NUCLEAR CONTAINMENT TESTING FOR TVA NUCLEAR POWER PLANTS

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INTRODUCTION

A significant part of the surveillance requirements for a nuclear power plant involves the assurance of isolation of radioactive contaminants from the environment in the event of a radiological accident. The primary containment serves as the final barrier of isolation in an accident. General Design Criteria 54 and 56 of Title 10 Code of Federal Regulations, Part 50 (10 CFR 50), specify design provisions for the reactor building primary containment. Appendix J to 10 CFR 50 defines the basis for a surveillance program to ensure that the primary containment will perform as designed for the life of the plant.

The most significant test prescribed by Appendix J, the reactor building containment integrated leak rate test, involves simulating as close as is practical the predicted conditions within the primary containment after the most severe postulated accident. The leakage of air from the primary containment to the environment is measured to demonstrate that offsite exposure to postulated radioactive contaminants will not exceed 10 CFR 50 guidelines, as implemented by the plant technical specifications.

Since the publication of Appendix J to 10 CFR 50, it has been customary to conduct reactor building containment leak rate tests (CILRT's) for at least 24 hours. This practice originated from experience gained in the ORNL-AEC containment proof program. The current national standard for the conduct of the CILRT, ANSI 45.4-1972, recommends tests be conducted for ". . .not less than twenty four hours of retained pressure. . ." This arbitrary test duration was set as a means to ensure the primary containment leakage would be accurately measured, with the instrumentation typically in use when the standard was prepared.

Experience gained by the Tennessee Valley Authority in the conduct of CILRT's has demonstrated that the primary containment leak rate may be accurately measured for tests conducted for considerably less than 24 hours. The purpose of this presentation is to discuss the techniques, equipment, and method of analysis TVA proposes to use to conduct future CILRT's of shorter duration than current practice. Data collected from two CILRT's conducted for 24 hours with the techniques and equipment described by this paper are discussed.

TEST OBJECTIVES

A. General

The reactor building primary containment is designed to prevent the release of radioactive contaminants to the environment either in normal operation of a nuclear power plant or as the consequence of an accident. Plant site meteorological conditions determine from the guidelines presented in 10 CFR 100 a maximum amount of radioactive contaminants that may be released to the environment.

Various plant design and reactor specific features determine a predicted maximum pressure expected to exist within the primary containment under accident conditions and a maximum rate of release of radioactive contaminants to the environment. Appendix J requires that the plant operator periodically demonstrate the ability of the primary containment to limit the release of contaminants below the calculated maximum.

The CILRT measures the rate of release, or the leak rate, of the primary containment atmosphere to the environment at a test pressure of either one-half or equal to the calculated peak pressure expected for the most severe accident. Lines that penetrate the primary containment are aligned with the configuration assumed automatically after an accident. Lines postulated to rupture inside the primary containment are drained to the extent practical of fluid and vented to the containment atmosphere for the duration of the test. Lines postulated to rupture outside the primary containment are drained to the extent practical of fluid and vented to the environment.

Before a nuclear power plant may return to operation, the CILRT must demonstrate that this measured rate of leakage is less than 75 percent of the design maximum. The 25-percent margin provides assurance that, with unforeseen degradation of performance, the maximum leakage will not be exceeded.

B. Specific Objectives

The specific objectives of the CILRT are:

1. Accurately measure the actual rate of primary containment atmosphere leakage under conditions close to those predicted for the most severe postulated accident.

2. Demonstrate that the primary containment leak rate has been accurately measured by the CILRT by a subsequent verification test.

3. Demonstrate that the measured rate of leakage is less than 75 percent of the design maximum before the nuclear plant may return to power operation.

4. Demonstrate that no potential means for the release of primary containment atmosphere has arisen since the previous CILRT.

5. Provide a statistical statement of the validity of the measured leak rate of the primary containment by calculating the confidence interval of the results.

TEST CRITERIA

A. Primary Containment Atmosphere Stabilization

During the pressurization of the primary containment, the containment atmosphere temperature will significantly increase. This heating, due to the work required to pressurize the air, can introduce instabilities of the containment atmosphere that may preclude the accurate measurement of leak rate. In a similar manner, the operation of large equipment within the containment can cause the apparent leak rate to change during the CILRT.

Appendix J requires that the primary containment atmosphere be allowed to stabilize at least 4 hours after the end of pressurization. This arbitrary requirement can prove of insufficient duration particularly when applied to high-pressure, small-volume containments. From the experience gained in the conduct of six CILRT's, the following guidelines were prepared to supplement the Appendix J requirement:

1. The average primary containment atmosphere temperature change should be less than 1^{o}F per hour before starting the CILRT.

2. A time versus temperature plot for the stabilization period should be approximately linear by the start of the CILRT.

3. Heat-producing equipment located within the primary containment should only be operated to maintain the safety of the reactor.

4. Any air circulation equipment operated during the CILRT should be operated continuously since intermittent operation could disturb the containment air temperature distribution.

5. Water levels within the reactor and any other vessel within the primary containment should be held as constant as is possible. Any required level changes should be made slowly.

B. Accuracy of the Measured Leak Rate

Since any measurement has some degree of uncertainty associated with random and systematic errors, the reported measured leak rate of the primary containment atmosphere is only an approximation to the "true" value. A statement of the goodness or degree of confidence of the CILRT results is necessary to provide assurance that the primary containment functions as designed. Following general testing practice, TVA reports a 95-percent upper confidence level for the reported leak rate.

A CILRT is considered satisfactory if the measured leak rate is less than 75 percent of the design maximum. To ensure adequate confidence in this leak rate, TVA further requires that the 95-percent upper confidence level be less than 75 percent of the design maximum leak rate.

TECHNIQUES OF ANALYSIS

A. Containment Modeling

The accurate measurement of primary containment leak rate pivots on the precise measurement of temperature, pressure, and vapor pressure. The primary containment is not constructed as a single homogenous pressure vessel but as a series of interconnected compartments. Although all compartments forming the primary containment are vented to each other for the CILRT, the flow of containment atmosphere may be restricted.

Pressure suppression containment designs incorporate special compartments that may have significantly different temperature and vapor pressure conditions from the rest of the primary containment. A boiling water reactor pressure suppression chamber is characterized by humidity approaching the saturation point. The ice condenser for a pressurized water reactor employs two large compartments far below the freezing point of water. Since a substantial portion of the primary containment free air volume is contained within these pressurization suppression compartments for both reactor designs, significant errors may result in the calculation of the leak rate if the containment atmosphere conditions are not correctly considered by the analysis.

To compensate for the compartmental construction of the primary containment, the leak rate is calculated from a model in which the containment is a multiple element system. Temperature, pressure, and vapor pressure are measured for each compartment. The mass of the air in each compartment is calculated from these measurements. The primary containment leak rate is calculated from the sum of the compartment air masses. Temperature, vapor

pressure, and pressure measurements are individually assigned volumetric weighting or influence factors determined by the relative volume each sensor represents within the compartment.

A primary containment model is developed from information provided in section 6.2 of the Final Safety Analysis Report. Any compartment that represents more than 10 percent of the containment free air volume is considered a compartment for the CILRT.

B. Method of Leak Rate Calculation

Several techniques have been used previously to calculate the primary containment leak rate. ANS 45.2-1972 recognizes the absolute and the reference vessel methods. The proposed standard for containment testing, ANSI 56.8, recognizes the same techniques. We have found the absolute, or mass loss, method yields the most accurate measurement of the primary containment leak rate.

The primary containment leak rate is calculated by the application of the ideal gas law. During the CILRT, the mass of the air in the containment is calculated periodically. The leak rate is computed from the slope of the least squares fit line to these data. The uncertainty of the measured leak rate is estimated by calculating the deviation of the individual mass points from the least squares fit line, with adjustments for the sample size.

C. Instrumentation Selection Guide

The accurate determination of leak rate by the absolute method requires the precise measurement of primary containment atmospheric temperature, vapor pressure, and total pressure. Since any measurement will include some error, the accuracy of these measurements determine the accuracy of the measured primary containment leak rate. Prior to the performance of the CILRT, the number of temperature, vapor pressure, and total pressure sensors required to accurately determine the leak rate must be estimated. Based on the expected leak rate and the anticipated conditions encountered in the test, this instrumentation selection guide determines the minimum instrumentation necessary to conduct the CILRT.

The basic criteria TVA uses for the selection of minimum CILRT instrumentation is that the primary containment leak rate should be accurately measured within the first 8 hours of data collection with an assumed leak rate equal to 25 percent of the maximum allowed under technical specifications. In addition, no temperature measurement may represent more than 10 percent of the containment free air volume. Appendix A presents an example of the estimation of sensors required for a typical boiling water reactor CILRT.

DATA ACQUISITION AND REDUCTION SYSTEMS

The precise measurement of many test variables is required to accurately calculate the primary containment leak rate. CILRT test data must, therefore, be acquired and analyzed rapidly. TVA has developed a leak rate measurement system that acquires and reduces test data automatically. The principal advantages afforded by this automatic system are highly accurate, reliable results and data collection speed. The purpose of this section is to describe the principal functions and features of the automatic data acquisition and reduction systems.

A. Data Acquisition System

The principal function of the data acquisition system is to periodically measure the test variables. A microprocessor controls the timing of periodic acquisition, the conversion from analog to digital values, and the transmission of data to the data reduction system. The microprocessor will periodically collect data at a set interval or, at the discretion of the test director, can be demanded to acquire data within the selected interval. A log of all collected data is printed for permanent records. Table 1 lists typical data collected for a boiling water reactor and a pressurized water containment. The data acquisition system is designed to allow for any combination of temperature, pressure, and vapor pressure measurements. Figure 1 depicts the components that form the data acquisition system.

The principal feature of the data acquisition system is the accurate, rapid measurement of test variables. In CILRT's previously conducted by TVA without the automatic data acquisition system, data could not be collected more frequently than once per hour. Even at this slow rate of

collection, mistakes by test personnel in the measurement of test variables degraded the results. For a typical ice condenser pressurized water reactor, the data acquisition can collect up to 20 samples of the test variables per hour. The significant increase in the volume of collected data improves the confidence of test results.

B. Data Reduction System

The primary purpose of the data reduction system is to accurately perform the necessary calculations to compute the primary containment leak rate. The central element of the data reduction system is a minicomputer system directly connected to the data acquisition system. All raw data collected by the data acquisition system is transmitted to the minicomputer and stored on flexible disks. These data are subsequently corrected according to each sensor's calibration data. The leak rate is automatically calculated and results are printed on a local printer. The system is designed to be tolerant of power failure. Figure 2 depicts the data reduction system.

Several features are included in the design of the data reduction system. The most significant is that the reliability of field test results is significantly enhanced because no manual data entry or calculations are required. The speed of data reduction is significantly increased. For a typical ice condenser, pressurized water reactor data can be collected by the acquisition system, stored, reduced, and the leak rate calculated in less than 2 minutes.

In addition to speed, the minicomputer offers several features to enhance test performance. Test variables or results may be automatically plotted by the minicomputer any time during the CILRT. The test engineer may also choose to redefine the time of the test start to any previously collected

sample while the test is conducted. This "base reset" feature allows the field evaluation of the effect of prolonging test duration.

INSTRUMENTATION TECHNIQUES

A. Temperature Measurement

Four-wire resistance temperature detectors (RTD's) are used by the leak rate measurement system to monitor primary containment atmosphere temperature. Before and after the performance of each CILRT, each RTD is individually compared with a standard certified by the National Bureau of Standards over a temperature range of 0-150°F. The uncertainty of the temperature standard is better than 0.005°F. A unique temperature as a function of resistance calibration curve is calculated for each RTD from this comparison.

When installed in the primary containment, each RTD is connected to a separate excitation bridge (wheatstone) by quick disconnect extension cables. Systematic errors due to lead length resistance, excitation bridge nonlinearity, and analog to digital conversion repeatable offset error are measured by substituting precision resistors in place of the RTD at the end of the extension cable. A unique resistance as a function of measured bridge output calibration curve is calculated for each measurement channel. The minicomputer automatically calculates and stores each calibration curve. For each temperature measurement, measured bridge voltage is first converted to resistance. The minicomputer then uses the individual RTD calibration curve to calculate the equivalent temperature from this resistance.

Tests have been conducted to determine the accuracy of temperature measurements by the integrated leak rate measurement system. Seven RTD's were compared with a standard certified by the National Bureau of Standards at five temperatures. This standard is certified with a measurement uncertainty of better than 0.005°F. Figure 3 depicts the difference between the temperature measured by the standard and the leak rate measurement system over the range of comparison. Analysis of the data indicates that the system uncertainty of temperature by the leak rate measurement system is better than 0.0202°F.

B. Vapor Pressure Measurement

Lithium chloride dewcels are used by the leak rate measurement system to monitor primary containment atmosphere moisture content. The principle of operation of a dewcel is that certain hygroscopic salt solutions will change the amount of water in the solution in relation to the moisture content of the air. The dewcel consists of a thin coating of lithium chloride between two gold wires. As the moisture content of the air changes, the salt solution will either absorb or liberate water. This change in moisture content of the salt solution changes the solution resistance proportionally. Passing a constant voltage through the two wires and the solution causes resistance heating. An RTD embedded in the support bobbin measures the induced heating. Since the temperature of the solution is directly related to the solution resistance, and hence the moisture content of the salt solution and the air, it is necessary only to measure this temperature to measure atmosphere moisture content.

Three-wire RTD's monitor the salt solution temperature. Before and after each CILRT, each dewcel RTD is individually compared with a standard certified to the National Bureau of Standards over a temperature range equivalent to a dewpoint from 0°F to 100°F. A unique temperature as a function of resistance calibration curve is calculated for each dewcel RTD from this comparison.

Each dewcel is connected to a separate excitation bridge (wheatstone) and constant voltage power supply by quick disconnect extension cables. As in the discussion of the air temperature measurement, a calibration curve of resistance as a function of measured bridge output is calculated by the substitution of precision resistors for the dewcel. Each dewpoint is first converted to equivalent resistance. The minicomputer then calculates the salt solution temperature from the dewcel's unique element temperature as a function of resistance curve. Equivalent dewpoint is calculated from data tabulated by the National Bureau of Standards.

C. Pressure Measurement

Precision quartz bourdon tube manometers were selected for containment total pressure measurement. Prior to the CILRT, a pressure cell is selected so that the rated pressure is just above the expected test pressure. Each manometer and cell is compared with a standard certified by the National Bureau of Standards before and after each CILRT over the range of the pressure cell. Proper selection of the pressure cell ensures the highest possible sensitivity to small changes of the primary containment pressure. The pressure measured by the quartz manometer is converted internally to digital values by a special encoder. The rated cell pressure corresponds to a digital output of four hundred thousand counts, with a resolution of one count.

To convert the digital signal acquired from the quartz manometer to pressure, the minicomputer linearly interpolates the true pressure from the pressure cell calibration data. This technique yields a certified system accuracy of better than 0.015 percent of reading.

D. Calibration of Test Instruments

All instruments included in the leak rate measurement system are compared with standards traceable to the National Bureau of Standards prior to and after each CILRT. Any instrument found to be out of tolerance in the range of measurement for the CILRT is rejected from consideration by eliminating all data collected from the sensor. Influence or volume weight factors are adjusted for the remaining sensors to compensate for the failure.

SYSTEM SOFTWARE

As a minicomputer performs all calculations required to determine the primary containment leak rate, the computer software system represents a complex element of the leak rate measurement system. This section describes the purpose and features of the software required to conduct the CILRT. Three basic tasks are performed by the software programs of the leak rate measurement system. First, before the CILRT, model definition, calibration data, and channel repeatable error correction data must be stored in the minicomputer. Secondly, software programs acquire the test data and perform the leak rate calculations during the CILRT. Finally, raw and corrected data must be summarized after the test for plant records.

A. Prior to the CILRT

Several programs are used to define the model of the primary containment before the CILRT is conducted. Based upon the number of temperature, vapor pressure, and pressure sensors, the minicomputer allocates storage space for the test data. In addition, the calibration data for each sensor must be stored prior to the test. Several programs are available to check various parts of the data entry process. The most significant is CHECK, which allows the computer to instantaneously compare the temperature of an installed RTD with a precision temperature standard. Table II lists and summarizes all software required in the preparation for the CILRT.

B. During the CILRT

As the CILRT is conducted, the raw data must be stored, corrected according to the calibration factors, and the results calculated. The

primary program, FORE, receives data from the acquisition system, corrects according to the sensor calibration factors, computes, stores, and displays the primary containment leak rate. Several other programs (BASE, TALLY, and LIST) provide the ability to change the sample considered the start of the test, provide statistical confidence intervals, and tabulate the test results.

Several unique features are included to prevent the loss of data and enhance the information provided to the test engineer. The most significant feature ensures that any time the data acquisition is prepared to transmit data, the minicomputer stops all activities so that the main data collection program, FORE, may execute. When these data have been received and results printed, the minicomputer completes the task interrupted by the acquisition of data. All programs are designed to be tolerant of power failure. No previous data is lost when power is restored. Table III lists and summarizes all software programs required during the CILRT.

C. After the CILRT

After the CILRT is completed, test data can be corrected for any instrument failure and arranged for inclusion in the permanent test record. Several software programs provide the ability to list all raw and corrected data, final test results, and calibration constants. Table IV lists and summarizes the software programs used after the CILRT is complete.

DISCUSSION OF TEST RESULTS

Two CILRT's have been conducted with the equipment and techniques described in this paper. Each type represents an extreme of conditions typically expected during the CILRT--small volume with moderately high pressure and low pressure with moderate volume. Both tests were conducted for at least 24 hours, with data collected at least every 15 minutes. This section presents a summary of the CILRT results. Complete reports have been filed with the NRC's Division of Operating Reactors.

A. Browns Ferry Nuclear Plant Unit 2, Conducted June 1978

Browns Ferry unit 2 is a boiling water reactor employing a steel pressure suppression Mark I containment. The maximum leak rate at a reduced pressure of 25 psig is limited by technical specification 4.7.a.2 to less than 0.04437 percentage per hour of containment air mass. The containment was modeled as two compartments--the pressure suppression chamber and the drywell. Twenty-nine temperature sensors, six humidity sensors, and two pressure gauges were used to measure the primary containment leak rate. The free air primary containment volume is approximately 300,000 cubic feet.

A 24-hour CILRT and a 12-hour verification test were conducted June 13-16, 1978. The final measured leak rate was 0.00949 percentage of containment air mass per hour. The observed 95-percent upper confidence limit for this measured leak rate was 0.00994 percentage of containment air mass. The mass leak rate calculated during this test is depicted in figure 4. Table 5 compares test duration with leak rate and upper confidence limit. Clearly, the primary containment leak rate was accurately determined within the first 4 hours of the test. Figure 4 indicates that data collected beyond the fourth hour of the test served only to improve the upper confidence limit of the leak rate. Figure 5 depicts the upper confidence interval as a function of the time of data collection. The rapid approach to the asymptotic limit demonstrates the value of proper instrument selection. Complete summaries of the calculated test results are included in appendix B.

B. Sequoyah Nuclear Plant Unit 1, Conducted March 1979

Sequoyah unit 1 is a pressurized water reactor employing an ice condenser pressure suppression primary containment. The maximum leakage of air at a test pressure of 12 psig is limited by technical specification 4.6.1.2 to less than 0.0078 percentage per hour of containment air mass. The primary containment contains four compartments--the lower ice condenser compartment which houses the energy absorbing ice beds, the upper ice condenser compartment which encloses support equipment for the ice condenser system, the lower compartment which encloses the reactor and main piping systems, and the upper compartment which encloses the refueling work area. The free air mass was calculated separately for each compartment, with the calculated leak rate derived from the sum of the compartment air masses. Based upon the instrument selection guide, 46 RTD's were used for containment atmosphere temperature measurement, 10 humidity sensors were used to monitor the containment atmosphere moisture content, and four quartz manometers monitored the total pressure. Total free air volume for the primary containment is approximately 1.19 million cubic feet.

A 24-hour CILRT and a 4-hour verification test were conducted March 13-16, 1979. The final measured leak rate was 0.00011 percentage of containment air mass. The observed 95-percent upper confidence limit was 0.00024 percentage of the containment air mass. The mass leak rate calculated is

depicted in figure 6. Table 5 compares test results with the duration of data collection. Clearly, the primary containment leak rate was accurately determined within the first 8 hours of data collection. Figure 7 depicts the upper confidence interval as a function of the time of data collection. Complete summaries of the calculated test results are included in appendix C.

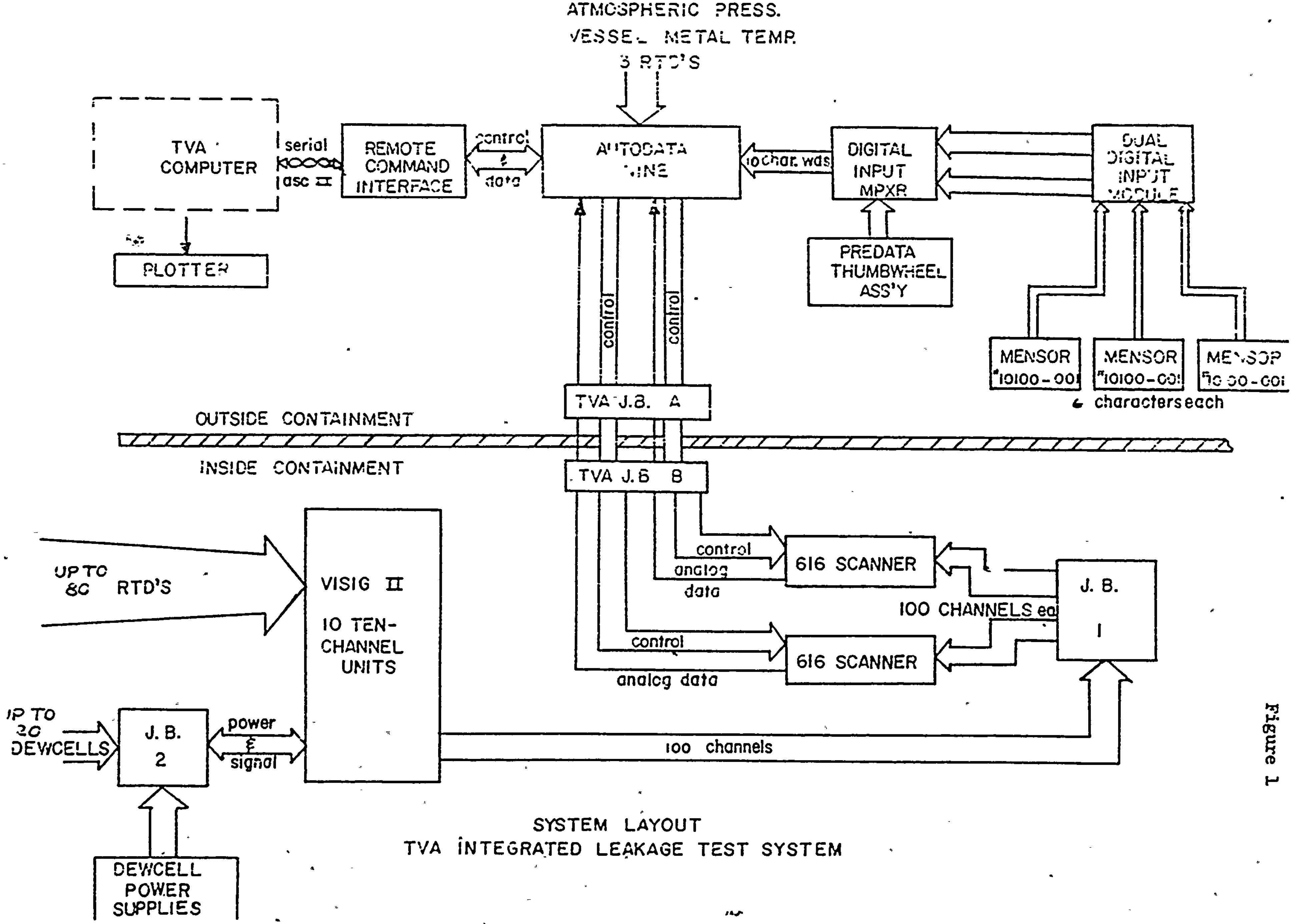
CONCLUSIONS

CILRT's conducted by TVA on a high-pressure boiling water reactor containment and a low-pressure ice condenser pressurized water reactor containment verify that the leak rate measurement system used with the techniques outlined in this paper measured the primary containment leak rate in far less than the 24 hours the tests were conducted. An analysis of the 95-percent upper confidence limit of the measured leak rate indicates that the primary containment leak rate was accurately determined with a high level of confidence within the first 4 hours of data collection.

To consistently achieve this accuracy for future CILRT's, this paper has outlined several key techniques. The model used to calculate the primary containment leak rate must compensate for areas of varying temperature, pressure, and moisture content. The test instrumentation must be capable of extremely accurate and repeatable measurement of the containment atmosphere conditions. Collected test data must be acquired quickly with reliable equipment. The test director must be provided with accurate results during the test.

TVA will conduct future CILRT's in accordance with the techniques described in this paper. Each CILRT will be conducted for at least 4 hours and extend until adequate confidence in the accuracy of the measured leak rate is achieved.

F I G U R E S



SYSTEM LAYOUT
TVA INTEGRATED LEAKAGE TEST SYSTEM

Figure 1

INTEGRATED LEAK RATE MEASUREMENT SYSTEM
DATA REDUCTION SYSTEM

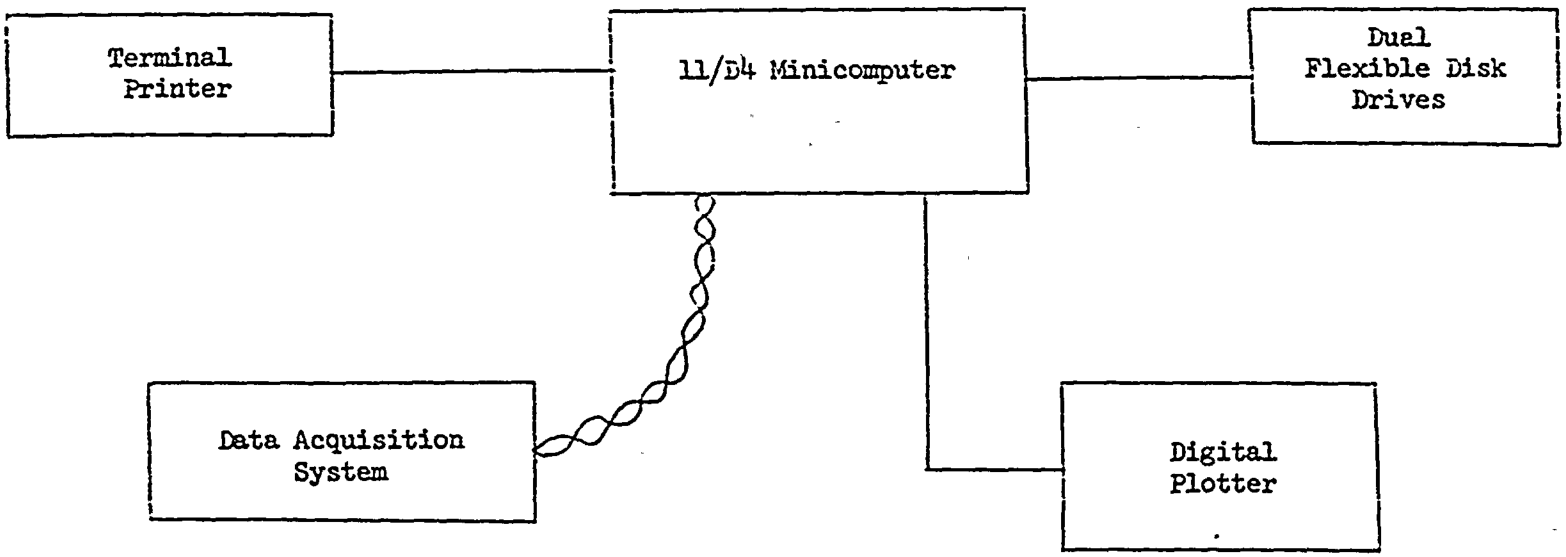


Figure 2

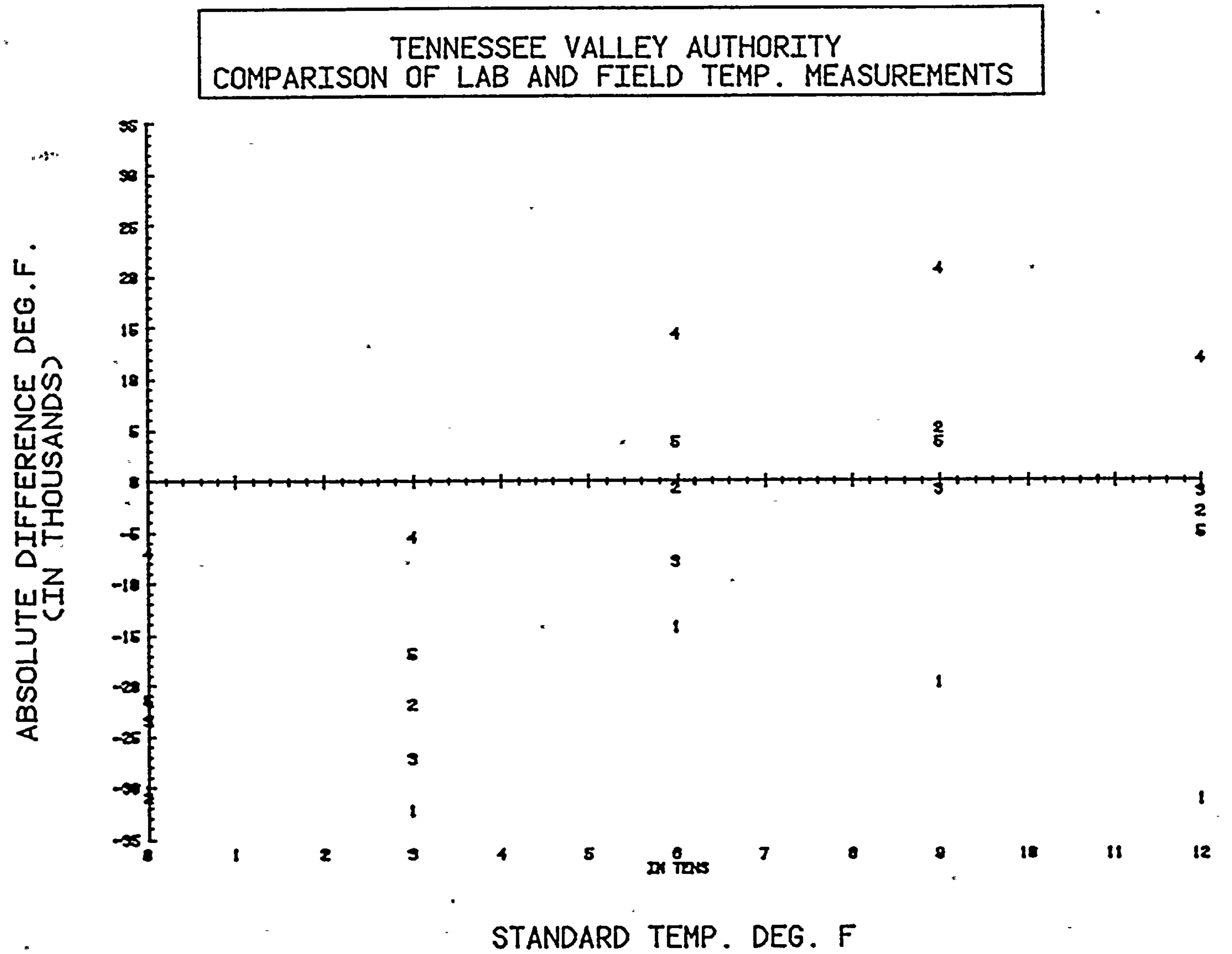

TENNESSEE VALLEY AUTHORITY
COMPARISON OF LAB AND FIELD TEMP. MEASUREMENTS
ABSOLUTE DIFFERENCE DEG.F.
(IN THOUSANDS)
IN TENS
STANDARD TEMP. DEG. F

Figure 3

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT
MASS LEAK RATE PLOT
(25 PSIG TEST)

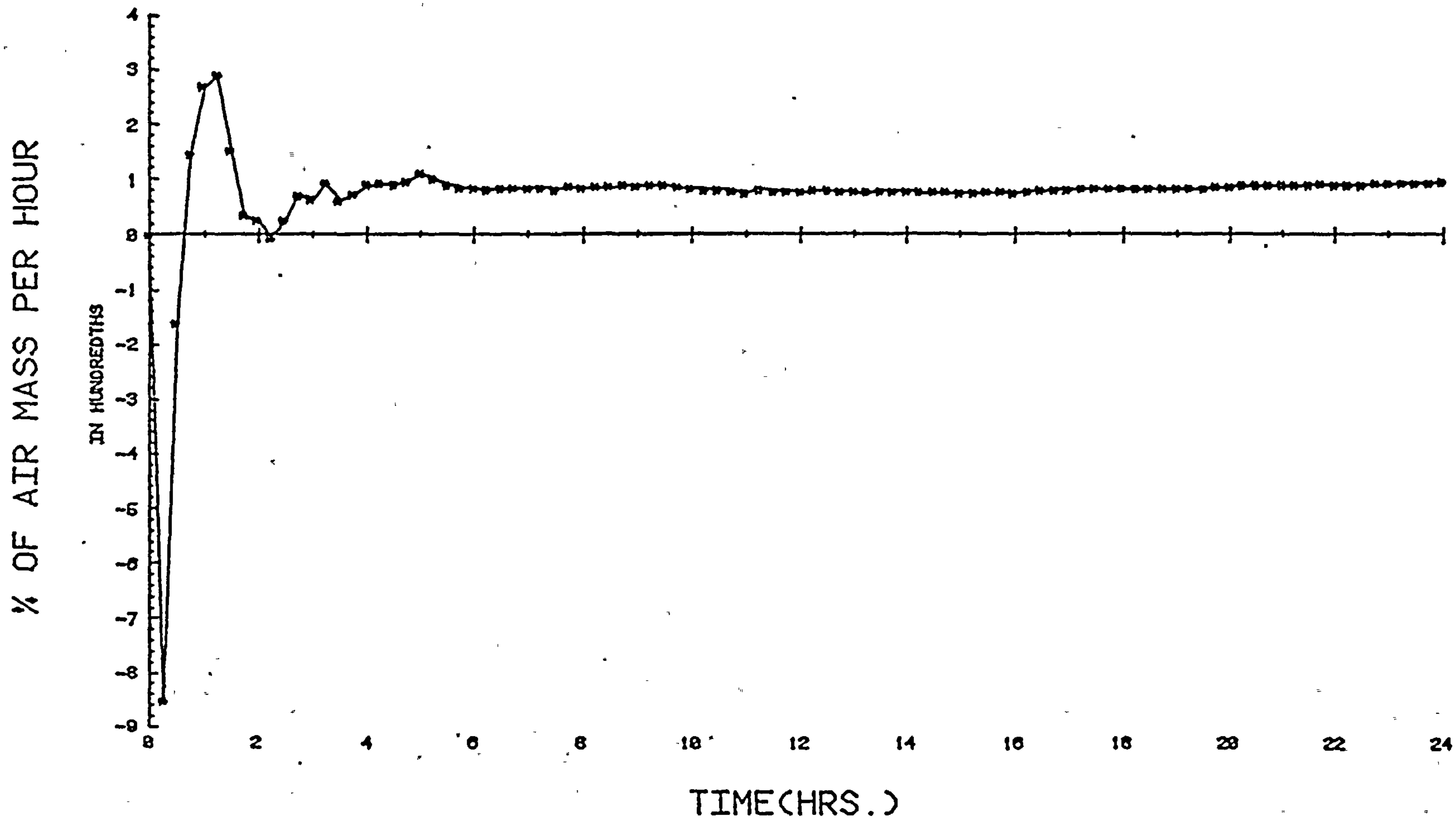


Figure 4

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT
UCL INTERVAL
(25 PSIG TEST PRESSURE)

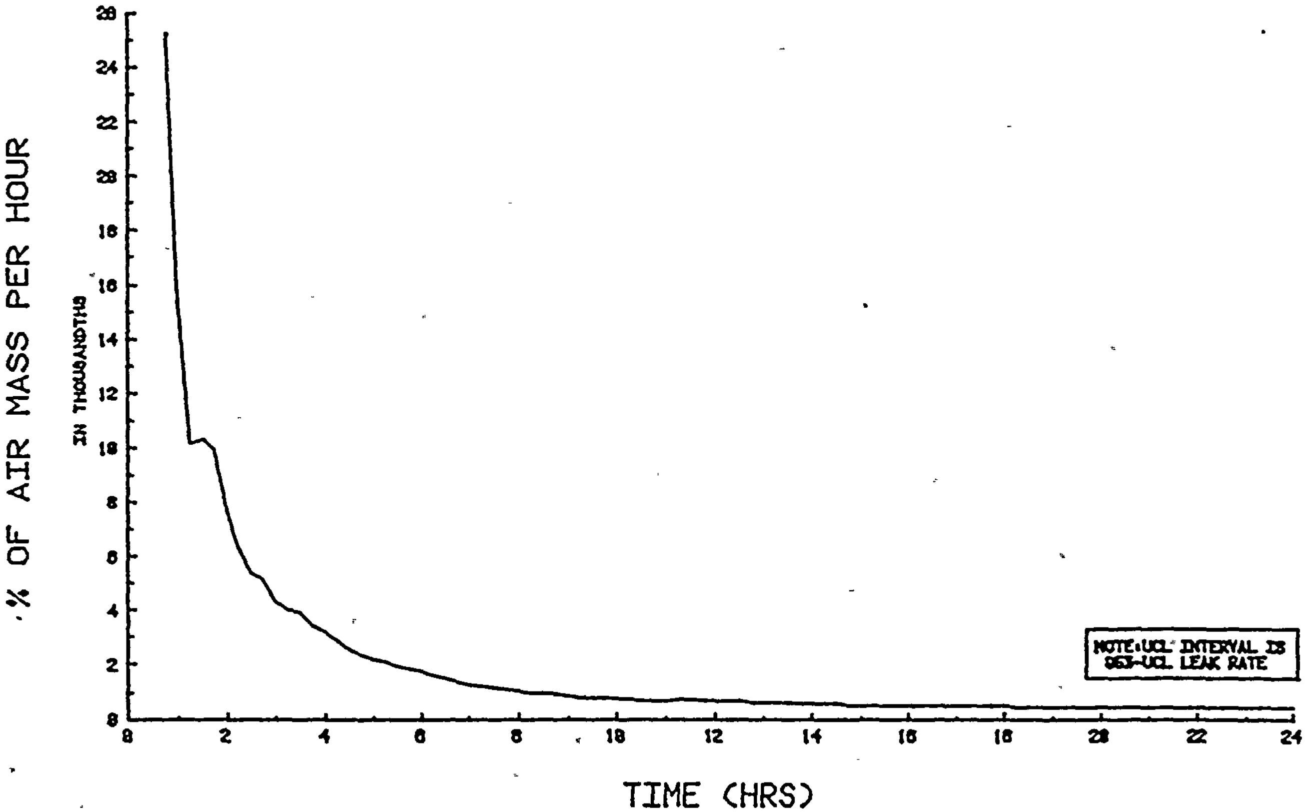


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Figure 5

TENNESSEE VALLEY AUTHORITY
SEQUOYAH NUCLEAR PLANT
MASS LEAK RATE PLOT
(12 PSIG TEST PRESSURE)

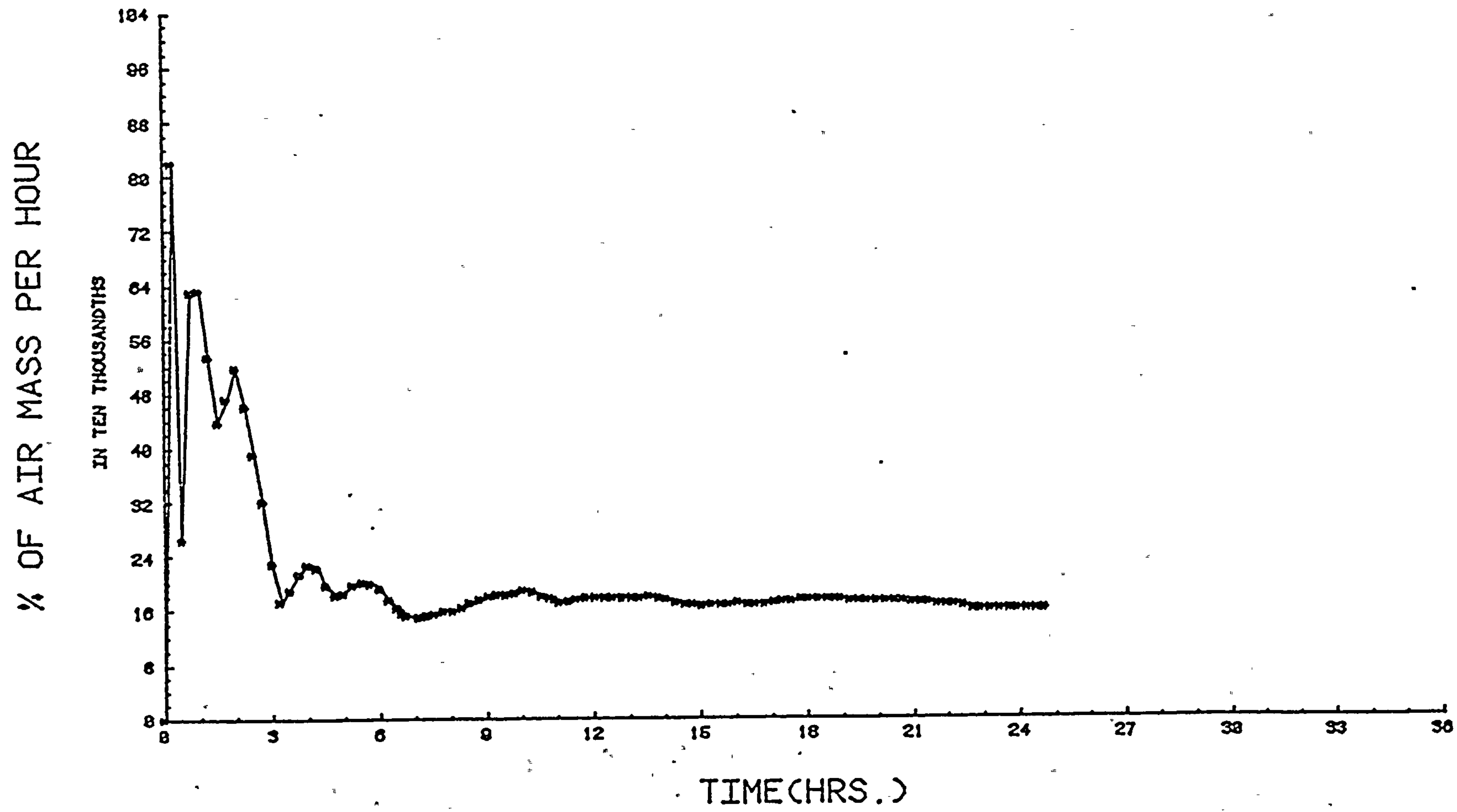

Figure 6

TENNESSEE VALLEY AUTHORITY
SEQUOYAH NUCLEAR PLANT
UCL INTERVAL
(12 PSIG TEST PRESSURE)

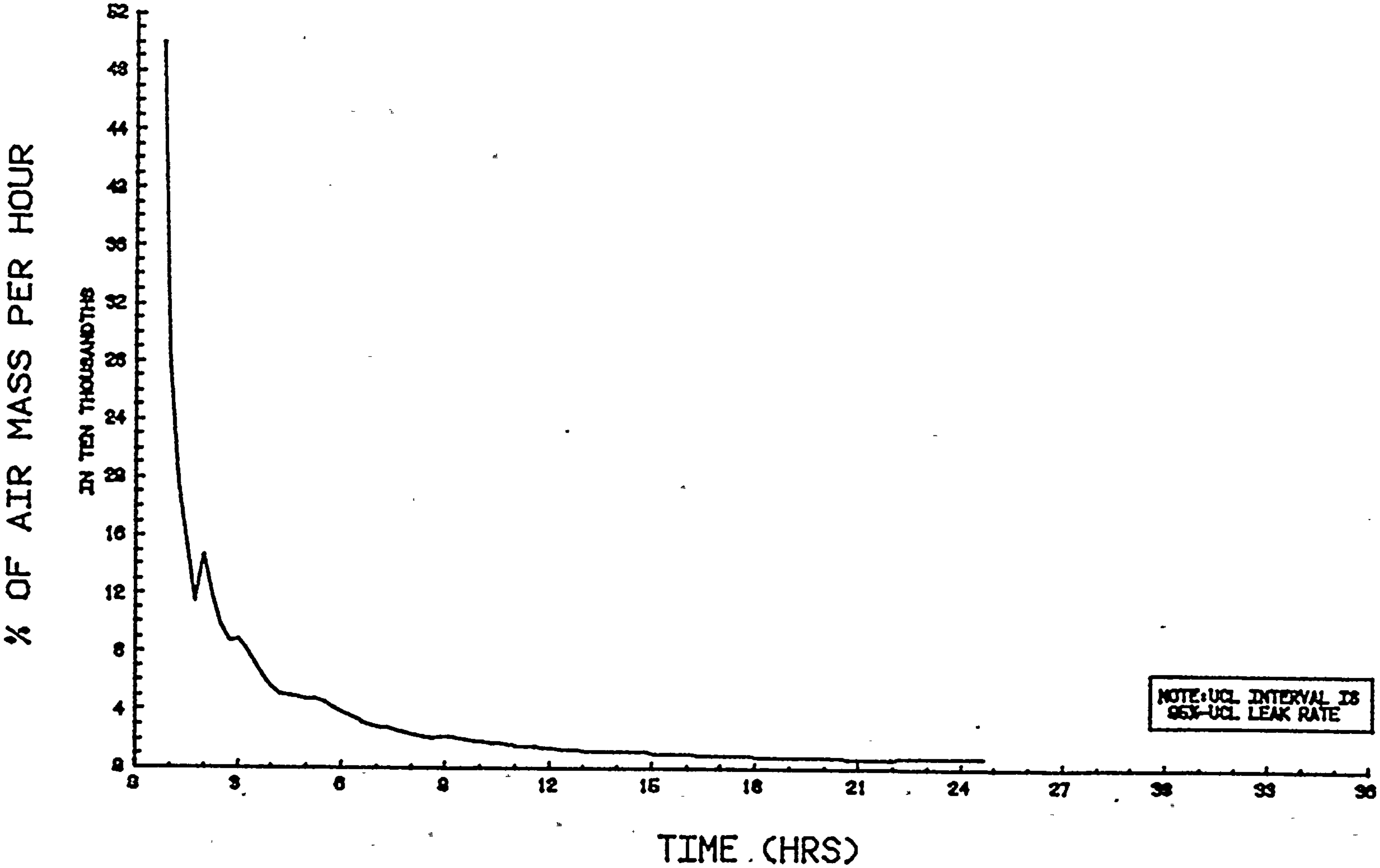

Figure 7

TABLES

TABLE I
DATA COLLECTED BY
AUTOMATIC ACQUISITION SYSTEM

1. Boiling Water Reactor, Pressure Suppression Containment

Quantity	Function
29	Resistance temperature detectors (RTD's) for containment atmospheric temperature measurement
6	Lithium chloride dewcels for containment atmospheric vapor pressure measurement
2	Precision quartz manometers for containment atmospheric total pressure measurement
4	RTD's for containment vessel metal temperature and test station temperature
1	Mass flowmeter for measurement of induced leak required for the verification test
1	Precision quartz manometer for atmospheric pressure
1	Suppression chamber water level
1	Reactor vessel water level

2. Pressurized Water Reactor, Ice Condenser Suppression Containment

Quantity	Function
46	RTD's for containment atmospheric temperature measurement
10	Lithium chloride dewcels for containment atmospheric vapor pressure measurement
4	Precision quartz manometers for containment atmospheric total pressure measurement
4	RTD's for containment vessel metal temperature and test station temperature measurement
1	Mass flowmeter for measurement of induced leak required for the verification test
1	Precision quartz manometer for atmospheric pressure

TABLE II
SYSTEM SOFTWARE REQUIRED PRIOR TO THE CILRT

Program Name(s)	Description
S1	Define the integrated leak rate system parameters: number of RTD's, dewcels, pressure gauges, analog inputs, and local RTD's. Create the required system files required to store the test data.
CREAM ENTAM ENTVW	Define the sensor calibration data and volume weights. Requires calibration reports on all dewcels and RTD's that may be used for the CILRT.
AM	Measure the integrated leak rate system analog to digital repeatable offset. Requires all temporary cables to be installed and integrated leak rate system to be operational.
STARTN	Define the calibration data for the quartz manometer pressure gauges and any plant process instrumentation, e.g., suppression chamber and reactor level transmitters.
CHECK	Verify in-place system temperature or dewpoint measurements. A standard for comparison is required for this program.
CHECK8	Print all stored calibration constants required to conduct the CILRT.

TABLE III
SYSTEM SOFTWARE REQUIRED DURING THE CILRT

Program Name(s)	Description
FORE	Acquire containment data from the data acquisition system, store, correct raw data, and calculate leak rate.
LIST	Print a summary of measured leak rate. Drive an online digital plotter to produce graphs of principal test results.
TALLY	Calculate confidence limits of the calculated leak rate.
BASE	Redefine the sample considered the start of the CILRT.

TABLE IV
SYSTEM SOFTWARE REQUIRED AFTER THE CILRT

Program Name(s)	Description
AM	Measure the integrated leak rate system analog to digital repeatable offset after test is completed.
DUMDEV	Print all raw and corrected test data.
AIRMASS	Print a compartment summary of the measured temperature, vapor pressure, pressure, and air mass. Correct the test results for any sensor found out of calibration.

TABLE V
CILRT RESULTS AS A FUNCTION OF TEST DURATION

Browns Ferry Nuclear Plant Unit 2

CILRT Duration (Hours)	Number of Mass Samples	PTP Leak* Rate % Per Hour	UCL PTP* Leak Rate % Per Hour	Mass Leak Rate % Per Hour	UCL Mass Leak Rate % Per Hour
8	33	0.00527	0.01693	0.00855	0.01036
12	49	0.00798	0.02318	0.00785	0.00893
24	97	0.00506	0.01921	0.00949	0.00994

Sequoyah Nuclear Plant Unit 1

CILRT Duration (Hours)	Number of Mass Samples	PTP Leak* Rate % Per Hour	UCL PTP* Leak Rate % Per Hour	Mass Leak Rate % Per Hour	UCL Mass Leak Rate % Per Hour
6	25	0.00456	0.00470	0.00193	0.00238
8	34	0.00323	0.00336	0.00159	0.00188
10	42	0.00254	0.00265	0.00190	0.00211
12	51	0.00296	0.00307	0.00178	0.00193
24	100	0.00248	0.00258	0.00162	0.00168

*As defined in ANS-274 (draft)

APPENDIX A

INSTRUMENT SELECTION GUIDE

The containment air mass is calculated by the application of the ideal gas law:

$$W = \frac{144 \times V \times (P - P_V)}{RT} \qquad (1)$$

By the mass point method the primary containment leak rate is the normalized slope of the mass loss curve:

$$W = At + B,$$

$$L_R = \left(\frac{dW}{dt}\right) \times \left(\frac{1}{W_0}\right) \times 100 \qquad (2)$$

The total differential of the calculated is mass is:

$$dW = 144 \frac{V}{R} \left[\frac{dP}{T} - \frac{dP_V}{T} + \frac{dT}{T^2}\right] \qquad (3)$$

Therefore,

$$LR = \left[\frac{dP}{dt} - \frac{dP_V}{dt} + \frac{dT}{dt} \frac{(P - P_V)}{T}\right] \times 100 \qquad (4)$$

The error in measurement of the independent variables, pressure, vapor pressure, and temperature determine the error in the leak rate. In general, an upper bound on the error in measurement of an independent variable X is:

$$E = \left[\frac{(e_x)^2 + \xi_x)^2}{\eta x}\right]^{1/2} \qquad (5)$$

An upper bound on the error in a dependent variable Y, as determined by the measurement of a set of independent variables X_1, X_2, . . . X_N is:

$$E_Y \leq \left[(E_{X_1})^2 + (E_{X_2})^2 + \ldots + (E_{X_N})^2\right]^{1/2} \qquad (6)$$

Therefore, the upper bound of error of the measured leak rate can be expressed as:

$$E_{LR} \leq \left[(E_P)^2 + (E_{PV})^2 + (E_T)^2\right]^{1/2} \qquad (7)$$

The minimum change that may be reliably detected in the measurement of an independent variable is determined by the error of measurement. In general,

$$dX \leq \left[\frac{(e_X)^2 + (\xi_X)^2}{n_X}\right]^{1/2} \tag{8}$$

Substituting for each independent variable differential in equation (7) yields:

$$LR = \left[\left|\frac{E_P}{dt}\right| + \left|\frac{E_{PV}}{dt}\right| + \left|\frac{E_T}{dt} \times \frac{(P - P_V)}{T}\right|\right] \times 100 \tag{9}$$

In the paper, "Describing The Uncertainties In Single Sample Experiments," by McClintock et. al., it was shown the contribution of the measurement of each independent variable should be equal for an optimal instrumentation system. Therefore, equation (9) may be rewritten:

$$L_R = \frac{E}{dt}\left[2 + \frac{(P - P_V)}{T}\right] \times 100 \tag{10}$$

If a bound on the error in leak rate is assumed, the error in the measurement of an independent variable can be bounded.

$$E = \frac{L_R \times dt}{100}\left[\frac{T}{2T + (P - P_V)}\right] \tag{11}$$

TVA selects test instrumentation so that 25 percent of the maximum allowable leak rate can be measured within 8 hours. It is assumed that data is collected every 30 minutes. Therefore, equation (11) is rewritten:

$$E = (.5)\frac{(.25 \times L_a \times .75)}{100}\left[\frac{T}{2T + (P - P_V)}\right] \tag{12}$$

Substituting into equation (8) and solving for the number of instruments yields:

$$n_X \leq \left[\frac{(e_x)^2 + (\xi_X)^2}{E2}\right]^{1/2} \tag{13}$$

Definition of Symbols

e	-	Absolute error of the measure of a variable
[illegible]	-	Absolute error of the indication of the measure of a variable
E_R	-	Relative error of a variable
L	-	Absolute error of leak rate, percent of containment air mass per hour
n	-	Number of replications of a measurement
N	-	Number of independent measurements
P	-	Absolute pressure, psia
R	-	Universal gas constant
S	-	Deviation from the mean of a population
t	-	Time of sample
t_{95}	-	Student's t distribution for N-1 degrees
T	-	Temperature, degrees Rankine
V	-	Containment air volume, scf
W	-	Absolute mass of containment air, lbm

Subscripts

A	-	Estimate corrected for replication and sample size
L	-	Lower bound
U	-	Upper bound
V	-	Vapor pressure

APPENDIX B

TENNESSEE VALLEY AUTHORITY
CONTAINMENT LEAKAGE MEASUREMENT
TEST SUMMARY

HOURS SINCE START	AVERAGE TEMPERATURE DEG F.	CORRECTED PRESSURE PSIA	TOTAL MASS OF AIR LBM	P-T-P LEAK RATE % PER HOUR	TOTAL TIME LEAK RATE % PER HOUR	MASS LEAK RATE % PER HOUR
0.000	83.1390	39.8087	57471.22	0.0000000	0.0000000	0.0000000
0.250	83.1489	39.8871	57483.46	-0.0851788	-0.0851788	-0.0851520
0.500	83.1452	39.8794	57475.82	0.0531127	-0.0160270	-0.0160397
0.750	83.1445	39.8893	57466.83	0.0626001	0.0101863	0.0144839
1.000	83.1462	39.8810	57460.21	0.0460322	0.0191468	0.0268793
1.250	83.1499	39.8850	57457.78	0.0169681	0.0187104	0.0289792
1.500	83.1368	39.8845	57473.14	-0.1069811	-0.0022339	0.0151926
1.750	83.1367	39.8837	57481.28	-0.0566027	-0.0100011	0.0034592
2.000	83.1307	39.8792	57471.01	0.0714629	0.0001835	0.0025374
2.250	83.1247	39.8818	57477.35	-0.0441257	-0.0047397	-0.0005062
2.500	83.1487	39.8729	57462.74	0.1016709	0.0059024	0.0024834
2.750	83.1501	39.8743	57451.62	0.0773065	0.0124000	0.0071055
3.000	83.1455	39.8790	57466.25	-0.1018252	0.0028841	0.0063095
3.250	83.1405	39.8779	57447.68	0.1292340	0.0126025	0.0093302
3.500	83.1362	39.8760	57475.41	-0.1930818	-0.0020937	0.0062264
3.750	83.1307	39.8706	57454.47	0.1457422	0.0077720	0.0072359
4.000	83.1124	39.8684	57445.72	0.0600900	0.0110900	0.0089636
4.250	83.1059	39.8757	57452.00	-0.0437366	0.0078668	0.0092504
4.500	83.1070	39.8688	57454.09	-0.0144959	0.0066247	0.0090839
4.750	83.1097	39.8710	57445.59	0.0591507	0.0093083	0.0096907
5.000	83.0003	39.8683	57434.01	0.0826464	0.0129494	0.0110533
5.250	83.0602	39.8694	57454.77	-0.1445703	0.0054530	0.0102247
5.500	83.0517	39.8690	57459.68	-0.0341842	0.0036518	0.0091119
5.750	83.0340	39.8655	57453.00	0.0400707	0.0052596	0.0085874
6.000	83.0535	39.8651	57449.51	0.0298036	0.0062950	0.0083621
6.250	83.0381	39.8615	57447.34	0.0150947	0.0066460	0.0082420
6.500	83.0135	39.8592	57441.44	0.0411243	0.0079722	0.0094126
6.750	82.9983	39.8578	57442.07	-0.0099559	0.0073084	0.0084184
7.000	82.9899	39.8503	57439.53	0.0232294	0.0078766	0.0085228
7.250	82.9800	39.8570	57439.18	0.0024402	0.0076074	0.0085650
7.500	83.0056	39.8626	57447.29	-0.0564464	0.0055526	0.0082111
7.750	83.0115	39.8583	57428.45	0.1311519	0.0096025	0.0086126
8.000	83.0052	39.8573	57437.93	-0.0660600	0.0072395	0.0085458
8.250	83.0000	39.8530	57430.57	0.0512790	0.0085731	0.0087107
8.500	82.9951	39.8533	57432.39	-0.0126783	0.0079404	0.0087412
8.750	82.9729	39.8504	57425.57	0.0474739	0.0090767	0.0089496
9.000	82.9605	39.8543	57433.45	-0.0548541	0.0073021	0.0089436
9.250	82.9492	39.8490	57425.03	0.0586272	0.0086003	0.0089553
9.500	82.9252	39.8453	57425.41	-0.0026121	0.0083909	0.0090162
9.750	82.9038	39.8515	57438.31	-0.0899086	0.0058725	0.0087013
10.000	82.8863	39.8430	57434.27	0.0281550	0.0064292	0.0084969
10.250	82.8605	39.8443	57434.49	-0.0015507	0.0062345	0.0082831
10.500	82.8753	39.8393	57427.15	0.0511460	0.0073031	0.0082438
10.750	82.8576	39.8393	57438.32	-0.0778154	0.0053250	0.0079415
11.000	82.8378	39.8384	57436.94	0.0096298	0.0054227	0.0076841
11.250	82.8407	39.8341	57395.25	0.2903228	0.0117498	0.0082442
11.500	82.8263	39.8361	57436.32	-0.2862530	0.0052797	0.0079511
11.750	82.8126	39.8293	57419.78	0.1152002	0.0076171	0.0079659
12.000	82.8037	39.8287	57426.47	-0.0465974	0.0064800	0.0078516

TENNESSEE VALLEY AUTHORITY
CONTAINMENT LEAKAGE MEASUREMENT
TEST SUMMARY

HOURS SINCE START	AVERAGE TEMPERATURE DEG. F.	CORRECTED PRESSURE PSIA	TOTAL MASS OF AIR LBM	P-T-P LEAK RATE % PER HOUR	TOTAL TIME LEAK RATE % PER HOUR	MASS LEAK RATE % PER HOUR
12.250	82.7857	39.8333	57404.26	0.1546803	0.0095106	0.0080902
12.500	82.7856	39.8291	57414.71	-0.0728381	0.0078653	0.0081222
12.750	82.7836	39.8290	57422.94	-0.0573141	0.0065884	0.0080095
13.000	82.7835	39.8315	57426.73	-0.0263939	0.0059546	0.0078340
13.250	82.8026	39.8340	57413.41	0.0927534	0.0075910	0.0078481
13.500	82.7961	39.8344	57403.37	0.0699706	0.0087440	0.0079779
13.750	82.8102	39.8244	57409.07	-0.0397132	0.0078646	0.0080109
14.000	82.7988	39.8300	57417.85	-0.0611832	0.0066328	0.0079106
14.250	82.7961	39.8266	57416.57	0.0088987	0.0066724	0.0078235
14.500	82.7883	39.8296	57417.32	-0.0052249	0.0064673	0.0077220
14.750	82.7857	39.8214	57404.39	0.0961017	0.0078335	0.0077692
15.000	82.7551	39.8263	57418.50	-0.0988808	0.0061059	0.0076406
15.250	82.7528	39.8200	57399.67	0.1317344	0.0081634	0.0077170
15.500	82.7442	39.8250	57391.89	0.0542246	0.0089052	0.0078550
15.750	82.7573	39.8196	57402.79	-0.0759592	0.0075599	0.0078570
16.000	82.7697	39.8264	57417.83	-0.1048232	0.0058858	0.0077019
16.250	82.7791	39.8165	57378.92	0.2710918	0.0090833	0.0079172
16.500	82.7841	39.8198	57377.47	0.0100757	0.0098060	0.0081109
16.750	82.7860	39.8190	57384.93	-0.0520126	0.0089634	0.0082270
17.000	82.7945	39.8287	57386.59	-0.0115175	0.0086624	0.0082954
17.250	82.7958	39.8173	57372.55	0.0978575	0.0099530	0.0084709
17.500	82.8002	39.8186	57392.13	-0.1365516	0.0078634	0.0084615
17.750	82.8016	39.8167	57398.66	-0.0454654	0.0071132	0.0083895
18.000	82.8353	39.8262	57396.35	0.0160612	0.0072372	0.0083311
18.250	82.8792	39.8265	57382.52	0.0963606	0.0084564	0.0083738
18.500	82.9001	39.8205	57388.52	-0.0417698	0.0077786	0.0083632
18.750	82.9200	39.8279	57379.11	0.0655357	0.0085474	0.0084057
19.000	82.9919	39.8319	57393.38	-0.0994202	0.0071289	0.0083430
19.250	83.0521	39.8277	57380.05	0.0928617	0.0082406	0.0083641
19.500	83.1159	39.8361	57357.46	0.1574504	0.0101504	0.0085247
19.750	83.1730	39.8413	57359.34	-0.0130758	0.0090567	0.0086553
20.000	83.2399	39.8475	57357.60	0.0116044	0.0098782	0.0087786
20.250	83.2960	39.8444	57350.43	0.0591521	0.0103742	0.0089314
20.500	83.3316	39.8587	57370.59	-0.1402004	0.0085415	0.0089420
20.750	83.3857	39.8589	57375.78	-0.0362226	0.0080038	0.0089172
21.000	83.4327	39.8582	57359.07	0.1165035	0.0092923	0.0089804
21.250	83.4315	39.8609	57357.80	0.0080804	0.0092873	0.0090405
21.500	83.4112	39.8536	57346.43	0.0792715	0.0100992	0.0091543
21.750	83.4059	39.8495	57351.63	-0.0362659	0.0095672	0.0092202
22.000	83.4113	39.8543	57376.63	-0.1743344	0.0074815	0.0091480
22.250	83.4034	39.8474	57363.13	0.0940598	0.0084526	0.0091415
22.500	83.4090	39.8477	57352.77	0.0722655	0.0091601	0.0091821
22.750	83.4051	39.8521	57348.73	0.0278156	0.0093645	0.0092308
23.000	83.4707	39.8500	57336.15	0.0880842	0.0102101	0.0093315
23.250	83.4805	39.8537	57336.25	-0.0096540	0.0101012	0.0094165
23.500	83.5103	39.8640	57352.77	-0.1152458	0.0087706	0.0094183
23.750	83.5733	39.8613	57318.91	0.0269165	0.0089610	0.0094291
24.000	83.4707	39.8651	57336.36	0.0074867	0.0097770	0.0094889

APPENDIX C

TENNESSEE VALLEY AUTHORITY
SEQUOYAH NUCLEAR PLANT -- UNIT 1
CONTAINMENT LEAKAGE MEASUREMENT
TEST SUMMARY
ALL COMPARTMENTS
12 PSIG CILRT

HOURS SINCE START	AIR MASS LOWER COMP. LBM	AIR MASS UPPER COMP. LBM	AIR MASS UPPER ICE LBM	AIR MASS LOWER ICE LBM	P-T-P LEAK RATE % PER HOUR	TOTAL TIME LEAK RATE % PER HOUR	MASS LEAK RATE % PER HOUR
0.000	53934.3	91140.5	7101.3	16969.5	0.00000	0.00000	0.00000
0.250	53937.8	91140.9	7100.0	16968.0	0.02820	0.00028	0.00821
0.500	53932.1	91144.1	7100.7	16966.7	-0.00208	0.00266	0.00266
0.750	53931.2	91139.6	7100.8	16965.0	0.01666	0.00733	0.00630
1.000	53930.1	91139.4	7102.8	16963.2	0.00277	0.00619	0.00633
1.250	53930.9	91139.6	7103.0	16962.1	-0.00046	0.00486	0.00534
1.500	53930.3	91142.5	7102.4	16963.6	-0.00037	0.00398	0.00439
1.750	53930.7	91142.5	7097.9	16959.1	0.01334	0.00532	0.00473
2.000	53929.8	91141.3	7097.6	16957.7	0.00887	0.00576	0.00518
2.250	53930.6	91142.6	7100.5	16956.6	-0.00901	0.00412	0.00463
2.500	53932.1	91143.2	7101.4	16955.6	-0.00401	0.00323	0.00391
2.750	53932.0	91145.0	7101.8	16954.6	-0.00277	0.00268	0.00322
3.000	53933.6	91148.9	7102.6	16953.8	-0.01278	0.00139	0.00229
3.250	53934.2	91151.2	7099.7	16952.4	0.00318	0.00153	0.00173
3.500	53932.4	91145.6	7098.9	16950.5	0.02373	0.00312	0.00191
3.750	53931.7	91146.2	7097.8	16949.3	0.00598	0.00331	0.00213
4.000	53931.9	91146.9	7097.4	16947.7	0.00248	0.00326	0.00228
4.250	53933.3	91148.9	7097.6	16947.1	-0.00728	0.00264	0.00223
4.500	53934.1	91149.7	7101.3	16946.6	-0.01130	0.00186	0.00197
4.750	53934.1	91151.4	7098.1	16945.5	0.00621	0.00209	0.00184
5.000	53934.4	91153.6	7092.6	16944.3	0.00991	0.00248	0.00186
5.250	53934.0	91152.1	7090.7	16943.1	0.01171	0.00292	0.00198
5.500	53933.3	91151.9	7094.1	16941.7	-0.00205	0.00266	0.00202
5.750	53935.4	91152.1	7096.2	16940.8	-0.00327	0.00241	0.00200
6.000	53934.4	91151.4	7098.6	16940.0	-0.00495	0.00210	0.00193
6.250	53935.0	91156.6	7098.0	16939.5	-0.01972	0.00159	0.00176
6.500	53935.9	91154.9	7096.8	16938.5	0.00499	0.00172	0.00164
6.630	53935.7	91155.0	7097.5	16937.9	0.00376	0.00176	0.00156
6.750	53935.1	91156.0	7095.9	16937.0	0.01057	0.00192	0.00152
7.077	53935.7	91155.7	7097.1	16935.3	0.00040	0.00105	0.00149
7.314	53935.1	91156.2	7093.7	16934.2	0.01178	0.00217	0.00153
7.544	53935.6	91156.3	7093.2	16932.9	0.00244	0.00218	0.00155
7.914	53935.0	91155.8	7093.4	16931.8	0.02499	0.00227	0.00160
8.064	53937.8	91157.9	7091.1	16931.3	-0.00525	0.00203	0.00159
8.311	53937.6	91157.9	7087.0	16930.1	0.01124	0.00231	0.00164

TENNESSEE VALLEY AUTHORITY
SEQUOYAH NUCLEAR PLANT -- UNIT 1
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HOURS SINCE START	AIR MASS LOWER COMP. LBM	AIR MASS UPPER COMP. LBM	AIR MASS UPPER ICE LBM	AIR MASS LOWER ICE LBM	P-T-P LEAK RATE % PER HOUR	TOTAL TIME LEAK RATE % PER HOUR	MASS LEAK RATE % PER HOUR
8.564	53934.5	91156.0	7090.9	16928.5	0.00839	0.00249	0.00171
8.814	53936.0	91155.5	7091.1	16927.1	0.00826	0.00243	0.00177
9.064	53936.3	91155.7	7091.5	16926.2	0.00022	0.00236	0.00180
9.314	53937.2	91156.1	7092.4	16925.5	-0.00384	0.00220	0.00182
9.564	53938.1	91156.8	7090.3	16924.8	0.00311	0.00222	0.00184
9.814	53938.4	91159.3	7085.3	16924.1	0.00673	0.00234	0.00186
10.064	53938.5	91160.4	7083.7	16922.8	0.00425	0.00238	0.00190
10.314	53939.1	91159.2	7091.7	16921.8	-0.01527	0.00196	0.00187
10.564	53939.7	91162.3	7093.2	16921.2	-0.01116	0.00165	0.00181
10.814	53941.2	91163.6	7086.6	16920.5	0.01060	0.00185	0.00178
10.924	53940.8	91167.5	7084.0	16920.2	-0.00278	0.00181	0.00175
11.064	53942.1	91168.6	7080.7	16920.2	0.00389	0.00183	0.00172
11.314	53941.2	91166.2	7070.3	16918.6	0.01737	0.00218	0.00174
11.564	53939.7	91167.2	7082.8	16916.5	0.00473	0.00223	0.00177
11.814	53939.0	91163.9	7085.8	16915.2	-0.00396	0.00210	0.00178
12.064	53939.6	91162.5	7087.1	16914.3	-0.00122	0.00203	0.00178
12.314	53940.3	91164.5	7085.5	16913.5	0.00166	0.00202	0.00178
12.564	53939.7	91162.5	7086.0	16912.6	0.00133	0.00207	0.00179
12.814	53937.4	91164.2	7088.9	16911.0	0.00096	0.00205	0.00179
13.064	53937.5	91163.2	7090.1	16910.1	0.00155	0.00204	0.00179
13.314	53937.2	91163.7	7090.8	16909.1	0.00007	0.00200	0.00179
13.564	53937.0	91163.8	7089.9	16909.3	0.00436	0.00205	0.00180
13.814	53937.6	91164.9	7090.5	16907.5	-0.00835	0.00186	0.00179
14.064	53938.8	91169.4	7090.6	16906.9	-0.00750	0.00169	0.00175
14.314	53939.7	91170.3	7090.1	16906.2	-0.00152	0.00163	0.00172
14.564	53939.8	91168.5	7088.7	16905.3	0.00949	0.00177	0.00170
14.814	53941.6	91172.6	7085.6	16904.4	-0.00146	0.00167	0.00168
15.064	53941.9	91173.7	7079.9	16903.4	0.01231	0.00184	0.00167
15.314	53940.1	91172.5	7079.6	16902.1	0.01101	0.00199	0.00158
15.564	53939.9	91171.9	7079.6	16900.6	0.00573	0.00205	0.00169
15.814	53939.2	91172.3	7080.0	16899.6	0.00174	0.00205	0.00170
16.064	53940.3	91174.6	7078.4	16899.2	-0.00314	0.00197	0.00171
16.314	53941.4	91175.7	7079.8	16898.4	-0.00665	0.00183	0.00170
16.564	53941.1	91178.3	7079.0	16897.3	-0.00288	0.00176	0.00169
16.814	53942.4	91176.6	7074.3	16896.3	0.01640	0.00198	0.00170

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HOURS SINCE START	AIR MASS LOWER COMP. LBM	AIR MASS UPPER COMP. LBM	AIR MASS UPPER ICE LBM	AIR MASS LOWER ICE LBM	P-T-P LEAK RATE % PER HOUR	TOTAL TIME LEAK RATE % PER HOUR	MASS LEAK RATE % PER HOUR
17.064	53941.1	91178.1	7072.9	16895.1	0.00551	0.00203	0.00171
17.314	53940.0	91174.6	7074.6	16893.8	0.00987	0.00215	0.00173
17.564	53940.4	91175.7	7077.8	16892.7	-0.01060	0.00196	0.00173
17.814	53940.6	91177.3	7073.2	16891.8	0.01182	0.00209	0.00175
18.064	53940.6	91177.6	7073.3	16890.7	0.00174	0.00209	0.00176
18.314	53949.4	91176.5	7079.8	16889.4	-0.00916	0.00193	0.00176
18.564	53940.2	91174.7	7081.2	16888.2	0.00399	0.00196	0.00176
18.814	53940.3	91176.9	7082.2	16887.4	-0.00569	0.00186	0.00176
18.936	53941.3	91178.2	7081.0	16887.4	-0.00962	0.00178	0.00175
19.186	53943.5	91179.3	7080.3	16886.7	-0.00255	0.00173	0.00173
19.436	53942.0	91180.1	7079.1	16885.5	0.00710	0.00180	0.00173
19.686	53940.9	91177.8	7079.1	16884.2	0.01135	0.00192	0.00173
19.936	53942.4	91178.4	7076.0	16883.3	-0.00041	0.00189	0.00173
20.186	53942.4	91177.6	7078.5	16882.4	0.00311	0.00190	0.00173
20.436	53942.5	91179.2	7078.6	16881.7	-0.00270	0.00165	0.00173
20.686	53942.3	91179.1	7078.6	16880.7	0.00303	0.00186	0.00173
20.936	53943.5	91179.6	7078.7	16880.2	-0.00299	0.00188	0.00172
21.186	53943.5	91180.5	7077.7	16879.3	0.00251	0.00181	0.00172
21.436	53943.6	91181.2	7077.9	16878.4	-0.00033	0.00179	0.00171
21.686	53943.4	91180.3	7078.7	16877.3	0.00299	0.00180	0.00170
21.936	53944.7	91181.9	7079.8	16876.7	-0.00780	0.00169	0.00169
22.186	53945.4	91184.1	7078.8	16876.5	-0.09397	0.00163	0.00168
22.436	53947.3	91187.3	7078.6	16876.0	-0.01020	0.00150	0.00166
22.686	53946.8	91188.9	7078.5	16875.6	-0.00603	0.00141	0.00163
22.936	53949.8	91191.7	7068.8	16875.1	0.01500	0.00156	0.00162
23.186	53949.6	91191.5	7062.2	16873.5	0.02026	0.00176	0.00162
23.436	53947.3	91189.3	7067.1	16871.9	0.00281	0.00177	0.00162
23.686	53945.6	91187.3	7070.8	16870.3	0.00356	0.00179	0.00162
23.936	53946.0	91183.1	7074.8	16869.3	0.00181	0.00179	0.00162
24.186	53946.0	91185.4	7074.0	16868.3	-0.00081	0.00177	0.00162
24.436	53946.6	91187.3	7073.8	16867.5	-0.00392	0.00171	0.00162
24.686	53946.0	91187.9	7074.8	16866.6	0.00022	0.00169	0.00161