent and initial leak rate using differential level, time, and regression analysis discussed in Irwin 1995. The graphs displayed in this report were developed using the Grapher software.

LEAK.EXE an independent software routine developed by Frank Schmittroth of Radiation Physics and Shielding, using level differential and hourly time data to establish an initial leak rate, a flow exponent, and an uncertainty analysis. LEAK.EXE is a closed form solution of hand calculations verified by Grapher and TK Solver which are validated through the WHC purchasing requirements. A listing of the computer program and a sample on the final KW leak test are provided in Appendices B and C, respectively. The program was developed on the Hanford Site Sun Unix system and recompiled for use on a MS-DOS⁴ PC by the use of Microsoft Fortran⁵

From Irwin 1995, (105-K Basin Isolation Barrier Leak Rate Test Analytical Development), the initial leak rate is determined from the polynomial regression curve fit of the data in Figure 3.

¹Grapher is a registered trademark of Golden Software, Inc., Boulder, Colorado.

²Windows is a registered trademark of Microsoft Corporation, Redmond, Washington.

³TK Solver is a registered trademark of Universal Technical Systems, Inc., Rockford, Illinois.

⁴MS-DOS is a registered trademark of Microsoft Corporation, Redmond, Washington.

⁵Microsoft Fortran is a registered trademark of Microsoft Corporation, Redmond, Washington.

Figure 3. Level Differential vs. Time (4/10/95)

A second order polynomial regression curve is fit to the differential height measurement, h , versus time data (Irwin 1995). The polynomial regression curve fitting is obtained by writing;

$$h(t) = x_1 + x_2 t + x_3 t^2 \quad (3)$$

where

$h(t)$	differential w/respect to time (L)
x_1, x_2, x_3	regression curve coefficient
t	time (t).

$$\begin{aligned}x_1 &= h_{ti} \\x_2 &= -h_{ti}^\alpha b \\x_3 &= \frac{\alpha}{2} b^2 h_{ti}^{2\alpha-1}\end{aligned}\tag{4}$$

where

h_{ti} initial level differential at time zero (L)
 α flow regime exponent (dimensionless)
 b flow coefficient (1/t).

The quantities, h_{ti} , b , and α , are readily found by inverting these equations:

The flow rate as a function of time can then be calculated from the following:

$$Q_j = \left(-\frac{x_2}{x_1^\alpha} \right) A^* (x_1 + x_2 t_j + x_3 t_j^2)^\alpha\tag{5}$$

where

Q_j barrier flow rate at time t_j $\left(\frac{L^3}{t} \right)$

A^* surface area parameter for basin and discharge chute (L^2).

Q_j is the instantaneous flow rate at any given time, t_j , less than a critical time, i.e., the time at which the differential height is zero. The values for x_1 , x_2 and x_3 are determined from the regression curve fit. The flow parameter, α , is determined in terms of x_1 , x_2 and x_3 from the equation noted above. At the initial time, $t_j = 0$, the flow rate, Q_i is at the initial differential height (specified to be 11 inches) is then determined by the following equation.

$$Q_j = -x_2 A^*.\tag{7}$$

The equation for A^* is repeated as follows (Irwin 1995).

$$\frac{1}{A^*} = \frac{1}{A_B} + \frac{1}{A_{DC}}.\tag{8}$$

where

A_B is surface area of basin
 A_{DC} is surface area of discharge chute

From the data from Alward 1991 for area of the basin, A_B , and area of the discharge chute, A_{DC} , the value of A^* is calculated to be 850.0 sq. ft. The value of x_2 , noted in Figure 3 is in units of inches per hour, therefore to convert to gallons per minute, the initial leak rate can be calculated from;

$$Q_j = -x_2 A^* = -x_2 \left(\frac{850 \cdot 7.48}{12 \cdot 60} \right) \times 60 = -8.83 \cdot x_2 \times 60. \quad (9)$$

Figure 4 contains the values of the second order polynomial regression exponents, the calculation of the flow parameter, α , and the initial leak rate. Figure 4 depicts the isolation barrier leak rate as a function of time. This figure was determined utilizing equation 6 above.

Figure 4. Isolation Barrier Leak Rate vs. Time (4/10/95)

LEAK.EXE utilized the same methodology as noted above. The results from this program agree with the method utilized above and as noted on Figure 3.

The TK!Solver analysis consisted of: a polynomial regression on basin and discharge chute levels; conversion of fitted basin levels to gallons per hour leak rate using basin surface area (Alward 3/91) and time differentials; and use of a power curve fit to establish the flow exponent and

extrapolate the flow to the 16 ft (4.9 m) level difference using the fitted test level differentials and calculated basin leak rate. A sample run of this analysis is provided in Appendix D.

The initial barrier leakage, Q_i , was determined from the field calculations and LEAK.EXE software and field calculations to be 4.41 gpm (16.5 lpm) at the 11.0465 in. (28.06 cm) level differential with a fully turbulent flow ($\alpha = 0.5$). This corresponds to a flow of 1058 gph (4005 lph) at a 16 ft (4.9 m) level differential.

Additional analysis with Grapher and LEAK.EXE account for data scatter to obtain 95% upper confidence limit (UCL) show a nominal $Q_i = 4.41 \pm 0.006$ gpm and $\alpha = 0.51 \pm 0.002$. Utilizing this

$$Q_{i \text{ extrapolated}} = Q_i \left(\frac{\Delta H_{16}}{\Delta H_{11}} \right)^\alpha \quad (10)$$

$$Q_{i \text{ extrapolated}} = 4.41 \text{ gpm} \left(\frac{16 \times 12}{11.05} \right)^{0.511} = 1138 \pm 9 \text{ gph}$$

where

$Q_{i \text{ extrapolated}}$	Leak rate extrapolated to the 16 ft (4.9 m) level differential
ΔH_{16}	16 ft (4.9 m) level differential
ΔH_{11}	11.05 in. (28.1 cm) level differential.

This leakage does not account for evaporation, discharge chute leakage and additions, or instrumentation effects. These effects are discussed below. Instrumentation affects are addressed in the test plan (McCracken 1995c).

6.1.2 Discharge Chute Leakage and Additions, Evaporation, and Instrumentation Effects

6.1.2.1 Discharge Chute Leakage and Additions

Test 1 was conducted both prior to and after the final leak test to validate the instrumentation network, and to establish baseline data for K-West. These test observations are in Appendix A, 105-K West Test 1 Observation Report. The data obtained from this shows there was no apparent leakage from the basin or discharge chute during the test.

The water that was sprayed during the test to minimize basin airborne contamination is considered negligible since the total water addition was under 6 gallons (22.7 l) over the 24 hours. This amount of water would have raised the discharge chute level a nominal $8.2\text{E-}4$ in. ($20.8 \mu\text{m}$) or change the leak rate by 0.25 gph (0.95 lph).

6.1.2.2 Evaporation Effects

Evaporation is included for the flow analysis because evaporation from the basin contributes to the basin level decrease and the discharge chute level increase. The level changes in the basin and discharge chute due to evaporation would cancel each other, but due to the basin and discharge chute surface area differences, the volumetric rates are different. The volumetric calculations for the discharge chute assumed that the evaporation rate was approximately equal on the basin and reactor sides of the banana wall (more conservative approach than McCracken 1995c).

Due to a lapse in execution of the ATP and an urgent need to move the test equipment from K-West to K-East basin to support its isolation barrier testing, a final vernier hook gauge reading was overlooked. However, evaporation was detectable by a USLD mounted above the vernier evaporation detector (VED) at an average rate of $7.4\text{E-}3$ in. (0.019 cm) per hour during the month prior to the final 24 hr. test. The data shown in Figure 5 was gathered during epoxy injections prior to the final performance of Test 2. Knowing the VED was not adjusted for water level, the following graph was made for evaporation rate over that time period in March 1995. This level data corresponds to an average VED, basin, and discharge chute evaporation rate of $1.3\text{E-}3$ gph ($4.5\text{E-}3$ lph), 4.1 gph (15.4 lph), and 0.45 gph (1.7 lph) respectively. Though this may appear high, it can be stated that the evaporation rate for the final leak test is bounded by these numbers.

The VED water temperature was maintained within ± 2 °F (1.11 °C) of the basin water temperature throughout the test. Vent and Balance team performed air flow checks to verify that there was no parallel airflow above the VED and basin water surfaces (Vent and Balance air flow data is available in Appendix A, Table A-1). With these conditions met, the VED water level difference is the equivalent basin and discharge chute water level difference due to evaporation.

Figure 5. KW-Basin VED History (2/24/95 to 3/17/95)

6.1.2.3 Instrumentation Sensitivity

The instrument sensitivity is defined as the sum of the squares of the instrument uncertainty. This effect was computed using the LEAK.EXE software and computed as ± 0.45 gph (1.7 lpm) at the 11 in (27.9 cm) level. The LEAK.EXE calculated a data uncertainty data reference as one standard deviation (1σ) at ± 0.006 gpm or ± 0.36 gph.

6.1.2.4 Instrument Calibration

The instrument calibration was verified from post-test calibration checks in the WHC Standards Lab. They show no apparent instrumentation corruption that could invalidate or bias the test results. The post-test calibrations are located in Appendix V of the 105-K West Isolation Barrier Test Report (McCracken 1995b).

6.1.3 Adjusted Isolation Barrier Leakage Computation

The final isolation barrier leakage is described from the following equation.

$$Q_{i_{corrected}} = Q_{i_{nominal}} + \Delta Q_{evap} + \Delta Q_{data\ E} + \Delta Q_{DC\ add} \quad (12)$$

(extrapolated with α at 95% UCL and h_i at 95% UCL).

The final leak rate at the 11 in. (27.9 cm) level differential is 4.49 gpm (17 lpm) as computed in Table 1.

Table 1. Error Analysis Table

Initial Barrier Leakage Q_{nom}	Discharge Chute Leakage and Additions $\Delta Q_{DC\ ADD}$ (+/-)	Basin Evap (+) DC Evap (-) ΔQ_{Evap} <small>+ Evaporation detracts from the basin leak rate - Evaporation adds to the discharge chute leak</small>	Data Uncertainty at 95% UCL 1.65×0.006 $\Delta Q_{Data\ E}$	Total Effects (+/-)	Final Barrier Leakage at 95% UCL
4.41	+0.004	+0.068 / -0.007	0.010	0.075	4.49
All values are in gpm at the 11 in. (27.9 cm) differential. Multiply by 3.79 to obtain lpm					

The final isolation barrier leak rate at 95% UCL with an $\alpha = 0.514$ (0.511 ± 0.003) given by Equation 10 is

$$Q_{extrapolated} = 4.492 \times \left(\frac{16 \times 12}{11.05} \right)^{0.514}$$

$$Q_{extrapolated} = 1169.6 \text{ gph.}$$

6.2 CONCLUSION

The K-West isolation barriers pass the 1,500 gph (5,680 lph) acceptance criteria. After the evaporation and instrumentation effects are accounted for the adjusted leak rate is 1,170 gpm (4,320 lpm) with a 95% UCL as shown in Figure 6.

The results of this acceptance test can be used for future in-place testing as a baseline to examine the isolation barrier seals and epoxy degradation. The posulated laminar flow condition in the Test Specification and Test Plan (McCracken 1995c), can be disregarded for future isolation barrier in-place

testing because flow through the isolation barrier was characterized as fully turbulent. The evaporation effects can also be dismissed because the rate is insignificant to the barrier leak rate over the 24 hour test duration.

Figure 6. Final Extrapolated Leak Rate with Acceptance Criteria Comparison

7.0 ACCEPTANCE TEST REPORT

The Acceptance Test Report (McCracken 1995b) will contain a copy of the signed ATP steps, the raw data generated from the baseline and final leak tests, all test logs, J-7 ATP revisions, and all instrumentation post-test calibrations.

8.0 QUALITY ASSURANCE

The Acceptance Test Report and the Test Results will be Quality Assurance reviewed and approved by post-test instrument calibrations.

9.0 REFERENCES

- McCracken, K. J., 1995a, *105-KW Isolation Barrier Leak Acceptance Test Procedure*, WHC-SD-SNF-ATP-004, Rev. 1, Westinghouse Hanford Company Richland, Washington.
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APPENDIX A

KW-BASIN BASELINE LEAK TEST FINAL OBSERVATIONS

A1.0 PURPOSE

The purpose of the initial test was two-fold: instrument operation check and basin or discharge chute leak detection. The instrumentation check consisted of the following items: establishing air flow patterns above and below the grating; installing the instrumentation; verifying communication from the remote data logger to the computer base station located outside the basin; checking the ultra-sonic level detectors (USLDs) for accurate basin level and discharge chute measurement; and observing any evaporation from the vernier evaporation detector (VED).

The leak detection was accomplished by observing the data from the USLDs and the VED. If the basin level remained constant over the duration of the test, with no water being added and subtracting evaporation, there would be no detectable leak.

A2.0 PROCEDURE

Vent and Balance established air flow patterns per WHC-SD-SNF-ATP-004 Section 8.2.3 and 8.2.4. By using hot wire anemometers manually positioned above and below the grating at certain points in the 105-KW building (see Figure A-1) and by verifying which ventilation fans were operating, the airflow patterns across the basin water surface was established.

Figure A-1. Air Flow Measurement Locations

The instrument installation was performed in accordance with the 105-KW Isolation Barrier Leak Test Procedure (WHC-SD-SNF-ATP-004) Sections 8, 9, and 10. Once the equipment was installed and powered, the communications link was established and data collection began.

A3.0 RESULTS AND DISCUSSION

A3.1 AIR FLOW MAPPING

The results of the air flow tests are presented in Table A-1.

Table A-1. Basin Air Velocities at Air/Water Interface

Map Point	Direction and velocity							
	Legend: below - 4 ft (1.22 m) below grating level level - grating level above - 4 ft (1.22 m) above grating level							
	N fpm	NE fpm	E fpm	SE fpm	S fpm	SW fpm	W fpm	NW fpm
1 below	0	0	0	0	0	0	0	0
1 level	0	35	38	38	0	35	38	38
1 above	0	0	0	0	0	0	0	0
2 below	0	0	0	0	0	0	0	0
2 level	0	0	0	0	0	0	0	0
2 above	0	0	0	0	0	0	0	0
3 below	0	0	0	0	0	0	0	0
3 level	0	40	41	34	0	40	41	34
3 above	24	0	0	0	24	0	0	0
4 below	0	0	0	0	0	0	0	0
4 level	0	0	0	0	0	0	0	0
4 above	0	0	0	0	0	0	0	0
5 below	0	0	0	0	0	0	0	0
5 level	0	0	0	0	0	0	0	0
5 above	0	0	0	0	0	0	0	0
6 below	0	0	0	0	0	0	0	0
6 level	0	0	0	0	0	0	0	0
6 above	0	0	0	0	0	0	0	0

Map Point	Direction and velocity							
	Legend: below - 4 ft (1.22 m) below grating level level - grating level above - 4 ft (1.22 m) above grating level							
	N fpm	NE fpm	E fpm	SE fpm	S fpm	SW fpm	W fpm	NW fpm
7 below	0	0	0	0	0	0	0	0
7 level	0	0	0	0	0	0	0	0
7 above	0	0	0	0	0	0	0	0
8 below	18	0	0	0	18	0	0	0
8 level	0	0	0	0	0	0	0	0
8 above	0	0	18	0	0	0	18	0
9 below	0	0	0	0	0	0	0	0
9 level	0	0	0	0	0	0	0	0
9 above	0	0	0	0	0	0	0	0
VED VELOCITIES								
ved level	26	0	0	22	26	0	0	22
ved above	0	0	0	0	0	0	0	0
Data taken by: Carrick, McCange, and Ward of Vent and Balance 11/17/94 Instrument info: Alnor 826-28-01-001 Last Cal. 3-9-94 Alnor 702-28-16-001 Last Cal. 2-3-94								

The results of the air flow readings show that the air flow below the grating in all areas are negligible and the air flow readings above the VED are also negligible. This means that the evaporation due to air flow over the VED is the same as over the basin.

A3.2 COMMUNICATIONS LINK

As a result of a ground fault traced to the USLDs, which was viewed as spikes in the original TEST 1 data, TEST 1 was re-run starting on 3/17/95 following a series of epoxy repair drawdowns. All starting conditions matched the initial baseline test.

The wireless data logger remote and base station communications link was successful from the inside of the basin zone to the outer clean zone. A data sample is shown in Table A-2. The test was started at 7:45am, March 17, 1995 and ended at 8:00am, March 19, 1994, approximate duration: 72 hours.

Table A-2. Data Sample Baseline Test (3/17/95 - 3/19/95)

data file: leakdye1.csv		For more data refer to Appendix T in Acceptance Test Report WHC-SD-NF-ATR-009					
TIME (s)	dc USLD (in)	bsn USLD (in)	ved USLD (in)	dew pt (°F)	bsn air temp (°F)	VED water tmp (°F)	bsn water tmp at tc2 (°F)
228152	11.9407	2.13976	5.01875	42.6706	58.3035	49.8068	52.5546
228211	11.8775	2.15094	4.96768	42.7231	58.393	50.3931	52.6062
228271	11.8773	2.13996	4.99241	42.7113	58.396	49.938	52.533
228331	11.8775	2.15771	5.04561	42.613	58.4346	49.9767	52.6099
228391	11.8771	2.15785	5.01875	42.5571	58.3892	50.2748	52.6787
228451	11.9407	2.13867	4.99224	42.4876	58.3451	49.7722	52.5582
228511	11.9407	2.15771	5.02138	42.4521	58.3056	50.5726	52.5949
228571	11.8771	2.15785	4.99233	42.4961	58.3098	49.7367	52.7135
228631	11.9409	2.15778	4.99233	42.3403	58.2929	50.3307	52.6202
228691	11.9011	2.15798	5.01875	42.1641	58.1232	50.4658	52.5644
228751	11.8777	2.15778	5.04569	42.303	58.1608	50.0835	52.564
228811	11.9407	2.15778	5.01875	42.2725	58.1835	50.2973	52.6631
228871	11.9434	2.15785	5.01875	42.2132	58.0902	49.7453	52.6839
228931	11.9407	2.15771	4.96615	42.2759	57.989	50.0255	52.6204
228991	11.9049	2.15812	5.01867	42.3487	58.0126	49.7818	52.606
229051	11.8773	2.15785	5.01859	42.4419	57.9814	49.6742	52.6129
229111	11.9458	2.15778	5.01875	42.4283	58.0815	49.7747	52.6751
229171	11.8775	2.15778	4.99224	42.4724	58.0011	49.6175	52.5945
229231	11.9407	2.15778	5.01875	42.4605	58.0782	50.4588	52.6718
229291	11.9407	2.15792	5.00554	42.4504	58.0252	49.9091	52.5805
229351	11.8773	2.15778	5.04772	42.3945	57.966	49.5823	52.5974

data file: leakdyel.csv		For more data refer to Appendix T in Acceptance Test Report WHC-SD-NF-ATR-009					
TIME (s)	dc USLD (in)	bsn USLD (in)	ved USLD (in)	dew pt (°F)	bsn air temp (°F)	VED water tmp (°F)	bsn water tmp at tc2 (°F)
229411	11.9407	2.1672	5.0002	42.281	57.967	49.8506	52.6747
229471	11.9066	2.15771	5.01884	42.0574	58.0011	50.2668	52.6326
229531	11.9407	2.15778	5.01884	42.1522	57.9379	49.8214	52.6074
229591	11.8773	2.15778	5.04561	42.0387	57.859	49.8567	52.6045
229651	11.8773	2.15778	5.01994	42.0421	57.8671	49.5975	52.5744
229711	11.9407	2.17662	5.01884	42.0387	57.7911	49.4829	52.5745
229771	11.9411	2.17682	5.01875	42.0082	57.8694	49.7908	52.5768
229831	11.9409	2.17675	5.01867	42.0811	57.8554	50.3878	52.6009
229891	11.8779	2.19573	5.04561	42.037	57.8419	49.6104	52.5874
229951	11.9249	2.17662	4.99699	42.0963	57.8465	49.5768	52.592

A3.3 USLD DATA

Figure A-2 shows the data gathered from the basin, discharge chute and VED USLD's during the final baseline test, which displays data with-in the calibration parameters. The specifications for each of the USLDs were ± 0.02 in. for a 4 in. (0.051 @ 10.22 cm) span and ± 0.06 in. for a 12 in. (0.15 @ 30.5 cm) span.

A3.4 EVAPORATION OBSERVATIONS

Due to an apparent chiller malfunction and subsequent rise in basin temperature during the week of 3/17/95 (see Figure A-3), evaporation observations were not calculated for the final baseline test. The minor rise in water temperature could cause minor errors from the evaporation effect to be propagated in the observed basin leak rate. A decision was made to complete evaporation observations on the initial 11/18/94 baseline data because the configuration more closely matched the final isolation barrier leak test configuration.

**Figure A-2. Basin, Discharge Chute and VED Levels vs. Time
(3/17/95 - 3/19/95)**

**Figure A-3. Basin Average Water Temperature vs. Time
(3/17/95 - 3/19/95)**

A3.4.1 Water Temperature

To determine the evaporation from the basin, the VED conditions needed to match the basin conditions as close as possible. It has already been established that the air flow across the VED matches that across the basin, so all that remains is to duplicate the water temperatures. Table A-3 shows some data for VED and average basin water temperature tracking while Figures A-4 and A-5 display the VED and basin temperature traces over the entire test duration (Baseline Test of 11/18/94 - 11/19/94).

Table A-3. VED Vs Basin Water Temperature Tracking Record Baseline Test 1

Time	Basin Temp °F	VED Temp °F	Adjust Set Point □ °F
11/18 7:47pm	49.7	48.3	--
8:45pm	49.7	48.3	--
9:40pm	49.8	48.5	--
10:40pm	49.8	48.5	--
11:45pm	49.9	48.5	--
11/19 7:00am	49.8	48.3	--
8:00am	49.8	48.4	--
8:45am	49.8	48.8	--

The VED detected 0.0059 in. (0.015 cm) drop in level which correlates to 32.7 gal (120 l) lost in the basin over the 12 hour initial baseline test duration due to evaporation which is 2.7 gph (10 lph) loss rate and 0.27 gph (1 lph) for the discharge chute.

Figure A-4. VED Temperature Trace (11/18/94 - 11/19/94)

Figure A-5. Basin Water Average Temperature Trace (11/18/94 - 11/19/94)

A3.4.2 Dew Point

The dew point sensor and thermocouple worked successfully throughout both the initial and final baseline tests. Figure A-6 displays the final baseline test data for dew point.

The dew point is needed, along with the total evaporation and basin water temperature, to calculate an evaporation constant for the basin. This can be provided if needed for future reference after the barrier leak test is performed.

The dew point correlates closely to the average Pacific Northwest Laboratory (PNL) weather data which means that no humidification is being added to the basin outside air inlet. The dew point can be obtained from PNL and no additional instruments are needed for future evaporation calculations, given the water temperature and the experimentally determined evaporation constant referred to above.

A3.4.3 Air Temperature

The air temperature definitely shows a slight diurnal trend as it slowly decreases at night and begins to rebound in the morning as shown in Figure A-7. Given any dew point temperature and corresponding air temperature, a relative humidity can be obtained to check with the K-Basin Operation's relative humidity.

Figure A-6. Dew Point Temperature Trace (3/17/95 - 3/19/95)

Figure A-7. Basin Air Temperature Trace (3/17/95 - 3/19/95)

A4.0 SUMMARY

Some trouble was encountered with the initial baseline test run. Data analysis displayed erroneous spikes in the level data but the remaining thermocouple and dew point sensor data were unaffected. The problem was a ground fault in the USLDs, it was repaired and another baseline test was conducted several months later. After the final baseline test, data analysis revealed an apparent chiller malfunction through the rising basin water temperature that was not accounted for in the VED water temperature. Therefore the VED evaporation rate would be slightly different than the basin evaporation rate. This error would have an effect on the basin leakage observations, but by combining the initial and final baseline tests data, an accurate baseline basin leak rate can be defined.

It was shown in a Appendix E. that due to instrument accuracy there was a negative leak rate in the basin, since water does not enter the basin without Operations support. Therefore, it is safe to conclude that there is approximately zero leakage through the construction joint to the ground at K-West.

APPENDIX B

**KW-BASIN ISOLATION BARRIER
LEAK TEST PROGRAM LEAK.EXE**

Program kbleak

```

c
Parameter (n0 = 5000, nx = 3)
Dimension h(n0), hc(n0), tm(n0)
Dimension b(n0, nx), bth(3), btbi(nx,nx)
Dimension x(nx), sigx(nx), covx(nx,nx)
Dimension fld(2), wka(nx)
Character*60 title
Data lun, lout / 5, 6/

c
c Read np measured times, heights, tm(k), h(k)
c
  Read(lun, '(a)') title
  Write(lout, '(1x, a)') title
c
  np = 0
15 Read(lun, *, end=16) fld
    np = np + 1
    tm(np) = fld(1)
    h(np) = fld(2)
    Goto 15
16 Continue
  Write(lout, '(/" No. of data points =", i4)') np
c
c Set up B-matrix
  Do 1 k = 1, np
    tk = tm(k)
    b(k,1) = 1.0
    b(k,2) = tk
    b(k,3) = tk*tk
  1 Continue
c
  Write(lout, '(" -- h(t), 1st 5 pts. + last pt. --"') )
  Do 20 k = 1, 5
20 Write(lout, 200) k, b(k,2), h(k)
    Write(lout, 200) np, b(np,2), h(np)
200 Format(1x, i5, 1P2E12.4)
c
c Calculate bbt-1 = BBt-1
  Do 2 i = 1, nx
    Do 2 j = 1, nx
      sm = 0.0
      Do 3 k = 1, np
3      sm = sm + b(k,i) * b(k,j)
      btbi(i,j) = sm
  2 Continue
c
  Call Invert(nx, nx, btbi, wka)
c Calculate x = BBt-1 Bt H
c

```

```

      Do 4 i = 1, nx
        sm = 0.0
        Do 5 k = 1, np
          5 sm = sm + b(k,i) * h(k)
        4 bth(i) = sm
      c
        Do 6 i = 1, nx
          sm = 0.0
          Do 7 j = 1, nx
            7 sm = sm + btbi(i,j) * bth(j)
          6 x(i) = sm
        c
      c Calculate sum of squared resid.
        hsig2 = 0.0
        Do 8 k = 1, np
          sm = 0.0
          Do 9 i = 1, nx
            9 sm = sm + b(k,i) * x(i)
          hc(k) = sm
          sm = h(k) - sm
          hsig2 = hsig2 + sm * sm
        8 Continue
        Write(*, '(/" hsig2 = ", 1PE10.3)') hsig2
      c
      c Calculate Cov(x,x)
        f = hsig2/(np-nx)
        Do 10 i = 1, nx
          Do 10 j = 1, nx
            10 covx(i,j) = f * btbi(i,j)
        c
      c Output x(i), std-dev
        Write(lout, '(/"      x(i)      std-dev.")' )
        Do 11 i = 1, nx
          sigx(i) = Sqrt(covx(i,i))
        11 write(*, '(2x,i5, 1P2E13.3)') i, x(i), sigx(i)
      c
        ca = 2.0 * x(1) / x(2)**2
        alf = ca * x(3)
        alfsig = ca * sigx(3)
        Write(*, '(/" alpha ", 2F10.3)') alf, alfsig
      c
        astr = 850.0
      c Conversion from in/ft and gal/ft3
        cq = astr * (7.48/12.0)
        ql = -cq * x(2)
        qlsig = cq * sigx(2)
        Write(*, '(/" q0, gal/hr", 2F10.2)') ql, qlsig
      c
      c Write h(t), hc(t) to file for plotting
        Open(10, FILE='lk.plt')

```

```

      Do 13 k = 1, np
      13 Write(10, 201) tm(k), h(k), hc(k)
      201 Format(1x, 1PE15.5,',',E15.5,',',E15.5,',')
c
      End
c-----
      Subroutine Invert(n, n0, a, wka)
      Dimension a(n0,*), wka(*), det(2)
      Data lunerr /6/
c
      Call Spoco(a, n0 , n, rcond, wka, ierr)
c
      if (ierr .ne. 0) then
        write(lunerr,300) ierr
      300  format(//' *** inversion error ierr= ',i5,' ***'//)
      else
        job = 1
        call Spodi(a, n0, n, det, job)
      endif
c Fill out the matrix
      Do 1 i = 1, n0
      Do 1 j = i, n0
      1  a(j,i) = a(i,j)
c
      Return
      End
c
      Subroutine P3mtrx(a, x)
      Character*(*) a
      Dimension x(3,3)
      write(*, '(a," matrix")' ) a
      write(*, 200) x(1,1), x(1,2), x(1,3)
      write(*, 200) x(2,1), x(2,2), x(2,3)
      write(*, 200) x(3,1), x(3,2), x(3,3)
      200  format(1x,1P3e12.3)
      Return
      End

```

APPENDIX C

**KW-BASIN ISOLATION BARRIER LEAK TEST #2
DATA ANALYSIS UTILIZING LEAK.EXE**

LEAK.EXE OUTPUT

No. of data points =1530 (4/10/95)

-- h(t), 1st 5 pts. + last pt. --

	Time (hrs)	Measured Ht(in)
1	0.0000E+00	1.1005E+01
2	1.6667E-02	1.0958E+01
3	3.3333E-02	1.0937E+01
4	5.0000E-02	1.0937E+01
5	6.6667E-02	1.0931E+01
1530	2.5470E+01	2.0884E+00

hsig2 = 3.699E+00

	x(i)	std-dev.
X1	1.105E+01	3.770E-03
X2	-4.999E-01	6.837E-04
X3	5.782E-03	2.599E-05

alpha .511 +/- .002

Qi, gal/hr 264.87 +/- 0.36

Qi, gal/min 4.41 +/- 0.006

APPENDIX D

KW-BASIN ISOLATION BARRIER LEAK TEST #2 TK SOLVER ANALYSIS

The data in these regression work sheets were compared to those of Grapher and found to be identical.

DC vs Time Polynomial Regression ($y=c_0+c_1*x+c_2*x^2+c_3*x^3+...$)

Time, hrs	DC, in	residuals	SUMMARY	STATS
2.515277778	1.95551	+3.172E-2	order	2
2.531944444	1.95551	+2.417E-2	resids	yes
2.548611111	1.95551	+1.662E-2		
2.565277778	1.95551	+9.080E-3	N	1555
2.581944444	1.95551	+1.539E-3	Syx	.039822824
2.598611111	1.98234	+2.083E-2	adj_R2	.999723993
2.615277778	2.01914	+5.010E-2		
2.631944444	2.01893	+4.236E-2	c0	.751430563
2.648611111	2.01914	+3.504E-2	c1	.479166097
2.665277778	2.02564	+3.401E-2	c2	-.00519618
2.681944444	2.01914	+1.999E-2	c3	0
2.698611111	2.01914	+1.247E-2	c4	0
2.715277778	2.01893	+4.740E-3	c5	0
2.731944444	2.01893	-2.774E-3	c6	0
2.748611111	2.02178	-7.435E-3	c7	0
2.765277778	2.08459	+4.787E-2	c8	0
2.781944444	2.08439	+4.016E-2	c9	0
2.798611111	2.08439	+3.266E-2	c10	0
2.815277778	2.08622	+2.699E-2		
2.831944444	2.08459	+1.786E-2		
2.848611111	2.08439	+1.017E-2		
2.865277778	2.08439	+2.675E-3		
2.881944444	2.14436	+5.516E-2		
2.898333333	2.14416	+4.760E-2		
2.915	2.14416	+4.011E-2		

WHC-SD-SNF-TRP-007, REV. 0

Basin vs Time Polynomial Regression Worksheet ($y=c_0+c_1*x+c_2*x^2+c_3*x^3+...$)

Time, hrs	BSN, in	residuals	SUMMARY	STATS
2.5152777778	2.99417	-1.259E-2	order	2
2.5319444444	2.97309	-3.287E-2	resids	yes
2.5486111111	2.98888	-1.629E-2		
2.5652777778	3.03686	+3.248E-2	N	1555
2.5819444444	2.99424	-9.345E-3	Syx	.027100077
2.5986111111	2.98366	-1.913E-2	adj_R2	.988029147
2.6152777778	2.97309	-2.891E-2		
2.6319444444	2.95209	-4.912E-2	c0	3.13012454
2.6486111111	2.95202	-4.840E-2	c1	-.05049643
2.6652777778	2.95202	-4.761E-2	c2	.000576004
2.6819444444	2.99485	-3.989E-3	c3	0
2.6986111111	3.01572	+1.767E-2	c4	0
2.7152777778	3.01565	+1.839E-2	c5	0
2.7319444444	3.01578	+1.931E-2	c6	0
2.7486111111	2.99417	-1.511E-3	c7	0
2.7652777778	2.97309	-2.180E-2	c8	0
2.7819444444	2.95276	-4.134E-2	c9	0
2.7986111111	2.95209	-4.123E-2	c10	0
2.8152777778	2.99417	+1.642E-3		
2.8319444444	2.95202	-3.972E-2		
2.8486111111	2.97303	-1.792E-2		
2.8652777778	2.97858	-1.159E-2		
2.8819444444	2.97309	-1.629E-2		
2.8983333333	2.99424	+5.632E-3		
2.915	3.01572	+2.790E-2		

Figure D-1. TK Solver Basin Regression
(ft/time)

Figure D-2. TK Solver Discharge Chute
Regression (ft/time)

The following are the variable sheets for TK solver power curve fit. They display the number of data points, a and b factors for $Y = aX^b$ equation, and the flow value (y) for the level differential (x) of 16 ft.

Using Power Curve fit to solve for exponent b.

VARIABLE SHEET					
St	Input	Name	Output	Unit	Comment
	n	1554			number of data points
	a	278.32338			coefficient
	b	.56919398			exponent
16	x				dependant variable
	y	1348.7378			independent variablesqrd

Input exponent of b = 0.5

VARIABLE SHEET					
St	Input	Name	Output	Unit	Comment
	n	1554			number of data points
	a	262.94743			coefficient
	b	.5			exponent
16	x				dependant variable
	y	1051.7897			independent variable
	rsqrd				

Input exponent of b = 0.523

VARIABLE SHEET					
St	Input	Name	Output	Unit	Comment
	n	1554			number of data points
	a	267.96174			coefficient
	b	.523			exponent
16	x				dependant variable
	y	1142.4246			independent variable
	rsqrd				

TK Solver Rule Sheet and procedure function for power curve fit

 RULE SHEET

S

Rule

```
n = count('x0)
call expon(;a,b,rsqrd)
y = a*x^b
```

" This program is used for a power curve fitting routine.
 " A power curve takes the form of $y = ax^b$.
 " By inputting positive variable pairs, the program will give the
 " coefficient and exponent to the equation. This can, in turn,
 " be used to estimate a point, given one variable, along the
 " curve using limited data.

 PROCEDURE FUNCTION: expon

Comment: a and b

Parameter Variables: n

Input Variables:

Output Variables: a,b,rsqrd

S Statement

```
sumlnx:= 0
sumlny:= 0
sumlnxy:= 0
sumlnxsqrd:= 0
sumlnysqrd:= 0
for i = 1 to n
  x:= 'x0[i]
  y:= 'y0[i]
  Lnx:= ln(x)
  Lny:= ln(y)
  sumlnx:= sumlnx + Lnx
  sumlny:= sumlny + Lny
  sumlnxy:= sumlnxy + Lnx * Lny
  sumlnxsqrd:= sumlnxsqrd + Lnx^2
  sumlnysqrd:= sumlnysqrd + Lny^2
next i
b = (sumlnxy - ((sumlnx * sumlny) / n)) / (sumlnxsqrd - (sumlnx^2 / n))
"b = 0.5 "Allows for exponent input
coeff = sumlny/n - b*(sumlnx/n)
a = exp(coeff)
```

K-West Basin Final Test 2 time : ~11:00 am Level and Flow Data date: 4/10/95												
bsn SA 8882.1	TIME HRS	int dc lev 11.96888	dc hgt	dc reght	int bsn lev 1.964773		bsn hgt	bsn reght	delta H ft	q cfs	Q gph	
		dc (in)			bsn (in)							
9055	2.515278	1.95551	15.08222	15.0796	2.99417	16.00245	16.00352	0.923922	35.22456	263.4797		
9115	2.531944	1.95551	15.08222	15.08023	2.97309	16.00069	16.00345	0.923227	35.21035	263.3734		
9175	2.548611	1.95551	15.08222	15.08085	2.98888	16.00201	16.00339	0.922532	35.19614	263.2671		
9235	2.565278	1.95551	15.08222	15.08148	3.03686	16.00601	16.00332	0.921838	35.18193	263.1608		
9295	2.581944	1.95551	15.08222	15.08211	2.99424	16.00246	16.00326	0.921143	35.16771	263.0545		
9355	2.598611	1.98234	15.08445	15.08274	2.98366	16.00157	16.00319	0.920449	35.1535	262.9482		
9415	2.615278	2.01914	15.08752	15.08337	2.97309	16.00069	16.00312	0.919755	35.13929	262.8419		
9475	2.631944	2.01893	15.0875	15.084	2.95209	15.99894	16.00306	0.919062	35.12508	262.7356		
9535	2.648611	2.01914	15.08752	15.08462	2.95202	15.99894	16.00299	0.918369	35.11087	262.6293		
9595	2.665278	2.02564	15.08806	15.08525	2.95202	15.99894	16.00293	0.917675	35.09666	262.523		
9655	2.681944	2.01914	15.08752	15.08588	2.99485	16.00251	16.00286	0.916983	35.08245	262.4167		
9715	2.698611	2.01914	15.08752	15.0865	3.01572	16.00425	16.00279	0.91629	35.06823	262.3104		
9775	2.715278	2.01893	15.0875	15.08713	3.01565	16.00424	16.00273	0.915598	35.05402	262.2041		
9835	2.731944	2.01893	15.0875	15.08776	3.01578	16.00425	16.00266	0.914906	35.03981	262.0978		
9895	2.748611	2.02178	15.08774	15.08838	2.99417	16.00245	16.0026	0.914214	35.0256	261.9915		
9955	2.765278	2.08459	15.09298	15.08901	2.97309	16.00069	16.00253	0.913523	35.01139	261.8852		
10015	2.781944	2.08439	15.09296	15.08963	2.95276	15.999	16.00246	0.912832	34.99718	261.7789		
10075	2.798611	2.08439	15.09296	15.09026	2.95209	15.99894	16.0024	0.912141	34.98296	261.6726		
10135	2.815278	2.08622	15.09311	15.09088	2.99417	16.00245	16.00233	0.91145	34.96875	261.5663		
10195	2.831944	2.08459	15.09298	15.09151	2.95202	15.99894	16.00227	0.91076	34.95454	261.46		

APPENDIX E

KW-BASIN BASELINE LEAK TEST ANALYSIS

DON'T SAY IT --- WRITE IT!

To: K. J. McCracken (L5-07)
cc: T. B. McCall (H0-33)

From: John Irwin HO-33 376-0615
Date: April 7, 1995

Figure E-1. K Basin Isolation Barrier Leak Test Water Level Data
(3/16/95)

Assumptions; at time equal 40 hours or more the level between the basin and the discharge chute are equal and there is a sufficient flow passage through the isolation barrier. Also assume that the evaporation rate (on a unit area basis) is the same from both the discharge chute and the basin.

The construction joint leakage can be determined from the above figure as follows;

- i) Use the fitted data for the Discharge chute and VED level only,
- ii) Determine the leak rate from the following equation;

$$Q_j (\text{gpm}) = \frac{7.48}{60 \cdot 12} A_c (\dot{h}_{dc} + \dot{h}_{ved})$$

where;

Q_j = Construction joint leakage, gpm,

A_t = Total area of Basin and Discharge Chute, 9820 sq. ft.,

h_{dc} = Rate of change in Discharge Chute level (from curve fit), in/hr,

h_{ved} = Rate of change in VED level (from curve fit), in/hr.

with h_{dc} and h_{ved} determined from the above Figure (developed in Grapher for Windows) as -0.000771813 in/hr and -0.000812519 in/hr. respectively the construction joint leakage was calculated to be -0.0042 gpm. The negative means that the flow is into the basin from the construction joint. This is improbable, therefore what this means is that the instrumentation system is not sensitive enough to measure a very small leakrate and that the leakrate through the construction joint is approximately zero.

APPENDIX F

K-BASIN ISOLATION BARRIER TEST EQUIPMENT AND INSTRUMENTATION

F1.0 INTRODUCTION

This document describes the equipment that needed to be manufactured and purchased for the K-Basin Isolation Barrier Leak Test. It characterizes purchases of Ultra-sonic Level Detectors (USLDs), thermocouples (TCs), dew point sensors, Vernier Evaporation Detector (VED), and data loggers. It also gives a description of the mounting brackets and the instrumentation stand that needed to be manufactured for each one of these instruments.

F2.0 INSTRUMENTATION DESCRIPTION

F2.1 LEVEL DETECTION AND MOUNTING

Level indication is needed because given the surface area of the basin and discharge chutes, leakage can be observed and the amount can be calculated from the level changes.

F2.1.1 USLDs

Many level indication devices were considered from many companies such as Omega Engineering Inc., Hewlett Packard, Fischer and Porter, and Kistler Morse dealing with resistance and capacitance measuring, RF transmitters, Ultra-sonic, and laser technology. The Fischer and Porter ultra-sonic flow meter was chosen over the others because of affordable accuracy and repeatability, availability, NIST traceability, and reliability. The Fischer and Porter model 50US3115 flow/level indicator (see Figure F 1) uses a transducer to generate a signal and receive the signal echo and the microcomputer in the transmitter unit averages the pulses per second from the transducer and temperature compensates for differing temperatures using a reference reflector a known distance from the transducer.

Figure F-1. Fischer and Porter Flow/Level Indicator (USLD)

The USLD accuracy (± 0.02 in. (0.051 cm) over a 4 in. (10.2 cm) span) was stated by the vendor and verified by WHC Standards Lab calibration. Instrument accuracy determined by the manufacturer as follows: the span (operator set) is broken into 8 bits of data or 256 increments (200 span increments and 28 over-span and under-span increments). Accuracy across a 4 in. (10.2 cm) span equals 4 in./200 (10.2 cm/200) increments which equals ± 0.020 in. (0.051 cm). The standards lab used a laser calibration system, NIST traceable, to calibrate the USLD. (Calibration papers are available in the K West Basin Isolation Barrier Leak Rate Test Procedure, WHC-SD-SNF-ATP-004.)

F2.1.2 USLD MOUNTING

Dampening the waves out of the basin water caused from the IXM pump operation and mounting the USLD transducer presented small hurdles. The water needed to be calm for the USLDs to have good and repeatable results; and the transducer needed to be within 24-30 in (of the water surface for maximum accuracy. The solution was to hang the USLD transducers and a stilling wells from the solid grating supports in the concrete basin walls (see Figure F-2).

Figure F-2. USLD and Stilling Well Mounting

The USLD transmitter units and the remaining instruments (dew point sensor, VED, and data logger) were mounted on a moveable table (see Figure F-3). The table needed to be easily movable because all instruments except the thermocouples would be removed from the basin after a baseline test to reduce the chance of damage during barrier installation and then reinstalled after the isolation barriers were completed.

Figure F-3. Instrumentation Table

F2.2 TEMPERATURE DETECTION AND MOUNTING

Water temperature and dew point indication are needed to obtain the water surface vapor pressure and the room vapor pressure for evaporation calculation (ASHRAE 1982). By knowing the vapor pressures and total evaporation determined from the VED, an evaporation constant can be calculated.

F2.2.1 THERMOCOUPLES

Type K (chromel-alumel) TCs were chosen because of their lower cost over RTDs, accuracy, and compatibility with a preliminary data logger without additional costs. The TCs are manufactured by Omega Engineering Inc. with 304 stainless steel 1/16 in. (0.16 cm) diameter sheaths for corrosion resistance and quick response.

F2.2.2 THERMOCOUPLE MOUNTING

The typical water temperature TC would need to be mounted where the TC tip would be submerged but near the water surface. A simple mount was constructed by strapping the TC to a 1/2" piece of conduit, lowering the conduit through the grating to the proper level and hose clamping it to the basin grating suspension system (see Figure F-4). The rigidity of basin grating suspension system was no concern since movement has little effect on the TC temperature indication.

One thousand feet of type K thermocouple extension wire was needed to transfer the TC mV signal from the TCs to the data logger located nearly half way across the basin from several of the temperature locations (see Figure F-5). The longest run of TC extension wire is only 140' ft (43 m) which is routed up and over the building support structure. The TC signal losses are negligible due to the relatively short extension wire length and only one junction from the TC to the data logger.

Figure F-4. Typical Thermocouple Mounting

Figure F-5. Instrument Locations

F2.2.3 DEW POINT TEMPERATURE DETECTION

Dew point chilled mirror technology was chosen because it has low errors, quick response times, and is easily maintained. Chilled mirror technology is the Standard in dew point indication. The dew point has a direct relationship to vapor pressure which is directly related to the evaporation rate. The General Eastern chilled mirror dew point sensor model DEW-T0 is powered by 120 VAC input, returns a 4-20 mA signal for 0-100 °F (-17.8 - 37.8 °C) dew point, and accurate to ± 2 °F (1.1 °C) is perfect for room vapor pressure indication.

Errors that arise in vapor pressure determination through relative humidity using dry bulb and wet bulb has many error possibilities. An estimated dry bulb error ranges between 0.05% of absolute temperature minimum and 2% of absolute temperature maximum while the estimated wet bulb temperature depression is 5 °F to 10 °F (-15 to -12 °C). Dew point is also not as susceptible to room air temperature gradients as would relative humidity.

F2.3 EVAPORATION DETECTION

To determine an accurate leak rate through the isolation barriers, evaporation must be taken into consideration over the test duration. Methods discussed to obtain evaporation rates were HVAC mass balances, past water level indications, or evaporation model.

The mass balance on the existing ventilation system to observe the amount of moisture entering and exiting the basin facility would have been costly and pointless without a truly air-tight facility. The existing data obtained over the years is not only observing evaporation but also a suspected basin leak that could be occurring all year round. A final suggestion was made by simulating the basin conditions (air temperature, water temperature, and air velocity across the water surface) in a known leak-free vessel, the evaporation off the vessel would be the evaporation off the basin, hence the VED came into existence.

F2.3.1 VED

The VED consists of a acrylic bath, an immersion heater/circulator/temperature controller, an immersion chiller, and a vernier hook gauge assembly capable of level measurement to the nearest 0.002 in. (0.005cm) (see Figure F-6).

Figure F-6. Vernier Evaporation Detector (VED)

The VED is placed in the basin for air temperature and air velocity compatibility. The immersion heater/circulator/temperature controller and the immersion chiller maintain the VED water temperature at the average basin water temperature. The vernier/hook gauge is used because the level change due to evaporation may be less than the USLD sensitivity. The hook gauge operates by adjusting the vernier

until the points of the hook gauge point and its mirror image touch. The mirror image is formed by observing from a position below the bath water line and observing the hook point and the water surface. The vernier reading is recorded and, after the test is completed, the hook gauge is reset and the reading recorded again. The level differences in VED multiplied by the basin surface area can give the evaporation of the entire basin in cubic feet. A subsequent evaporation rate may be determined in units of cubic feet per hour or gallons per hour.

F2.4 DATA ACQUISITION

The output signals (mV or mA) from all the instruments has to be sent to a computer to perform the necessary data analysis. This can be accomplished by a data logger either internal or external to that computer.

F2.4.1 DATA LOGGER

Many manufacturers and distributors of data acquisition systems (DAS) were researched including Omega Engineering Inc., Cole Pramer, Fluke, and Hewlett Packard. With most (DASs), the data logger needed to be physically wired to the computer or the instruments were directly wired to a computer expansion card. Neither choice was desirable because the computer was to be located outside of the fuel storage basin zone for monitoring and ALARA purposes. In these cases the instrumentation wires or RS-232 cables would have to be routed through the basin walls. Fluke is the only DAS on the market that has a wireless data logger. This meant the information may be gathered at a remote site and radio transmitted to a computer base station through walls.

The Fluke model 2625 wireless data logger is capable of reading 20 channels of instruments and transmitting the information, at 900 MHz, to the computer base station. The instruments are hard wired to the remote station inside the basin and transmits the data to the computer base station outside. The base station can store the information in an ASCII file, and display the data graphically or numerically as it is received. Figure 7 shows a wiring diagram of the instrumentation set-up.

Figure F-7. Instrument Schematic

The most vital instruments to this test were the USLDs and the data logger. An additional USLD (the VED USLD) and data logger were purchased and calibrated as backups.

F3.0 SUMMARY

The accuracy and dependability of this state of the art instrumentation is not surpassed in the field. This equipment can be used in future tests or in daily monitoring. The data obtained from recent operations was received via a strong signal, with little or no transmission or data errors.