WEDCO CORPORATION

PREOPERATIONAL INTEGRATED LEAK RATE TEST OF THE REACTOR CONTAINMENT BUILDING

CONSOLIDATED EDISON CORPORATION

INDIAN POINT UNIT 3

prepared for

WEDCO CORPORATION

by

GILBERT ASSOCIATES, INC.

READING, PENNSYLVANIA

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1.0 SYNOPSIS

The Indian Point Nuclear Station Unit 3 reactor containment building was subjected to a preoperational integrated leak rate test during the period from January 15, 1975 to January 19, 1975. The purpose of this test was to demonstrate the acceptability of building leakage rates at internal pressures of 41 psig (P_a) and 21 psig (P_t). Testing was performed in conformance with the requirements of 10 CFR 50, Appendix J, ANSI N45.4-1972 and Indian Point Nuclear Station Unit 3 FSAR.

Leakage rates based on the point-to-point method of analysis were found to be 0.027 percent by weight per day at 41 psig and 0.005 percent by weight per day at 21 psig. These leakage rates are well below the acceptable test leakage rates of 0.075 percent per day at 41 psig and 0.014 percent per day at 21 psig.

L_{tm}/L_{am} is therefore established at 0.185. In accordance with 10 CFR 50, Appendix J and the Indian Point Nuclear Station Unit 3 FSAR, Section 15.4.4, Revision 10 (Technical Specifications), subsequent integrated leakage rate tests may be performed at P_t with a maximum allowable leakage value of 0.019%/day based on an L_t value of L_a (L_{tm}/L_{am}), since L_{tm}/L_{am} is less than 0.7. Therefore, the acceptable leakage (L_{tm}) for subsequent test should be less than the 0.75 L_t value which is 0.014 percent per day.

Since several penetrations were being used to conduct the leakage rate tests, the addition of the local leakage rate of penetrations YY, XX and RR to the measured values of L_{am} and L_{tm} was warranted. However, subsequent to the leak rate test the combined local leakage rate of these penetrations was measured and found to be zero.

The supplemental instrumentation verification at P_a and P_t was 16 percent and 15.8 percent, respectively; well within the 25 percent requirement of 10 CFR 50, Appendix J, Section III A.3.b.

All testing was performed by Wedco Corporation for Consolidated Edison Corporation with the technical assistance of Gilbert Associates, Inc. and Energy Incorporated. Calculations were checked by Gilbert Associates, Inc.

2.0 INTRODUCTION

The objective of the preoperational integrated leak rate test was the establishment of the degree of overall leak tightness of the reactor containment building at the design basis accident pressure of 40.6 psig and to establish a reference test for subsequent periodic integrated leak rate tests at 21 psig. The allowable leakage is defined by the design basis accident applied in the safety analysis in accordance with site exposure guidelines specified by 10 CFR 100. For Indian Point Nuclear Station Unit 3, maximum allowable integrated leak rate is as follows:

Conditions		Maximum Allowable Leak Rate (Percent per day)
Design Basis Accident		
(40.6 psig, P_a)	L_a	0.100

Testing was performed in accordance with Wedco Corporation procedural requirements as stated in Indian Point Unit 3 Test Procedure, INT-TP-4.11.9.[1] This procedure was approved by Indian Point Nuclear Station Unit 3 Joint Test Group prior to the commencement of the Test.

Prior to the accomplishment of the preoperational integrated leak rate test, the structural integrity test was performed at the peak internal pressure of 54 psig for the reactor containment. The results of the structural integrity test are presented in a separate report.

The combined local leakage rates from reactor containment building isolation valves and penetrations which are required to be tested under 10 CFR 50, Appendix J was less than 60 percent of the maximum allowable leakage rate (L_a) prior to the commencement of the integrated leak rate test.

Leakage rate testing was accomplished at each pressure level of 21 psig and 41 psig for a period of 24 hours. Each 24 hour period was followed by an eight hour supplemental test for a verification of the test instrumentation. During testing at P_t, reactor containment building internal temperature was maintained at $76.17 \pm 0.12^{o}F$, and at P_a reactor containment building internal temperature was maintained at $78.34 \pm 0.15^{o}F$.

3.0 ACCEPTANCE CRITERIA AND CONCLUSIONS

3.1 Acceptance Criteria

Acceptance criteria established prior to the test and as specified by 10 CFR 50, Appendix J,[2] ANSI N45.4-1972[3] and the Indian Point Nuclear Station Unit 3 FSAR, Section 15.4.4., Revision 10, are as follows:

a. The measured leakage rate (L_{am}), corrected from test conditions to design basis accident conditions, at the design basis accident pressure of 40.6 psig (P_a) shall be less than 75 percent of the maximum allowable leakage rate (L_a), specified as 0.1 weight percent of the building atmosphere per day by the Indian Point Nuclear Station Unit 3 FSAR, Section 15.4.4., Revision 10. The acceptance criteria is then determined as follows:

$$L_a = 0.1\%/\text{day}$$

$$0.75\ L_a = 0.075\%/\text{day}$$

b. The measured leakage rate (L_{tm}), corrected from test conditions to design basis accident conditions, at the reduced pressure of 21 psig (P_t) shall be less than 75 percent of the maximum allowable leakage rate (L_t), at P_t. The value of L_t is determined as follows:

1) $L_t = L_a\ (L_{tm}/L_{am})$ if $L_{tm}/L_{am} < .7$

2) $L_t = L_a (P_t/P_a)^{1/2}$ if $L_{tm}/L_{am} > .7$

Based on the test results (Section 3.2), L_t was determined using criterion 1) above, as follows:

$$L_t = L_a (L_{tm}/L_{am})$$

$$L_t = 0.1 \ (.005/.027)$$

$$L_t = 0.019\%/\text{day}$$

The acceptance criterion for the leakage rate at P_t was then determined, as follows:

$$L_t = 0.019\%/\text{day}$$

$$0.75L_t = 0.014\%/\text{day}$$

c. The acceptance criterion that the test instrumentation be verified by means of a supplemental test within 25 percent L_a (or L_t) was established in accordance with 10 CFR 50, Appendix J.

3.2 Conclusions

a. The measured leakage rate (L_{tm}) at a containment internal pressure of 21 psig (P_t) was 0.005 percent per day. This value is well below the above stated acceptance criterion of 0.014 percent per day. Therefore, reactor containment building leakage at reduced pressure (P_t) of 21 psig is considered to be acceptable.

b. The measured leakage rate (L_{am}) at a containment internal pressure of 40.6 psig (P_a) was 0.027 percent per day. This value is well below the above stated acceptance criterion of 0.075 percent per day. Therefore, reactor containment building leakage at design basis accident pressure (P_a) of 40.6 psig is considered to be acceptable.

c. Verification of test accuracy at P_t and P_a was accomplished by means of a supplemental test in each case, during which a superimposed, controlled leakage rate from the containment was instituted. Appendix J of 10 CFR 50 requires that the difference between the supplemental test results and type A test results be within 25 percent of L_a at peak pressure (P_a) and within 25 percent of L_t at reduced pressure (P_t).

The following summary indicates values for these tests:

	24 Hour Leakage Rate (%/day)	Supplemental Test Leakage Rate (%/day)	Difference (%/day)
P_a	0.027	0.011	0.016
P_t	0.005	0.002	0.003

A comparison of these results yields the following:

$$\text{At } P_a\text{:}\quad \frac{|L_{am} - L'_{am}|}{L_a} = \frac{|0.027 - 0.011|}{0.10\%/\text{day}} =$$

0.16, or 16% of L_a

$$\text{At } P_t: \frac{|L_{tm} - L'_{tm}|}{L_t} = \frac{|0.005 - 0.002|}{0.019\%/\text{day}} =$$

$$0.158, \text{ or } 15.8\% \text{ of } L_t$$

These comparisons are both well below the 25 percent limit specified by Appendix J of 10 CFR 50. Therefore, the supplemental tests are considered to have satisfactorily verified the acceptability of the test instrumentation.

d. In accordance with 10 CFR 50, Appendix J, the following conclusion was reached concerning the value of L_t to be used for subsequent reactor containment building integrated leak rate tests:

$$L_t = L_a \ (L_{tm}/L_{am})$$

$$L_t = 0.1 \ (0.005/0.027)$$

$$L_t = 0.019\%/\text{day}$$

This determination of L_t was used since (L_{tm}/L_{am}) was less than 0.7 (i.e., $L_{tm}/L_{am} = 0.19$).

The acceptance criterion for subsequent integrated leak rate tests then becomes 0.014 percent per day. This value was determined as follows:

$$L_t = 0.019\%/\text{day}$$

$$0.75 \ L_t = 0.014\%/\text{day}$$

4.0 TEST INSTRUMENTATION

4.1 Summary of Instruments

Test instruments employed are described, by system, in the following subsections.

4.1.1 Temperature Indicating System

Overall system accuracy: $\pm$ 0.17°F

Overall system repeatability: $\pm$ 0.17°F

Components:

a. Resistance Temperature Detectors

Number	24
Manufacturer	YSI Sostman
Type	Model 4150-1/4-11 1/2-2-6-139Y-J 1/2 1/2 - E
Range, °F	50-120
Accuracy, °F	$\pm$ 0.04
Repeatability, °F	$\pm$ 0.03

b. Indicating Readout Devices

Number	1
Manufacturer	Hewlett-Packard
Type	Model HP-3460B with volts to ohm converter Model HP-3461A

Accuracy, ^{o}F	* $\pm$ 0.004% of reading + 0.002% of full scale
	** $\pm$ 0.008% of reading + 0.002% of full scale
Repeatability, ^{o}F	* $\pm$ 0.004% of reading + 0.002% of full scale
	** $\pm$ 0.008% of reading + 0.002% of full scale

4.1.2 Dewpoint Indicating System

Overall system accuracy: $\pm$ 1.0^{o}F

Overall system repeatability: $\pm$ 0.50^{o}F

a. Dewcel Elements

Number	6
Manufacturer	Foxboro
Type	Model 2701 RG

b. Dewpoint Recorder

Number	1
Manufacturer	Foxboro-Yew
Type	Model ERB/6
Range	0-150^{o}F

* Denotes instrument model HP-3460B
** Denotes instrument model HP-3461A

4.1.3 Pressure Monitoring System

Overall system accuracy: $\pm$ 0.015% of indicated pressure

Overall system repeatability: $\pm$ 0.0005% of indicated pressure

Precision Pressure Gauges

Number	2
Manufacturer	Texas Instruments
Type	Model 145-02
Range, psia	0-100

4.1.4 Supplemental Test Flow Monitoring System

Overall system accurancy: $\pm$ 1% Full Scale Accuracy

Flow Meter

Number	2
Manufacturer	Wallace and Tiernan
Range, scfm, at 0 psig and 90^{o}F	0-10.4

4.2 Schematic Arrangement

The basic arrangement of the four measuring systems summarized in Section 4.1 is depicted in Appendix A.

Temperature sensors were placed throughout the reactor containment building volume to permit monitoring of internal temperature variations at 24 locations. A temperature survey was performed after the sensors were installed which verified there were no large areas of temperature variation. Dewcels were placed in 6 locations as shown. Placement of temperature sensors and dewcels was as follows:

Location	No. of Temperature Indicators	No. of Dewcels
Mezzanine floor	6	2
Operating floor	4	1
Crane bridge	8	2
Spray ring	6	1

These 30 sensors, placed as indicated, made possible the most representative measurements of reactor containment building internal atmospheric conditions, especially since continuous mixing of the atmosphere was taking place through the building recirculation units.

4.3 Calibration Checks

Temperature and pressure measuring systems were checked for calibration before the test runs as recommended by ANSI N45.4-1972, Section 6.2 and 6.3. The supplemental tests at 21 psig and 41 psig, confirmed the instrumentation acceptability.

4.4 Systematic Error Analysis

Systematic error, in this test, is induced by the operation of the temperature indicating system, dewpoint indicating system and the one pressure indicating system.

Justification of instrumentation selection was accomplished as follows, using manufacturer's repeatability tolerances stated in Section 4.1.

The leakage rate, in percent per day (%/day), based on an interval of measurement of 24 hour duration is

$$L = 100 \left[1 - \frac{P_{24}\ T_o}{P_o\ T_{24}} \right] \%/\text{day}$$

where:

$P_o = P_{T_o} - P_{wvo}$, psia = partial pressure of air at start

$P_{24} = P_{T_{24}} - P_{wv_{24}}$, psia = partial pressure of air at finish

T_o = building mean ambient temperature at start, ^oR.

T_{24} = building mean ambient temperature at finish, ^oR.

The change, or uncertainty level, in L due to uncertainties in the systematic measured variables is given by

$$\delta L = 100 \left[\left(\frac{\partial L}{\partial P_{24}} \tau P_{24} \right)^2 + \left(\frac{\partial L}{\partial P_o} \tau P_o \right)^2 + \left(\frac{\partial L}{\partial T_o} \tau T_o \right)^2 + \left(\frac{\partial L}{\partial T_{24}} \tau T_{24} \right)^2 \right]^{1/2}$$

where τ is the systematic error for each variable. The error in L after differentiation is

$$e_L = 100 \left[\left(\frac{T_o\ e_{P_{24}}}{P_o\ T_{24}} \right)^2 + \left(\frac{P_{24}\ T_o\ e_{P_o}}{P_o{}^2\ T_{24}} \right)^2 + \left(\frac{P_{24}\ e_T}{P_o\ T_{24}} \right)^2 + \left(\frac{P_{24}\ T_o\ e_T}{P_o\ T_{24}{}^2} \right)^2 \right]^{1/2}$$

where:

$$e_{P_o} \text{ and } e_{P_{24}} = \tau P_{24}$$

$$e_T = \tau T_{24}$$

Since the the values of T_o and T_{24} are essentially the same, within 0.12^oF and 0.15^oF, and P_o and P_{24} are essentially the same, within 0.013 psia and 0.025 psia at 21 psig and 41 psig respectively, let $T_o = T_{24}$ and $P_o = P_{24}$. The systematic error in L then becomes

$$e_L = 141.4 \left[\left(\frac{e_P}{P_o} \right)^2 + \left(\frac{e_T}{T_o} \right)^2 \right]^{\frac{1}{2}} \qquad (1)$$

where the error in pressure (e_p) may be expressed as

$$e_P = \left(e_{Pa}{}^2 + e_{Pb}{}^2 \right)^{\frac{1}{2}}$$

and

e_{Pa} = error induced by two precision pressure gauges

At 41 psig, the repeatability error is

$$e_{Pa} = \pm \frac{(0.00005) \quad (55.783) \text{ psia}}{(2)^{\frac{1}{2}}}$$

$$e_{Pa} = \pm\ 0.000197 \text{ psia}$$

and

e_{Pb} = error induced by six Dewcels, or

$$e_{Pb} = \pm \frac{.500}{(6)^{\frac{1}{2}}}\ ^oF$$

$$e_{Pb} = \pm\ 0.204\ ^oF$$

From steam tables,[4] at a dewpoint of 53.63°F, the pressure equivalent to $\pm$ 0.204°F is

$$e_{Pb} = \pm\ 0.001510 \text{ psia}$$

Therefore,

$$e_P = \left[(0.000197)^2 + (0.001510)^2\right]^{1/2} \text{ psia}$$

$$e_P = \pm\ 0.001522 \text{ psia}$$

The error in temperature (e_T) may be expressed as

$$e_T = \pm\ \frac{0.17}{(24)^{1/2}}$$

$$e_T = \pm\ 0.034701^{\circ}\text{F}$$

Hence, for values at P_a,

$$P_o = 55.783 \text{ psia}$$

$$T_o = 538.00\ ^{\circ}\text{R}$$

and substitution into equation (1) yields

$$e_{La} = 141.4 \left[\left(\frac{0.001510}{55.783}\right)^2 + \left(\frac{0.034701}{538.00}\right)^2\right]^{1/2}$$

$$e_{La} = \pm\ 0.010 \text{ \%/day}$$

At 21 psig (P_t) with a dewpoint of 49.72°F and

$$P_o = 35.775 \text{ psia}$$

$$T_o = 535.95\ ^{\circ}\text{R}$$

Then,

$$e_{Lt} = \pm\ 0.011\ \%/\text{day}$$

The maximum expected systematic errors of the test instrumentation package are e_{La} and e_{Lt}.

Containment leakage rate computations are a function of changes in temperature and pressure relative to each other, not absolute values. Therefore, repeatability error analysis is more meaningful and all future references to test instrumentation error analysis will be based upon repeatability.

A conclusion reached from the above calculations was that the instrumentation selected yielded an error value approximately 10 times less than the allowable leakage rate value of approximately 0.1 percent per day and that the instrumentation combination was of sufficient sensitivity for this test.

4.5 Supplemental Verifications

In addition to the calibration checks described in Section 4.3, test instrumentation operation was verified by a supplemental test subsequent to the completion of the 24 hour leakage rate tests at pressures P_t and P_a. These tests consisted of imposing a known, calibrated leakage rate on the reactor containment building.

At P_t, flowmeter FI-1 was placed in service and a flow rate from the reactor containment building of 0.80 SCFM at 21 psig and 73°F was established. This flow rate was equivalent to a leakage rate of 0.034 percent per day at pressure P_t and design basis accident conditions. At P_a, flowmeter FI-1 was again placed in service and a flow rate from the reactor containment of 1.50 SCFM at 41 psig and 72°F was established. This flow rate was equivalent to a leakage rate of 0.052 percent per day at pressure P_a and design basis accident conditions. After the flow rate was established it was not altered for the duration of the supplemental test.

During the supplemental test phases, the measured leakage rate was

$$L_c = L'_{am}\ (L'_{tm}) + L_o$$

where,

L_c = Composite point-to-point leakage rate of the reactor building plus the flow rate through FI-1.

L_o = Known leakage rate through FI-1.

$L'_{am}(L'_{tm})$ = Leakage rate of the reactor building during this test phase.

Rearranging the above equation,

$$L'_{am}(L'_{tm}) = L_c - L_o$$

The reactor containment building leakage during the supplemental test can be calculated by subtracting the known superimposed leakage rate from the measured leakage rate.

The reactor containment building leakage rate during the supplemental test was then compared to the measured reactor containment building leakage rate during the preceding 24 hour test to determine instrumentation acceptability. Instrumentation is considered acceptable if the difference between the two building leakage rates is within 25 percent of the maximum allowable leakage rate at that pressure.

5.0 TEST PROCEDURE

5.1 General

Following the satisfaction of the basic prerequisites, stated in Section 5.2, reactor containment building pressurization was initiated at a rate of 2.5 psi per hour. Building temperature was maintained at approximately 75°F. Building pressure and temperature and the amperage required by the five recirculation unit fans were monitored hourly.

Prior to the test, the barometric gauge was equalized to the barometric pressure within the primary auxiliary building. This gauge was then used to obtain data for use in calculating the reactor containment building internal gauge pressure. Leak rate testing was initiated at 21 psig and 41 psig.

A minimum of four hours elapsed between the stabilization of reactor containment building pressure and the taking of any official data. During this period and for the duration of the 24 hour leak rate test and 8 hour supplemental test (total 32 hour period) at each test pressure level (21 psig and 41 psig), service water flow rate was varied to maintain average internal containment temperature within a band of $\pm$ 0.3°F. (see Appendix B).

During each test the following occurred hourly (see Appendix C):

a. The six dewcel dewpoint values were recorded. The average of the six values was converted to vapor pressure using steam tables.

b. The twenty-four RTD temperatures were recorded and an average calculated. This average value also served as the variable controlled for the performance of the tests.

c. Pressures indicated by each of the two precision gauges were recorded and an average was calculated. This permitted correction of the average pressure to the pressure of air by subtracting the vapor pressure.

The use of vapor pressure (P_{wv}), average temperature (T) and the total pressure (P_T) is described in more detail in Section 6.1.

The plot of average temperature and leakage rate was performed hourly.

Temperature stability was maintained by varying the heat removal capability of the service water system.

Calculations of the point-to-point and total time leakage values were performed on site using a WANG-600 programmable calculator.

When convenient, the available hourly values of P_{wv}, T and P_T were transmitted to the Gilbert Associates, Inc., home office for further analysis using the CLERCAL computer program. Computer program results were returned to the site via telephone which included a least squares fit of the observed on-site data.

Following the end of each 24 hour test, superimposed leakage rate was established for an additional 8 hour period for instrument verification. See Section 4.5.

A final computer run using the CLERCAL program was made after data for each test period was available.

5.2 Prerequisites

Prior to commencement of reactor containment building pressurization, the following basic prerequisites were satisfied:

a. Proper operation of all test instrumentation was verified.

b. The following reactor containment isolation valves were closed during the test:

   1. Valves which are closed automatically by a safeguards signal.

2. Valves which are closed manually in the post accident safeguards sequence.

3. Valves which are normally closed during power operation except those used for venting.

c. Systems that are required to maintian the plant in a safe condition during the test shall be operable in their normal mode, and not vented.

d. Equipment within the reactor containment building, subject to damage, was protected from external differential pressures.

e. Portions of fluid systems, which under post-accident conditions become extensions of the containment boundary, were vented.

f. The penetration pressurization and weld channel systems were cross connected to the building pressurization system.

g. Local leakage rate testing of containment isolation valves and penetrations was concluded.

h. Containment recirculation fans were operational and orifices were installed to prevent motor overload at high test pressure.

i. Potential pressures sources such as gas bottles were removed from the containment.

5.3 Test Performance

5.3.1 Structural Integrity Testing

Pressurization of the reactor building containment was started on January 12, 1975 at 1515. The pressurization rate was approximately 2.5 psi per hour. At 12 psig, pressurization was halted and a thorough inspection of the containment interior and exterior was made. The inspection revealed the following:

a. No oil haze was seen in the containment, indicating clean pressurization air.

b. First elbow outside penetration "O" was found to be leaking. A temporary cap was installed inside the containment and the elbow repaired. The cap was removed and the elbow was soap bubble tested. No leakage was indicated.

c. A small leak at penetration "Y" was discovered and repaired. After completion of the 12 psig inspection and structural data requirements, pressurization was continued to 21 psig. At 21 psig, structural test data was obtained and an external inspection was made for leaks. Slight leakage was detected at spare electrical penetration H-65 and penetration H. These leaks were repaired prior to the integrated leak rate test.

After completion of the 21 psig inspection, pressurization was continued to 41 psig. At 37 psig, four of the five recirculation fans tripped on overload. Pressurization was halted and it was discovered that the overload set points had not been reset to the full load value. The overload set points were reset and pressurization to 41 psig continued. At 41 psig, structural test data was obtained, and an external inspection for leaks was made. Prior to completing an external check for leakage, recirculation fan 35 tripped on overload. It was decided not to attempt to restart this fan until immediately prior to the integrated leak rate test. Slight leakage was discovered at valve 885B container and the equipment hatch personnel lock. It was concluded that the small magnitude of these leaks would not affect a successful integrated leak rate test. After the leakage investigation, all the electrical and mechanical penetrations and weld channels were blown down to atmospheric pressure. This was done to determine whether any in-leakage to the components existed from the reactor building. Since the normal integrated leak rate test checks the tightness of the second leakage barriers for all weld channels and penetrations, this was done to check the integrity of the first leakage barrier. Zone 2 could not be blown to atmospheric pressure using the zone isolation valve, because the solenoid valves SOV-1342 (Personnel lock) and SOV-1345 (Equipment hatch) were leaking in the reverse direction. The individual Zone 2 racks were isolated and bled to atmospheric pressure. This problem was not considered to affect the integrated leak rate test and was investigated after completion of the test. The primary purpose of this test was to verify that no major leaks from containment to the weld channels and penetrations existed, and this was accomplished by verifying that no pressure buildup occurred in these systems after they has been bled down to atmospheric pressure.

After all checks had been completed at 41 psig, weld channels and penetrations were again opened to the containment atmosphere. Then pressurization was continued to 54 psig. The remaining four recirculation fans tripped on motor overload or were removed from service at approximately 43 psig. It was agreed not to restart the recirculation fans until pressure was below 43 psig during the depressurization phase of the Structural Integrity Test. At 53.5 psig, three compressors were secured to decrease the rate of pressure increase. Pressure was increased to 54 psig and structural test data was taken. An external inspection for leaks revealed a pinhole leak in penetration "Q".

After holding 54 psig for one hour, depressurization to 41 psig was started. At 41 psig, structural data was obtained, weld channels and penetrations were isolated for repairs, and depressurization continued to 18 psig. Five recirculation fans were restarted at approximately 37 psig. Containment recirculation fan 35 tripped on overload at approximately 36.5 psig. It was agreed to attempt to restart containment recirculation fan 35 at 18 psig. Repairs were made to penetrations Q, H and H-65 during depressurization. These penetrations were checked, found to be leak tight and were returned to service.

At 18 psig, structural data was obtained and containment inspection was completed. Containment recirculation fan 35 was restarted. After one hour at 18 psig, two compressors were started to pressurize the containment to 21 psig to begin the integrated leak rate test. All five containment recirculation fans were in service.

5.3.2 Integrated Leakage Rate Testing

When containment pressure reached 21 psig, the compressors were secured. Temperature control was maintained by throttling valve SWN-61 on the discharge side of the cooling water to the containment recirculation fans.

After waiting approximately 22 hours, leak rate testing was started. Temperature had stabilized at approximately 76°F. The dewpoint temperature continued to increase slightly, however, total building pressure is corrected for water vapor pressure.

After 24 hours of leakage data was obtained and evaluated to be acceptable, a known leak rate was imposed on the building through a calibrated flowmeter for a period of 8 hours. Agreement between the calculated leakage rate and the measured leakage rate was excellent.

After the 21 psig data was obtained, pressurization was started to 41 psig. Containment recirculation fan 35 tripped on motor overload at approximately 25 psig. A post test inspection revealed that the flexible joint on the fan inlet had collapsed into the screen. This allowed air to bypass the restricting orifice thus increasing the load on the fan motor. This fan was secured for the remainder of the test. When containment pressure reached 41 psig, the compressors were secured. Stabilization was reached after approximately 4.5 hours and integrated leak rate testing at this plateau was started. Temperature stabilized at approximately 78°F. Dewpoint temperature continued to increase slightly, however, total building pressure is corrected for water vapor pressure.

After 24 hours of leakage data was obtained and evaluated to be acceptable, a known leakage rate was imposed for 8 hours and good agreement between the measured and calculated values was again achieved.

After the 41 psig data was obtained depressurization was started to 12 psig. After structural data was obtained, depressurization to atmospheric pressure was resumed.

A post test inspection of the building revealed the following:

a. The flexible joint on containment recirculation fan 35 inlet and the steel retaining straps had collapsed into the fan suction screen.

b. Containment recirculation sump contained approximately 8 inches of water which was a result of leakage from an accumulator line which was vented to containment.

5.3.3 Post Test Corrective Actions

The following post test actions were taken:

a. The flexible joint on containment recirculation fan 35 inlet was satisfactorily repaired.

b. No action was required on the containment recirculation fan motor overload trips at approximately 43 psig. The orifice plates were sized for the post accident intake flow path while the test was performed using the normal intake flow path which caused higher motor load. The containment recirculation fans performed satisfactorily during the integrated leak rate test and will perform satisfactorily in a design basis accident environment.

c. Solenoid valves SOV-1434, 1334, 1437 and 1337 for the equipment and personnel hatches were found to leak from the containment to the penetration pressurization system when the valves were closed. These solenoid valves will be repaired or replaced and tested to demonstrate that they do not leak at pressure greater than the design basis accident pressure.

6.0 METHODS OF ANALYSIS

6.1 General Discussion

Two methods of computing the leakage rate from a reactor containment building by using the absolute method are recognized by ANSI 45.4-1972. These methods are point-to-point (PP) and total time (TT). Both methods used the equation

$$L,\ \%/\text{day} = \frac{2400}{h}\left[1 - \frac{T_1\ P_2}{T_2\ P_1}\right]$$

where,

h, = length of test interval, hours

T_1 = Average absolute temperature of the reactor building at the start of each hourly test period (point-to-point method) or at the beginning of the test (total time method), ^oR

T_2 = average absolute temperature of the reactor building at the end of each hourly test period (point-to-point method and total time method), ^oR

P_1 = partial pressure of air in the reactor building at the same time stated for T_1, psia

P_2 = partial pressure of air in the reactor building at the same time stated in T_2, psia

Computation of the hourly point-to-point and total time percent per day leakage rates and the least squares fit of this data to obtain L_{mean} (%/day) during the test were performed on the WANG 600 programmable calculator.

The Gilbert Associates, Inc., CLERCAL computer code was used to verify calculations performed during the test. This computer code also calculates the percent per day leakage rate for each hour by the point-to-point and total time methods.

For the two methods mentioned, P and T are calculated as follows:

$$P_{ave.} = \frac{P_{T_1} + P_{T_2}}{2} - P_{wv}$$

where,

P_{T_1} = true corrected pressure of PI-1, psia

P_{T_2} = true corrected pressure of PI-2, psia

P_{wv} = partial pressure of water vapor determined by averaging the six dewpoint temperature and converting to vapor pressure with the use of steam tables, psia

and,

$$T_{ave.} = \frac{\text{sum of 24 RTD's}}{24} + 459.69^{o}R$$

The total time method is entirely dependent on the first data point and, if it were a bad point (caused by instrumentation fluctuation) the entire run would be adversely affected. Therefore, the results presented in this report as the official leakage values are based on the point-to-point method of data analysis.

6.2 Least Squares Fit

The least squares fit parameter is represented mathematically by

$$L = \Sigma(L_i - L_L)^2$$

where

L_i = observed values of leakage rate

L_L = calculated values of leakage rate

Based on past experience with leakage rate testing, the time independent form of L_L will be used in the least squares fit analysis.

With

$$L_L = K \text{ (constant)}$$

Then $L = \Sigma\ (L_i - K)^2$

Minimizing L with respect to K, i.e.,

$$\frac{\partial L}{\partial K} = 0$$

the following results:

$$\frac{\partial L}{\partial K} = 0 = 2\Sigma(L_i - K)\ (-1)$$

$$0 = \Sigma(L_i - K)$$

$$\Sigma K = \Sigma L_i$$

$$KN = \Sigma L_i$$

$$K = \frac{\Sigma L_i}{N}$$

since i ranges from 1 to N-1, then

$$L_{mean} = \frac{\Sigma L_i}{N-1}$$

which yields the mean leakage rates reported in Sections 7.1 and 7.2.

6.3 Random Error

Random error is somewhat of an intangible and, unlike systematic error, evaluated in Section 4.4.1, cannot be evaluated beforehand. After the test data was collected, each set of data was processed using the CLERICAL[5] computer code, providing the following statistical parameters:

a. Standard deviation of the mean (σ)

b. Limits of 95 percent confidence level of the mean (C_{LM})

The significance of the random error can then be evaluated by comparing the limits of the 95 percent confidence levels with the systematic error. The limits of the 95 percent confidence levels define a band about the leakage rate value in which there exists 95 percent confidence that a repeated test value would occur.

6.3.1 Standard Deviation

Standard deviation (σ) is classically defined as

$$\sigma = \left[\frac{N\Sigma L_i^{\ 2} - (\Sigma L_i)^2}{N(N-1)} \right]^{\frac{1}{2}}$$

and is an expression of the difference in the measurement (of a constant) of observed data points relative to the mean of the data points.

This statistical parameter can be directly applied to the total time and point-to-point methods of analysis since 24 leakage rates are available to determine one constant leakage rate.

6.3.2 Confidence Limit

As stated in a draft of Appendix J to 10 CFR 50, issued in August, 1971, a confidence limit of 95 percent was published as a representative guide to the acceptability of experimental data.

The definition of the 95 percent confidence limit (C_{LM}) for the mean value of the leakage rates determined by the total time and point-to-point methods may be expressed as follows:

$$C_{LM} = \frac{t_{95}\sigma}{(N-1)^{\frac{1}{2}}}$$

where,

t_{95} = the Student's t distribution with N-1 degrees of freedom

7.0 DISCUSSION OF RESULTS

7.1 Results at P_t

Data obtained during the leak rate test at P_t indicated the following changes during the 24 hour test period:

Variable	Maximum Change
P_T	0.013 psia
P_{wv}	0.008 psia
T	0.220°F

The methods used in calculating the leakage rate are as defined in Section 6.0. The results of the calculations are as follows:

Method	Leakage Rate (%/Day)	Corrected Leakage Rate (%/Day)
Point-to-Point	0.004	0.005

In accordance with Indian Point Nuclear Station Unit 3 FSAR, Section 15.4.4, Revision 10, leakage rates have been corrected from test conditions to design basis accident conditions. Therefore, these values are more conservative than normally required.

Based upon the point-to-point method of calculation, the leakage rate (L_{tm}) was 0.005%/day. (see Appendix D)

The confidence limit associated with this leakage rate derived from a least squares fit of the data is 0.041 percent per day. Correcting for systematic error (e_{L_t} = 0.011%/day), this value reduces to 0.030 percent per day. The random error introduced is three times less than the maximum allowable leakage rate value of 0.10 percent per day and therefore it may be concluded that random error was not of any major significance.

7.2 Results at P_a

Data obtained during the leak rate test of P_a indicated the following changes during the 24 hour test period:

Variable	Maximum Change
P_T	0.025 psia
P_{wv}	0.009 psia
T	0.290°F

The methods used in calculating the leakage rate are defined in Section 6.0. Results of these calculations are as follows:

Method	Leakage Rate (%/Day)	Corrected Leakage Rate (%/Day)
Point-to-Point	0.023	0.027

In accordance with Indian Point Nuclear Station Unit 3 FSAR, Section 15.44, Revision 10, leakage rates have been corrected from test conditions to design basis accident conditions. Therefore, these values are more conservative than normally required.

Based upon the point-to-point method of calculation, the leakage rate (L_{am}) was 0.027 %/day. (see Appendix D)

The confidence limit associated with this leakage rate derived from a least squares fit of the data is 0.046 percent per day. Correcting for systematic error (e_{L_a} = 0.010%/day), this value reduces to 0.036 percent per day. The random error introduced is approximately two and one-half to three times less than the maximum allowable leakage rate value of 0.10 percent per day and therefore it may be concluded that random error was not of any major significance.

7.3 Supplemental Test Results

The results of the supplemental test at pressure P_t are as follows:

$$L'_{tm} = L_c - L_o$$
$$L'_{tm} = 0.036 - 0.034$$
$$L'_{tm} = 0.002\%/\text{day}$$

This value compares favorably with the measured leakage rate L_{tm} of 0.005 percent per day. This agreement is 15.8 percent of L_t, well below the 25 percent of L_t which is allowable.

The results of the supplemental test at pressure P_a are as follows:

$$L'_{am} = L_c - L_o$$
$$L'_{am} = 0.063 - 0.052$$
$$L'_{am} = 0.011\%/\text{day}$$

This value compares favorably with the measured leakage rate of 0.027 percent per day. This agreement is 16 percent of L_a, well below the 25 percent of L_a which is allowable.

This verification, through supplemental tests, clearly established the acceptability of the test instrumentation.

The two measured leakage rates values (L_c), mentioned above, are L_{mean} as determined by the point-to-point method.

8.0 REFERENCES

1. INT-TP-4.11.9, "Vapor Containment Structural Integrity Test and Leakage Rate Test", Wedco Corporation Test Procedure. (1-8-75)

2. Code of Federal Regulations, Title 10, Part 50, Appendix J. (1-1-74)

3. ANSI N45.4-1972, Leakage Rate Testing of Containment Structures for Nuclear Reactors, American Nuclear Society, (March 16, 1972).

4. Steam Tables, American Society of Mechanical Engineers, (1967).

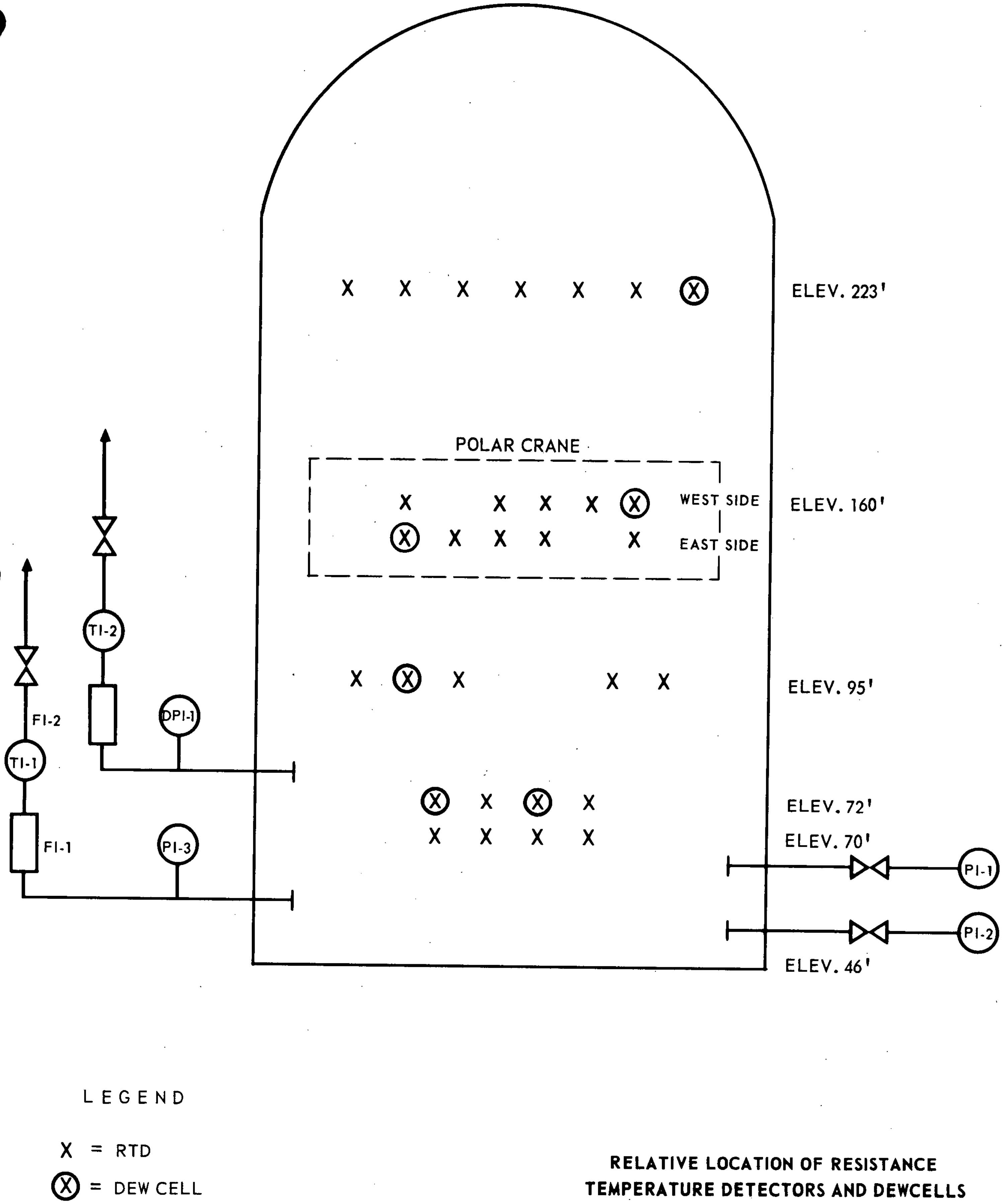
5. CLERCAL, Computer Code, Gilbert Associates, Inc.

A P P E N D I C E S

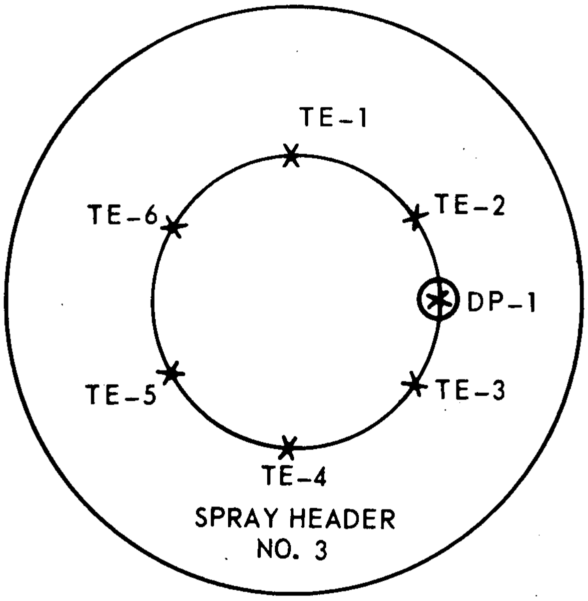
A P P E N D I X A

INSTRUMENTATION SCHEMATIC

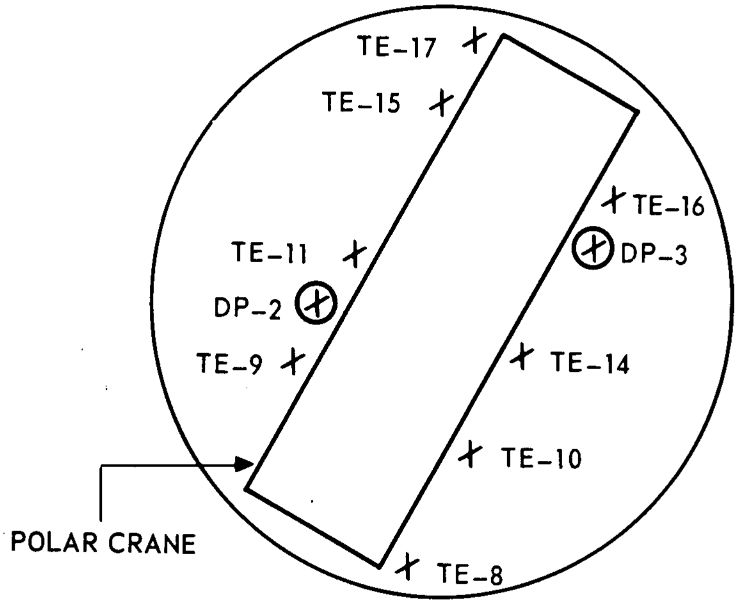
APPENDIX A



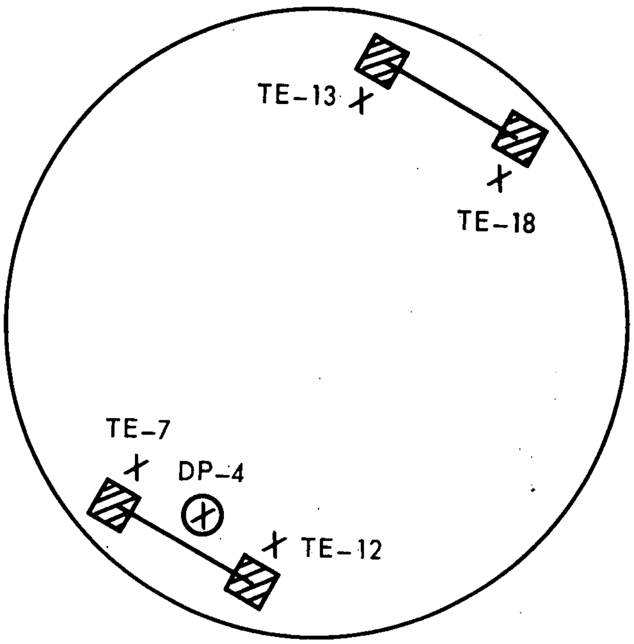
RELATIVE LOCATION OF RESISTANCE TEMPERATURE DETECTORS AND DEWCELLS



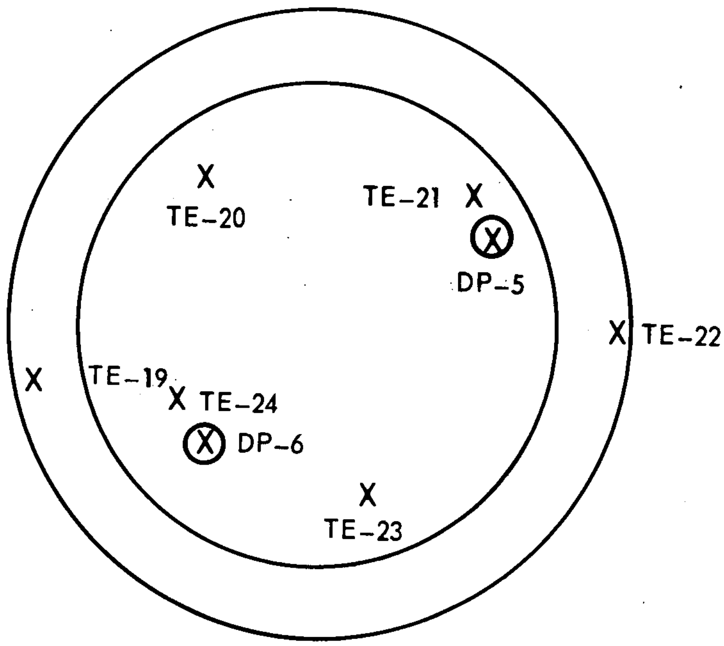
ELEVATION 223'-6"



ELEVATION 160'-0"



ELEVATION 95'-0"



ELEVATION 70'-0" (TE-20, 21, 23, 24)
ELEVATION 72'-0" (TE-19, 22, DP-5, 6)

LEGEND

X = RTD

(X) = DEWCELL

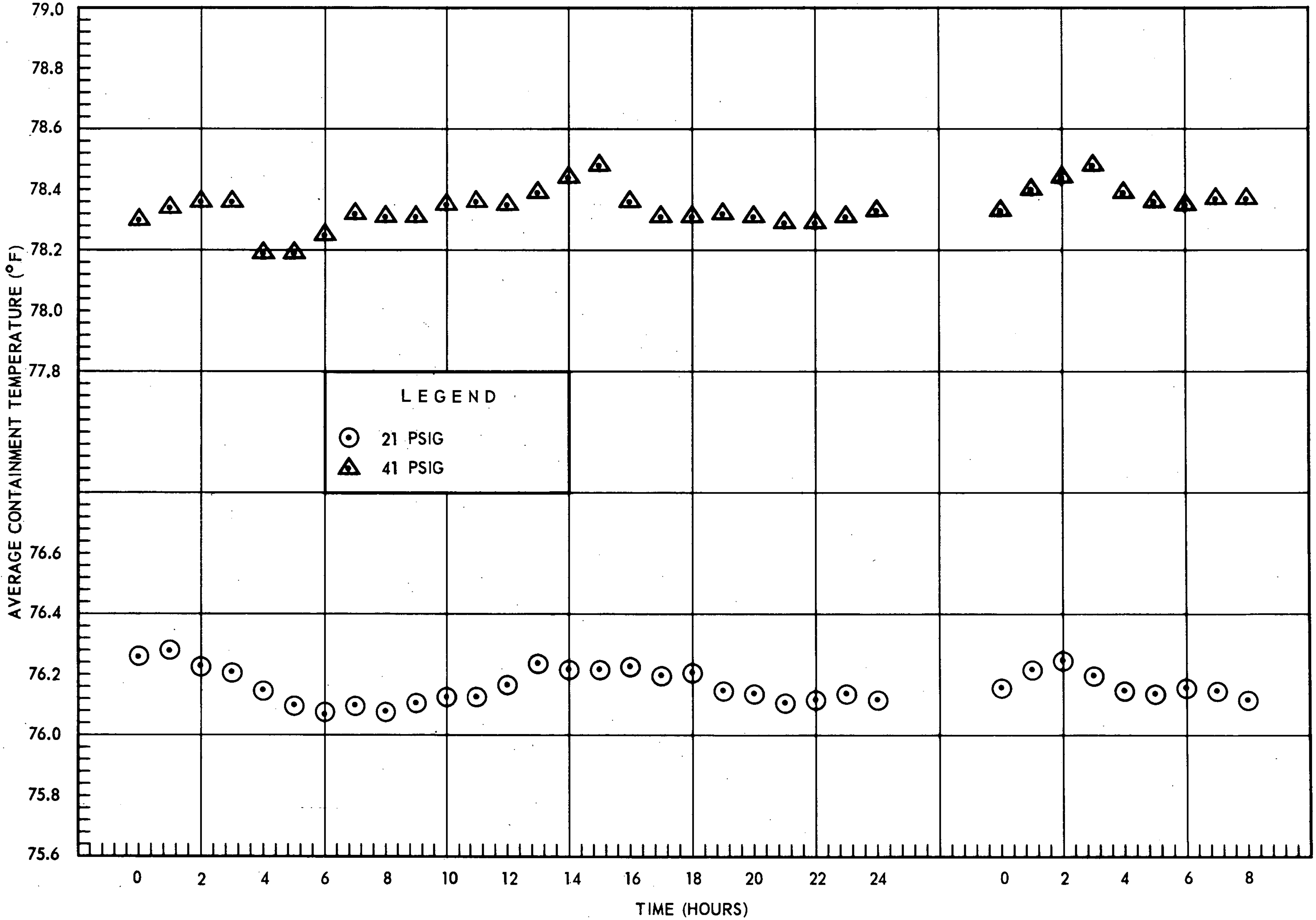
RELATIVE LOCATION OF RESISTANCE TEMPERATURE DETECTORS AND DEWCELLS

A P P E N D I X B

AVERAGE CONTAINMENT TEMPERATURE VERSUS
TIME AT 21 AND 41 PSIG

APPEND

AVERAGE CONTAINMENT TEMPERATURE VERSUS TIME



A P P E N D I X C

REDUCED LEAKAGE RATE DATA AT 21 AND 41 PSIG

APPENDIX C

REDUCED TEST DATA

LEAKAGE RATE AT 21 PSIG

	Time	Average Containment Pressure (psia)	Partial Pressure of Containment Water Vapor (psia)	Partial Pressure of Containment Air (psia)	Average Containment Temperature (°R)	Superimposed Flow Rate (lbm/hr)
1/16/75	1300	35.775	.171	35.604	535.95	-
	1400	35.777	.173	35.604	535.98	-
	1500	35.775	.174	35.601	535.92	-
	1600	35.773	.175	35.597	535.90	-
	1700	35.770	.176	35.594	535.83	-
	1800	35.766	.175	35.591	535.78	-
	1900	35.765	.176	35.589	535.76	-
	2000	35.765	.175	35.590	535.79	-
	2100	35.767	.176	35.591	535.78	-
	2200	35.768	.176	35.592	535.81	-
	2300	35.770	.176	35.594	535.83	-
	2400	35.772	.176	35.596	535.83	-
1/17/75	0100	35.773	.176	35.597	535.87	-
	0200	35.777	.176	35.601	535.93	-
	0300	35.777	.177	35.601	535.91	-
	0400	35.777	.177	35.600	535.91	-
	0500	35.777	.177	35.600	535.92	-
	0600	35.776	.177	35.599	535.89	-
	0700	35.776	.176	35.600	535.90	-
	0800	35.773	.177	35.596	535.84	-

APPENDIX C

REDUCED TEST DATA

LEAKAGE RATE AT 21 PSIG

Time	Average Containment Pressure (psia)	Partial Pressure of Containment Water Vapor (psia)	Partial Pressure of Containment Air (psia)	Average Containment Temperature (^oR)	Superimposed Flow Rate (lbm/hr)
0900	35.772	.177	35.595	535.83	-
1000	35.772	.177	35.595	535.80	-
1100	35.773	.179	35.594	535.81	-
1200	35.773	.177	35.596	535.83	-
1300	35.772	.179	35.593	535.81	-
1400	35.776	.180	35.596	535.86	-
1500	35.779	.180	35.599	535.91	5.75
1600	35.781	.179	35.602	535.94	5.79
1700	35.778	.180	35.598	535.89	5.79
1800	35.773	.178	35.595	535.84	5.76
1900	35.772	.179	35.593	535.83	5.76
2000	35.774	.181	35.593	535.85	5.76
2100	35.772	.181	35.591	535.84	5.76
2200	35.770	.181	35.589	535.81	5.75

APPENDIX C

REDUCED TEST DATA

LEAKAGE RATE AT 41 PSIG

	Time	Average Containment Pressure (psia)	Partial Pressure of Containment Water Vapor (psia)	Partial Pressure of Containment Air (psia)	Average Containment Temperature (^{o}R)	Superimposed Flow Rate (lbm/hr)
1/18/75	1400	55.785	.208	55.577	538.00	-
	1500	55.788	.206	55.582	538.03	-
	1600	55.790	.204	55.586	538.05	-
	1700	55.788	.205	55.583	538.05	-
	1800	55.773	.206	55.567	537.88	-
	1900	55.769	.205	55.564	537.88	-
	2000	55.773	.206	55.567	537.94	-
	2100	55.779	.207	55.572	538.02	-
	2200	55.778	.206	55.572	538.00	-
	2300	55.778	.205	55.573	538.00	-
	2400	55.778	.205	55.573	538.03	-
1/19/75	0100	55.778	.203	55.575	538.04	-
	0200	55.779	.206	55.573	538.03	-
	0300	55.780	.204	55.576	538.07	-
	0400	55.786	.203	55.583	538.13	-
	0500	55.788	.201	55.587	538.17	-
	0600	55.778	.203	55.575	538.06	-
	0700	55.769	.203	55.566	538.00	-
	0800	55.770	.200	55.570	538.00	-
	0900	55.769	.200	55.569	538.01	-

APPENDIX C

REDUCED TEST DATA

LEAKAGE RATE AT 41 PSIG

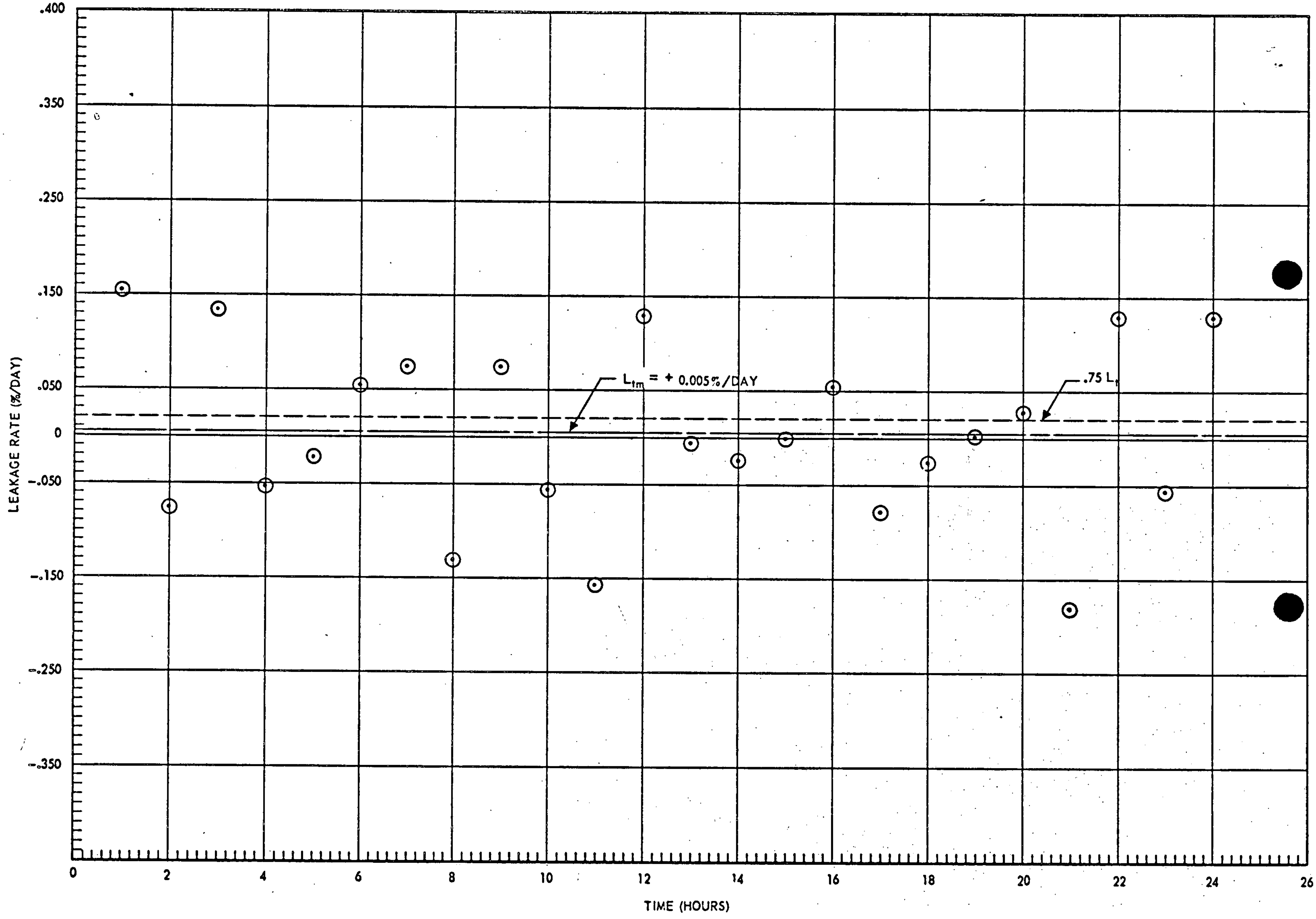
Time	Average Containment Pressure (psia)	Partial Pressure of Containment Water Vapor (psia)	Partial Pressure of Containment Air (psia)	Average Containment Temperature (^oR)	Superimposed Flow Rate (lbm/hr)
1000	55.768	.201	55.567	538.00	-
1100	55.766	.199	55.567	537.98	-
1200	55.765	.199	55.566	537.98	-
1300	55.767	.202	55.565	537.99	-
1400	55.767	.201	55.566	538.02	-
1500	55.769	.203	55.566	538.09	13.59
1600	55.777	.200	55.577	538.13	13.55
1700	55.779	.202	55.577	538.17	13.58
1800	55.771	.199	55.572	538.08	13.55
1900	55.765	.199	55.566	538.06	13.55
2000	55.763	.198	55.565	538.04	13.53
2100	55.762	.203	55.559	538.06	13.54
2200	55.760	.200	55.560	538.06	13.54

A P P E N D I X   D

POINT-TO-POINT LEAKAGE RATE
VERSUS TIME AT 21 AND 41 PSIG

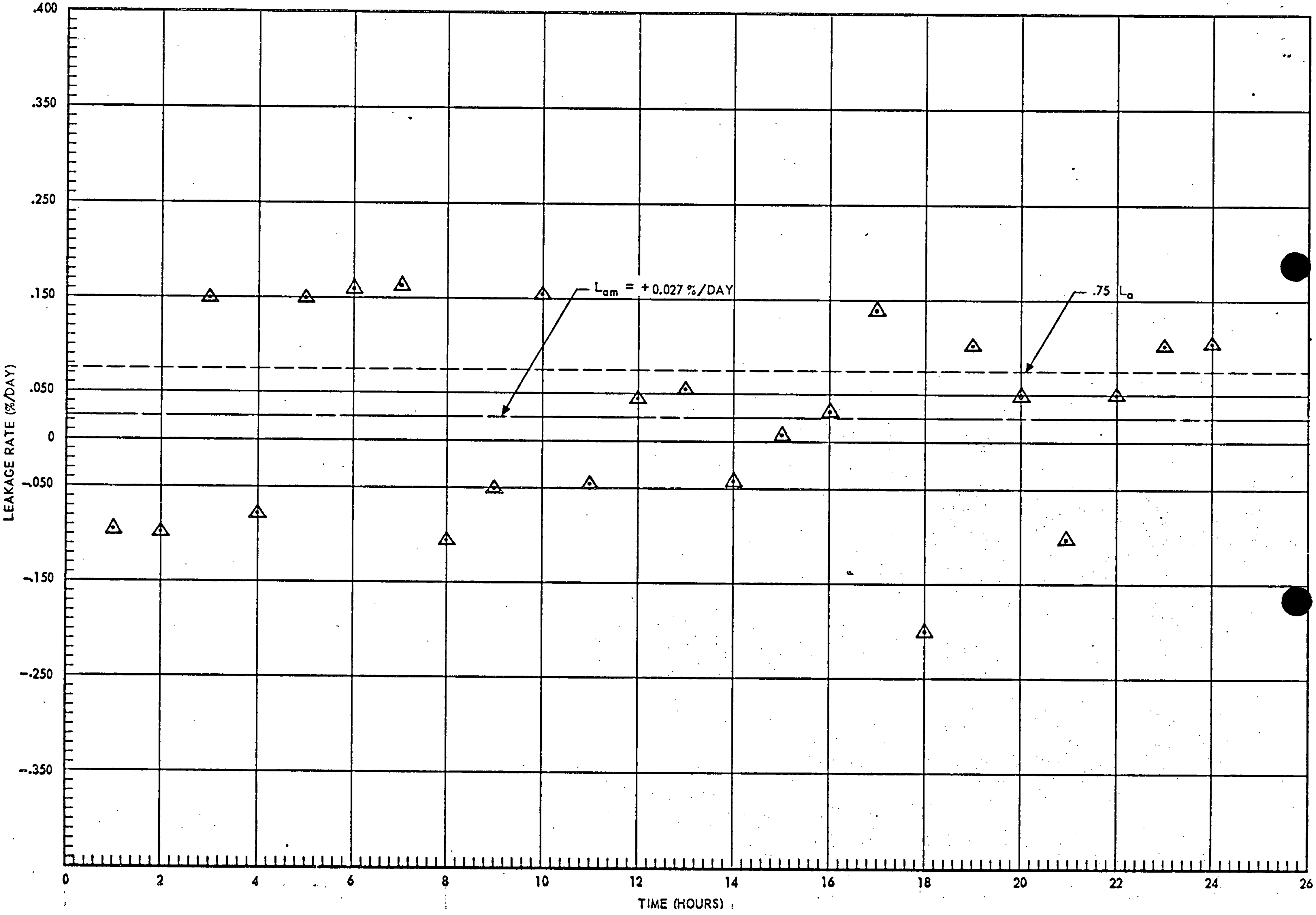
APPENDIX D

21 PSIG POINT-TO-POINT LEAKAGE RATE VERSUS TIME



APPENDIX D

41 PSIG POINT-TO-POINT LEAKAGE RATE VERSUS TIME



APPENDIX E

DEFINITION OF TERMS

APPENDIX E

DEFINITION OF TERMS

1. $\underline{P_a}$ (psig) means the calculated peak containment internal pressure related to the design basis accident and specified in either the technical specifications or associated bases.

2. $\underline{P_t}$ (psig) means the containment vessel reduced test pressure selected to measure the integrated leakage rate during periodic Type A tests.

3. $\underline{L_a}$ (percent/24 hours) means the maximum allowable leakage rate at pressure P_a, as specified for preoperational tests in the technical specifications or associated bases, and as specified for periodic tests in the operating license.

4. $\underline{L_t}$ (percent/24 hours) means the maximum allowable leakage rate at pressure P_t, derived from the preoperational test data as specified by 10 CFR 50, Appendix J.

5. $\underline{L_{am}}$ (percent/24 hours) means the total measured containment Leakage rate at pressure P_a, obtained from testing the containment with components and systems in the state as close as practical to that which would exist under design basis accident conditions.

6. $\underline{L_{tm}}$ (percent/24 hours) means the total measured containment leakage rate at pressure P_t, obtained from testing the containment with components and systems in the state as close as practical to that which would exist under design basis accident conditions.

7. $\underline{L_c}$ (percent/24 hours) means the composite leakage through the calibrated orifice plus containment leakage.

8. $\underline{L_o}$ (percent/24 hours) means the average leakage rate through the calibrated orifice.

9. $\underline{L_{am}'}$ (percent/24 hours) means the containment leakage rate during the superimposed leak rate test at pressure P_a.

10. $\underline{L_{tm}'}$ (percent/24 hours) means the containment leakage rate during the superimposed leak rate test at pressure P_t.