DISTRIBUTION SHEET

To Distribution	From K. J. McCracken Mechanical Engineering	Page 1 of 1 Date 5/26/95
Project Title/Work Order 105 K East Isolation Barrier Acceptance Analysis Report / L1175		EDT No. 612137 ECN No. N/A
Name	MSIN	Text With All Attach.
		Text Only
		Attach./ Appendix Only
		EDT/ECN Only

C. L. Bennett	X3-79	X
K. R. Conn	X3-79	X
J. I. Diehl	X3-78	X
J. J. Irwin	H0-33	X
R. J. Kuhta	X3-76	X
K. J. McCracken	H5-56	X
J. W. Schmidt	X3-78	X
C. A. Thompson	X3-72	X
J. B. Truitt	H5-56	X
J. T. Vistica	X3-80	X
R. D. Warner	X7-74	X
J. C. Wiborg	R3-86	X
Central Files (2) + orig.	L8-04	X
Technical Reference Center		X
OSTI (2)	L8-07	X

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

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

MAY 31 1995

ENGINEERING DATA TRANSMITTAL

Page 1 of 2

1. EDT No. 612137

2. To: (Receiving Organization) R. J. Kuhta K-Basin Field Engineering	3. From: (Originating Organization) K. J. McCracken Mechanical Engineering	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: 57400/L1175	6. Cog. Engr.: K. J. McCracken	7. Purchase Order No.: N/A
8. Originator Remarks: This document is the test results and analysis of the K-East Basin Isolation Barrier ATR.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks:		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Desig- nator	Reason for Trans- mittal	Origi- nator Dispo- sition	Receiv- er Dispo- sition
1	WHC-SD-SNF-TRP-006		0	105 K East Isolation Barrier Acceptance Analysis Report	ESQ			

16. KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

(G)	(H)	17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)								(G)	(H)
Reason	Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	Reason	Disp.
/	/	Cog.Eng. K. J. McCracken	<i>[Signature]</i>	5/30/95	H5-56	J. P. Schmidt	<i>[Signature]</i>	5/30/95	X3-78	/	/
/	/	Cog. Mgr. J. B. Truitt	<i>[Signature]</i>	5/30/95	H5-56	C. A. Thompson	<i>[Signature]</i>	5/30/95	X3-72	/	/
/	/	QA D. W. Smith	<i>[Signature]</i>	5/30/95	H5-85	C. L. Bennett	<i>[Signature]</i>	5/30/95	X3-77	/	/
/	/	Safety J. T. Vistica	<i>[Signature]</i>	5/30/95	X3-80	J. C. Wiborg			B3-55		
/	/	Env. R. G. Gant	<i>[Signature]</i>	5/30/95	X3-79						
/	/	J. J. Irwin	<i>[Signature]</i>	5/30/95	H10-33						
/	/	R. J. Kuhta	<i>[Signature]</i>	5/30/95	X3-76						

18. K. J. McCracken <i>[Signature]</i> 5/30 Signature of EDT Originator Date	19. R. J. Kuhta <i>[Signature]</i> 5/30-95 Authorized Representative Date for Receiving Organization	20. J. B. Truitt <i>[Signature]</i> 5/30/95 Organizant Manager Date	21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
--	--	--	---

BD-7400-172-2 (04/94) GEF097

BD-7400-172-1

RELEASE AUTHORIZATION

Document Number: WHC-SD-SNF-TRP-006 Rev. 0

Document Title: 105 K East Isolation Barrier Acceptance Analysis Report

Release Date: 5/30/95

**This document was reviewed following the
procedures described in WHC-CM-3-4 and is:**

APPROVED FOR PUBLIC RELEASE

WHC Information Release Administration Specialist:

V. L. Birkland
V.L. Birkland

5/30/95

TRADEMARK DISCLAIMER. 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 or its contractors or subcontractors.

This report has been reproduced from the best available copy. Available in paper copy and microfiche. Printed in the United States of America. Available to the U.S. Department of Energy and its contractors from:

U.S. Department of Energy
Office of Scientific and Technical Information (OSTI)
P.O. Box 62
Oak Ridge, TN 37831
Telephone: (615) 576-8401

Available to the public from: U.S. Department of Commerce
National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
Telephone: (703) 487-4650

SUPPORTING DOCUMENT	1. Total Pages 53
----------------------------	--------------------------

2. Title 105 K East Isolation Barrier Acceptance Analysis Report	3. Number WHC-SD-SNF-TRP-006	4. Rev No. 0
5. Key Words 105 K EAST Isolation Barrier Test Report	6. Author Name: K. J. McCracken Signature Organization/Charge Code 57400 / L1175	

7. Abstract

This report displays the results and analysis of the 105K East Isolation Barrier Acceptance test.

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, makes 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.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED	8. RELEASE STAMP
	<div style="border: 1px solid black; padding: 5px;"><p>OFFICIAL RELEASE BY WHC DATE MAY 31 1995 35 Station 21</p></div>

105 K EAST ISOLATION BARRIER ACCEPTANCE ANALYSIS REPORT

Prepared by:

Kurt J. McCracken
ICF-KH Engineering Technology Support Services

John J. Irwin
WHC Thermal/Fluid Mechanics Engineering

ICF Kaiser Hanford Company
P.O. Box 8888
Richland, WA 99352

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

INDEPENDENT REVIEW

Document Reviewed 105-KE Isolation Barrier Leak Rate Acceptance Test Report

Author K. J. McCracken Report No. WHC-SD-SNF-TRP-006 EDT No. 612137

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

D. A. Wallace

Da Wallace
Reviewer

5/30/95

Date

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed 105-KE Isolation Barrier Leak Rate Acceptance Test ReportAuthor K. J. McCracken

Yes	No	N/A
-----	----	-----

☒	☐	☐	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.
☒	☐	☐	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 N/ADan A. Wallace

Reviewer

5-30-95

Date

TABLE OF CONTENTS

1.0 INTRODUCTION	1
2.0 DEFINITIONS	1
3.0 TEST SPECIFICATION REVIEW	2
4.0 ACCEPTANCE TEST PROCEDURE/ACCEPTANCE TEST REPORT	3
5.0 ACCEPTANCE TEST RESULTS	3
6.1 RESULTS DISCUSSION	4
6.1.1 Field Isolation Barrier Leakage Estimate	5
6.1.2 Discharge Chute Leakage and Additions, Evaporation, and Instrumentation Effects	9
6.1.3 Adjusted Isolation Barrier Leakage Computation	12
6.2 CONCLUSION	12
7.0 ACCEPTANCE TEST REPORT	13
8.0 QUALITY ASSURANCE	13
9.0 REFERENCES	14
APPENDICES	
APPENDIX A. KE-BASIN BASELINE LEAK TEST FINAL OBSERVATIONS	A-i
APPENDIX B. KE-BASIN ISOLATION BARRIER LEAK TEST PROGRAM LEAK.EXE	B-i
APPENDIX C. KE-BASIN ISOLATION BARRIER LEAK TEST #2 DATA ANALYSIS UTILIZING LEAK.EXE	C-i
APPENDIX D. KE-BASIN ISOLATION BARRIER LEAK TEST #2 TK SOLVER ANALYSIS	D-i
APPENDIX E. KE-BASIN ISOLATION BARRIER TEST EQUIPMENT AND INSTRUMENTATION	E-i

FIGURES

Figure 1. Revised Isolation Barrier Acceptance Criteria	3
Figure 2. Acceptance Test Basin and Discharge Chute Level Data	4
Figure 3. Level Differential vs. Time (4/10/95)	6
Figure 4. Isolation Barrier Leak Rate vs. Time (4/18/95)	8
Figure 5. Final Extrapolated Leak Rate with Acceptance Criteria Comparison	12

TABLE

Table 1. Error Analysis Table	12
-------------------------------------	----

1.0 INTRODUCTION

The objective of this document is to report and interpret the findings of the isolation barrier acceptance tests performed in 105KE/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 and the 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 1994) limit.

Two modes of water loss were considered; basin and/or discharge chute leakage, and evaporation. An initial test (Test 1, 3/22/95) established baseline leakage data and instrumentation performance. For the initial 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 100KE 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 100KE 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. 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) were 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. The entire drawdown was monitored but the initial data was not stored until 15 minutes after the pump start. The entire drawdown was monitored but the initial data was not stored until 15 minutes after the pump start. Test 2 began at T_{+1} 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 4.89 gpm (18.5 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 is an independent software routine developed by Frank Schmittroth of Radiation Physics and Shielding. It uses 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_t , 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).

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

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:

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

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.

$$Q_j = -x_2 A^* \quad (7)$$

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

$$\frac{1}{A^*} = \frac{1}{A_B} + \frac{1}{A_{DC}} \quad (8)$$

where

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

The data from Alward 1991 for area of the basin, A_B , and area of the discharge chute, A_{DC} . Calculates the value of A^* 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 leakrate as a function of time. This figure was determined utilizing equation 6 above.

Figure 4. Isolation Barrier Leak Rate vs. Time (4/18/95).

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

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 1991) 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 4.89 gpm (18.5 lpm) at the 11.1142 in. (28.20 cm) level differential with a fully turbulent flow ($\alpha = 0.5$). This corresponds to a flow of 1,170 gph (4,430 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 $Q_i = 4.89 \pm 0.004$ gpm (18.5 ± 0.023 lpm) and $\alpha = 0.524 \pm 0.001$. Utilizing this

$$Q_{i_{\text{extrapolated}}} = Q_i \left(\frac{\Delta H_{16}}{\Delta H_{11}} \right)^\alpha \times 60 \quad (10)$$

$$Q_{i_{\text{extrapolated}}} = 4.89 \text{ gpm} \left(\frac{16 \times 12}{11.05} \right)^{0.524} \times 60 = 1,304 \pm 1 \text{ gph}$$

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}	11.126 in. (28.26 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 East. These test observations are in Appendix A, 105 K East 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. (A more conservative approach than McCracken 1995c.)

The vernier evaporation detector (VED) detected a 0.028 in. (0.07 cm) level change over the 24 hour test period. This level change corresponds to an average VED, basin, and discharge chute evaporation rate of 1.9E-3 gph (7.2E-3 lph), 6.35 gph (24 lph), and 0.7 gph (2.7 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.

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 ± 0.28 gph (0.98 lpm) at the 11 in (27.9 cm) level. The LEAK.EXE calculated a data uncertainty data reference as one standard deviation (1 σ) at ± 0.005 gpm.

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 East 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.

$$Q_{i_corrected} = Q_{i_nominal} + \Delta Q_{evap} + \Delta Q_{data\ E} + \Delta Q_{DC\ add} \quad (11)$$

(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 5.00 gpm (18.9 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 1.65×0.005 $\Delta Q_{Data E}$	Total Effects (+/-)	Final Barrier Leakage at 95% UCL
4.89	+0.004	+0.106 / -0.012	0.008	0.107	5.00
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 $\alpha = 0.527$ (0.525 ± 0.002) given by Equation 10 is

$$Q_{extrapolated} = 5.00 \times \left(\frac{16 \times 12}{11.1142} \right)^{0.527} \times 60$$

$$= 1,344.8 \text{ gph.} \quad (12)$$

6.2 CONCLUSION

The K East 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 1,350 gph (5,110 lph) with a 95% UCL as shown in Figure 5.

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 5. 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

- Alward, L. D., 1991, *100 KE/KW Basin Water Surface Area Calculation*, WHC-SD-NR-ANAL-004, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Irwin, J. J., 1995, *105-K Basin Isolation Barrier Leak Rate Test Analytical Development*, WHC-SD-SNF-ER-006, Westinghouse Hanford Company Richland, Washington.
- McCracken, K. J., 1995a, *105-KE Isolation Barrier Leak Acceptance Test Procedure*, WHC-SD-SNF-ATP-005, Rev. 1, Westinghouse Hanford Company Richland, Washington.
- McCracken, K. J., 1995b, *105-KE Isolation Barrier Leak Acceptance Test Report*, WHC-SD-SNF-ATR-005, Rev. 0, Westinghouse Hanford Company Richland, Washington.
- McCracken, K. J., 1995c, *105-KE/KW Isolation Barrier Leak Test Specification and Test Plan*, WHC-SD-SNF-TP-009, Rev. 1A, Westinghouse Hanford Company Richland, Washington.
- SAR, 1994, *Safety Analysis of Irradiated N-reactor Fuel*, WHC-SD-WM-SAR-062, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

KE-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-005 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-KE 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	0	0	0	0	0	0	0
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	0	0	0	0	0	0	0
3 above	0	0	0	0	0	0	0	0
4 below	23	14	0	0	23	19	0	0
4 level	24	22	0	18	24	22	0	18
4 above	13	0	0	0	13	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	0	0	0	0	0	0	0	0
8 level	0	0	0	0	0	0	0	0
8 above	0	0	0	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	30	37	32	22	30	37	32	22
ved above	0	0	0	0	0	0	0	0
Data taken by: Knutson, Mergel, and Sparks of Vent and Balance 1/18/95 Instrument info: Alnor 799-28-01-005 Cal. due date 12/11/95								

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

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 4:00 p.m., April 1, 1995 and ended at 8:00a.m., April 19, 1994, approximate duration: 16 hours.

Table A-2. Data Sample Baseline Test (4/18/95 - 4/19/95)

ketest2.csv 04/17/95 14:51:54 ke test 2		For more data refer to Appendix T in Acceptance Test Report WHC-SD-SNF- ATR-005				
TIME (s)	dc (in.)	bsn (in.)	dewpt (°F)	AirTp (°F)	airved (°F)	B1 (°F)
93967	12.0831	2.03095	40.4072	56.215	65.8475	48.4417
94027	12.0829	1.99572	40.2922	56.3547	66.705	48.5056
94087	12.1475	2.02142	40.1367	56.1716	67.1279	48.398
94147	12.1483	2.01668	40.255	56.3702	66.5314	48.3684
94207	12.1475	2.04008	39.8881	56.314	66.135	48.3883
94267	12.1152	2.05882	39.7275	56.3239	66.4097	48.4365
94327	12.0829	2.01668	39.5669	56.3016	65.7823	48.3377
94387	12.1483	2.03772	39.9507	56.0553	65.1589	48.2431
94447	12.1789	2.05875	39.8763	56.2036	65.647	48.3157
94507	12.1702	2.03853	39.9439	56.3201	65.6115	48.4326
94567	12.2102	2.03772	39.8763	56.2403	65.9483	48.4289
94627	12.1337	2.01682	39.9524	56.318	65.4581	48.4687
94687	12.1501	2.03772	39.9338	56.0773	65.105	48.2651
94747	12.1475	2.03772	40.0674	56.1616	65.9457	48.3499
94807	12.0204	2.05868	40.0285	56.1565	65.4488	48.2684
94867	12.0206	2.01675	39.9135	56.191	65.8235	48.3029
94927	12.0204	2.05875	39.5821	56.1966	66.699	48.2322
94987	12.0204	2.03778	39.5195	56.2793	65.9114	48.3917
95046	12.0202	2.03765	39.8442	56.1384	65.355	48.1737
95107	12.0204	2.05875	39.8053	56.3799	65.7089	48.3782
95167	12.0833	2.05875	39.643	56.1121	65.9342	48.2237
95227	12.0831	2.03778	39.5635	56.281	65.7618	48.2788
95286	12.0963	2.01675	39.7833	56.0911	65.0052	48.088
95347	12.0833	2.03778	39.5584	56.1638	65.8722	48.2375
95406	12.1475	2.06578	39.1966	56.3727	65.7017	48.4473
95466	12.1477	2.05889	39.5618	56.2481	65.3885	48.3603
95526	12.1475	2.03772	39.7647	56.3175	64.8522	48.2009

ketest2.csv 04/17/95 14:51:54 ke test 2		For more data refer to Appendix T in Acceptance Test Report WHC-SD-SNF-ATR-005				
TIME (s)	dc (in.)	bsn (in.)	dewpt (°F)	AirTp (°F)	airved (°F)	B1 (°F)
95586	12.1495	2.03772	39.6362	56.3814	65.9374	48.3033
95646	12.1477	2.03772	39.7038	56.2534	65.9613	48.0983
95706	12.0831	2.05889	39.7292	56.2146	65.7714	48.1739
95766	12.1475	2.05889	39.6565	56.4214	66.9982	48.4199
95826	12.0833	2.05882	39.7833	56.2012	66.3255	48.1986
95886	12.1477	2.03772	39.6785	56.2957	66.495	48.2935
95946	12.1477	2.05882	39.763	56.2266	66.9558	48.2624
96006	12.0831	2.03772	39.7207	56.1937	66.5827	48.0765
96066	12.0243	2.05882	39.8019	56.2774	66.2878	48.1606
96126	12.0829	2.03792	39.7495	56.1515	66.4273	48.1487
96186	12.0829	2.03772	39.6311	56.3164	66.5157	48.238
96246	12.0204	2.03772	39.1746	56.2354	66.4729	48.233
96306	12.02	2.01668	38.7789	56.2763	66.5514	48.3123

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.

Figure A-2. Basin, Discharge Chute and VED Levels vs. Time.

A3.4 EVAPORATION OBSERVATIONS

When the initial KE test was conducted the fan conditions did not match the conditions noted during the vent and balance airflow measurements. Vent and balance was rescheduled to retake the measurements after the final barrier test but when KE Test 2 was performed the fan conditions were the same as the vent and balance noting. KE Test 1 was rerun directly following KE Test 2 to eliminate any evaporation errors.

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-3 and A-4 display the VED and basin temperature traces over the entire test duration (Baseline Test of 4/18/95 - 4/19/95).

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

Time	Basin Temp °F	VED Temp °F	Adjust Set Point Δ °F
4/18 4:53pm	47.9	46.9	--
7:53pm	48.0	47.0	--
10:53pm	48.2	47.2	--
11:50pm	48.0	47.0	--
4/19 1:58pm	48.0	47.0	--
6:00am	48.0	47.0	--
7:00am	48.0	47.0	--
9:00am	48.0	47.2	--

The VED detected 0.0028 in. (0.070 cm) drop in level which correlates to 152.5 gal (580l) lost in the basin over the 16 hour initial baseline test duration due to evaporation which is 9.5 gph (36 lph) loss rate and 0.1.1 gph (4 lph) for the discharge chute.

Figure A-3. VED Temperature Trace (4/18/95-4/19/95).

Figure A-4. Basin Water Average Temperature Trace (4/17/95 - 4/19/95).

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-5. Dew Point Temperature Trace (4/17/95 - 4/19/95).

Figure A-6. Basin Air Temperature Trace (4/17/95 - 4/19/95).

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

**KE-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 bbti = 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

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

The following calculation is from the LEAK.EXE PC program:

No. of data points =1502 KETEST2 @ 4/17/95

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

Time (hrs) Measured Ht (in)

1	0.0000E+00	1.1142E+01
2	1.6667E-02	1.1078E+01
3	3.3333E-02	1.1078E+01
4	5.0000E-02	1.1067E+01
5	6.6667E-02	1.1057E+01
1502	2.5002E+01	1.3025E+00

hsig2 = 2.090E+00

	x(i)	std-dev.
X1:	1.109E+01	2.887E-03
X2:	-5.523E-01	5.333E-04
X3:	7.220E-03	2.065E-05

alpha .525 +/- .002

Qi, gal/hr 292.65 +/-0.28

Qi, gal/min 4.88 +/-0.005

APPENDIX D

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

TABLE: Works					
Title: Basin vs Time Polynomial Regression Worksheet (y=c0+c1*x+c2*x^2+)					
Element	Time	Basin level	residuals	SUMMARY STATS	
1	.8497222222	16.307889667	+2.843E-4	'order	2
2	.8663888889	16.309823	+2.286E-3	'resids	'yes
3	.8830555556	16.307901334	+4.319E-4		
4	.8997222222	16.3078955	+4.940E-4	'N	1499
5	.9163888889	16.307889667	+5.561E-4	'Syx	.001857034
6	.9330555556	16.307038834	-2.269E-4	'adj_R2	.992044922
7	.9497222222	16.3061255	-1.072E-3		
8	.9663888889	16.3061255	-1.005E-3	'c0	16.3111074
9	.9830555556	16.306131334	-9.309E-4	'c1	-.004163
10	.9997222222	16.304367167	-2.627E-3	'c2	4.89343E-5
11	1.016388889	16.304812167	-2.115E-3	'c3	0
12	1.033055556	16.3060805	-7.785E-4	'c4	0
13	1.049722222	16.305691334	-1.100E-3	'c5	0
14	1.066388889	16.3070105	+2.868E-4	'c6	0
15	1.083055556	16.3063455	-3.106E-4	'c7	0
16	1.099722222	16.305466334	-1.122E-3	'c8	0
17	1.116388889	16.307934667	+1.414E-3	'c9	0
18	1.133055556	16.307901334	+1.448E-3	'c10	0
19	1.149722222	16.307016334	+6.305E-4		
20	1.166111111	16.307912167	+1.593E-3		
21	1.182777778	16.305911334	-3.406E-4		
22	1.199444444	16.304378834	-1.806E-3		
23	1.216111111	16.309107167	+2.990E-3		
24	1.232777778	16.306142167	+9.243E-5		
25	1.249444444	16.306131334	+1.490E-4		

TABLE: Works

Title: DC vs Time Polynomial Regression Worksheet (y=c0+c1*x+c2*x²+c3*

Element	Time	DC level	residuals	SUMMARY STATS	
1	.8497222222	15.382436819	-2.088E-3	'order	2
2	.8663888889	15.382436819	-2.789E-3	'resids	'yes
3	.8830555556	15.382436819	-3.489E-3		
4	.8997222222	15.387830153	+1.204E-3	'N	1499
5	.9163888889	15.387830153	+5.038E-4	'Syx	.001881538
6	.9330555556	15.387830153	-1.958E-4	'adj_R2	.999915631
7	.9497222222	15.387796819	-9.285E-4		
8	.9663888889	15.387830153	-1.594E-3	'c0	15.3483798
9	.9830555556	15.387830153	-2.293E-3	'c1	.043009877
10	.9997222222	15.393190153	+2.369E-3	'c2	-.00055638
11	1.016388889	15.393207653	+1.688E-3	'c3	0
12	1.033055556	15.393207653	+9.901E-4	'c4	0
13	1.049722222	15.393207653	+2.926E-4	'c5	0
14	1.066388889	15.393224319	-3.880E-4	'c6	0
15	1.083055556	15.393207653	-1.102E-3	'c7	0
16	1.099722222	15.393207653	-1.798E-3	'c8	0
17	1.116388889	15.393240986	-2.461E-3	'c9	0
18	1.133055556	15.398567653	+2.170E-3	'c10	0
19	1.149722222	15.398567653	+1.474E-3		
20	1.166111111	15.398567653	+7.902E-4		
21	1.182777778	15.398584319	+1.118E-4		
22	1.199444444	15.398584319	-5.830E-4		
23	1.216111111	15.398567653	-1.294E-3		
24	1.232777778	15.398584319	-1.972E-3		
25	1.249444444	15.403775153	+2.526E-3		

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.

TK obtaining exponent

VARIABLE SHEET				
St Input	Name	Output	Unit	Comment
	n	1501		number of data points
	a	283.22453		coefficent
	b	.49220661		exponent
16	x			dependant variable
	y	1108.6812		independant variable

0.5 exponent

VARIABLE SHEET				
St Input	Name	Output	Unit	Comment
	n	1501		number of data points
	a	285.16679		coefficent
	b	.5		exponent
16	x			dependant variable
	y	1140.6672		independant variable

0.528 exponent

VARIABLE SHEET				
St Input	Name	Output	Unit	Comment
	n	1501		number of data points
	a	292.25546		coefficent
	b	.528		exponent
16	x			dependant variable
	y	1263.3916		independant variable

 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-East Basin Final Test 2 time: ~3pm Level and Flow Data TKSolver date: 4/17/95												
bas SA 8882.1	time	int. dc level 12.04749		dc (in.)	dc hgt	dc reght	int. basin level 2.034604		bsnreg	deltaH (ft)	q cfm	Q gph
		dc	dc hgt				bsn (in.)	bsnhgt				
2999	0.833056	1.98673	15.38244	15.38383	3.07942	16.3079	16.30767	0.923848	36.24478	271.111		
3059	0.849722	1.98673	15.38244	15.38453	3.07928	16.30789	16.30761	0.923079	36.23029	271.0026		
3119	0.866389	1.98673	15.38244	15.38523	3.10248	16.30982	16.30754	0.92231	36.2158	270.8942		
3179	0.883056	1.98673	15.38244	15.38593	3.07942	16.3079	16.30747	0.921541	36.20132	270.7859		
3239	0.899722	2.05145	15.38783	15.38663	3.07935	16.3079	16.3074	0.920773	36.18683	270.6775		
3299	0.916389	2.05145	15.38783	15.38733	3.07928	16.30789	16.30733	0.920005	36.17234	270.5691		
3359	0.933056	2.05145	15.38783	15.38803	3.06907	16.30704	16.30727	0.919237	36.15785	270.4607		
3419	0.949722	2.05105	15.3878	15.38873	3.05811	16.30613	16.3072	0.91847	36.14337	270.3524		
3479	0.966389	2.05145	15.38783	15.38943	3.05811	16.30613	16.30713	0.917703	36.12888	270.244		
3539	0.983056	2.05145	15.38783	15.39013	3.05818	16.30613	16.30706	0.916937	36.11439	270.1356		
3599	0.999722	2.11577	15.39319	15.39082	3.03701	16.30437	16.30699	0.91617	36.0999	270.0273		
3659	1.016389	2.11598	15.39321	15.39152	3.04235	16.30481	16.30693	0.915404	36.08541	269.9189		
3719	1.033056	2.11598	15.39321	15.39222	3.05757	16.30608	16.30686	0.914639	36.07093	269.8105		
3779	1.049722	2.11598	15.39321	15.39292	3.0529	16.30569	16.30679	0.913873	36.05644	269.7021		
3839	1.066389	2.11618	15.39322	15.39362	3.06873	16.30701	16.30672	0.913108	36.04195	269.5938		

APPENDIX E

K-BASIN ISOLATION BARRIER TEST EQUIPMENT AND INSTRUMENTATION

E1.0 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.

E2.0 INSTRUMENTATION DESCRIPTION

E2.1 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.

E2.1.1 USLDs

Many level indication devises 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 E-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 E-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.)

E2.1.2 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 E-2).

Figure E-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 E-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 E-3. Instrumentation Table

E2.2 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.

E2.2.1 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.

E2.2.2 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 E-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 E-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 E-4. Typical Thermocouple Mounting

Figure E-5. Instrument Locations

E2.2.3 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-10 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.

E2.3 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.

E2.3.1 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 E-6).

Figure E-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.

E2.4 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.

E2.4.1 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 E-7 shows a wiring diagram of the instrumentation set-up.

Figure E-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.

E3.0 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.