REACTOR CONTAINMENT BUILDING

INTEGRATED LEAK RATE TEST

QUAD-CITIES NUCLEAR POWER STATION

UNIT ONE

NOVEMBER 14-15, 1989

0483H/0214Z

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INTRODUCTION

This report presents the test method and results of the Integrated Primary Containment Leak Rate Test (IPCLRT) successfully performed on November 14-15, 1989 at Quad-Cities Nuclear Power Station, Unit One. The test was performed in accordance with 10 CFR 50, Appendix J, and the Quad-Cities Unit One Technical Specifications.

For the fifth time at Quad-Cities a short duration test (less than 24 hours) was conducted using the general test method outlined in BN-TOP-1, Revision 1 (Bechtel Corporation Topical Report) dated November 1, 1972. The first short duration test was conducted on Unit One in December, 1982.

Using the above test method, the total primary containment integrated leak rate was calculated to be 0.3786 wt %/day at a test pressure greater than 48 PSIG. The calculated leak rate was within the 0.750 wt %/day acceptance criteria (75% of L_A). The associated upper 95% confidence limit was 0.4480 wt %/day.

The supplemental induced leakage test result was calculated to be 1.3502 wt %/day. This value should compare with the sum of the measured leak rate phase result (0.3786 wt %/day) and the inducted leak of 8.26 SCFM (1.0123 wt %/day). The calculated leak rate of 1.3502 wt %/day lies within the allowable tolerance band of 1.3909 wt %/day ± 0.250 wt %/day.

SECTION A - TEST PREPARATIONS

A.1 Type A Test Procedure

The IPCLRT was performed in accordance with Quad-Cities Procedure QTS 150-1 Rev. 16, including checklists QTS 150-S2 through S8, S10 through S13, S17 through S23, and subsections T2, T6, T8, T10, T11, T12, T13, T14, T15, and T16. Approved Temporary Procedures 5962, 5963, and 5964 were written in conjunction withg the test. Procedure 5962 was written to revise the pretest operations checklist for the IPCLRT. Procedure 5963 was written to revise the Instrument Maintenance Department pretest checklist to correct the equipment piece number of the Reactor Water level Transmitter. Procedure 5964 was written to revise the pre-test valve line-up of valve checklist QTS 150-S5.

These procedures were written to comply with 10 CFR 50 Appendix J, ANS/ANSI N45.4-1972, and Quad-Cities Unit One Technical Specifications, and to reflect the Commission's approval of a short duration test using the BN-TOP-1, Rev. 1 Topical Report as a general test method.

A.2 Type A Test Instrumentation

Table One shows the specifications for the instrumentation utilized in the IPCLRT. Table Two lists the physical locations of the temperature and humidity sensors within the primary containment. Figure 1 is an idealized view of the drywell and suppression chamber used to calculate the primary containment free air subvolumes. Plant personnel performed instrumentation calibrations using NBS traceable standards. Quad Cities procedure QTS 150-9 was used to perform the calibration.

TABLE ONE
INSTRUMENT SPECIFICATIONS

INSTRUMENT	MANUFACTURER	MODEL NO.	SERIAL NO.	RANGE	ACCURACY	REPEATABILITY
Precision Pressure Gages (2)	Volumetrics	PPM-1000	10141-1 10141-2	0.4 - 150 PSIA	±0.015% Rdg ±0.005% F.S.	±0.001% F.S.
Thermistors (30)	Volumetrics	418905000	10602-1 to 10602-35 inclusive	50° - 135°F	0.25°F	0.01°F
Dewcells (10)	Volumetrics	Lithium Chloride	2809-1 to 2809-10 inclusive	40-100°F	1.5°F	0.003°F
Thermocouple	Pall Trinity Micro	14-T-2H		0-600°F	±2.0°F	±.1°F
Flowmeter	Fischer & Porter	10A3555S	8405A0348A1	1.15-11.10 scfm	±.111 scfm	
Level Indicator LT 1-646B	GEMAC	555111BCAA 3AAA		0-60" H_2O		

TABLE TWO
SENSOR PHYSICAL LOCATIONS

RTD NUMBER	SERIAL NUMBER	SUBVOLUME	ELEVATION	AZIMUTH*
1	44233	1	670'0"	180°
2	44210	1	670'0"	0°
3	44211	2	657'0"	20°
4	44212	2	657'0"	197°
5	44123	3	639'0"	70°
6	44214	3	639'0"	255°
7	44215	4(Annular Ring)	643'0"	55°
8	44216	4	615'0"	225°
9	44217	5	620'0"	5°
10	44218	5	620'0"	100°
11	44219	5	620'0"	220°
12	44220	6	608'0"	40°
13	44221	6	608'0"	130°
14	44222	6	608'0"	220°
15	44223	6	608'0"	310°
16	44224	7	598'0"	70°
17	44225	7	598'0"	160°
18	44226	7	598'0"	250°
19	44227	7	598'0"	340°
20	44228	8	587'0"	10°
21	44230	8	587'0"	100°
22	44232	8	587'0"	190°
23	44233	8	587'0"	280°
24	44234	9(CRD Space)	595'0"	170°
25	44235	9(CRD Space))	580'0"	170°
26	44236	10(Torus)	578'0"	70°
27	44237	10(Torus)	578'0"	140°
28	44238	10(Torus)	578'0"	210°
29	44229	10(Torus)	578'0"	280°
30	44231	10(Torus)	578'0"	350°
Thermocouple	(inlet to clean-up HX)	11(Rx Vessel)		

DEWCELL NO.	SERIAL NUMBER	SUBVOLUME	ELEVATION	AZIMUTH
1	5835-1	1	670'0"	180°
2	5835-2	2,3,4	653'0"	90°
3	5835-3	2,3,4	653'0"	270°
4	6084-4	5	620'0"	0°
5	6084-9	6	605'0"	45°
6	5835-6	7	600'0"	220°
7	6084-7	8,9	591'0"	0°
8	6084-8	8,9	591'0"	202°
9	5835-9	10	578'0"	90°
10	5835-10	10	578'0"	270°
Thermocouple (Saturated)		11	---	---

Idealized View of Drywell and Torus
Used to Calculate Free Volumes

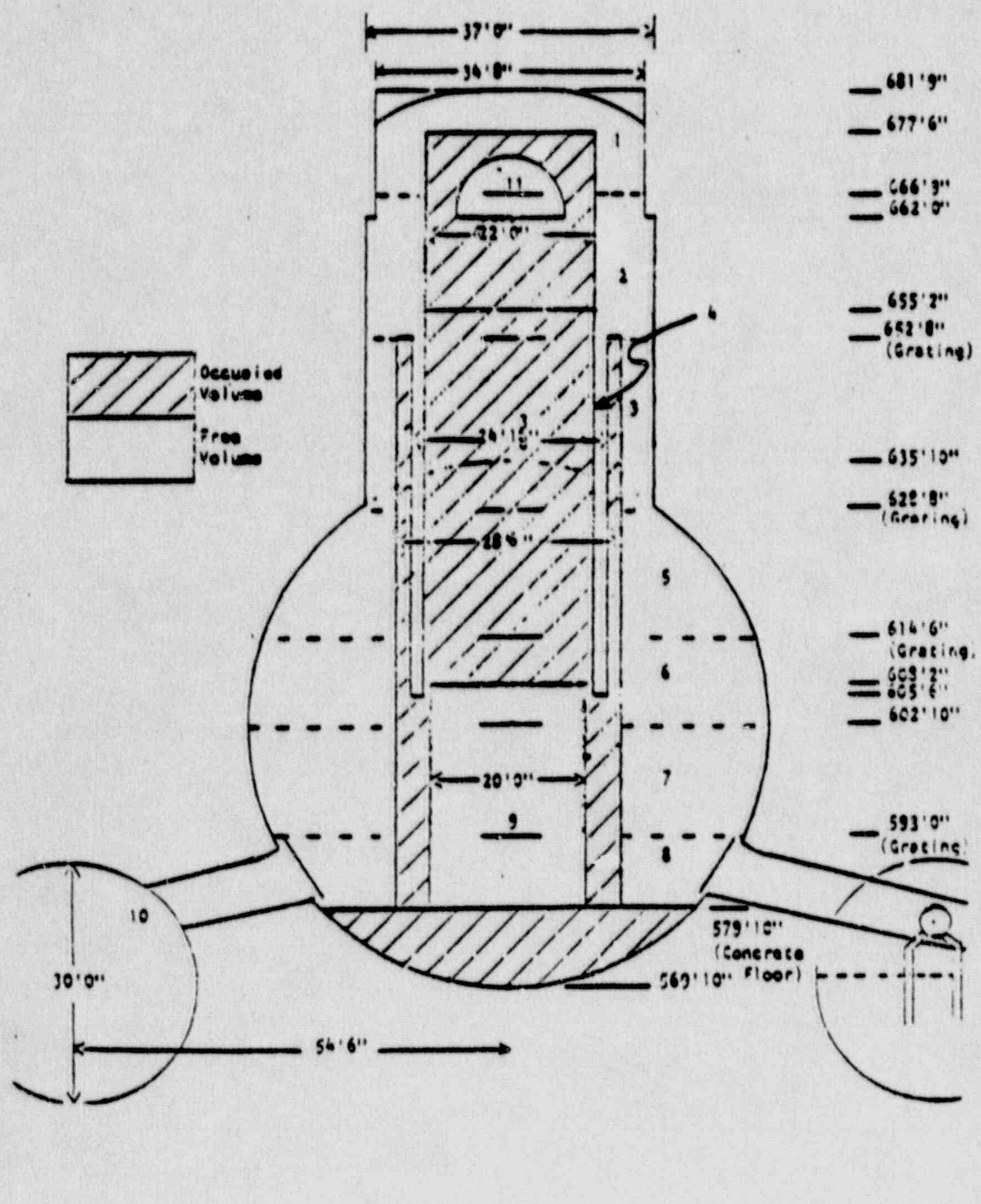


FIGURE 1

A.2.a. Temperature

The location of the 30 thermistor's was chosen to avoid conflict with local temperature variations and thermal influence from metal structures. A temperature survey of the containment was previously performed to verify that the sensor locations were representative of average subvolume conditions.

The Thermistors ae hermitcally sealed, glass encapsulated units manufactured by YSI Inc. These sensors have a recommended operating range between -110 and 390 degrees F. A stability of better than 0.018 degrees F per ten months can be expected when the units are stored at or below 212 degrees F. Interchangeable Thermistors, model 46043 were chosen. YSI certifies each sensor to follow the same Resistance verses Temperature curve within 0.1 degrees F over the range of 50 to 135 degrees F.

Each sensor is connected to a signal conditioning card. The Thermistor resistance is converted by this card to a known voltage. The voltage output from the cards is a function of the resistance in. As seen in Table 1, the Thermistor's change in resistance with temperature is very nonlinear.

Therefore, the variation of output voltage with temperature is nonlinear. In order to allow direct reading of temperature values from the DAS, two sixth order polynominal curve fits are programmed into the DAS's EPROMs. As recommended in ANS 56.8, the DAS output and display has a resolution of 0.01 degrees F.

A.2.b. Pressure

Two volumetrics PPM-1000 Precision Pressure Monitors were utilized to measure total containment pressure. Each precision pressure gauge was calibrated from 62.8-65.8 PSIA in approximately 0.5 PSI increments. Primary containment pressure was sensed by the pressure gauges in parallel through a 3/8" tygon tube connected to a special one inch pipe penetration to the containment.

Each instrument contains a pressure-sensing element that delivers an electrical frequency (in relation to the applied pressure) to a microprocessor circuit. The microprocessor corrects the signal for nonlinearity, offset, scaling, and temperature effects and displays the corrected pressure value on a 5-1/2 digit LED readout.

The sensor is the vibrating cylinder type. The cylinder is a vibrating mechanical system. A vacuum reference in maintained on the outside of the cylinder. The pressure differential across the wall creates stress on the wall varying the natural resonant frequency of vibration. The resonant frequency depends upon the physical properties of the element such as mass, stress, elasticity, dimensions and temperature. The cylinder is made from a special nickel iron alloy, and closely controlled manaufacturing techniques eliminate mass, dimension, and elasticity effects. Temperature is measured using a calibrated diode and corrected by the microprocessor.

The sensor's electronic ciruict conditions the frequency wave and sends it to the pulse rate converter board which counts the period. The period is sent in a 16-bit word to the microprocessor controlled panel meter (MPM).

The sensor's temperature sensing diode voltage is converted to a 15-bit digital signal using the analog-to-digital converter in the MPM. The pressure is calculated by the MPM and displayed in appropriate units on the 5-1/2 digit seven-segment LED display.

Each PPM-1000 was calibrated from 62.8 - 65.0 PSIA in approximately 0.5 PSI increments by volumetrics on October 12, 1989.

A.2.c. Vapor Pressure

Ten lithium chloride dewcells were used to determine the partial pressure due to water vapor in the containment. The dewcells were calibrated by volumetrics on October 11, 1989.

A.2.d. Flow

A rotameter flowmeter, Fischer-Porter serial number 8405A0348A1, was used for the flow measurement during the induced leakage phase of the IPCLRT. The flowmeter was calibrated by Fischer-Porter on October 16, 1989, to within ±1% of full scale (0.9 - 11.4 SCFM) using NBS traceable standards, to standard atmospheric conditions.

Plant personnel continuously monitored the flow during the induced leakage phase and corrected any minor deviations from the induced flow rate of 8.26 SCFM by adjusting a 3/8" needle valve on the flowmeter inlet. The flow meter outlet was unrestricted and vented to the atmosphere.

A.3 Type A Test Measurement

The IPCLRT was performed utilizing a direct interface with the station prime computer. This system consists of a Data Acquisition System (DAS) and a multiplexer in containment.

Upon initiation of data acquisition cycle, the DAS reads the selected OPERATE mode of single, continuous, or interval, and either block or sequential scan. Once the system has determined which channels to scan (user-defined), it addresses the analog scanner to select the first channel for sampling. This address information (three BCD digits from the Printer/Scanner Interface Card) is transmitted at RS-232C voltage levels.

The scanner selects the channel and routes the analog signal to the Analog to Digital Converter (ADC) housed in the DAS. After a relay stabilizing time of approximately ten milliseconds, the Central Processing Card (CPU) initiates the ADC. Although the ADC is capable of 20 conversions per second, the actual scan rate is 10 per second because the CPU has numerous other functions to perform.

Upon conversion request, the ADC resets and selects a 0.1V or 1.0V full scale conversion factor as designated by the CPU. The CPU is then interrupted by the ADC to read the converted data and the ADC status word. The status work indicates the polarity of the input voltage and if it was an overrange. The data is stored in a buffer in RAM. The CPU addresses the scanner for data from the next channel, and the acquisition process continues until all the data from the channels programmed to be scanned is stored in the buffer.

Numerical calculation of the raw data may now begin. The CPU selects the most recent data entry from the buffer and divides it by 65536, the full scale count value of the ADC, to obtain the voltage value. The CPU checks the channel's format byte to determine the channel's assigned engineering unit (0-15). That unit's associated slope and intercept values (m and b) are user-accessible in CMOS RAM>. The slope (m) is multiplied by the voltage value (x), then added to the intercept (b) to obtain the final data value (y).

The final data value is printed out on all enabled outputs. The printout includes the channel number, the final data, the assigned engineering unit, and the channel header. Digital input data, headers, date, and time are also printed out.

The PRIME computer was used to compute and print the leak rate data using either the ANSI/ANS mass plot method (ANSI/ANS 56.8), a total time method based on ANSI/ANS n45.4, or the BN-TOP-1 method. Key parameters, such as total time measure leak rate, volume weighted dry air pressure and temperature, and absolute pressure were monitored using a Tektronix 4208 terminal and a Tektronix plotter. Plant personnel also plotted a large number of other parameters, including reactor water level and temperature, dry air mass, volume weighted partial pressures and temperature, total time leak rate, statistically averaged leak rate and UCL, and all sensor outputs in engineering units. In all cases, data was plotted hourly and computer summaries were obtained at 10 minute time intervals. The plotting of data and the computer printed summaries of data allowed rapid identification of any problems as they might develop. Figure 2 shows a schematic of the data acquisition system.

A.4 Type A Test Pressurization

1500 and 1200 SCFM diesel driven oil-free air compressors were used to pressurize the primary containment. The compressors were physically located outside the Reactor Building. The compressed air was piped using flexible metal hose to the Reactor Building, through an existing four inch fire header penetration, and piped to a temporary spool piece that, when installed, allowed the pressurization of the drywell through the "A" containment spray header. The inboard, containment spray isolation valve, MO-1-1001-26A was open during pressurization. Once the containment was pressurized, the MO-1-1001-26A valve was closed and the spool piece was removed and replaced with a blind flange.

Measurement System Schematic Arrangement

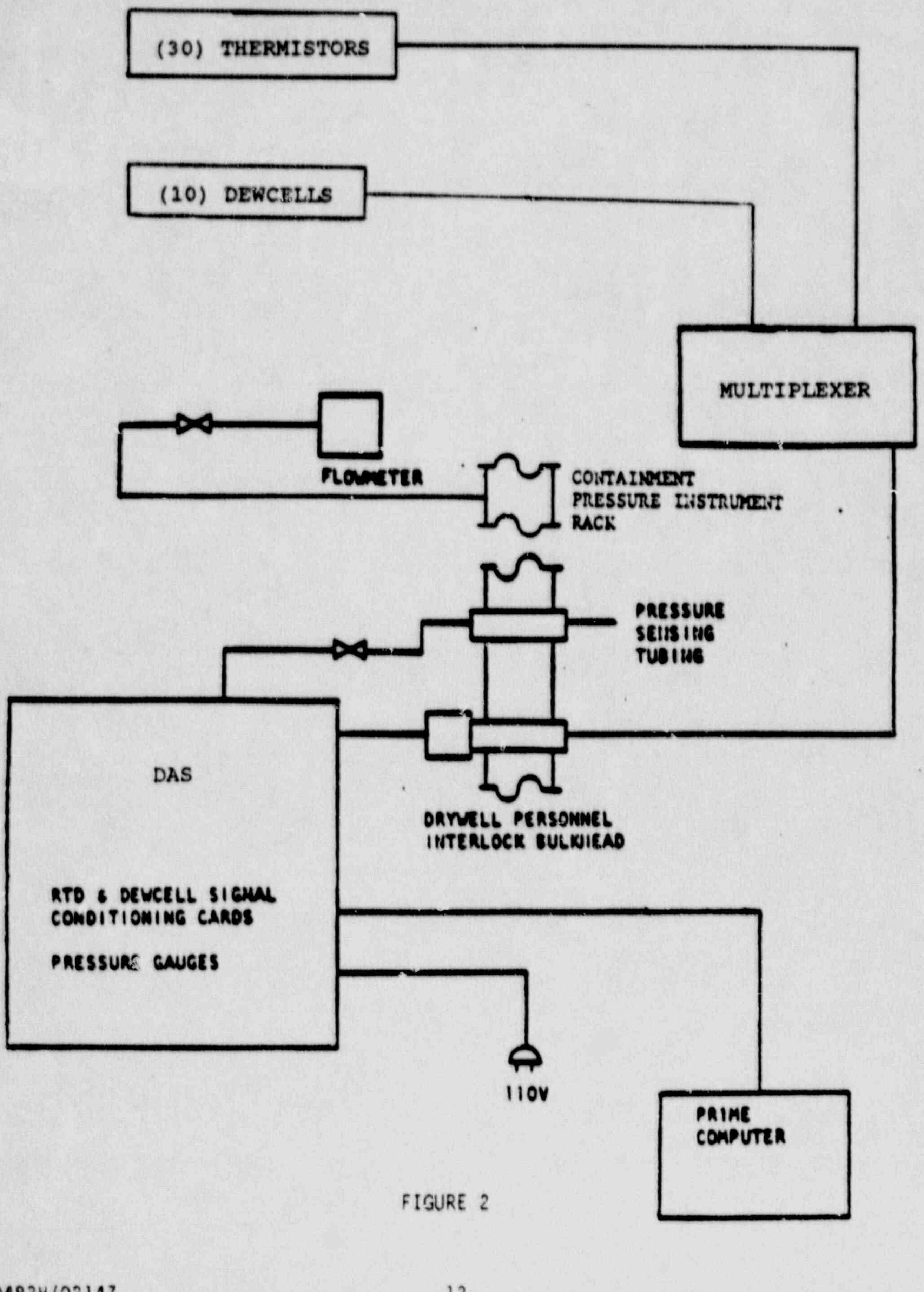


FIGURE 2

SECTION B - TEST METHOD

B.1 Basic Technique

The absolute method of leak rate determination was used. The absolute method uses the ideal gas laws to calculate the measured leak rate, as defined in ANSI N45.4-1972. The inputs to the measured leak rate calculation include subvolume weighted containment temperature, subvolume weighted vapor pressure, and total absolute air pressure.

As required by the Commission in order to perform a short duration test (measured leak rate phase of less then 24 hours), the measured leak rate was statistically analyzed using the principles outlined in BN-TOP-1, Rev. 1. A least squares regression line for the measured total time leak rate versus time since the start of the test is calculated after each new data set is scanned. The calculated leak rate at a point in time, t_i, is the leak rate on the regression line at the time t_i.

The use of a regression line in the BN-TOP-1, Rev. 1 report is different from the way it is used in the ANSI/ANS 56.8 standard. The latter standard uses the slope of the regression line for dry air mass as a function of time to derive a statistically averaged leak rate. In contrast, BN-TOP-1, Rev. 1 calculates a regression line for the measured leak late, which is a function of the change in dry air mass. For the ANSI/ANS calculations one would expect to always see a negative slope for the regression line, because the dry air mass is decreasing over time due to leakage from the containment. For the regression line computed in the BN-TOP-1, Rev.1 method the ideal slope is zero, since you presume that the leakage from the containment is constant over time. Since it is impossible to instantaneously and perfectly measure the containment leakage, the slope of the regression line will be positive or negative depending on the scatter in the measured leak rate values obtained early in the test. Since the measured leak rate is a total time calculation, the values computed early in the test will scatter much more than the values computed after a few hours of testing.

The computer printouts titled "Leak Rate Based on Total Time Calculations" attached to the BN-TOP-1, Rev. 1 topical report are misleading in that the column titled "Calculated Leak Rate" actually has printed out the regression line values (based on all the measured leak rate data computed from the data sets received up until the last time listed on the printout). The calculated leak rate as a function of time (t_i) can only be calculated from data available up until that point in time, t_i. This is significant in that the calculated leak rate may be decreasing over time, despite a substantial positive slope in the last computed regression line. Extrapolation of the regression line is not required by the BN-TOP-1, Rev. 1 criteria to terminate a short duration test. What is required is that the calculated leak rate be decreasing over time or that an increasing calculated leak rate be extrapolated to 24 hours. The distinction between the regression line values and the calculated leak rate as a function of time is made in Section 6.4 of BN-TOP-1, Rev. 1. Calculated leak rates, as a function of time, are correctly printed out in the "Trends Based on Total Time Calculations" computer printouts in Appendix B of BN-TOP-1, Rev. 1.

Associated with each calculated leak rate is a statistically derived upper confidence limit. Just as the calculated leak rate in BN-TOP-1, Rev. 1 and the statistically averaged leak rate in the ANSI/ANS standards are not the same (and do not necessarily yield nearly equal values), the upper confidence limit calculations are greatly different. In the BN-TOP-1, Rev. 1 topical report the upper confidence limit is defined as the calculated leak rate plus the product of the two sided 97.5% T-distribution value (as opposed to the one-sided 95% T-distribution used in the ANS/ANSI standard) and the standard deviation of the measured leak rate data about the computed regression line (which has no relationship to the value computed in the ANSI/ANS standards).

There are two important conclusions that can be derived from data analyzed using the BN-TOP-1, Rev. 1 method: 1) the upper confidence limit for the same measured leak rate data can be substantially greater than the value calculated using the ANSI/ANS method, and 2) the upper confidence limit does not converge to the calculated leak rate nearly as quickly as usually observed in the latter method as the number of data sets becomes large. With this in mind, the upper confidence limit can become the critical parameter for concluding a short duration test, even when the measured leak rate seems to be well under the maximum allowable leak rate. A graphical comparison of the two methods can be made by referring to Figure 3 for the BN-TOP-1, Rev. 1 calculated leak rate and upper confidence limit and to Figure F-1 in Appendix F for the statistically averaged leak rate and upper confidence limit based on ANSI/ANS 56.8-1981. This data supports the contention of many that BN-TOP-1, while it may not give the best estimate of containment leakage, is a conservative method of testing. The ANSI/ANS 56.8 data contained in Appendix F is provided for information only. The reported test results are based on BN-TOP-1, only.

B.2 Supplemental Verification Test

The supplemental verification test superimposes a known leak of approximately the same magnitude as L_A (8.16 SCFM or 1.0 wt %/day as defined in Technical Specifications). The degree of detectability of the combined leak rate (containment calculated leak rate plus the superimposed, induced leak rate) provides a basis for resolving any uncertainty associated with measured leak rate phase of the test. The allowed error band is $\pm$ 25% of L_A.

There are no references to the use of upper confidence limits to evaluate the acceptability of the induced leakage phase of the IPCLRT in the ANS/ANSI standards or in BN-TOP-1, Rev. 1.

B.3 Instrument Error Analysis

An instrument error analysis was performed prior to the test in accordance with BN-TOP-1, Rev. 1 Section 4.5. The instrument system error was calculated in two parts. The first was to determine the system accuracy uncertainty. The second and more important calculation (since the leak rate is impacted most by changes in the containment parameters) was performed to determine the system repeatability uncertainty. The results were 0.1447 wt %/day and 0.0191 wt %/day for a 6-hour test, respectively. These values are inversely proportional to the test duration.

The instrumentation uncertainty is used only to illustrate the system's ability to measure the required parameters to calculate the primary containment leak rate. The mathematical derivation of the above values can be found in Appendix D. The method of calculating the equipment uncertainty is in conformance with the method outlined in BN-TOP-1.

It is extremely important during a short duration test to quickly identify a failed sensor and in real time back the spurious data out of the calculated volume weighted containment temperature and vapor pressure. Failure to do so can cause the upper confidence limit value to place a short duration test in jeopardy. It has been the stations experience that sensor failures should be removed from all data collected, not just subsequent to the apparent failure, in order to minimize the discontinuity in computed values that are related to the sensor failure (not any real change in containment conditions). For this test, no instrument failures were encountered before or after the start of the test.

SECTION C - SEQUENCE OF EVENTS

C.1 Test Preparation Chronology

The pretest preparation phase and containment inspection was completed on November 14, 1989 with no apparent structural deterioration being observed. Major preliminary steps included:

1) Blocking open three pairs of drywell to suppression chamber vacuum breakers.

2) Installation of all IPCLRT test equipment in the suppression chamber.

3) Completion of all repairs and installations in the drywell affecting primary containment.

4) Venting of the reactor vessel to the drywell by opening the manual head vent line to the drywell equipment drain sump.

5) Installation of the IPCLRT data acquisition system including computer programs, instrument console, locating instruments in the drywell, and associated wiring.

6) Completion of the pre-test valve line-up.

This test was conducted at the end of the refuel outage to test the containment in an "As Left" condition with repairs and adjustments. The Station has an exemtpion to 10CFR50, Appendix J requirements to allow performing the test at the end of the refuel outage.

C.2 Test Pressurization and Stabilization Chronology

DATE	TIME	EVENT
11-14-89	1304	Began pressurizing containment.
	1530	Snooped all accessible penetrations in Reactor Building. No leaks observed.
	1530	Snooped top of torus. No major leaks observed.
	1700	Snopped personnel interlock and CR bank. No leakage.
	1800	Torus water level leakage is approximately 0.1 in/hr.
	1848	Containment pressurized to 65 PSIA.
	1903	Containment fully pressurized and the compressor is isolated. Beginning containment stabilization phase.
	2200	Operating tightened the 1402-34B valve torus leakage appears to have stopped.

C.3 Measured Leak Rate Phase Chronology

DATE	TIME	EVENT
11-15-89	0035	Containment temperature stable below 0.5°F/hr. for the last 4.0 hr. Rx water level stable below 1.25 in/hr for the last 1 hour. Rx water temperature stable below 2°F/hr fo r the last 1 hour.
	0035	Began measured phase base data set #56 of buffile
	0300	Rx level from process computer failed. Configuration file will no longer compensate for changes in Rx Vessel Level.
	0645	Terminated measured leak rate phase at 6 hour 10 min. point, base data set #93 of buffile. Calculated leak rate was 0.3786 wt%/day and decreasing over time. The average measured leak rate over the last five hours was 0.3836 wt%/day. The upper confidence limit was 0.4480 wt%/day all other BN-TOP-1.

C.4 Induced Leakage Phase Chronology

DATE	TIME	EVENT
11-15-89	0715	Valved in flowmeter at 8.26 SCFM (75.7% scale reading) began induced stabilization base data set #96 of buffile.
	0725	Radiation Protection is collecting a sample
	0825	Began induced phase of the test base data set #103 of buffile the 1-hour stabilization required by BN-TOP-1 was complete.
	1145	Terminated induced phase. Base data set #123 of buffile calculated leak rate of 1.3502 wt%/day.

C.5 Depressurization Phase Chronology

DATE	TIME	EVENT
11-15-89	1215	Began depressurization using procedure for venting through the standby gas treatment system.
	1630	Containment depressurized.

DATE	TIME	EVENT
11-15-89	1700	Technical Staff personnel entered drywell. No apparent structural damage and instruments are still in place. Checked sump levels in Drywell. Sumps were not pumped during the test. Over the duration of the test, Drywell Floor Drain Sump level increased from 17.0" to 20.0". The Drywell Equipment Drain Sump increased from 7.0" to 19.0".
	1700	Made initial entry to suppression chamber. No apparent damage and all instruments still in place.

SECTION D - TYPE A TEST DATA

D.1 Measured Leak Rate Phase Data

A summary of the computed data using the BN-TOP-1, Rev. 1 test method for a short duration test can be found in Table 3. Graphic results of the test are found in Figures 3-7. For comparison purposes only, the statistically averaged leak rate and upper confidence limit using the ANS/ANSI 56.8-1981 standard are graphed in Figure F-1. A summary of the computed data using the ANS/ANSI standard is found in Appendix F.

D.2 Induced Leakage Phase Data

A summary of the computed data for the Induced Leakage Phase of the IPCLRT is found in Table 4. The calculated leak rate and upper confidence limit using the BN-TOP-1, Rev. 1 method are shown in Figure 8. The measured leak rate and last computed regression line are shown in Figure 9. Containment conditions during the Induced Leakage Phase are presented graphically in Figures 10-12.

Measured Leak Rate Test Results
TABLE 3

DATA SET	TIME	TEST DURATION	AVE. TEMP.	DRY AIR PRESS.	MEAS. LEAK RATE	CALC. LEAK RATE	UPPER CONF. LIMIT
56	00:35:48	0.000	93.6	64.2778	---	---	---
57	00:45:48	0.167	93.6	64.2738	0.2299	---	---
58	00:55:48	0.333	93.6	64.2697	0.3740	---	---
59	01:05:48	0.500	93.6	64.2659	0.2585	0.3017	1.3293
60	01:15:48	0.667	93.5	64.2606	0.3876	0.3661	0.7677
61	01:25:48	0.833	93.5	64.2567	0.3953	0.3979	0.6510
62	01:35:48	1.000	93.5	64.2534	0.3681	0.3987	0.6034
63	01:45:48	1.167	93.5	64.2494	0.3520	0.3906	0.5731
64	01:55:48	1.333	93.5	64.2456	0.3488	0.3834	0.5488
65	02:05:48	1.500	93.4	64.2412	0.3816	0.3906	0.5374
66	02:15:48	1.667	93.4	64.2379	0.3764	0.3933	0.5272
67	02:25:48	1.833	93.4	64.2340	0.3723	0.3936	0.5183
68	02:35:48	2.000	93.4	64.2308	0.3707	0.3931	0.5106
69	02:45:48	2.167	93.4	64.2268	0.3811	0.3953	0.5058
70	02:55:48	2.333	93.4	64.2232	0.3677	0.3933	0.4995
71	03:05:48	2.500	93.3	64.2199	0.3679	0.3917	0.4939
72	03:15:48	2.667	93.3	64.2169	0.3778	0.3925	0.4903
73	03:25:48	2.833	93.3	64.2136	0.3701	0.3914	0.4860
74	03:35:48	3.000	93.3	64.2103	0.3644	0.3893	0.4813
75	03:45:48	3.167	93.3	64.2071	0.3730	0.3891	0.4782
76	03:55:48	3.333	93.3	64.2043	0.3658	0.3875	0.4743
77	04:05:48	3.500	93.3	64.2010	0.3556	0.3843	0.4698
78	04:15:48	3.667	93.2	64.1986	0.3507	0.3807	0.4652
79	04:25:48	3.833	93.2	64.1949	0.3617	0.3793	0.4618
80	04:35:48	4.000	93.2	64.1919	0.3678	0.3791	0.4595
81	04:45:48	4.167	93.2	64.1889	0.3609	0.3778	0.4565
82	04:55:48	4.333	93.2	64.1857	0.3548	0.3758	0.4531
83	05:05:48	4.500	93.2	64.1833	0.3616	0.3750	0.4507
84	05:15:48	4.667	93.2	64.1803	0.3561	0.3735	0.4479
85	05:25:48	4.833	93.2	64.1764	0.3657	0.3734	0.4462
86	05:35:48	5.000	93.1	64.1747	0.3511	0.3714	0.4432
87	05:45:48	5.167	93.2	64.1686	0.4127	0.3773	0.4492
88	05:55:48	5.333	93.1	64.1692	0.3557	0.3757	0.4467
89	06:05:48	5.500	93.2	64.1617	0.4242	0.3822	0.4539
90	06:15:48	5.667	93.1	64.1643	0.3594	0.3807	0.4517
91	06:25:48	5.833	93.1	64.1619	0.3476	0.3780	0.4488
92	06:35:48	6.000	93.1	64.1595	0.3495	0.3758	0.4461
93	06:45:48	6.167	93.1	64.1518	0.3954	0.3786	0.4480

Induced Leakage Phase Test Results
TABLE 4

DATA SET	TIME	TEST DURATION	AVE. TEMP.	DRY AIR PRESS.	MEAS. LEAK RATE	CALC. LEAK RATE	UPPER CONF. LIMIT
103	08:25:48	0.000	93.0	64.0966	---	---	---
104	08:35:48	0.167	93.0	64.0900	1.2358	---	---
105	08:45:48	0.334	93.0	64.0833	1.2154	---	---
106	08:55:48	0.500	93.0	64.0772	1.2699	1.2573	1.5541
107	09:05:48	0.667	93.0	64.0707	1.2786	1.2773	1.3865
108	09:15:48	0.834	93.0	64.0641	1.2675	1.2788	1.3583
109	09:25:48	1.000	92.9	64.0571	1.2882	1.2897	1.3497
110	09:35:48	1.167	92.9	64.0516	1.2452	1.2756	1.3510
111	09:45:48	1.334	92.9	64.0436	1.2886	1.2846	1.3495
112	09:55:48	1.500	92.9	64.0379	1.2533	1.2769	1.3423
113	10:05:48	1.667	92.9	64.0314	1.2752	1.2791	1.3382
114	10:15:48	1.834	92.9	64.0252	1.2655	1.2774	1.3330
115	10:25:48	2.000	92.9	64.0192	1.2632	1.2753	1.3282
116	10:35:48	2.167	92.9	64.0127	1.2550	1.2715	1.3229
117	10:45:48	2.334	92.9	64.0066	1.2621	1.2703	1.3192
118	10:55:48	2.500	92.9	63.9967	1.3850	1.2990	1.3796
119	11:05:48	2.667	92.9	63.9902	1.3834	1.3215	1.4102
120	11:15:48	2.834	92.9	63.9842	1.3700	1.3366	1.4244
121	11:25:48	3.000	92.9	63.9783	1.3461	1.3439	1.4281
122	11:35:48	3.167	92.9	63.9729	1.3405	1.3487	1.4299
123	11:45:48	3.334	92.9	63.9662	1.3272	1.3502	1.4296

MEASURED LEAK RATE PHASE
GRAPH OF CALCULATED LEAK RATE
AND UPPER CONFIDENCE LIMIT

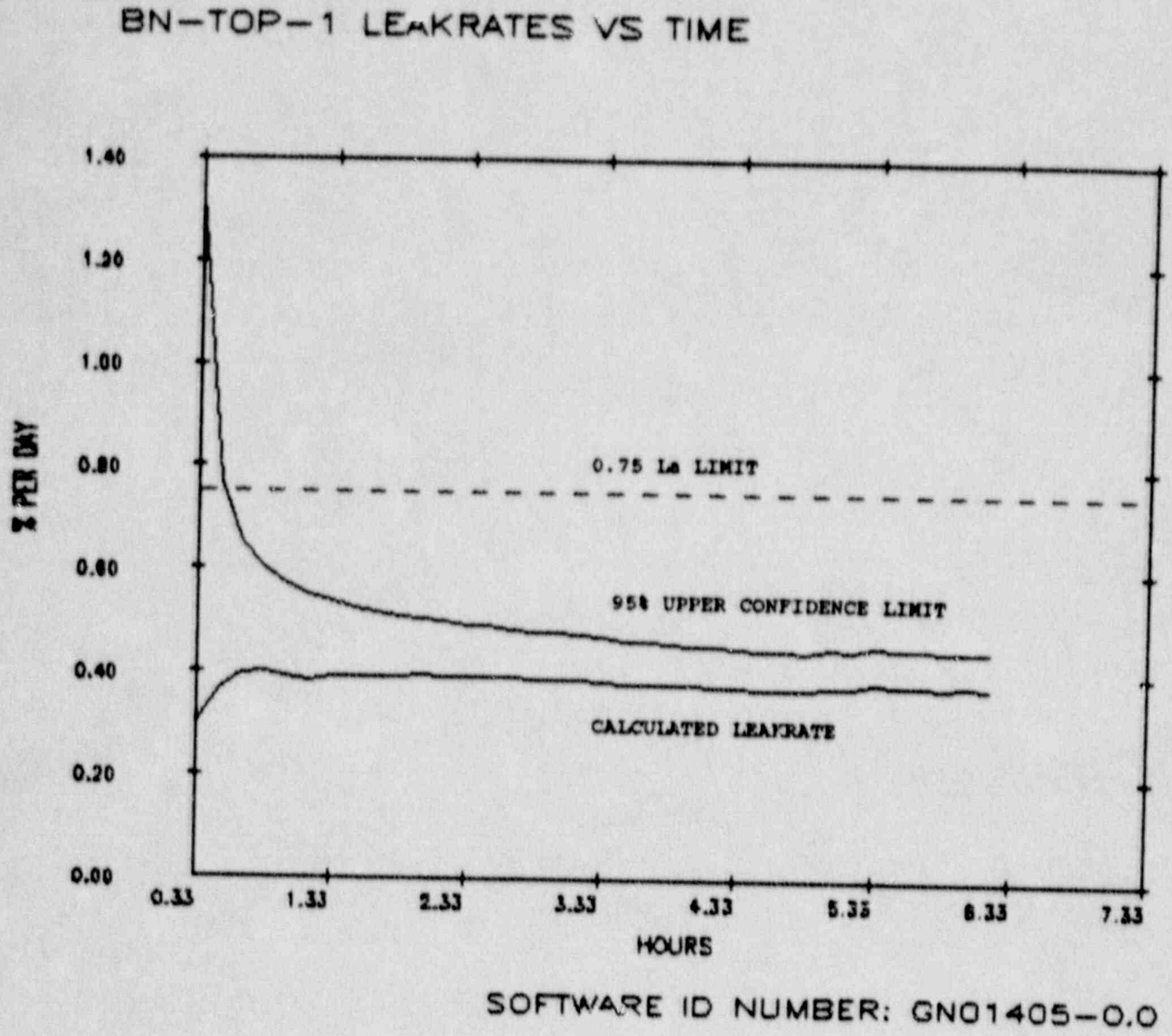


FIGURE 3

MEASURED LEAK RATE PHASE
GRAPH OF TOTAL TIME MEASURED
LEAK RATE AND REGRESSION LINE

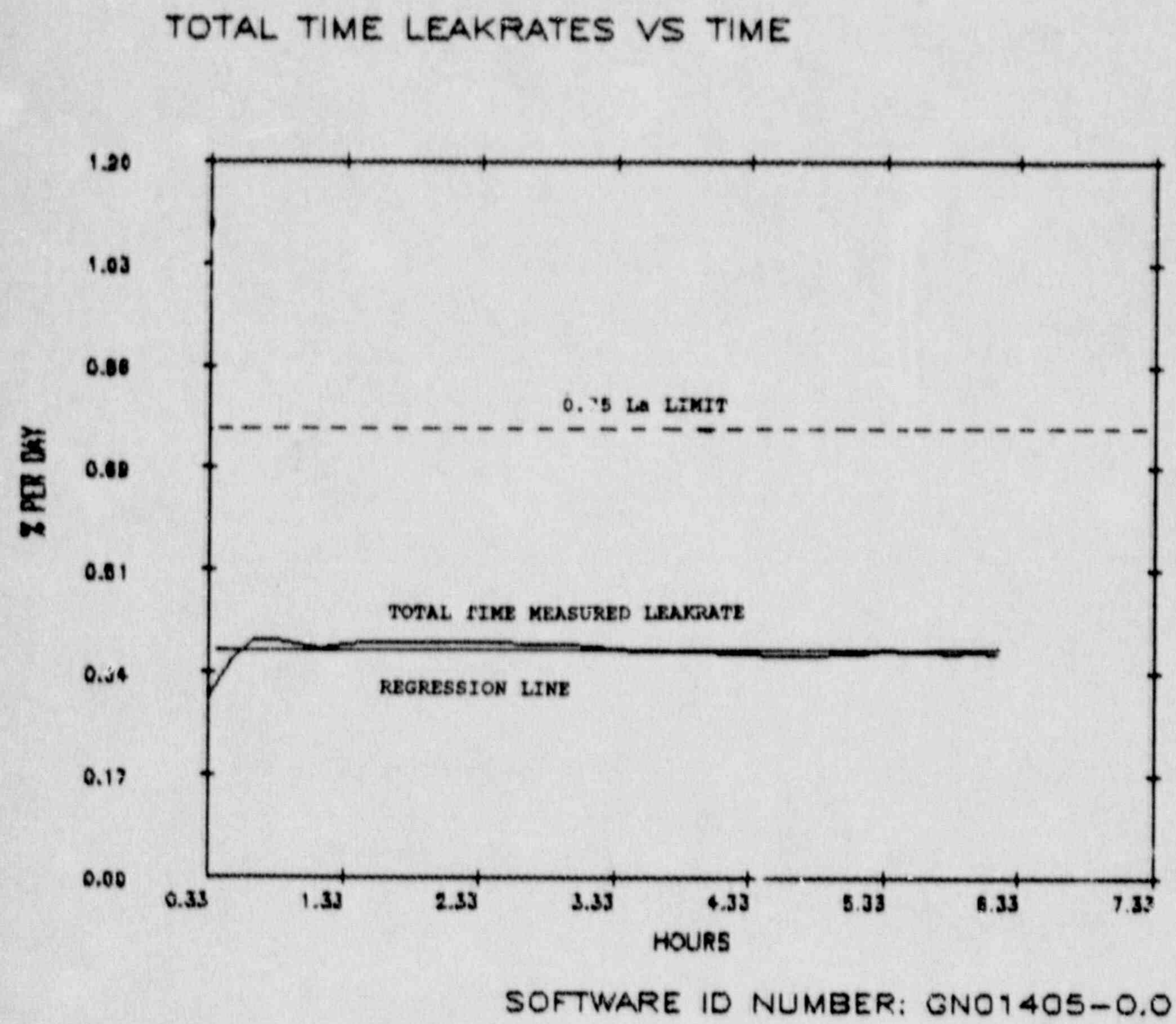


FIGURE 4

MEASURED LEAK RATE PHASE
GRAPH OF DRY AIR PRESSURE

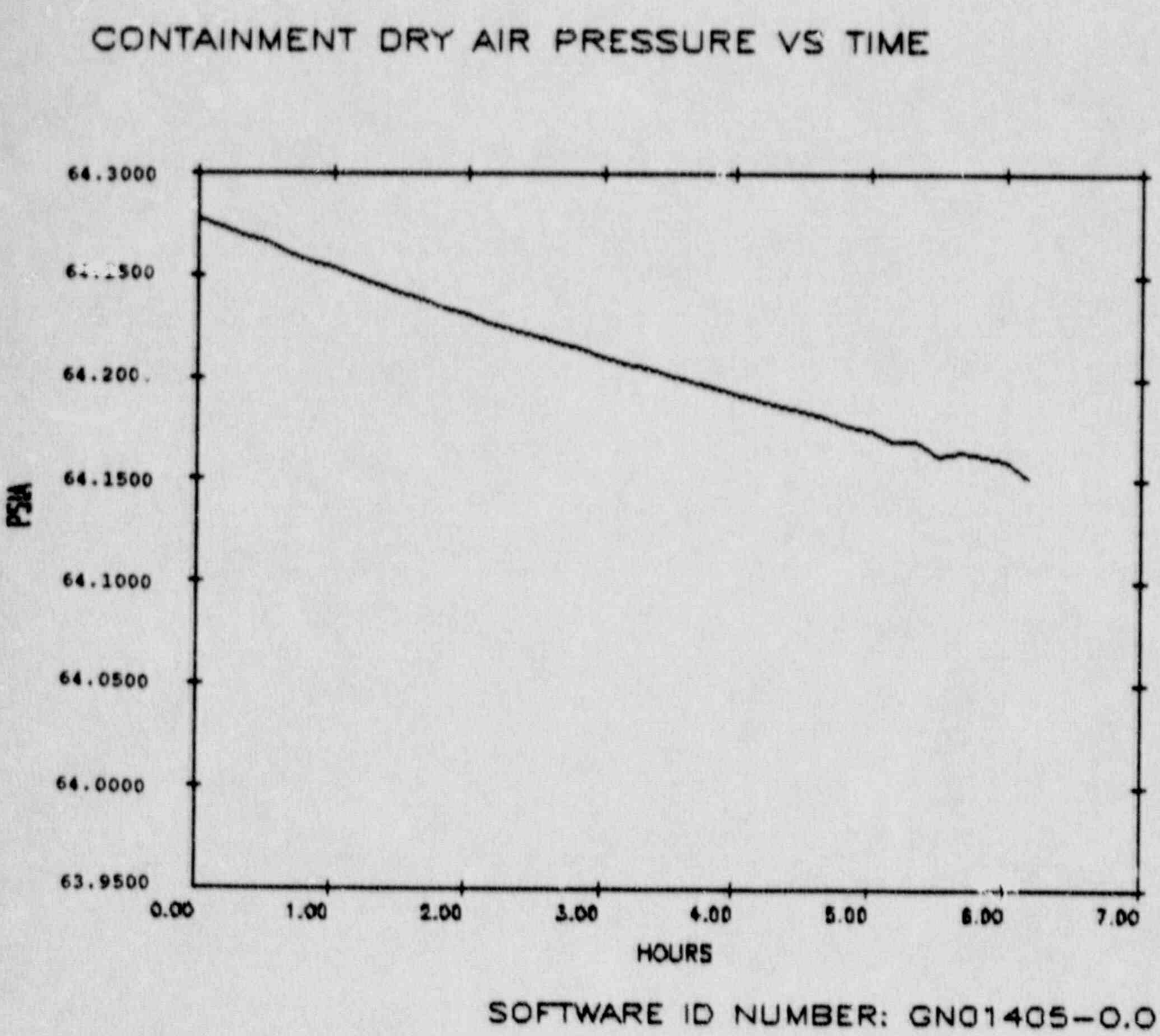


FIGURE 5

MEASURED LEAK RATE PHASE
GRAPH OF VOLUME WEIGHTED
AVERAGE CONTAINMENT VAPOR PRESSURE

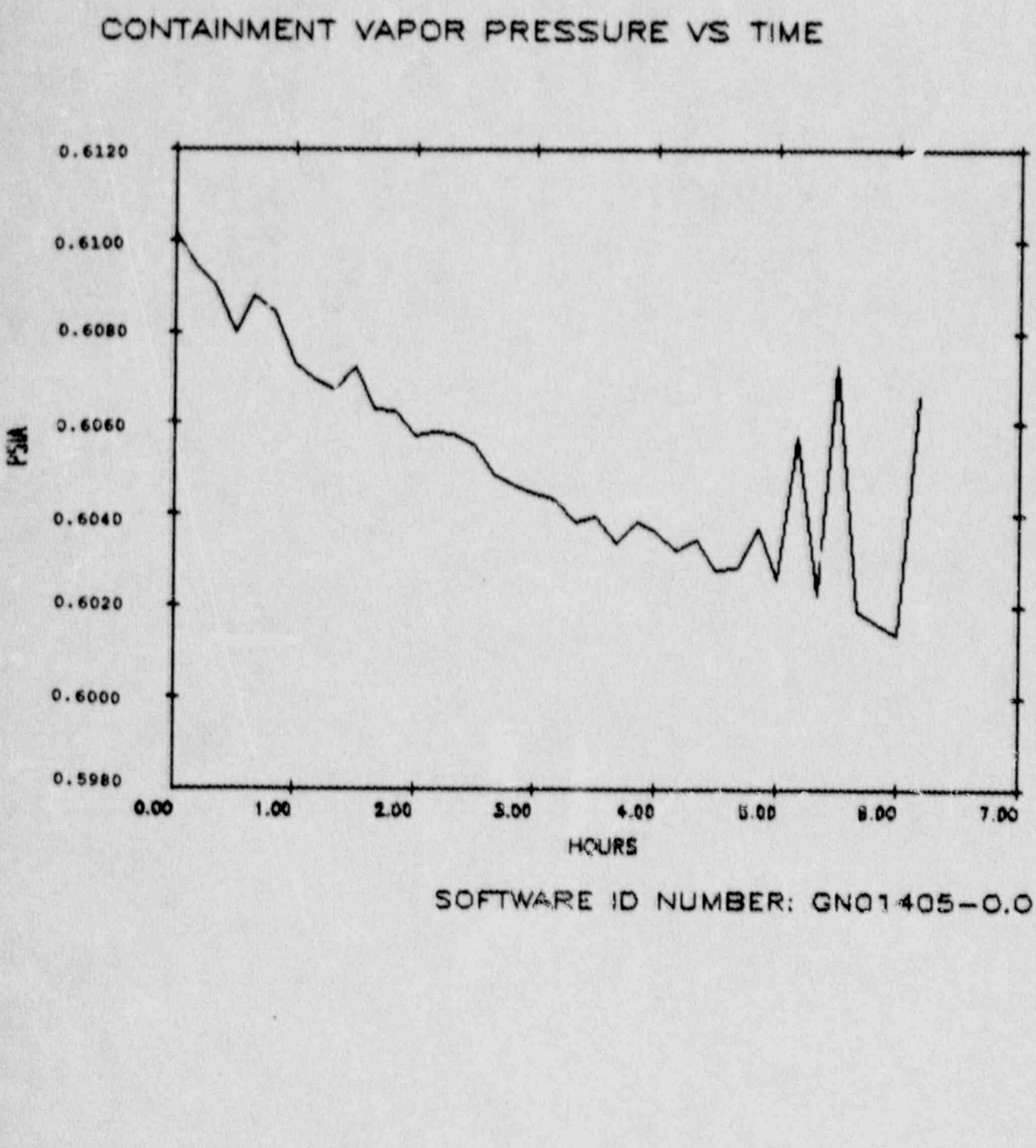
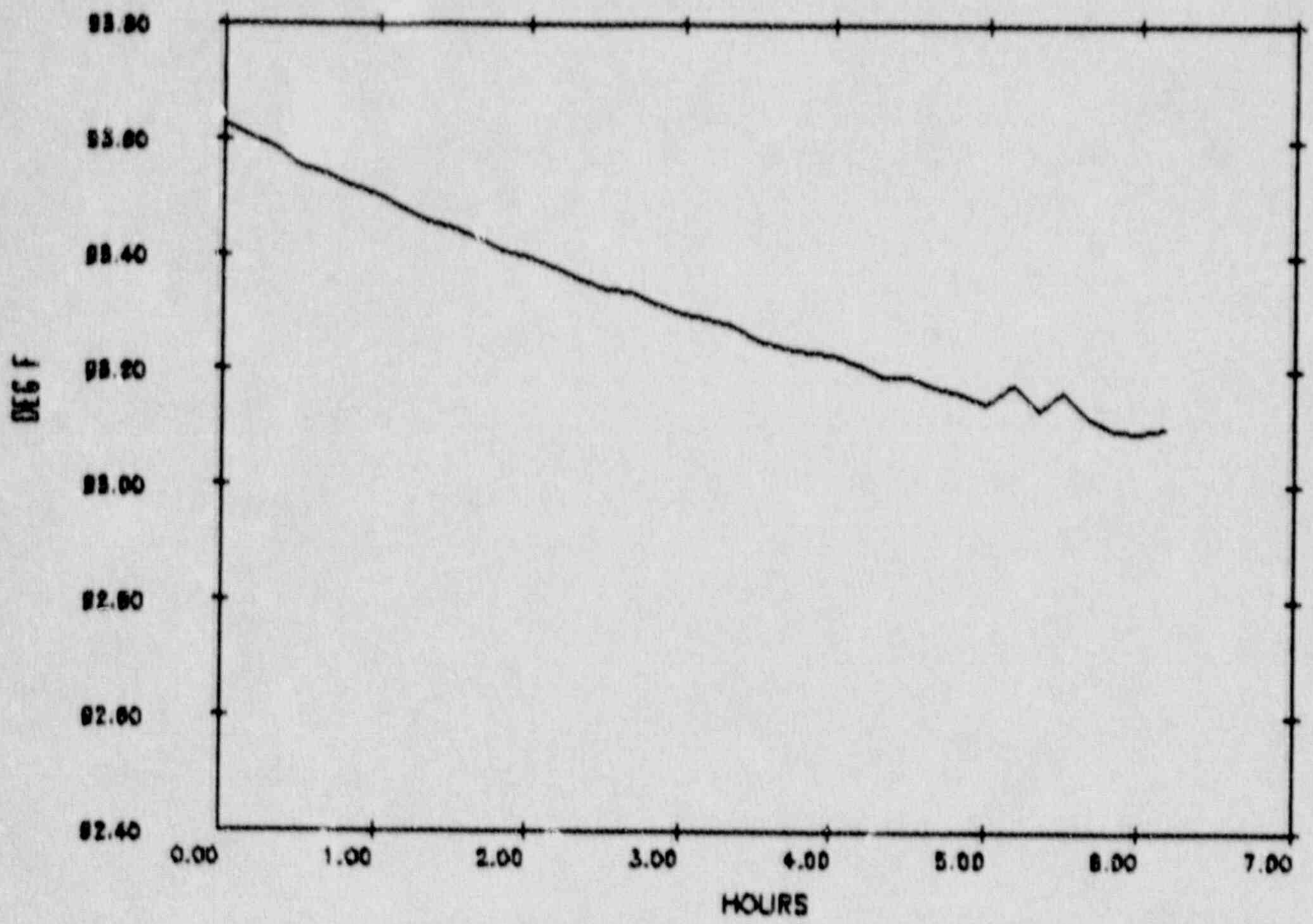


FIGURE 6

MEASURED LEAK RATE PHASE
GRAPH OF VOLUME
WEIGHTED AVERAGE CONTAINMENT TEMPERATURE

CONTAINMENT AIR TEMPERATURE VS TIME

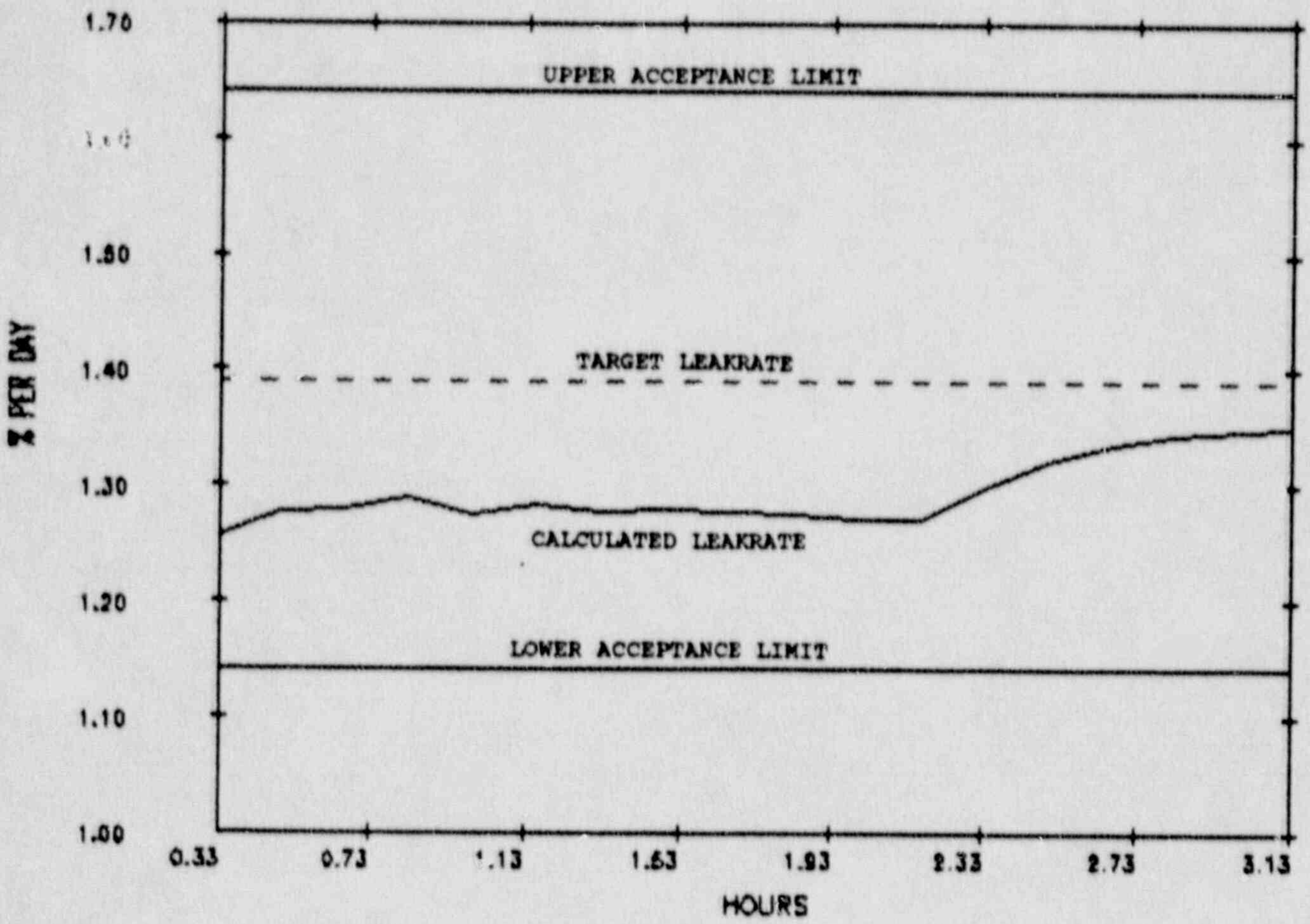


SOFTWARE ID NUMBER: GN01405-0.0

TABLE 7

INDUCED LEAKAGE PHASE
GRAPH OF CALCULATED
LEAK RATE

BN-TOP-1 LEAKRATES VS TIME



SOFTWARE ID NUMBER: GN01405-0.0

FIGURE 8

INDUCED LEAKAGE PHASE
GRAPH OF TOTAL TIME
MEASURED LEAK RATE AND REGRESSION LINE

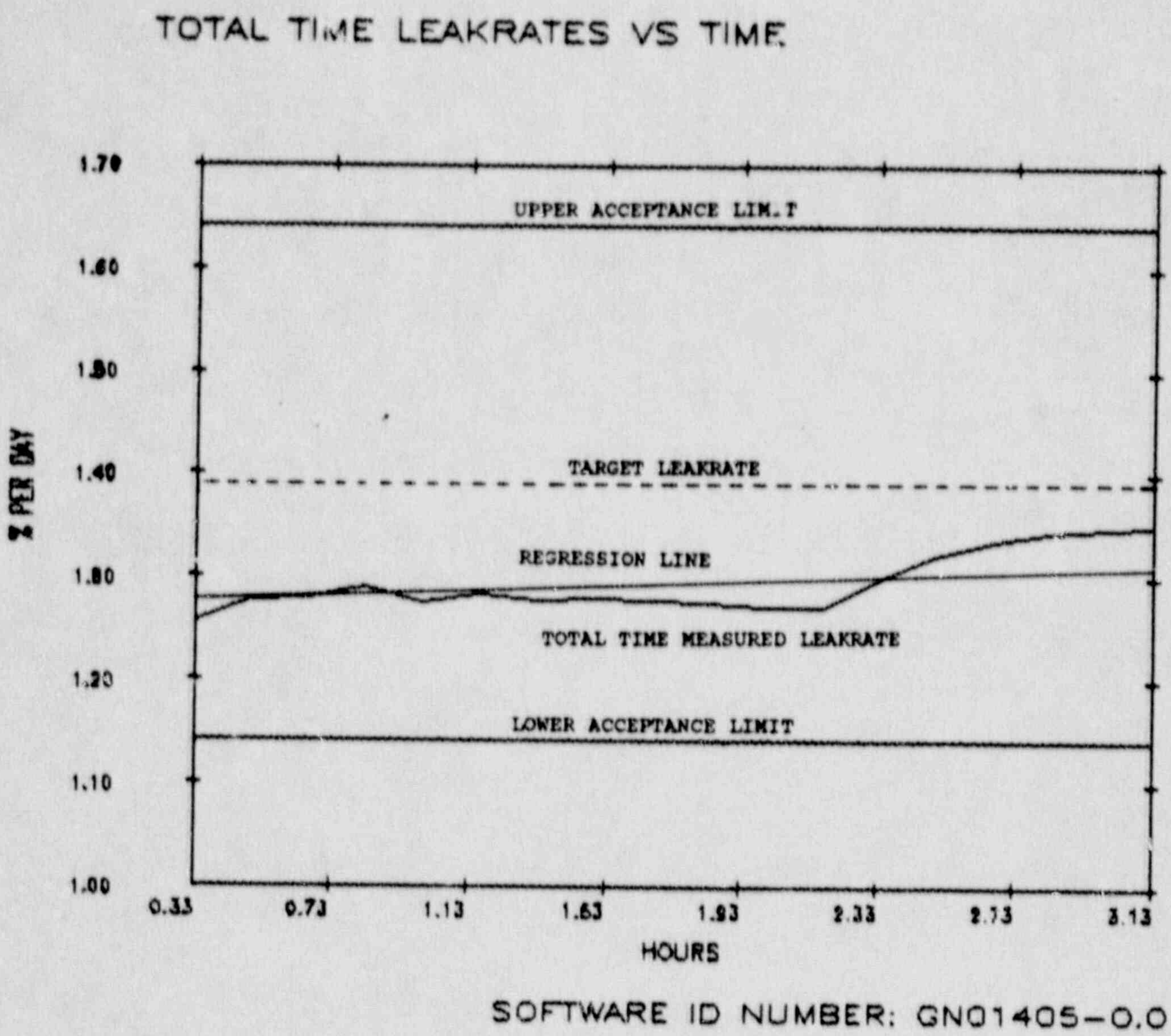
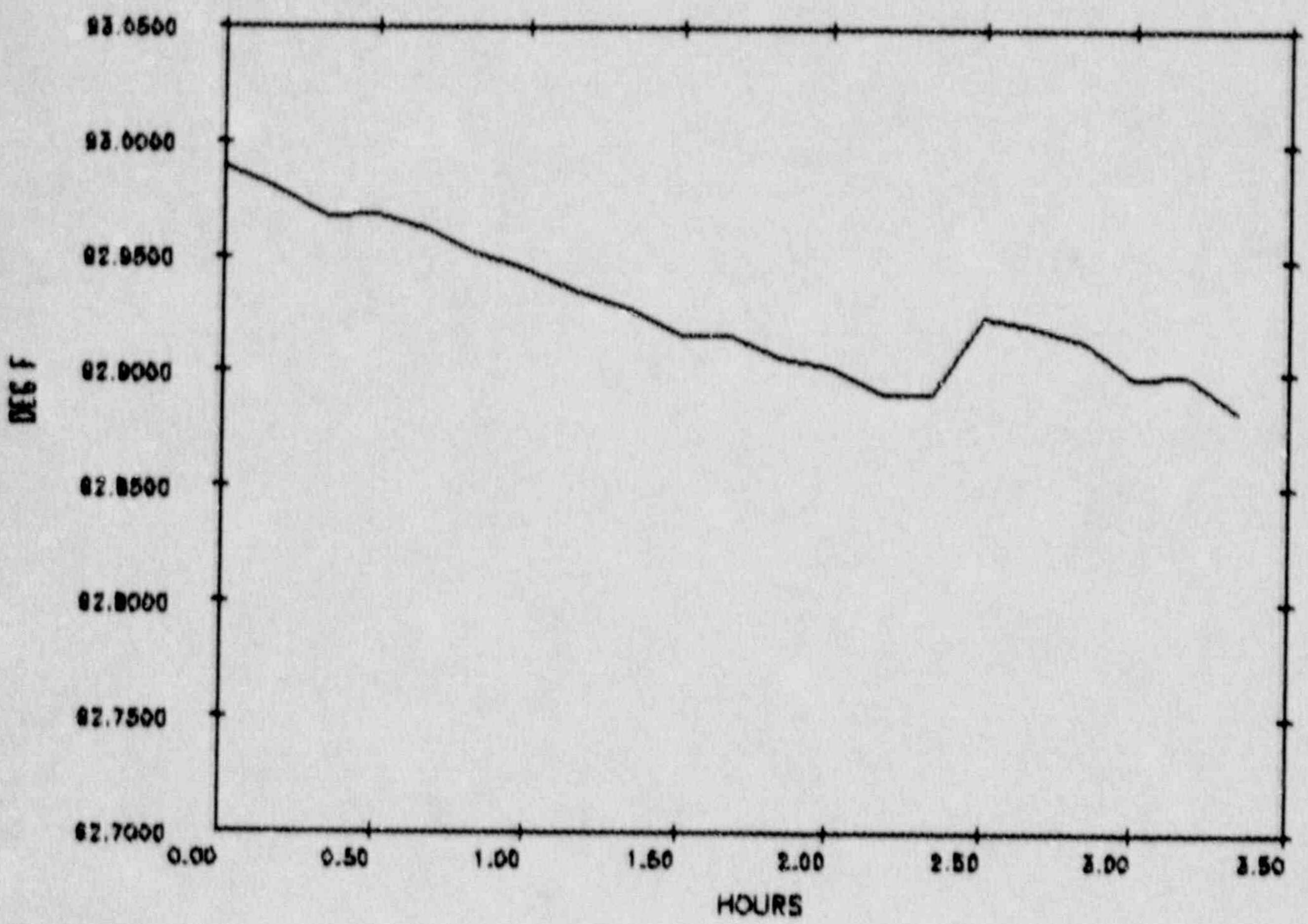


FIGURE 9

INDUCED LEAKAGE PHASE
GRAPH OF VOLUME
WEIGHTED AVERAGE CONTAINMENT TEMPERATURE

CONTAINMENT AIR TEMPERATURE VS TIME

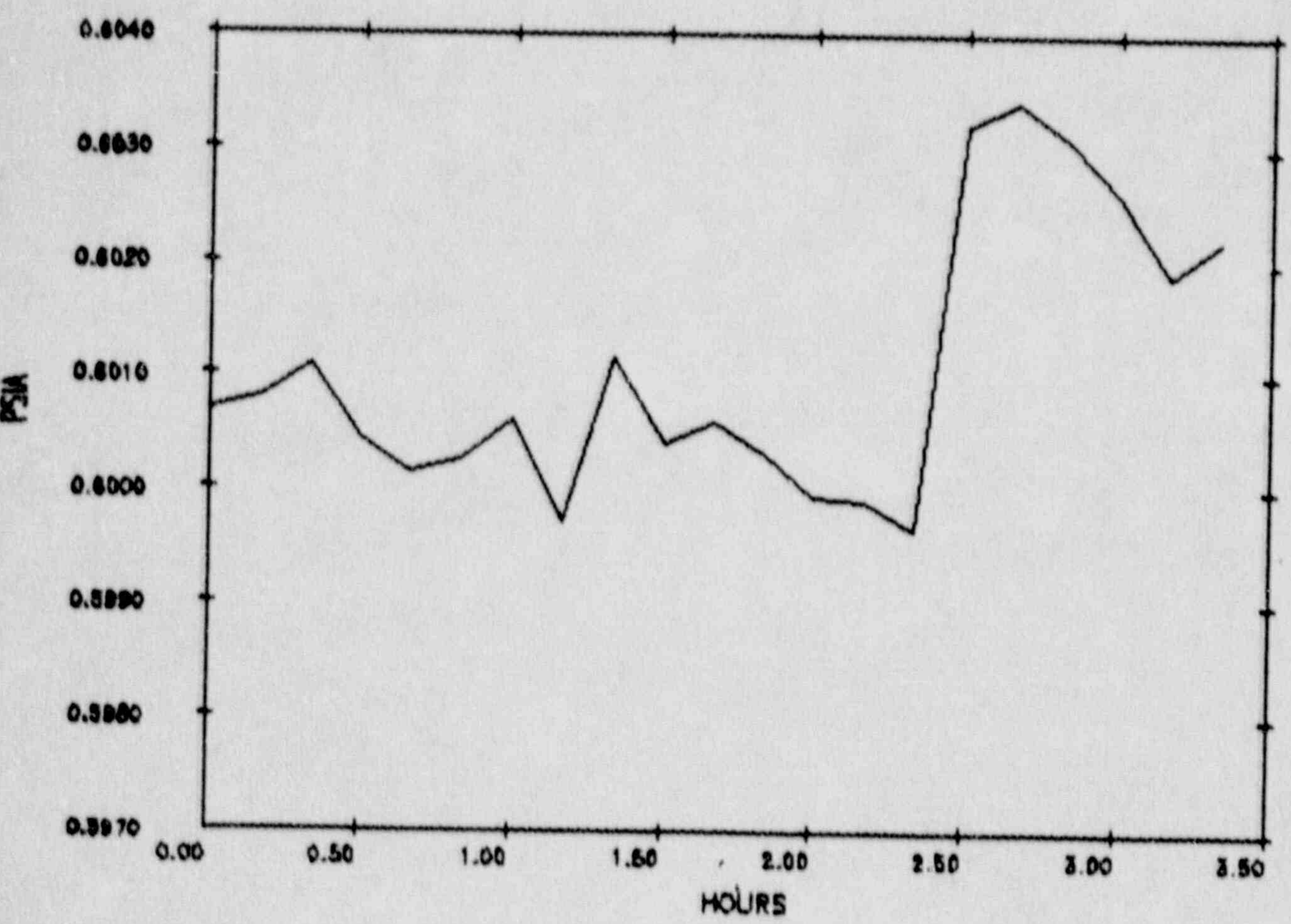


SOFTWARE ID NUMBER: GN01405-0.0

FIGURE 10

INDUCED LEAKAGE PHASE
GRAPH OF VOLUME
WEIGHTED AVERAGE CONTAINMENT VAPOR PRESSURE

CONTAINMENT VAPOR PRESSURE VS TIME



SOFTWARE ID NUMBER: GN01405-0.0

FIGURE 11

INDUCED LEAKAGE PHASE
GRAPH OF DRY AIR PRESSURE

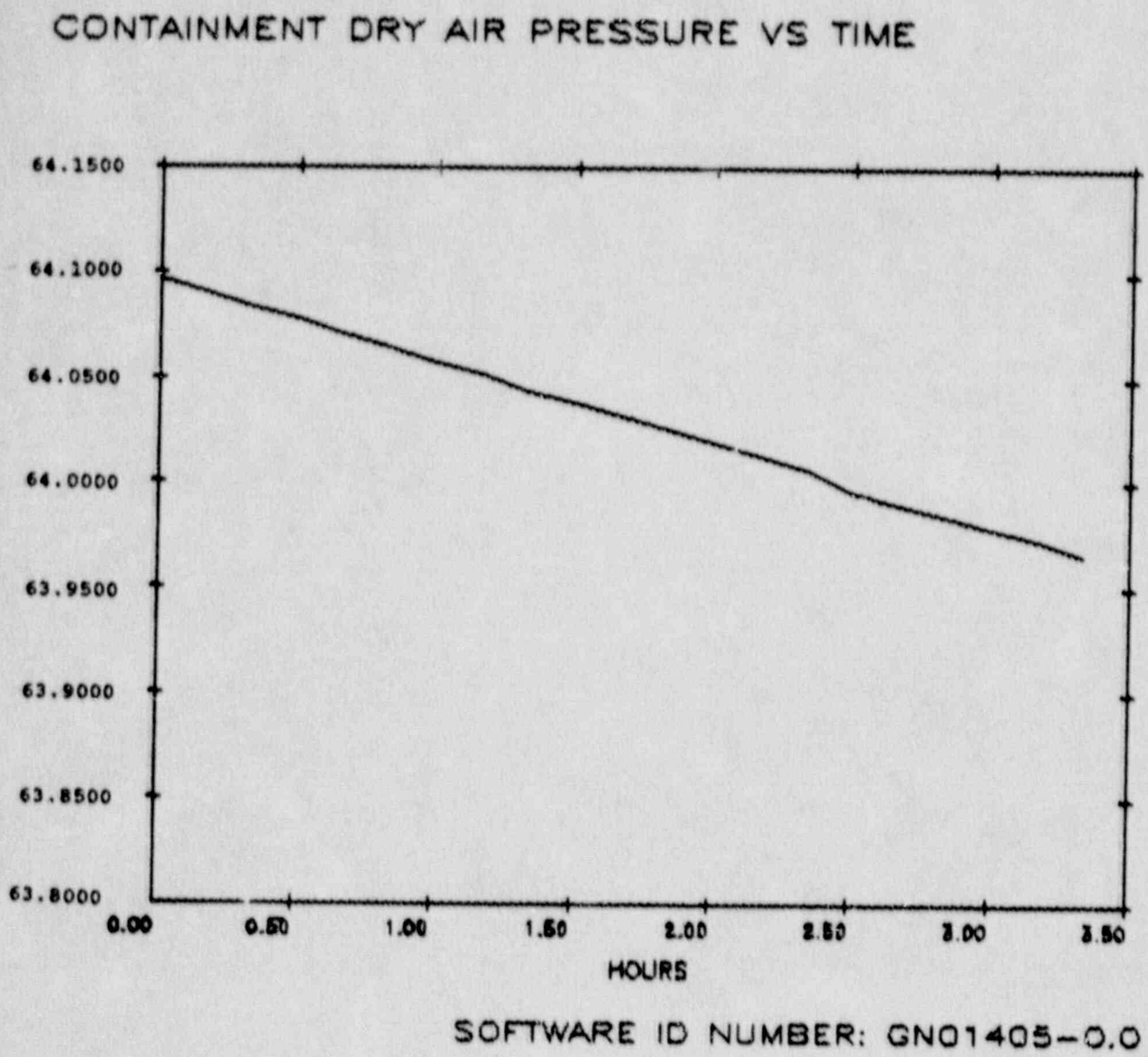


FIGURE 12

GRAPH OF REACTOR WATER LEVEL
THROUGH TESTING PERIOD

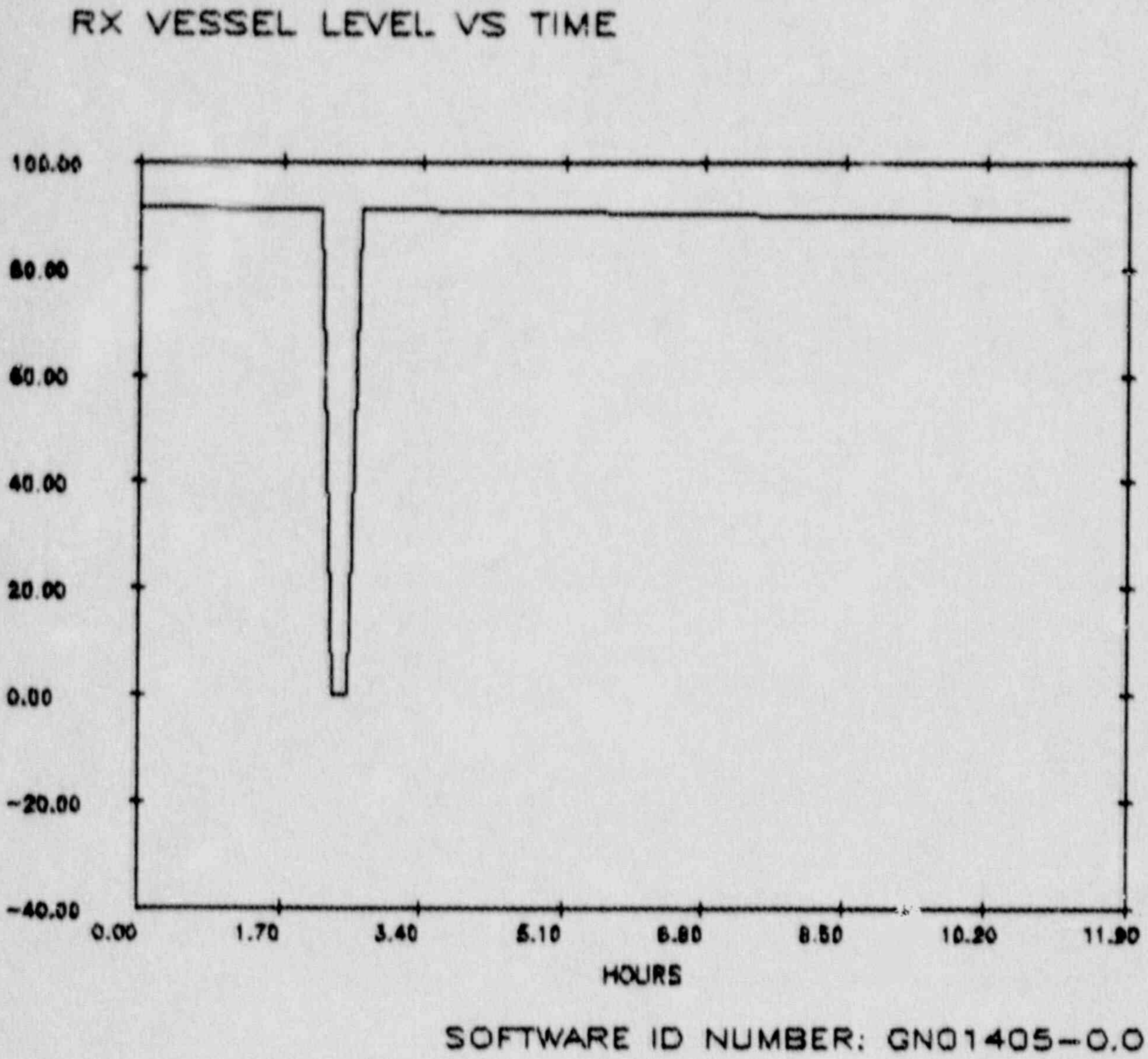


FIGURE 13

GRAPH OF TORUS WATER LEVEL
THROUGH TESTING PERIOD

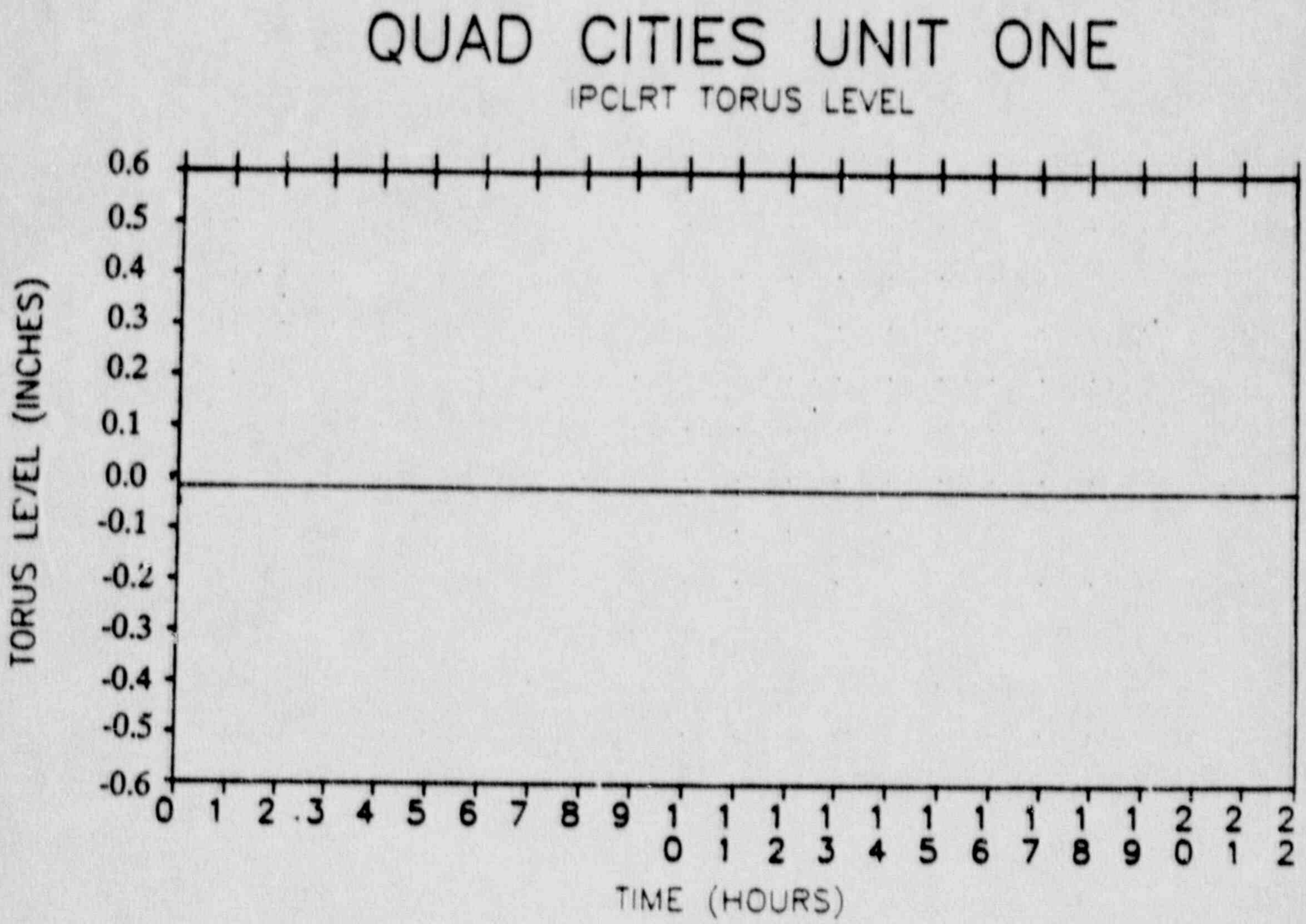


FIGURE 14

SECTION E - TEST CALCULATIONS

Calculations for the IPCLRT are based on the BN-TOP-1, Rev. 1 test method and are found in the functional requirements specification CECo Generic ILRT computer code Software ID No. GN1405-0.0, Document ID No. ILRT-FRS-0.0. A reproduction of the BN-TOP-1, Rev. 1 test method can be found in Appendix C. In preparing for the first Quad Cities short duration test using BN-TOP-1, Rev. 1 a number of editorial errors and ambiguous statements in the topical report were identified. These errors are presented in Appendix E and are editorial in nature only. The Station has made no attempt to improve or deviate from the methodology outlined in the topical report.

Section 2.3 of BN-TOP-1, Rev. 1 gives the test duration criteria for a short duration test. By station procedure some of these duration criteria have been made more conservative and in some cases these changes may be required by regulations.

A. "Containment Atmosphere Stabilization"

Once the containment is at test pressure the containment atmosphere shall be allowed to stabilize for about four hours (4 hours required by Quad Cities procedure and actual stabilization: 5 hrs, 32 min) The atmosphere is considered stabilized when:

1. The rate of change of average temperature is less than 1.0°F/hour averaged over the last two hours.

DATA SET*	AVE. CONTAINMENT TEMP.	ΔT
55	93.649	
49	93.801	0.152
43	93.971	0.170
	average:	0.0161°F/hour

* Approximate time interval between data sets is 10 minutes.

or

2. "The rate of change of temperature changes less than 0.5°F/hour/hour averaged over the last two hours."

(Not required if A.1 satisfied)

B. Data Recording and Analysis

1. "The Trend Report based on Total Time calculations shall indicate that the magnitude of the calculated leak rate is tending to stabilize at a value less than the maximum allowable leak rate (L_A)..."

By Quad Cities procedure the calculated leak rate must be less than 0.75 L_A. The actual value was 0.3786 L_A, stable, and decreasing (no extrapolation required).

and

2. "The end of the test upper 95% confidence limit for the calculated leak rate based on total time calculations shall be less than the maximum allowable leak rate."

   By Quad Cities procedure the upper confidence limit must be less than 0.75 L_A. The actual value was 0.4480 L_A.

<u>and</u>

3. "The mean of the measured leak rates based on Total Time calculations over the last five hours of the test or last 20 data points, whichever provides the most data, shall be less than the maximum allowable leak rate."

   By Quad Cities procedure this average must be less than 0.75 L_A. The actual value was 0.3678 L_A for the last 5 hours.

<u>and</u>

4. "Data shall be recorded at approximately equal intervals and in no case at intervals greater than one hour."

   At Quad Cities data scans are automatically performed on 10 minute intervals. No data sets were missed or lost during the 6 hour test period. No computer failures were encountered.

<u>and</u>

5. "At least twenty (20) data point shall be provided for proper statistical analysis."

   There were 38 data sets taken for this test.

<u>and</u>

6. "In no case shall the minimum test duration be less than six (6) hours."

   Quad Cities' procedure limits a short duration test to a minimum of six (6) hours. The data taken during this test supports the argument that a shorter duration test can be conducted. All of the above termination criteria were satisfied in six (6) hours.

<u>SECTION F - TYPE A TEST RESULTS</u>

F.1 <u>Measured Leak Rate Test Results</u>

Based upon the data obtained during the short duration test, the following results were determined: (L_A = 1.0 wt %/day)

1) Calculated leak rate at 6 hours equals 0.3786 wt %/day and declining steadily over time (<0.7500 wt %/day).

2) Upper confidence limit equals 0.4480 wt %/day and declining (<0.750 wt %/day).

3) Mean of the measured leak rates for the last 5 hours (31 data sets) equals 0.3836 wt %/day (<0.750 wt %/day).

4) Data sets were accumulated at approximately 10 minute time intervals and no intervals exceeded 1 hours.

5) There were 38 data sets accumulated in 6 hours measured phase.

6) The minimum test duration (by procedure) of 6 hours was successfully accomplished ($\geq$ 6 hours).

F.2 <u>Induced Leakage Test Results</u>

A leak rate of 8.26 scfm (1.0123 wt %/day) was induced on the primary containment for this phase of the test. The leak rates during this phase of the test were as follows.

BN-TOP-1 Calculated Leak Rate (Measured Leak Rate Phase)	0.3786	0.3786
Induced Leak (8.26 scfm)	1.0123	1.0123
Allowed Error Band	+0.2500	-0.2500
	1.6409	1.1409
BN-TOP-1 Calculated Leak Rate (Induced Leak Rate Phase)	1.3502 wt %/day	

The induced phase of the test has a duration criteria given in Section 2.3.C of BN-TOP-1. The test duration requirements are listed below and were satisfied by the test procedure and the data analysis:

1. Containment atmospheric conditions shall be allowed to stabilize for about one hour after superimposing the known leak. (actual: 1 hour, 10 minutes).

2. The verification test duration shall be approximately equal to half the integrated leak rate test duration. (actual: 3 hours, 20 minutes for a 6 hour test)

3. Results of this verification test shall be acceptable provided the correlation between the verification test data and the integrated leak rate test data demonstrate an agreement within plus or minus 25 percent. (actual: see results above)

F.3 Pre-Operational Results vs Test Results

Past IPCLRT reports have compared the results of each test with the pre-operational IPCLRT, performed April 20-21, 1971. Over the last 15 years, different test equipment, sensor locations and number of sensors, test methods, and test duration have been used. This test yielded results that compare favorably with recent tests and demonstrate that there has been no substantial deterioration in containment integrity.

TEST DATA	TEST DURATION (HOURS)	CALCULATED LEAK RATE (BN-TOP-1)	STATISTICALLY AVE. LEAK RATE (ANSI/ANS)
April, 1971	24	Not Avail.	0.111
February, 1979	24	Not Avail.	0.3175
December, 1982	12	0.4532	0.3796
July, 1984	24	0.4281	0.2297
March, 1986	12	0.2286	0.2286
December, 1987	6	0.3194	0.3162
November, 1986	6	0.3786	0.3714

F.4 TYPE A TEST PENALTIES

During the type A test, there were a number of systems that were not drained and vented outside the containment. The isolation valves for these systems or penetrations were not "challenged" by the type A test. Even though these systems would not be drained and vented during a DBA event, historically, penalties for these systems have been added to the type A test results.

	AS LEFT MINIMUM PATHWAY LEAKAGE SCFH	WT%/DAY
Primary Sample Valves	0.035	0.00007
ACAD	1.5	0.00306
RHR A	3.02	0.00616
RHR B	7.72	0.01576
Feedwater	6.72	0.01372
DWFDS	0.0	0.0
DWEDS	0.0	0.0
RCIC Steam Ex.	4.22	0.00861
RCIC Drain	5.0	0.01021
HPCI Steam Ex.	1.61	0.00329
HPCI Drain	0.5	0.00102
All Electrical Penetrations	4.83	0.00986
Oxygen Analyzer	0.0	0.0
Tip Purge Check Valves	9.0	0.01837
CAM-Isolation Valves & Panels	0.0	0.0
1-262-2-3A, B & 4A, B	0.0	0.0
	44.155	0.09012

This penalty increases the type A test result to 0.4687 wt%/day with an upper confidence limit of 0.5381 wt%/day.

F.5 EVALUATION OF INSTRUMENT FAILURES

Prior to the start of the test and during the test no instrument failures were encountered.

F.6 AS FOUND TYPE A TEST RESULTS

The following table summarizes the results of all type B and C testing, as well as the IPCLRT results to arrive at an "As Found" type A test result. Since the total is more than the 0.750 wt %/day, the present schedule of performing a type A test every refuel outage must be maintained.

SUMMARY OF ALL CONTAINMENT
LEAK RATE TESTING DURING
UNIT TWO REFUEL OUTAGE
SPRING, 1988

	AS FOUND (SCFH) MINIMUM PATHWAY LEAKAGE	AS LEFT (SCFH) MINIMUM PATHWAY LEAKAGE
(1) MSIV's @ 25 PSIG	20.74	10.96
(2) MSIV's converted to 48 PSIG*	32.77	17.32
(3) All Type C Tests (Except MSIV's)	2419.03	65.49
(4) All Type B Tests	40.13	24.43
TOTAL (2 + 3 + 4)	2491.93	107.24

(1) Type A Test Integrated Leak Rate Test)	= 0.3786 wt %/day	
(2) Upper Confidence Limit of Type A Test Result	= 0.4480 wt %/day	
(3) Correction for Unvented Volumes During Type A Test	= 0.0901 wt %/day	
(4) Correction for Repairs Prior to Type A Test (As Found - As Left)	= 4.8708 wt %/day	(2491.93 - 107.24) / 489.59
(5) Correction for Change in Sump Levels	= 0.003 wt %/day	
TOTAL (2 + 3 + 4 + 5)	5.412 wt %/day (As Found ILRT Result)	

* Leak Rate at 25 PSIG converts to Leak Rate at 48 PSIG using conversion ratio of 1.58. REFERENCE ORNL - NISC - 5, Oak Ridge National Laboratory, Aug. 1965, page 10.55.

APPENDIX A
TYPE B AND C TESTS

Presented herin are the results of local leak rate tests conducted on all penetrations, double-gasketed seals, and isolation valves since the previous IPCLRT in December, 1987. Total leakage for double gasketed seals and total leakage for all penetrations and isolation valves following repairs satisfied the Technical Specification limits.

REFUEL OUTAGE LOCAL
LEAK RATE TEST SUMMARY

QTS 100-S1
Revision 7
May 1987

APPROVED

SEP 09 1987

Q.C.O.S.R.

UNIT ONE
TEST DIRECTOR Jay Rolfe
OPERATING ENG. [signature]
TECH STAFF SUPV. Alan L. Marsh

DESCRIPTION	VALVE(S)/ PENETRATION	AS FOUND (SCFH) DATE	AS FOUND TOTAL	AS FOUND MINIMUM PATHWAY	AS FOUND MAXIMUM PATHWAY	AS LEFT (SCFH) DATE	AS LEFT TOTAL	AS LEFT MINIMUM PATHWAY	AS LEFT MAXIMUM PATHWAY
'A' MSIV	AO 203-1A,2A	9-10-89	35.71	8.06	27.65	~~10-21-89~~ 10-31-89	~~6.91~~ 6.91	~~3.46~~ 3.46	~~6.91~~ 6.91
'B' MSIV	AO 203-1B,2B	9-10-89	6.91	3.46	6.91	9-10-89	6.91	3.46	6.91
'C' MSIV	AO 203-1C,2C	9-10-89	6.91	3.46	6.91	9-10-89	6.91	3.46	6.91
'D' MSIV	AO 203-1D,2D	9-10-89	29.95	5.76	24.19	11-2-89	1.15	0.58	1.15
		TOTAL		79.48		TOTAL		10.96	
		TOTAL CORRECTED *		125.58		TOTAL CORRECTED *		17.32	
MSL DRAIN	MO 220-1,2	9-10-89	1.59	0.80	1.59	9-10-89	1.59	0.80	1.59
PRIMARY SAMPLE	AO 220-44,45	10-31-89	0.07	0.035	0.07	10-31-89	0.07	0.035	0.07
'A' FEEDWATER	CV 220-58A,62A	10-5-89	31.18	6.72	24.46	10-5-89	31.18	6.72	24.46
'B' FEEDWATER	CV 220-58B,62B	~~[illegible]~~ 9-12-89	UD	522.76	UD	11-13-89	0.448	0.0	0.448
RHR TO RADWASTE	MO 1001-20,21	9-11-89	5.2	0.0	5.2	9-11-89	5.2	0.0	5.2
'A' DW SPRAY	MO 1001-23A,26A	9-18-89	2.24	1.12	2.24	~~9-18-89~~ 10-28-89	~~2.24~~ 22.56	1.12	~~2.24~~ 21.44
'A' RHR RETURN	MO 1001-29A	9-16-89	3.02	3.02	3.02	9-16-89	3.02	3.02	3.02
'A' TORUS COOLING SPRAY	MO 1001-34,36,37A	9-14-89	4.54	2.27	4.54	9-14-89	4.54	2.27	4.54
'B' DW SPRAY	MO 1001-23B,26B	10-17-89	5.58	2.79	5.58	10-17-89	5.58	2.79	5.58
'B' RHR RETURN	MO 1001-29B	10-17-89	15.44	7.72	15.44	10-17-89	15.44	7.72	15.44
'B' TORUS COOLING/SPRAY	MO 1001-34,36,37B	10-17-89	2.81	1.41	2.81	10-17-89	2.81	1.41	2.81
PAGE TOTAL (EXCEPT. MSIV'S)		NA	UD	548.65	UD	NA	~~72.12~~ 91.32	25.89	~~65.40~~ 84.6

10/0168s UD : undetermined

-1-

REFUEL OUTAGE LOCAL
LEAK RATE TEST SUMMARY

QTS 100-S1
Revision 7

UNIT ____________

DESCRIPTION	VALVE(S)/ PENETRATION	AS FOUND (SCFH)				AS LEFT (SCFH)			
		DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY	DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY
SHUTDOWN COOLING	MO 1001-47,50	9-28-89	3.12	1.56	3.12	9-28-89	3.12	1.56	3.12
HEAD SPRAY	MO 1001-60,63 *	—	—	—	—	—	—	—	—
CLEAN UP SUCTION	MO 1201-2,5	9-14-89	860.0	430.0	860.0	11-8-89	5.54	2.77	5.54
RCIC STEAM SUPPLY	MO 1301-16,17	9-10-89	0.1	0.05	0.1	9-10-89	0.10	0.05	0.10
RCIC STEAM EXHAUST	CV 1301-41	9-10-89	4.22	4.22	4.22	9-10-89	4.22	4.22	4.22
RCIC VAC. PUMP EX.	CV 1301-40	9-10-89	5.0	5.0	5.0	9-10-89	5.00	5.00	5.00
DW/TORUS PURGE SUPPLY	AO 1601-21,22,55,56	XP 9-10-89	0.0	0.0	0.0	9-10-89	0.00	0.00	0.00
DW/TORUS PURGE EX	AO 1601-23,24,60, 61,62,63	XP 9-10-89	522.0	261.00 ~~522~~ XP 9-11-89	522.0	11-13-89	18.0	9.0	18.0
'A' TORUS VENT	AO 1601-20A, CV 1601-31A	XP 9-10-89	0.625	0.312 ~~0.625~~ XP 9-10-89	0.625	9-10-89	0.625	0.312	0.625
'B' TORUS VENT	AO 1601-20B, CV 1601-31B	XP 9-10-89	0.03	0.02 ~~0.03~~ XP 9-10-89	0.03	9-10-89	0.03	0.02	0.03
DW/TORUS PURGE	AO 1601-57,58,59	11-10-89	3.5	1.75	3.5	11-10-89	3.5	1.75	3.5
DW FLOOR DRAIN SUMP	AO 2001-3,4	9-26-89	0.0	0.0	0.0	9-26-89	0.0	0.0	0.0
DW EQ. DR. SUMP	AO 2001-15, 16	9-26-89	0.0	0.0	0.0	9-26-89	0.0	0.0	0.0
HPCI STEAM SUPPLY	MO 2301-4,5	9-10-89	4.61	2.305	4.61	9-10-89	4.61	2.31	4.61
HPCI STEAM EX.	CV 2301-45	9-10-89	1135.06	1135.06	1135.06	10-19-89	1.61	1.61	1.61
HPCI DRAIN POT EX.	CV 2301-34	9-10-89	0.5	0.5	0.5	9-10-89	0.5	0.5	0.5
DW PNEUMATIC	AO 4720, 4721	9-18-89	0.4	0.0	0.4	9-18-89	0.4	0.0	0.4
PAGE TOTAL		NA	2539.17	1841.78	2539.17	NA	47.26	29.10	47.26

APPROVED
SEP 09 1987
Q.C.O.S.R.

10/0168a

* Line is capped on both sides.

-2-

REFUEL OUTAGE LOCAL
LEAK RATE TEST SUMMARY

QTS 100-S1
Revision 7

UNIT One

DESCRIPTION	VALVE(S)/ PENETRATION	AS FOUND (SCFH) DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY	AS LEFT (SCFH) DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY
O_2 ANALYZER	AO 8801A, 8802A	10-10-89	0.0	0.0	0.0	10-10-89	0.0	0.0	0.0
O_2 ANALYZER	AO 8801B, 8802B	10-10-89	3.8	0	3.8	10-10-89	3.8	0.0	3.8
O_2 ANALYZER	AO 8801C, 8802C	10-10-89	0.7	0	0.7	10-10-89	0.7	0.0	0.7
O_2 ANALYZER	AO 8801D, 8802D	10-10-89	0.8	0	0.8	10-10-89	0.8	0.0	0.8
O_2 ANALYZER	AO 8803, 8804	10-10-89	UD	2.0	UD	11-11-89	2.0	0.0	2.0
TIP BALL VALVE	733-1	9-18-89	0.0	0.0	0.0	11-10-89	0.0	0.0	0.0
TIP BALL VALVE	733-2	9-18-89	4.5	4.5	4.5	11-10-89	0.0	0.0	0.0
TIP BALL VALVE	733-3	9-18-89	0.2	0.2	0.2	10-89	0.0	0.0	0.0
TIP BALL VALVE	733-4	9-18-89	0.3	0.3	0.3	11-10-89	0.0	0.0	0.0
TIP BALL VALVE	733-5	9-18-89	0.0	0.0	0.0	11-10-89	0.0	0.0	0.0
TIP PURGE CHECK	700-743	9-18-89	9.0	9.0	9.0	9-18-89	9.0	9.0	9.0
CAM	SO 2499-1A,2A	9-14-89	0.0	0.0	0.0	9-14-89	0.0	0.0	0.0
CAM	SO 2499-1B,2B	9-14-89	0.0	0.0	0.0	9-14-89	0.0	0.0	0.0
CAM	SO 2499-3A,4A	9-14-89	0.0	0.0	0.0	9-14-89	0.0	0.0	0.0
CAM	SO 2499-3B,4B	9-14-89	0.0	0.0	0.0	9-14-89	0.0	0.0	0.0
ACAD	AO 2599-2A,23A	9-19-89	4.0	0.0	4.0	9-25-89	5.0	0.9	4.1
ACAD	AO 2599-2B,23B	9-19-89	73.26	0.4	72.86	9-25-89	0.0	0.0	0.0
ACAD	AO 2599-3A,24A	9-19-89	0.7	0.0	0.7	9-25-89	0.4	0.0	0.4
ACAD	AO 2599-3B,24B	9-19-89	0.4	0.0	0.4	9-25-89	0.9	0.0	0.9
ACAD	AO 2599-4A,5A	9-14-89	4.5	0.6	3.9	9-14-89	4.5	0.6	3.9
ACAD	AO 2599-4B,5B	9-14-89	0.4	0.0	0.4	9-14-89	0.4	0.0	0.4
PAGE TOTAL		NA	UD	17.0	UD	NA	27.5	10.5	26.0

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REFUEL OUTAGE LOCAL
LEAK RATE TEST SUMMARY

QTS 100-S1
Revision 7

UNIT 1

DESCRIPTION	VALVE(S)/ PENETRATION	AS FOUND (SCFH) DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY	AS LEFT (SCFH) DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY
EQUIPMENT HATCH	X-1	9-10-89	0.0	0.0	0.0	11-13-89	0.0	0.0	0.0
DW ACCESS HATCH	X-4	11-10-89	1.0	0.5	1.0	11-10-89	1.0	0.5	1.0
CRD HATCH	X-6	10-4-89	0.0	0.0	0.0	[illegible]	0.0	0.0	0.0
TIP PENETRATION	X-35A	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
TIP PENETRATION	X-35B	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
TIP PENETRATION	X-35C	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
TIP PENETRATION	X-35D	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
TIP PENETRATION	X-35E	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
TIP PENETRATION	X-35F	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
TIP PENETRATION	X-35G	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
TORUS HATCH	X-200A	9-10-89	0.0	0.0	0.0	[illegible]	0.0	0.0	0.0
TORUS HATCH	X-200B	9-10-89	0.0	0.0	0.0	[illegible]	0.0	0.0	0.0
DRYWELL HEAD	----	9-10-89	12.0	~~12.0~~ 6.0	12.0	11-10-89	0.0	0.0	0.0
SHEAR LUG INSP. HATCH	SL-1	10-25-89	0.0	0.0	0.0	10-25-89	0.0	0.0	0.0
SHEER LUG INSP. HATCH	SL-2	10-25-89	0.0	0.0	0.0	10-25-89	0.0	0.0	0.0
SHEAR LUG INSP. HATCH	SL-3	10-25-89	0.0	0.0	0.0	10-25-89	0.0	0.0	0.0
SHEER LUG INSP. HATCH	SL-4	10-25-89	0.0	0.0	0.0	10-25-89	0.0	0.0	0.0
SHEAR LUG INSP. HATCH	SL-5	10-25-89	0.0	0.0	0.0	10-25-89	0.0	0.0	0.0
SHEER LUG INSP. HATCH	SL-6	10-25-89	0.0	0.0	0.0	10-25-89	0.0	0.0	0.0
SHEAR LUG INSP. HATCH	SL-7	10-26-89	0.0	0.0	0.0	10-26-89	0.0	0.0	0.0
SHEER LUG INSP. HATCH	SL-8	10-26-89	0.0	0.0	0.0	10-26-89	0.0	0.0	0.0
	PAGE TOTAL	NA	13.0	6.5	13.0	NA	1.0	0.5	1.0

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UNIT *One*

REFUEL OUTAGE LOCAL
LEAK RATE TEST SUMMARY

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DESCRIPTION	VALVE(S)/ PENETRATION	AS FOUND (SCFH) DATE	AS FOUND TOTAL	AS FOUND MINIMUM PATHWAY	AS FOUND MAXIMUM PATHWAY	AS LEFT (SCFH) DATE	AS LEFT TOTAL	AS LEFT MINIMUM PATHWAY	AS LEFT MAXIMUM PATHWAY
MECH. PENETRATION	X-7A	9-20-89	0.5	0.25	0.5	9-20-89	0.5	0.25	0.5
MECH. PENETRATION	X-7B	9-20-89	1.1	0.55	1.1	9-20-89	1.1	0.55	1.1
MECH. PENETRATION	X-7C	9-20-89	0	0	0	9-20-89	0.0	0.0	0.0
MECH. PENETRATION	X-7D	9-20-89	0.6	0.3	0.6	9-20-89	0.6	0.3	0.6
MECH. PENETRATION	X-8	9-20-89	0.6	0.3	0.6	9-20-89	0.6	0.3	0.6
MECH. PENETRATION	X-9A	9-20-89	0.2	0.2	0.2	9-20-89	0.2	0.1	0.2
MECH. PENETRATION	X-9B	9-20-89	0	0	0	9-20-89	0.0	0.0	0.0
MECH. PENETRATION	X-10	9-20-89	0	0	0	9-20-89	0.0	0.0	0.0
MECH. PENETRATION	X-11	9-20-89	0	0	0	9-20-89	0.0	0.0	0.0
MECH. PENETRATION	X-12	9-11-89	11.0	5.5	11.0	9-11-89	11.0	5.5	11.0
MECH. PENETRATION	X-13A	9-20-89	0.4	0.20	0.4	9-20-89	0.4	0.2	0.4
MECH. PENETRATION	X-13B	9-20-89	0	0	0	9-20-89	0.0	0.0	0.0
MECH. PENETRATION	X-14	9-11-89	0.6	0.3	0.6	[illegible]	~~0.6~~ 0.0	~~0.3~~ 0.0	~~0.6~~ 0.0 WEN 11-16-89
MECH. PENETRATION	X-23	9-20-89	3.7	1.85	3.7	9-20-89	3.7	1.85	3.7
MECH. PENETRATION	X-24	9-20-89	0	0	0	9-20-89	0.0	0.0	0.0
MECH. PENETRATION	X-25	9-20-89	3.5	1.75	3.5 [illegible]	9-20-89	3.5	1.75	3.5
MECH. PENETRATION	X-26	9-20-89	0.20	0.1	0.2	9-20-89	0.2	0.1	0.2
MECH. PENETRATION	X-36	9-20-89	0.2	0.1	0.2	9-20-89	0.2	0.1	0.2
MECH. PENETRATION	X-4[illegible]	9-20-89	0	0	0	9-20-89	0.0	0.0	0.0
MECH. PENETRATION	X-17	9-20-89	0	0	0	9-20-89	0.0	0.0	0.0
MECH. PENETRATION	X-16A	9-20-89	0.2	0.1	0.2	9-20-89	0.2	0.1	0.2
PAGE TOTAL		NA	22.8	11.4	24.6 ~~22.8~~ DSR 10-23-89	NA	22.2 ~~22.8~~	11.1 ~~11.4~~	22.2 ~~22.8~~ WEN 11-16-89

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REFUEL OUTAGE LOCAL
LEAK RATE TEST SUMMARY

QTS 100-S1
Revision 7

UNIT One

DESCRIPTION	VALVE(S)/ PENETRATION	AS FOUND (SCFH) DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY	AS LEFT (SCFH) DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY
MECH. PENETRATION	X-18B	9-11-89	17.0	8.5	17.0	*1			
ELECTRICAL PENETRATION	X-100A	9-22-89	0.4	0.2	0.4	9-22-89	0.4	0.2	0.4
ELECTRICAL PENETRATION	X-100B	9-22-89	0.4	0.2	0.4	9-22-89	0.4	0.2	0.4
ELECTRICAL PENETRATION	X-100C	9-22-89	0.2	0.1	0.2	9-22-89	0.2	0.1	0.2
ELECTRICAL PENETRATION (UNIT ONE ONLY)	X-100D	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
ELECTRICAL PENETRATION	X-100E	9-21-89	0.0	0.0	0.0	9-21-89	0.0	0.0	0.0
ELECTRICAL PENETRATION	X-100F	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
ELECTRICAL PENETRATION	X-100G	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
ELECTRICAL PENETRATION	X-101A	9-21-89	3.75	1.88	3.75	9-21-89	3.75	1.88	3.75
ELECTRICAL PENETRATION	X-101B	9-21-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
ELECTRICAL PENETRATION	X-101D	9-21-89	0.0	0.0	0.0	9-21-89	0.0	0.0	0.0
ELECTRICAL PENETRATION (UNIT ONE ONLY)	X-102A	9-21-89	0.9	0.45	0.9	9-21-89	0.9	0.45	0.9
ELECTRICAL PENETRATION (UNIT TWO ONLY)	X-102B								
ELECTRICAL PENETRATION	X-103	9-21-89	0.0	0.0	0.0	9-21-89	0.0	0.0	0.0
ELECTRICAL PENETRATION (UNIT TWO ONLY)	X-104A								
ELECTRICAL PENETRATION	X-104B	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
ELECTRICAL PENETRATION	X-104C	9-21-89	0.0	0.0	0.0	9-21-89	0.0	0.0	0.0
	PAGE TOTAL	NA	22.65	11.33	22.65	NA	5.65	2.83	5.65

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*1 Appendix J requirements met by Type "A" Test Reference Mod M-4-1-87-54A

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REFUEL OUTAGE LOCAL
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OTS 100-S1
Revision 7

UNIT *One*

DESCRIPTION	VALVE(S)/ PENETRATION	AS FOUND (SCFH) DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY	AS LEFT (SCFH) DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY
ELECTRICAL PENETRATION (UNIT TWO ONLY)	X-104D								
ELECTRICAL PENETRATION	X-104F	9-22-89	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
ELECTRICAL PENETRATION (UNIT ONE ONLY)	X-105A	9-22-87	0.0	0.0	0.0	9-22-89	0.0	0.0	0.0
ELECTRICAL PENETRATION (UNIT ONE ONLY)	X-105B	9-22-87	0.4	0.2	0.4	9-22-89	0.4	0.2	0.4
ELECTRICAL PENETRATION	X-105C	9-22-89	3.6	1.8	3.6	9-22-89	3.6	1.8	3.6
ELECTRICAL PENETRATION (UNIT ONE ONLY)	X-105D	9-21-89	0.0	0.0	0.0	9-21-89	0.0	0.0	0.0
ELECTRICAL PENETRATION (UNIT TWO ONLY)	X-106A								
ELECTRICAL PENETRATION (UNIT TWO ONLY)	X-106B								
ELECTRICAL PENETRATION	X-107A	9-21-87	0.0	0.0	0.0	9-21-87	0.0	0.0	0.0
ELECTRICAL PENETRATION (UNIT TWO ONLY)	X-107B								
TORUS PENETRATION	X-227A	10-12-89	0.0	0.0	0.0	10-12-89	0.0	0.0	0.0
TORUS PENETRATION	X-227B	10-12-89	0.0	0.0	0.0	10-12-89	0.0	0.0	0.0
'A' TORUS LEVEL FLANGES	----	10-14-89	0.0	0.0	0.0	10-14-89	0.0	0.0	0.0
PAGE TOTAL		NA	4.0	2.0	4.0	NA	4.0	2.0	4.0

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0483H/0214Z

UNIT ________

REFUEL OUTAGE LOCAL
LEAK RATE TEST SUMMARY

QTS 100-S1
Revision 7

DESCRIPTION	VALVE(S)/ PENETRATION	AS FOUND (SCFH)				AS LEFT (SCFH)			
		DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY	DATE	TOTAL	MINIMUM PATHWAY	MAXIMUM PATHWAY
'B' TORUS LEVEL FLANGES	----	10-14-89	0.0	0.0	0.0	10-14-89	0.0	0.0	0.0
SRM/IRM PURGE (UNIT TWO ONLY)	----	—	—	—	—	—	—	—	—
PERSONNEL INTERLOCK X-2	X-2	9-19-89	13.7	6.9	13.7	11-23-89	13.7	6.9	13.7
H_2/O_2 MONITORING SYSTEM (TOTAL)	----	~~10-13-89~~ 10-24-89	2.0	2.0	2.0	11-17-89	1.1	1.1	1.1
PAGE TOTAL		NA	15.7	8.9	15.7	NA	14.8	8.0	14.8
TEST TOTAL +		NA	UD	2456.46 *2459.16	UD **	NA	~~194.63~~ 213.73 JJR 11-24-89	89.92	~~186.31~~ 205.51 *208.21 JJR 11-24-89

*To determine the corrected leakage of the MSIV's (as if they had been tested at 48 PSIG), multiply by 1.58.

**When the maximum pathway leakage exceeds 0.6 La (293.75 SCFH), write an LER immediately.

+The test total is the sum of all page totals in the checklist (exclude MSIV's from all test totals).

Reference: QTS 150-8, "Determination of Total Containment Leak Rate."

* As Found and As left leakages of 1-46 99-46, 47 values were used to correct the totals.

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(final)

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APPENDIX B

TEST CORRECTION FOR SUMP LEVEL CHANGES

The total time measured leak rate, given by the functional requirements specification CECo Generic ILRT Computer Code, Document ID No. GN01405-0.0, Document ID No. ILRT-FRS-0.0 (see Appendix C), assumes that the containment free air space is 280,327.5 ft^3 at a water level in the reactor of 35", torus water level is zero, and that any change in reactor water level is due to a water leakage from the containment changing the free air volume. If the water leakage is from the containment and due to the operation of the shutdown cooling mode of RHR to maintain reactor water temperature, this leakage would not be representative of accident conditions when shutdown cooling would be isolated.

During the stabilization phase of the test considerable effort went into reducing the rate of level decline to approximately 0.14 inches/hour (3.5 ft^3/hr or 0.47 GPM) that was experienced during the test. Since the leakage could not be reduced further and level indication for the suppression pool indicated that most of the water leaving the reactor was not entering the suppression pool, but leaving containment, the computer program option for including the vessel level in the leak rate calculation was selected.

The test verification during the induced phase of the test demonstrates the accuracy of this model and the change was completely explained to the NRC inspector witnessing the test.

A hand calculation, using a complete water balance, is included in this Appendix to show that the leak rate reported is not significantly affected by a more detailed analysis, including changing subvolume free air space due to water leaking from the reactor vessel to the drywell sumps and suppression pool.

To perform a leak rate calculation with a changing containment free air space, the dry air mass for each containment subvolume is calculated using the following equation:

$$W_i = \frac{2.6995 \times P_i \times V_i}{(T_i + 459.69)}$$

where P_i = dry air pressure in i^{th} subvolume,

V_i = free air space in the i^{th} subvolume, and

T = average temperature in the i^{th} subvolume.

The total containment dry air mass is given by the sum of the dry air masses for all of the subvolumes.

$$W^t = \sum_{i=1}^{11} W_i$$

The computed leak rate will be the total time leak rate and is given by:

$$L^t = -\frac{2400}{H} \times \frac{W^t - W^\circ}{W^\circ}$$

where W° = dry air mass of the containment at the start of the test,

W^t = dry air mass of the containment at time t,

H = duration of the test from start to time t in hours, and

L^t = total time leak rate at time t.

There are 3 subvolumes to consider in evaluating the effects of water leakage from the vessel: the vessel itself (subvolume 11), the suppression pool (subvolume 10), and the subvolume for the drywell equipment drain sump (DWEDS) and the drywell floor drain sump (DWFDS) (subvolume 9). Any water leaking from the vessel in excess of that added to the sumps and suppression pool will be assumed to have leaked from the containment through the shutdown cooling mode of RHR.

DATE	TIME	DWFDS*	DWEDS*
11/14/89	1300	17.0	7.0
11/15/89	1630	20.0	19.0
Rate of level change (in/hr)		0.1824	0.7164
Rate of free air vol change (ft^3/hr);		0.6970	2.736

*The sumps are assumed to have filled at a constant rate during the period when the containment was fully pressurized. Each sump holds 1200 gallons and is 42" deep.

The following table gives the extrapolated values of the subvolume free air spaces using the above data:

SUBVOLUME NO. (i)	6 HOUR TEST V_i t=0	6 HOUR TEST V_i t=6	INDUCED TEST V_i t=0	INDUCED TEST V_i t=3
1	10,550	10,550	10,550	10,550
2	9,596	9,596	9,596	9,596
3	10,990	10,990	10,990	10,990
4	3,783	3,783	3,783	3,783
5	24,125	24,125	24,125	24,125
6	32,265	32,265	32,265	32,265
7	27,618	27,618	27,618	27,618
8	26,071	26,071	26,071	26,071
9*	8,790	8,769	8,764	8,752
10*	119,252	119,252	119,252	119,252
11*	5,158	5,187	5,187	5,211

* $V_9 = 6{,}901 - \frac{DWFDS}{42} \times 1200 \times .13368 - \frac{DWEDS}{42} \times 1200 \times .13368$

$V_{10} = 119{,}268 - 863.75 \left(\frac{ft^3}{in}\right) \times \text{Torus level (in)}$

$V_{11} = 6571.0 - 25(\text{Level} - 35)$

Using the subvolume vapor pressure, subvolume temperature, and the subvolume free air space, the dry air mass for each subvolume can now be calculated. The following table gives the necessary data for the start of the test as 00:35:48 on 11/14/89(Data Set No. 56).

SUBVOLUME NO.	VAPOR PRESSURE (PSI)	DRY AIR PRESSURE (PSIA)	SUBVOLUME TEMPERATURE °F	DRY AIR MASS (lbs. mass)
1	.671	64.217	103.0	3250.25
2	.609	64.279	111.835	2913.45
3	.609	64.279	107.315	3363.28
4	.609	64.279	105.230	1161.99
5	.568	64.320	104.093	7429.93
6	.552	64.336	100.612	10001.08
7	.566	64.322	96.182	8627.01
8	.486	64.402	88.132	8273.72
9	.486	64.402	89.205	2784.08
10	.571	64.317	84.748	38030.08
11	2.697	62.191	137.340	1450.43

$W° = \sum_{i=1}^{11} W_i = 87{,}285.$[illegible]

The following table gives the necessary data for the end of the 6 hour test at 06:45:48 on 11/14/89 (Data Set No. 93).

SUBVOLUME NO.	VAPOR PRESSURE (PSI)	DRY AIR PRESSURE (PSIA)	SUBVOLUME TEMPERATURE °F	DRY AIR MASS (lbs. mass)
1	.681	64.077	102.290	32[illegible].26
2	.623	64.135	111.850	2906.85
3	.623	64.135	107.820	3352.76
4	.623	64.135	105.820	1158.17
5	.591	64.167	104.597	7405.64
6	.572	64.186	101.457	9962.74
7	.583	64.175	96.440	8603.30
8	.489	64.269	87.465	8266.7
9	.489	64.269	88.870	2773.39
10	.547	64.211	83.402	38061.42
11	2.635	62.123	136.44	1459.19

$W^6 =$ 87,197.42

The leak rate for the 6 hour tcst is:

$$L^{6th} = -\frac{2400}{6.167} \times \frac{87,197.42 - 87,285.22}{87,197.42}$$

L^{6hr} = 0.3915 wt % / day (compared to 0.3954 comp:ted ignoring sump level changes)

The following table gives the necessary data for the start of the induced phase of the test at 08:25:48 on 11/14/89 (Data Set No. 103).

SUBVOLUME NO.	VAPOR PRESSURE (PSI)	DRY AIR PRESSURE (PSIA)	SUBVOLUME TEMPERATURE °F	DRY AIR MASS (lbs. mass)
1	.674	64.023	102.045	3245.94
2	.619	64.078	111.780	2904.62
3	.619	64.078	107.925	3349.16
4	.619	64.078	106.085	1156.60
5	.588	64.109	104.857	7395.53
6	.573	64.124	101.525	9951.91
7	.582	64.115	96.550	8594.02
8	.486	64.211	87.305	8261.66
9	.486	64.211	88.730	2770.01
10	.538	64.159	83.130	38049.66
11	2.609	62.088	136.060	1459.30

$W^{start}_{induced}$ = 87,138.41

The following table gives the necessary data for the end of the induced phase of the test at 11:45:48 on 11/14/89 (Data Set No. 123).

SUBVOLUME NO.	VAPOR PRESSURE (PSI)	DRY AIR PRESSURE (PSIA)	SUBVOLUME TEMPERATURE °F	DRY AIR MASS (lbs. mass)
1	.679	63.889	101.585	3241.80
2	.626	63.942	111.585	2899.44
3	.626	63.942	108.110	3340.96
4	.626	63.942	106.345	1153.62
5	.598	63.970	105.143	7375.76
6	.582	63.986	101.755	9926.42
7	.590	63.978	87.095	8574.08
8	.489	64.079	88.645	8247.84
9	.489	64.079	88.645	2760.96
10	.535	64.033	82.868	37993.27
11	2.564	62.004	135.390	1465.71

$W^{end}_{induced}$ = 86,979.86

The leak rate for the induced phase is

$$L\ (\text{induced}) = -\ \frac{2400}{3.333} \times \frac{(86979.86 - 87138.41)}{87138.41}$$

$= 1.3114$ wt % / day (compared to 1.3272 computed assuming constant reactor water level and ignoring sump level changes)

The above calculations show that the leakage from the reactor vessel did not significantly affect the reported leak rate. The difference between the leak rates computed using a complete correction for free air volume changes due to water leakage and the values computed ignoring the changes is less than 2%.

APPENDIX C

COMPUTATIONAL PROCEDURE

D. INPUT PROCESSING .

Calculations perfomed by the software are outlined below:

D.1 Average temperature of subvolume #i (T_i)
- The average of all RTD temps in subvolume #i

$$T_i = \frac{1}{N} \sum_{j=1}^{N} T_{i,j}$$

where N = The number of RTDs in subvolume #i

D.2 Average dew temperature of subvolume #i (D_i)
- The average of all dew cell dew temps in subvolume #i

$$D_i = \frac{1}{N} \sum_{j=1}^{N} D_{i,j}$$

where N = The number of RTDs in subvolume #i

D.3 Total corrected pressure #1, (P_1)

C_1 First correction factor for raw pressure #1, (from program initialization data set).

M_1 Second correction factor for raw pressure #1, (from program initialization data set).

Pr_1 Raw pressure #1, from BUFFILE.

$P_1 = C_1 + M_1 Pr_1/1000$, for 5 digit pressure transmitters

$P_1 = C_1 + M_1 Pr_1/10000$, for 6 digit pressure transmitters

D.4 Total corrected pressure #2, (P_2)

C_2 First correction factor for raw pressure #2, (from program initialization data set.

M_2 Second correction factor for raw pressure #2, (from program initialization data set.

Pr_2 Raw pressure #2, from BUFFILE.

$P_2 = C_2 + M_2 Pr_2/1000$, for 5 digit pressure transmitters

$P_2 = C_2 + M_2 Pr_2/10000$, for 6 digit pressure transmitters

D.5 Whole Containment Volume Weighted Average Temperature, (T_c)

Approximate Method

$$T_c = \sum_{i=1}^{N} f_i T_i$$

Exact Method

$$T_c = \frac{1}{\sum_{i=1}^{N} \frac{f_i}{T_i}}$$

where: f_i = The volume fraction of the i^{th} subvolume
N = The total # of subvolumes in containment

D.6 Average Vapor Pressure of Subvolume i, (Curve fit of ASME steam tables.) (Pv_i)

$$Pv_i = 0.01529125 + 0.001653476\, D_i - 1.44734 \times 10^{-6} (D_i)^2 + 7.081828 \times 10^{-7} (D_i)^3 - 2.28128 \times 10^{-9} (D_i)^4 + 3.03544 \times 10^{-11} (D_i)^5$$

D.7 Whole Containment Average Vapor Pressure, (Pv_c)

Approximate Method

$$Pv_c = \sum_{i=1}^{N} f_i Pv_i$$

Exact Method

$$Pv_c = T_c \sum_{i=1}^{N} \frac{f_i Pv_i}{T_i}$$

N = The total of subvolumes in containment
f_i = Volume fraction of the i^{th} subvolume

D.8 Whole Containment Average Dew Temperature, (D_c)

Approximate Method

$$D_c = \sum_{i=1}^{N} f_i D_i$$

Exact Method: The whole containment average vapor pressure, (Pv_c) calculated with the exact method is used to find D_c. An initial value of D_c is guessed and used with the equation in D.6 to calculate Pv_c. This value is then compared to the known value from D.7. A new value of D_c is guessed and the process is repeated until a value of D_c is found that results in a calculated value of Pv_c that is within .0001 psia of the value from D.7.

D.9 Average total containment pressure, (P)

$$P = (P_1 + P_2) / 2$$

Average total containment dry air pressure, (P_d)

$$P_d = P - Pv_c$$

D.10 Total Containment dry air mass, (M)

Type 1:

$$M = \frac{P_d V_c}{R T_c}$$

where: R = Perfect gas constant, V_c = Total containment free volume.

Type 2: Type 2 dry air mass accounts for changes in Reactor Vessel level.

For uncorrected dry air mass, (Type 1) the below definitions apply.

$$V_c = \sum_{i=1}^{N} V_i \quad \text{and} \quad f_i = V_i/V_c$$

where V_i is the user entered free volume in subvolume i.

For corrected dry air mass, (Type 2) the same definitions for V_c and f_i apply, except that one of the V_is is corrected for changes in vessel level. If k is the subvolume number of the corrected subvolume then:

$$V_k = V_{ko} - a(C - b)$$

a is the number of cubic feet of free volume per inch of vessel level.

b is the base level of the reactor vessel, in inches.

C is the actual water level in the reactor vessel, in inches.

V_{ko} is the volume of the subvolume k when C equals b.

The volume fractions (f_i) are then calculated with the corrected volume, and all other calculations are subsequently performed as previously specified for Type 1 dry air mass.

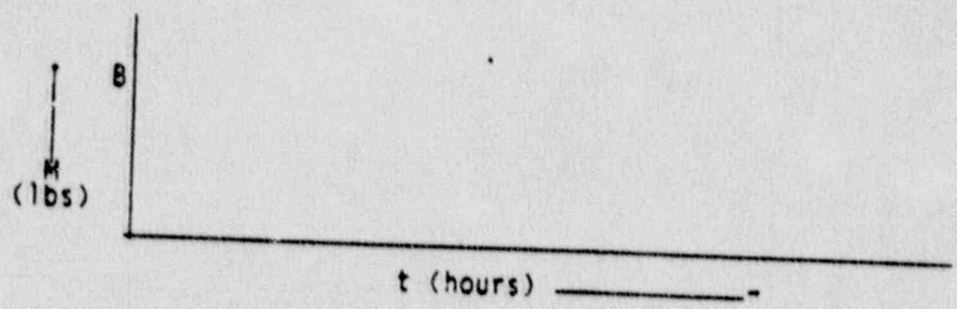
D.11 Leakrate Calculations using Mass-Plot Method:

This method assumes that the leakage rate is constant during the testing period, a plot of the measured contained dry air mass versus time would ideally yield a straight line with a negative slope.

Based on the least squares fit to the data obtained, the calculated containment leakage rate is obtained from the equation:

$$M = At + B$$

Where
- M = containment dry air mass at time t (lbs.)
- B = calculated dry air mass at time $t=0$ (lbs.)
- A = calculated leakage rate (lbs/hr)
- t = time interval since start of test (hours)



The values of the constants A and B such that the line is linear least squares best fitted to the leak rate data are:

$$A = \frac{N\Sigma(t_i)(M_i) - (\Sigma t_i)(\Sigma M_i)}{N\Sigma(t_i)^2 - (\Sigma t_i)^2}$$

$$B = \frac{\Sigma M_i - A\Sigma t_i}{N}$$

By definition, leakage out of the containment is considered positive leakage. Therefore, the statistically averaged least squares containment leakage rate in weight percent per day is given by:

$$L = (\text{[illegible]} (2400)/B \qquad \text{(weight \%/day)}$$

In order to calculate the 95% confidence limit of the least squares averaged leak rate, the standard deviation of the least squares slope and the student's T-Distribution function are used as follows:

$$\sigma = \left[\frac{1}{(N-2)} \left(\frac{N\Sigma(M_i)^2 - (\Sigma M_i)^2}{N\Sigma(t_i)^2 - (\Sigma t_i)^2} - A^2 \right) \right]^{1/2} \frac{(2400)}{B} \qquad \text{(weight \% per day)}$$

$$UCL = L + \sigma\,(T)$$

where

$$T = \frac{1.6449(N-2) + 3.5283 + 0.85602/(N-2)}{(N-2) + 1.2209 - 1.5162/(N-2)}$$

N	=	Number of data sets	
t_i	=	test duration at the i^{th} data set	(hours)
σ	=	standard deviation of least squares slope	(weight%/day)
T	=	Value of the single-sided T-Distribution function with 2 degrees of freedom	
L	=	calrulated leak rate in weight %/day	
UCL	=	95% upper confidence limit	(%/day)
B	=	calculated containment dry air mass at time $t=0$	(lbs.)

D.12 Point to Point Calculations

This method calculates the rate of change with respect to time of dry air mass using the Point to Point Method.

For every data set, the rate of change of dry air mass between the most recent, (t_i) and the previous time (t_{i-1}) is calculated using the two point method shown below:

$$\dot{M}_i = \frac{2400}{(t_i - t_{i-1})} (1 - M_i/M_{i-1})$$

Then the least square fit of the point to point leakrates is calculated as described for dry air masses in section D.11

D.13 Total Time Calculations

This method calculates the rate of change with respect to time of dry air mass using the Total Time Method

Initially, a reference time (t_r) is chosen. For every data set the rate of change of dry air mass between t_r and the most recent time, t_i is calculated using the two point method shown below.

$$\dot{M}_i = \frac{2400}{(t_i - t_r)} \quad (1 - M_i/M_r)$$

Then the least squares fit and 95% UCL of the Total Time leakrates are calculated as shown below:

$$B = \frac{\Sigma \dot{M}_i \, \Sigma(t_i)^2 - \Sigma t_i \, \Sigma \dot{M}_i \, t_i}{N \, \Sigma (t_i)^2 - (\Sigma t_i)^2}$$

$$A = \frac{(N \, \Sigma t_i \dot{M}_i - \Sigma t_i \, \Sigma \dot{M}_i)}{N \, \Sigma (t_i)^2 - (\Sigma t_i)^2}$$

$$L = B + At$$

$$T = \frac{1.6449(N-2) + 3.5283 + 0.85602/(N-2)}{(N-2) + 1.2209 - 1.5162/(N-2)}$$

Note: N is the number of data sets minus one.

$$F = \frac{1}{N} + \frac{(t_p - \Sigma (t_i) / N)^2}{\Sigma (t_i)^2 - (\Sigma t_i)^2 / N}$$

$$\sigma = \sqrt{\frac{F}{N}} \quad \sqrt{\Sigma (\dot{M}_i)^2 - B \Sigma \dot{M} - A \Sigma \dot{M}_i t_i}$$

$$UCL = L + T\sigma$$

Note: This equation is calculated for information only from the start of the test up to 24 hours, then it becomes the official leakrates for future times.

D.14 BN-TOP-1

This method calculates the rate of change with respect to the time of dry air mass using the Total Time Method.

Initially, a reference time (t_r) is chosen. For every data set the rate of change of the data item between t_r and the most recent time, (t_i) is calculated using the two point method shown below:

$$\dot{M}_i = \frac{2400}{(t_i - t_r)} (1 - M_i/M_r)$$

Then the least squares fit of the Total Time leakrates and the BN-TOP-1 95% UCLs are calculated as shown below.

$$B = \frac{(\Sigma \dot{M}_i \Sigma (t_i)^2 - \Sigma t_i \Sigma \dot{M}_i t_i)}{N \Sigma (t_i)^2 - (\Sigma t_i)^2}$$

Note: N is the number of data sets minus one.

$$A = \frac{(N \Sigma t_i \dot{M}_i - \Sigma t_i \Sigma \dot{M}_i)}{N \Sigma (t_i)^2 - (\Sigma t_i)^2}$$

$$L = B + At$$

$$T = 1.95996 + \frac{2.37226}{(N - 2)} + \frac{2.8225}{(N - 2)^2}$$

$$F = 1 + \frac{1}{N} + \frac{(t_p - \Sigma (t_i) / N)^2}{\Sigma (t_i)^2 - (\Sigma t_i)^2 / N}$$

$$\sigma = \sqrt{\frac{F}{N}} \sqrt{\Sigma (\dot{M}_i)^2 - B \Sigma \dot{M}_i - A \Sigma \dot{M}_i t_i}$$

$$UCL = L + T\sigma$$

Note: This equation is calculated for information only from the start of the test up to 24 hours, then it becomes the official leakrates for future times.

D.15 Temperature stabilization checking per ANSI 56.8-1981

T_i Weighted average containment air temperature at hour i.

$T_{i,n}$ Rate of change of weighted average containment air temperature over an n hour period at hour i, using a two point backwards difference method,

$$T_{i,n} = \frac{T_i - T_{i-n}}{n}$$

Z_i is the ANSI 56.8-1981 Temperature stabilization criteria at hour i.

$Z_i = | T_{i,4} - T_{i,1} |$ i must be ≥ 4.

Per ANSI 56.8-1981, Z must be less than or equal to 0.5 °F/hr

NOTE: If the data sampling interval is less than one hour, then:

Option #1 Use data collected at hourly intervals

Option #2 Use average of data collected in previous hour for that hour's data.

D.16 Calculation of Instrument Selection Guide, (ISG)

$$ISG = \frac{2400}{t} \sqrt{\frac{2}{N_p}(e_p/p)^2 + \frac{2}{N_r}(e_r/T)^2 + \frac{2}{N_d}(e_d/p)^2}$$

where: t is the test time, in hours
p is test pressure, psia
T is the volume weighed average containment temperature, °R
N_p is the number of pressure transmitters
N_r is the number of RTDs
N_d is the number of dew cells
e_p is the combined pressure transmitters' error, psia
e_r is the combined RTDs' error, °R
e_d is the combined dew cells' error, °R

$$e_p = \sqrt{(S_p)^2 + (RP_p + RS_p)^2}$$

where: S_p is the sensitivity of a pressure transmitter
RP_p is the repeatability of a pressure transmitter
RS_p is the resolution of pressure transmitter

$$e_r = \sqrt{(S_r)^2 + (RP_r + RS_r)^2}$$

where: S_r is the sensitivity of an RTD
RP_r is the repeatability of an RTD
RS_p is the resolution of an RTD

$$e_d = \frac{\Delta P_v}{\Delta T_d}\Bigg|_{T_d} \sqrt{(S_d)^2 + (RP_d + RS_d)^2}$$

where: S_d is the sensitivity of a dew cell
RP_d is the repeatability of a dew cell
RS_d is the resolution of a dew cell

$$\frac{\Delta P_v}{\Delta T_d}\Bigg|_{T_d} = \frac{\text{change in vapor pressure}}{\text{change in saturation temperature}}$$

The above ratio is from ASME steam tables and evaluated at the containment's saturation temperature at that time.

D.17 BN-TOP-1 Temperature Stabilization Criteria Calculation

A. The rate of change of temperature is less than 1 °F/Hr averaged over the last two hours.

$K_1 = |T_i - T_{i-1}|$ $K_2 = |T_{i-1} - T_{i-2}|$
K_1 and K_2 must both be less than 1 to meet the criteria listed in A.

B. The rate of change of temperature changes less than 0.5 °F/hour/hour averaged over the last two hours.

$$K_1 = (T_i - T_{i-1})/(t_i - t_{i-1})$$
$$K_2 = (T_{i-1} - T_{i-2})/(t_{i-1} - t_{i-2})$$
$$Z = |(K_1 - K_2)/(t_i - t_{i-1})|$$

Z must be less than 0.5 to meet the criteria listed in B.

D.18 Reactor Vessel Free Volume Mass Calculation

As shown in section D.10, the free volume of the Reactor Vessel subvolume κ is given by the below equation.

$$V_\kappa = V_{\kappa 0} - a\,(c-b)$$

The dry air mass in subvolume κ can then be written as:

$$M_\kappa = 144\,(\bar{P}-\bar{P}_{v\kappa})\,V_\kappa/R\bar{T}_\kappa$$

Where: M_κ is the dry air mass in subvolume κ, (lbm)

R is the gas constant of air

$\overline{T_\kappa}$ is the average temperature of subvolume κ, (°R)

$\overline{P_{v\kappa}}$ is the average vapor pressure of subvolume κ, (pisa)

$\bar{P}$ is the average containment pressure, (psia)

V_κ is the free air volume in subvolume κ, (ft^3)

D.19 Torus Free Volume Calculation

Free volume calculations of the Torus rely upon narrow range Torus water level inputs. These values range between plus and minus five inches. It is assumed that the Torus subvolume free air volume is that subvolume's volume when the Torus level equals zero. The user may enter three constants to model the variation of Torus air volume with water level.

The equations for Torus free volume in subvolume t are given:

$$V_t = V_{to} - (aL + bL + cL^3) \text{ when } L \geq 0$$
$$V_t = V_{to} + (-aL + bL^2 - cL^3) \text{ when } L \leq 0$$

The dry air mass in subvolume t can then be written as:

$$M_t = 144\ (\bar{P}-\bar{P}_{vt})\ V_t/R\bar{T}_t$$

Where: Mt is the dry air mass in subvolume τ, (lbm)

$\bar{P}$ is the average containment pressure, (psia)

$\overline{P_{vt}}$ is the average vapor pressure of subvolume t (pisa)

V_t is the free volume in subvolume t, (ft^3)

R is the gas constant of air

T_t is the average temperature in subvolume t (^oR)

L is the Torus level, (inches)

a,b,c are Torus level constants

V_{to} is the free volume in subvolume T when L equals zero, taken from standard free volume inputs, (ft^3)

E. OUTPUTS

E.1 OUTPUT DEVICE TYPES: The below output devices shall be supported. There are no special constraints on output device locations.

PRINTERS:	PRIME High Speed Line Printer	
	OKIDATA 2410	
	OKIDATA 93	
	LA120	
PLOTTERS:	Hewlet Packard	7475A 8.5" X 11"
	Hewlet Packard	7585A 8.5" X 11"
	Hewlet Packard	7585A 11" X 17"
CRTs:	Wyse Wy75	
	View Point 60	
	Ampex Dialogue 80 & 81	
GRAPHICS TERMINALS:	PRIME	PT200
	RamTech	6200
	RamTech	6211
	Tektronix	4107
	Tektronix	4208
	Tektronix	4014

APPENDIX D

INSTRUMENT ERROR ANALYSIS

IPCLRT SAMPLE ERROR ANALYSIS
FOR SHORT DURATION TEST

A. ACCURACY ERROR ANALYSIS

Per Topical Report BN-TOP-1 the measured total time leak rate (M) in weight percent per day is computed using the Absolute Method by the formula:

$$M\ (\%\ /\ DAY) = \frac{2400}{H} * \left(1 - \frac{T_1 \bar{P}_N}{T_N \bar{P}_1}\right) \quad (1)$$

where: $\bar{P}_1$ = total (volume weighted) containment dry air pressure (PSIA) at the start of the test;

$\bar{P}_N$ = total (volume weighted) containment dry air pressure (PSIA) at data point N after the start of the test;

H = test duration from the start of the test to data point N in hours;

T_1 = containment volume weighted temperature in °R at the start of the test;

T_N = containment volume weighted temperature in °R at the data point N.

The following assumptions are made:

$\bar{P}_1 = \bar{P}_N = \hat{P}$ where $\hat{P}$ is the average dry air pressure of the containment (PSIA) during the test;

$T_1 = T_N = \hat{T}$ where $\hat{T}$ is the average volume weighted primary containment air temperature (°R) during the test;

$P_1 = P_N$ where P is the total containment atmospheric pressure (PSIA);

$P_{V1} = P_{VN}$ Where P_V is the partial pressure of water vapor in the primary containment.

Taking the partial derivative in terms of pressure and temperature of (1) equation and substituting in the above assumptions yields the following equation found in Section 4.5 of BN-TOP-1 Rev. 1:

$$e_M = \pm \frac{2400}{H} * \left[2\left(\frac{e_p}{\hat{P}}\right)^2 + 2\left(\frac{e_t}{\hat{T}}\right)^2 \right]^{1/2}$$

where e_p = the error in the total pressure measurement system,

$e_p = \pm [(e_{p_T})^2 + (e_{p_V})^2]^{1/2}$;

e_{p_T} = (instrument accuracy error) / $\sqrt{\text{no. of inst.}}$ in measuring total containment pressure;

e_{p_V} = (instrument accuracy error) / $\sqrt{\text{no. of inst.}}$ in measuring vapor partial pressure;

e_T = (instrument accuracy error) / $\sqrt{\text{no. of inst.}}$ in measuring containment temperature;

e_M = the error in the measured leak rate;

H = duration of the test.

NOTE

Subvolume #11, the free air space above the water in the reactor vessel, is treated separately from the rest of the containment volume. The reason for the separate treatment is that neither the air temperature or the partial pressure of water vapor is measured directly. The temperature of the air space is assumed to be the temperature of the reactor water, as measured in the shutdown cooling or clean-up demineralizer piping before the heat exchangers. The partial pressure of water vapor is computed assuming saturation conditions at the temperature of the water. Volume weighting the errors for the two volumes (Subvolume #11 and Subvolumes #1-10) is the method used.

B. EQUIPMENT SPECIFICATIONS

INSTRUMENT	RTD (°F)	PPG (PSIA)	DEWCELL (°F)	FLOWMETER (SCFM)	THERMOCOUPLE (°F)
Range	50-135	0.4-150	40 - 100	0.90-11.40	0 - 600
Accuracy	±0.25	±0.015%	±1.5	±1.0% Max Flow	±2.0
Repeat-ability	±0.01	±0.001%	±0.003	±0.02	±.10

C. COMPUTATION OF INSTRUMENT ACCURACY UNCERTAINTY

1. Computing " e_T "

Volume Fraction for Volume #11 = .02344
Volume Fraction for Volumes #1-10 = .97656

$$e_T = \pm \left(0.97656 * \frac{0.25}{\sqrt{30}} + .02344 * \frac{2.0}{\sqrt{1}}\right)$$

$e_T = \pm$ 0.0914°R

2. Computing " e_{p_T} "

$$e_{p_T} = \pm \frac{0.015}{\sqrt{2}}$$

$e_{p_T} = \pm$ 0.0106 PSIA

3. Computing " e_{p_V} "

At a dewpoint of 65°F (assumed), an accuracy of ± 1°F corresponds to ± .011 PSIA. For subvolume #11 at an average temperature of 140°F, an accuracy of ± 2°F corresponds to ± .150 PSI.

$$e_{p_V} = \pm \left(0.97656 * \frac{0.011}{\sqrt{10}} + 0.02344 * \frac{0.150}{\sqrt{1}}\right)$$

$e_{p_V} = \pm$ 0.0069 PSIA

4. Computing " e_p "

$$e_p = \pm \left[(0.0106)^2 + (0.0069)^2 \right]^{1/2}$$

$e_p = \pm$ 0.0126 PSIA

5. Computing total instrument accuracy uncertainty " e_M^A "

$$e_M^A = \pm \frac{2400}{H} * \left[2 * \left(\frac{0.0126}{63.0}\right)^2 + 2 * \left(\frac{0.0914}{544.7}\right)^2 \right]^{1/2}$$

assuming $\hat{P} = 63.0$ PSIA

$\hat{T} = 544.7°R$

Therefore, for a 6 hour test (H),

$e_M^A = \pm 0.1447$ wt % / DAY

D. COMPUTATION OF INSTRUMENT REPEATABILITY UNCERTAINTY

1. Computing " e_T "

$$e_T = \pm \frac{0.01}{\sqrt{30}}$$

$e_T = \pm 0.0018°R$

2. Computing " e_{p_T} "

$$e_{p_T} = \pm \frac{0.001}{\sqrt{2}}$$

$e_{p_T} = \pm 7.071X10^{-4}$ PSIA

3. Computing " e_{p_V} "

$$e_{p_V} = \pm (.97656 * \frac{.006}{\sqrt{10}} + .02344 * \frac{.008}{\sqrt{1}})$$

$e_{p_V} = \pm 0.0020$ PSIA

4. Computing " e_p "

$e_p = [(7.071X10^{-4})^2 + (0.0020)^2]^{1/2}$

$e_p = \pm 0.00212$ PSIA

5. Computing the total instrument repeatability uncertainty " e_M^R"

$$e_M^R = \frac{2400}{H} * \left[2 \left(\frac{0.00212}{63.0}\right)^2 + 2 \left(\frac{0.0018}{544.7}\right)^2 \right]^{1/2}$$

Therefore, for a 6 hour test,

$$e_M^R = \pm 0.01912 \text{ wt \% / DAY}$$

E. <u>COMPUTING TOTAL INSTRUMENT UNCERTAINTY</u>

$$e_M = \pm 2 * [(e_M^A)^2 + (e_M^R)^2]^{1/2}$$

$$e_M = \pm 2 * [(0.1447)^2 + (0.01912)^2]^{1/2}$$

$e_M = \pm$ 0.0191 weight % / DAY for a 6 hour test.

APPENDIX E

BN-TOP-1, REV. 1 ERRATA

APPENDIX E

BN-TOP-1, REV. 1 ERRATA

The Commission has approved short duration testing for the IPCLRT provided the Station uses the general test method outlined in the BN-TOP-1, Rev. 1 topical report. The primary difference between that method and the ones previously used is in the statistical analysis of the measured leak rate data.

Without making any judgments concerning the validity of this test method, certain errors in the editing of the mathematical expressions were discovered. The intent here is not to change the test method, but rather to clarify the method in a mathematically precise manner that allows its implementation. The errors are listed below.

<u>EQUATION 3A, SECTION 6.2</u>

Reads: $L_i = A + B\ t_i$

Should Read: $L_i = A_i + B_i\ t_i$

Reason: The calculated leak rate (L_i) at time t_i is computed using the regression line constants A_i, B_i (computed using equations 6 and 7). The summation signs in equation 6 are defined as $\Sigma = \sum_{i=1}^{n}$, where n is the number of data sets up until time t_i. The regression line constants change each time a new data set is received. The calculated leak rate is not a linear function of time.

<u>PARAGRAPH FOLLOWING EQ. 3A, SECTION 6.2</u>

Reads: The deviation of the measured leak rate (M) from the calculated leak rate (L) is shown graphically on Figure A.1 in Appendix A and is expressed as:

Deviation = $M_i - L_i$

Should Read: The deviation of the measured leak rate (M_i) from the regression line (N_i) is shown graphically on Figure A.1 in Appendix A and is expressed as:

Deviation = $M_i - N_i$

where $N_i = A_p + B_p * t_i$,

A_p, B_p = Regression line constants computed from all data sets available from the start of the test to the last data set at time t_p,

t_i = time from the start of the test to the ith data set.

Reason: The calculated leak rate as a function of time during the test is based on a regression line. The regression line constants, A_i and B_i, are changing as each additional data set is received. Equation 3A is used later in the test to compute the upper confidence limit as a function of time. For the purpose of this calculation, it is the deviation from the last computed regression line at time t_p that is important.

EQUATION 4, SECTION 6.2

Reads: $SSQ = \Sigma (M_i - L_i)^2$

Should Read: $SSQ = \Sigma (M_i - N_i)^2$

Reason: Same As Above

EQUATION 5, SECTION 6.2

Reads: $SSQ = \Sigma [M_i - (A + Bt_i)]^2$

Should Read: $SSQ = \Sigma [M_i - (A_p + B_p * t_i)]^2$

Reason: Same As Above

EQUATION ABOVE EQUATION 6, SECTION 6.2

Reads: $$B = \frac{(t_i - \bar{t})(M_i' - \bar{M})}{\Sigma(t_i - t)^2}$$

Should Read: $$B_i = \frac{\Sigma[(t_i - \bar{t})(M_i - \bar{M})]}{\Sigma(t_i - \bar{t})^2}$$

Reason: Regression line constant B_i changes over time (as a function of t_p) as each additional data set is received. Bar of "t" left out of denominator. Summation signs omitted.

EQUATION 6, SECTION 6.2

Reads: $$B = \frac{n \Sigma t_i M_i - (\Sigma t_i) (\Sigma M_i)}{n \Sigma t_i^2 - (\Sigma t_i)^2}$$

Should Read: $$B_i = \frac{n \Sigma t_i M_i - (\Sigma t_i) (\Sigma M_i)}{n \Sigma t_i^2 - (\Sigma t_i)^2}$$

Reason: Same As Above

EQUATION 7, SECTION 6.2

Reads: $A = \bar{M} - B \bar{t}$

Should Read: $A_i = \bar{M} - B_i \bar{t}$

Reason: Same As Above

EQUATION 10, SECTION 6.2

Reads: $$A = \frac{(\Sigma M_i)(\Sigma t_i^2) - (\Sigma t_i)(\Sigma t_i M_i)}{n \Sigma t_i^2 - (\Sigma t_i)^2}$$

Should Read: $$A_i = \frac{(\Sigma M_i)(\Sigma t_i^2) - (\Sigma t_i)(\Sigma t_i M_i)}{n \Sigma t_i^2 - (\Sigma t_i)^2}$$

Reason: Same As Above

EQUATION 13, SECTION 6.3

Reads: $$\sigma^2 = s^2 \left[1 + \frac{1}{n} + \frac{(t_p - t)^2}{(t_i - t)^2}\right]$$

Should Read: $$\sigma^2 = s^2 \left[1 + \frac{1}{n} + \frac{(t_p - \bar{t})^2}{\Sigma (t_i - \bar{t})^2}\right]$$

where t_p = time from the start of the test of the last data set for which the standard deviation of the measured leak rates (M_i) from the regression line (N_i) is being computed;

t_i = time from the start of the test of the i^{th} data set;

n = number of data sets to time t_p;

$\Sigma = \sum_{i=1}^{n}$; and

$\bar{t} = \frac{1}{n} \Sigma t_i$.

Reason: Appears to be error in editing of the report. Report does a poor job of defining variables.

EQUATION 14, SECTION 6.3

Reads: $\sigma = s [1 + \frac{1}{n} + \frac{(t_p - t)^2}{(t_i - t)^2}]$

Should Read: $\sigma = s [1 + \frac{1}{n} + \frac{(t_p - \bar{t})^2}{\Sigma (t_i - \bar{t})^2}]$

Reason: Same As Above

EQUATION 15, SECTION 6.3

Reads: Confidence Limit = L ± T

Should Read: Confidence Limits = L ± T x σ

where L = calculated leak rate at time t_p,

T = T distribution value based on n, the number of data sets received up until time t_p;

σ = standard deviation of measured leak rate values (M_i) about the regression line based on data from the start of the test until time t_p.

Reason: Same As Above

EQUATION 16, SECTION 6.3

Reads: UCL = L + T

Should Read: UCL = L + T * σ

Reason: Same As Above

EQUATION 17, SECTION 6.3

Reads: LCL = L - T

Should Read: LCL = L - T * σ

Reason: Same As Above

APPENDIX F

TYPE A TEST RESULTS
USING MASS - PLOT METHOD
MEASURED LEAK RATE PHASE

TYPE A TEST RESULTS
USING MASS-PLOT METHOD
MEASURED LEAK RATE PHASE

DATA SET #	DATA SET TIME DAY HH MM SS	TEST TIME, (HR)	DRY AIR MASS, (LBM)	LEAK RATE (%/D)	95% UP CONF LIMIT, (%/D)
56	319 00:35:48	0.000	0.87912484E+05		
57	319 00:45:48	0.167	0.87911078E+05		
58	319 00:55:48	0.333	0.87907922E+05	0.3739E+00	0.1088E+01
59	319 01:05:48	0.500	0.87907750E+05	0.2844E+00	0.4718E+01
60	319 01:15:48	0.667	0.87903015E+05	0.3646E+00	0.5038E+01
61	319 01:25:48	0.833	0.87900422E+05	0.3963E+00	0.4876E+01
62	319 01:35:48	1.000	0.87899000E+05	0.3901E+00	0.4515E+01
63	319 01:45:48	1.167	0.87897437E+05	0.3762E+00	0.4230E+01
64	319 01:55:48	1.333	0.87895453E+05	0.3664E+00	0.4034E+01
65	319 02:05:48	1.500	0.87891515E+05	0.3766E+00	0.4075E+01
66	319 02:15:48	1.667	0.87889500E+05	0.3800E+00	0.4052E+00
67	319 02:25:48	1.833	0.87887484E+05	0.3801E+00	0.4008E+00
68	319 02:35:48	2.000	0.87885328E+05	0.3793E+00	0.3966E+00
69	319 02:45:48	2.167	0.87882234E+05	0.3824E+00	0.3974E+00
70	319 02:55:48	2.333	0.87881062E+05	0.3796E+00	0.3929E+00
71	319 03:05:48	2.500	0.87878797E+05	0.3776E+00	0.3893E+00
72	319 03:15:48	2.667	0.87875578E+05	0.3792E+00	0.3896E+00
73	319 03:25:48	2.833	0.87874078E+05	0.3779E+00	0.3872E+00
74	319 03:35:48	3.000	0.87872437E+05	0.3753E+00	0.3840E+00
75	319 03:45:48	3.167	0.87869219E+05	0.3755E+00	0.3833E+00
76	319 03:55:48	3.333	0.87867828E+05	0.3738E+00	0.3811E+00
77	319 04:05:48	3.500	0.87866890E+05	0.3699E+00	0.3775E+00
78	319 04:15:48	3.667	0.87865375E+05	0.3656E+00	0.3738E+00
79	319 04:25:48	3.833	0.87861703E+05	0.3647E+00	0.3722E+00
80	319 04:35:48	4.000	0.87858594E+05	0.3653E+00	0.3722E+00
81	319 04:45:48	4.167	0.87857391E+05	0.3643E+00	0.3707E+00
82	319 04:55:48	4.333	0.87856172E+05	0.3622E+00	0.3685E+00
83	319 05:05:48	4.500	0.87852875E+05	0.3619E+00	0.3677E+00
84	319 05:15:48	4.667	0.87851609E+05	0.3605E+00	0.3661E+00
85	319 05:25:48	4.833	0.87847750E+05	0.3612E+00	0.3664E+00
86	319 05:35:48	5.000	0.87848172E+05	0.3591E+00	0.7644E+00
87	319 05:45:48	5.167	0.87834375E+05	0.3682E+00	0.3784E+00
88	319 05:55:48	5.333	0.87843000E+05	0.3662E+00	0.3760E+00
89	319 06:05:48	5.500	0.87827031E+05	0.3759E+00	0.3891E+00
90	319 06:15:48	5.667	0.87837875E+05	0.3738E+00	0.3864E+00
91	319 06:25:48	5.833	0.87838219E+05	0.3701E+00	0.3825E+00
92	319 06:35:48	6.000	0.87835672E+05	0.3671E+00	0.3792E+00
93	319 06:45:48	6.167	0.87823172E+05	0.3714E+00	0.3836E+00

TYPE A TEST RESULTS
USING MASS - PLOT METHOD
INDUCED LEAK PHASE

DATA SET #	DATA SET TIME DAY HH MM SS	TEST TIME, (HR)	DRY AIR MASS, (LBM)	LEAK RATE (%/D)	95% UP CONF LIMIT, (%/D)
103	319 08:25:48	0.000	0.87765844E+05		
104	319 08:35:48	0.167	0.87758297E+05		
105	319 08:45:48	0.334	0.87751000E+05	0.1215E+01	0.1316E+01
106	319 08:55:48	0.500	0.87742625E+05	0.1262E+01	0.1344E+01
107	319 09:05:48	0.667	0.87734656E+05	0.1280E+01	0.1325E+01
108	319 09:15:48	0.834	0.87727187E+05	0.1277E+01	0.1304E+01
109	319 09:25:48	1.000	0.87718734E+05	0.1288E+01	0.1311E+01
110	319 09:35:48	1.167	0.87712703E+05	0.1268E+01	0.1296E+01
111	319 09:45:48	1.334	0.87702984E+05	0.1280E+01	0.1305E+01
112	319 09:55:48	1.500	0.87697094E+05	0.1269E+01	0.1292E+01
113	319 10:05:48	1.667	0.87688109E+05	0.1273E+01	0.1291E+01
114	319 10:15:48	1.834	0.87680969E+05	0.1271E+01	0.1286E+01
115	319 10:25:48	0.000	0.87673453E+05	0.1268E+01	0.1281E+01
116	319 10:35:48	2.167	0.87666390E+05	0.1264E+01	0.1276E+01
117	319 10:45:48	2.334	0.87658125E+05	0.1263E+01	0.1273E+01
118	319 10:55:48	2.500	0.87639219E+05	0.1303E+01	0.1345E+01
119	319 11:05:48	2.667	0.87630922E+05	0.1332E+01	0.1378E+01
120	319 11:15:48	2.834	0.87623859E+05	0.1349E+01	0.1394E+01
121	319 11:25:48	3.000	0.87618172E+05	0.1354E+01	0.1395E+01
122	319 11:35:48	3.167	0.87610594E+05	0.1357E+01	0.1393E+01
123	319 11:45:48	3.334	0.87604031E+05	0.1355E+01	0.1388E+01

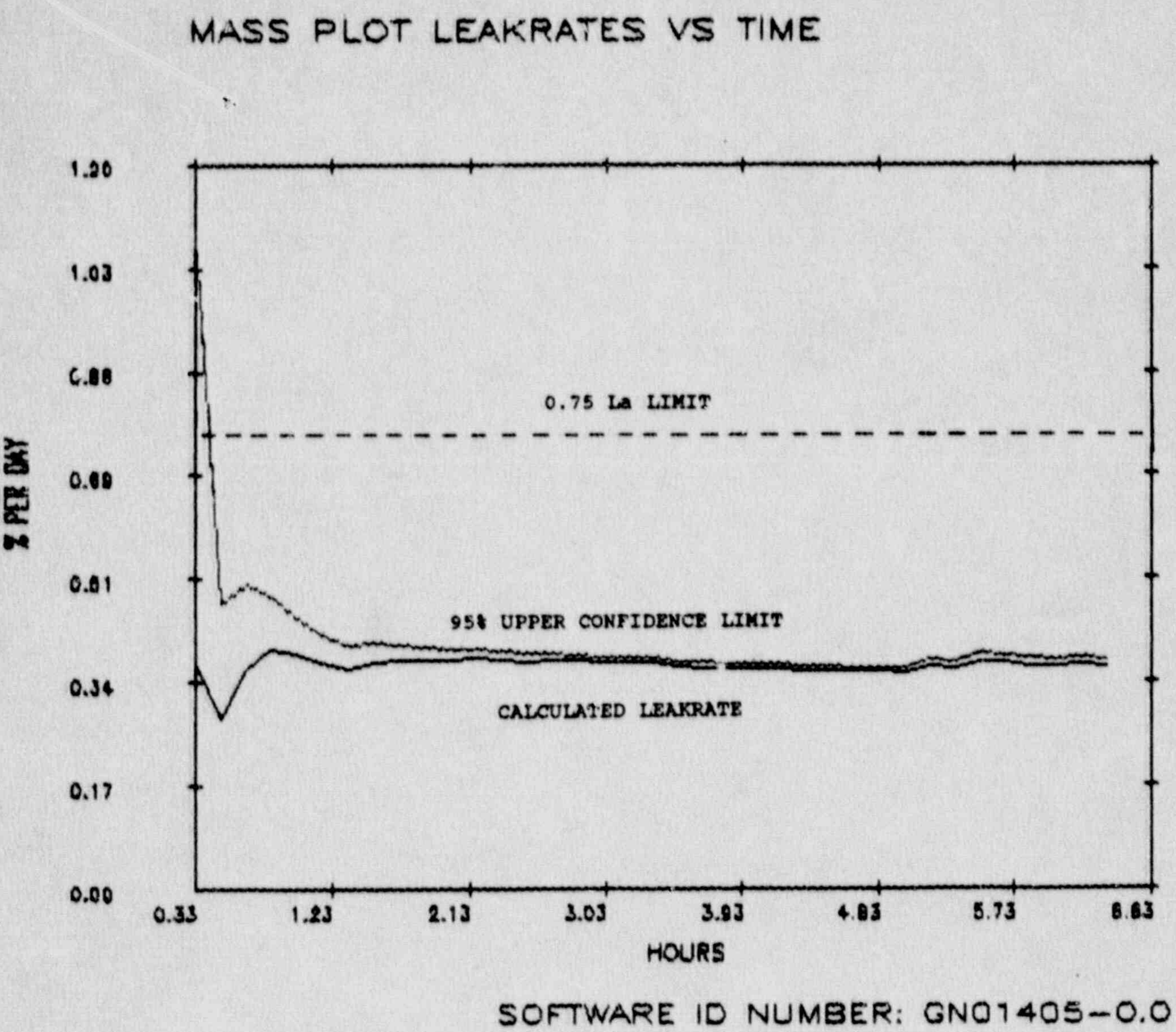
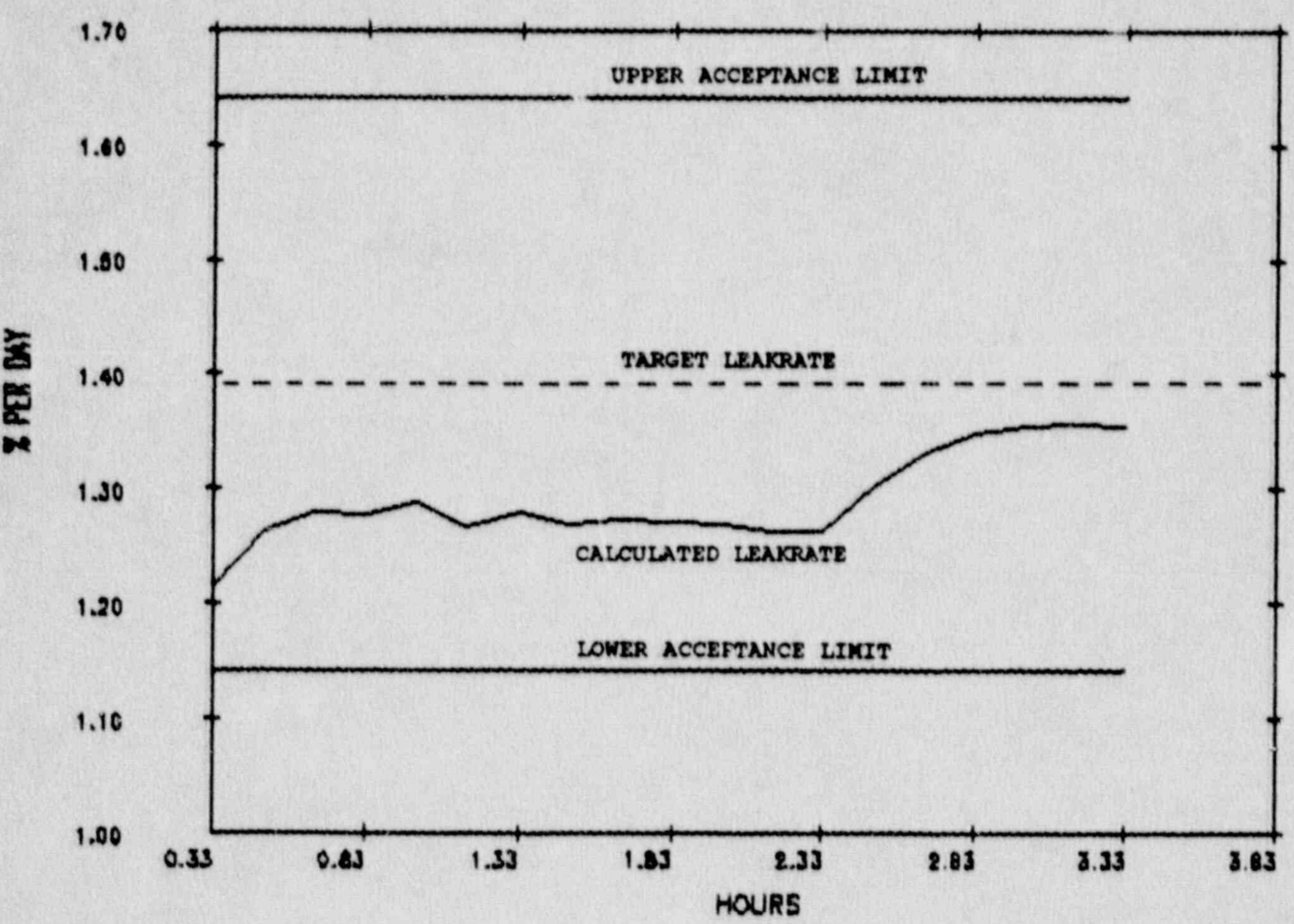

MASS PLOT LEAKRATES VS TIME
1.20
1.03
0.86
0.69
0.51
0.34
0.17
0.00
% PER DAY
0.75 La LIMIT
95% UPPER CONFIDENCE LIMIT
CALCULATED LEAKRATE
0.33
1.23
2.13
3.03
3.93
4.83
5.73
6.63
HOURS
SOFTWARE ID NUMBER: GN01405-0.0

FIGURE F-1

MASS PLOT LEAKRATES VS TIME



SOFTWARE ID NUMBER: GN01405-0.0

FIGURE F-2