B8.0 INSTRUMENTATION

Table 3

LIST OF CILRTs BY CATEGORIES

Category Number	Description	Number of Tests	Percent of Total
1	Failed as-found	6	30
2	Failed as-found and initial as-left	3	15
3	Failed initial as-left	0	0
4	Passed as-found and initial as-left	11	55

It is significant that no test fell into Category 3. If the total as-found local leakage was less than the 0.75 La criteria, then the additional leakage measured during the subsequent Type A test was never enough to put the total over the acceptance criteria. This, in effect, says that passage or failure of the Type A tests was always determined by local leak test results performed before the Type A test began. Leakage from the structure and other parts of containment detectable only by Type A testing is almost always very low and does not change much over time. The leaks found during Type A tests were usually caused by either omissions in the local leakage testing program, or leaks in non B&C tested instrument lines and manifolds. NRC Information Notice 86-16 also mentions cases where CILRTs found deficiencies in Type B and C testing programs.

There were three instances in Table 2 where the total as-left local leakage (third column) were low and the subsequent Type A test identified large leaks. Test 18 was a Pre-Op test where most of the leakage was from instrument liens not subject to local leak testing. In another case (test #2) the leakage was from an area that was improperly locally leak tested prior to the CILRT. The third case (Test 11) was a leak from a fan cooler tube, an area that is not locally leak tested. This system was depressurized during the CILRT, but during unit operation or post-accident conditions, it would have been maintained at greater than accident pressure. This leakage would have been found prior to startup when the system was re-pressurized.

Type A testing has definitely been useful in finding the above types of problems. Accelerated schedules in response to failures due to leaks found during the Type A test seems reasonable. In contrast, 66% of the as-found failures found here were due solely to high local leakage paths (Category 1). The performance of additional Type A tests in response to these failures yields no new information. NRC Information Notice 85-71 states that, in some cases, a high degree of containment integrity may be better achieved through improved maintenance and testing programs for containment penetration boundaries and isolation valves rather than by performing more frequent CILRTs. To implement this, after failing two consecutive CILRTs, the licensee would submit a corrective action plan as an Appendix J exemption request. If approved, the licensee may implement the plan in lieu of going on an accelerated CILRT schedule.

A corrective action plan would address correction and surveillance of the specific source(s) of leakage responsible for the Type A test failure. The vast majority of major leaks are from valves, closures, and penetrations. Since surveillance of these areas can be performed by local leak testing alone, implementation of corrective action plans could sharply reduce the number of unnecessary CILRTs performed. If even a small fraction of the cost per CILRT saved is applied toward the permanent fixes of recurring problem containment isolation systems, overall containment integrity would be improved.

A good corrective action plan would:

(1) Address the root cause(s) of leakage in such a way as to prevent recurrence.

(2) Ensure that the unit in question has a comprehensive Type B and C testing program.

(3) Ensure that the local leak tests performed next outage in place of the accelerated CILRT are as-found tests on the problem areas.

(4) Not include any additional costly requirements (such as mid-cycle testing) that add nothing to safety and thereby induce the utility to reject the plan.

The ultimate purpose of determining the as-found integrated leak rate is to verify the adequacy of the maintenance performed since the last CILRT. The requirement to perform more frequent CILRTs in response to as-found failures can help achieve the above objective only by shortening the time between leakage discoveries, the thereby decreasing total unit operation time with diminished containment integrity. For plants with comprehensive local leak rate testing programs, this benefit will be realized only if the leaks found are of the kind only detectable by Type A testing, since Type B and C tests are performed every outage anyway.

By far, the most common cause of as-found Type A test failures has been shown to be leaks in locally tested areas. The requirement to perform additional Type A tests for those cases makes little sense. In some cases, the source of the leakage is not adequately addressed and the next test fails for the same reason. If, instead, a corrective action plan that addressed permanently eliminating the specific source of leakage is implemented, then accelerated Type A testing would serve little purpose. By implementing a root cause specific corrective action plan, both cost and Man-Rem would be reduced while improving confidence in the integrity of the primary containment system.

B7.6 ACCEPTANCE CRITERIA

B7.6.1 Type A Testing

The intent of 10CFR50 Appendix J Type A testing is to verify the primary containment is capable of maintaining its leak-tight integrity during normal and post-accident conditions. Leakage rate criteria are based on 10CFR100 calculations. Consistent with 10CFR50 Appendix J, the CILRT is either conducted in the "as-is" condition of the CILRT LSLR is adjusted to provide an as-found leakage rate. The as-found criterion has been established as $\leq$1.0 La. This verifies that containment leakage was acceptable throughout the previous operating cycle. The as-left criterion has been established as $\leq$0.71 La. This provides a 25% margin for primary containment degradation over the operating cycle. Both of the above limits are consistent with he proposed 10CFR50 Appendix J rule changed published in the Federal Register on October 29, 1986.

B7.6.2 Type B/C Testing

As was established for Type A test criteria, the Type B and C test criteria also have a margin for primary containment isolation barrier degradation. Prior to startup, the sum of all Type B and C components must be ≤0.6 La using MXPLRs. This provides a 40 margin of degradation and is consistent with 10CFR50 Appendix J. Appendix J does not explicitly require running totals during unit operation; its intent is to ensure primary containment integrity is maintained during operation. Therefore, if R/As are performed during operation, the Running Total Containment Leakage Rate must be adjusted and verified to be ≤1.0 La.

This provides adequate assurance that primary containment integrity is maintained as established by 10CFR100 calculations.

B8.1 GENERAL REQUIREMENTS

The practices as described in Section 8.1 are standard throughout the nuclear industry. 10CFR50 Appendix J does not provide guidance in these areas. Generally, post-test calibrations are used in all cases; performance of a verification test however, is not a normal practice, but is done with the CILRT. A verification test as described in Section 9.9 is in itself a calibration check of the Type A test instrumentation and thus precludes the need for costly post test calibrations.

B8.2 INSTRUMENT PERFORMANCE AND CALIBRATION REQUIREMENTS FOR TYPE A TESTS

Instrumentation requirements are consistent with the characteristics of commonly used equipment. Experience has shown that the calibration interval required for each instrument may be different. The licensee may select his own calibration interval based on a documented performance history of each instrument.

B8.2.8 Atmospheric Conditions

Since measurements of the environmental atmospheric changes are not used in the leakage rate calculations, the precision of the measuring equipment shall be such that significant atmospheric changes could be recorded for possible correlation with test data. Hourly recordings of atmospheric temperature to 1°F and pressure to 1 inch mercury are sufficient. NBS traceability is not required.

B8.2.9 Water Level Measurement

Experience has shown that the accuracies given for water level measurement in the reactor vessel and in the suppression chamber are adequate to account for water level differences when calculating the Type A leakage rate.

B8.3 INSTRUMENT PERFORMANCE AND CALIBRATION REQUIREMENTS FOR TYPE B AND C TESTS

Instrument requirements are consistent with the characteristics of commonly used equipment. Experience has shown that the calibration interval required for each instrument may be different. The licensee may select his own calibration interval based on a documented performance history of each instrument.

B9.1 GENERAL

Although allowed by Reference 10, the reference volume method is not recommended. Past experience has shown that the absolute method is far superior. Specific areas of difficulty with the reference volume method are temperature stabilization and test volume leakage.

B9.2 CONTAINMENT INSPECTION

This requirement is consistent with 10CFR50 Appendix J.

B9.3 TEMPERATURE SURVEY

Area temperature surveys of primary containment must be conducted prior to the Type A test. The survey is used to determine placement of the temperature measuring instruments and assignment of volume fractions. Unidentified temperature variations have the potential to effect the measurement of the containment dry air mass and, in effect, create large data scatter. It is acceptable to use fans or other means to circulate air within he containment to reduce temperature stratifications, as long as the survey is conducted under the same conditions. It is also acceptable to use a survey of a different unit if it can be shown to be identical. This is consistent with ANSI N45.4 and 56.8.

B9.4.1 Minimum Number of Sensors

No minimum number of drybulb temperature and dewpoint sensors are specified because quadrature theory shows that, in many cases, the quantity volume fraction per sensor is not a relevant factor in good containment modeling. A better basis for determining the number of required temperature elements is a containment temperature survey which determines temperature gradients within the containment.

B9.4.2 System Performance

The instrument selection guide formula is consistent with Reference 9. For purposes of instrument selection and loss of sensor criteria, the ISG is only calculated for t = 24 hours. The ISG need not be calculated for a smaller t if a shorter duration BN-TOP-1 test is run, because the BN-TOP-1 method contains a factor (97.5% UCL) that corrects the measured leakage rate for ending the test in less than 24 hours. This 97.5% UCL calculation so conservatively compensates for a short duration (<24 hours) test, that no addition conservatism in instrument accuracy is required.

B9.5 PRESSURIZATION

No specific pressurization rate has been dictated by this document. Due to the vast variety of containments, no one pressurization criterion could ensure equipment safety from in-gassing. The intent of Section 9.5 is to ensure that the reader is aware of the potential for equipment damage.

B9.6 CONTAINMENT STABILIZATION

Containment stabilization tests are performed following pressurization but prior to beginning the Type A test.

B9.6.1 BN-TOP-1 Requirements

Reference 16, Section 2.2.B, requires that plots be made of both the average containment air temperature and the containment air pressure versus time. That section also stipulates that the pressure-time curve should follow the temperature-time curve.

Reference 16, Section 2.3.A, requires that the containment be allowed to stabilize for about four hours, and that the containment satisfy stabilization criteria 9.6.1.1 or 9.6.1.2. is this report's interpretation of this requirement. The equation chosen is a first-order, two-point, backwards finite difference approximation for this rate of rate of change.

Reference 18 provides NRC acceptance of BN-TOP-1 Revision 1.

B9.6.2 Dry Air Mass Method

The dry air mass method tests for containment stability by examining both the rate of change of containment dry air mass and the amount of scatter of those masses. The two specific tests chosen are intentionally simple. The parameters required to perform the required calculations are currently available at most plants, and most plants have the capability to perform the calculations without requiring software changes.

Other methods test for containment stability by examining the rate of change of containment temperature. If a containment is properly modeled and instrumented, it may have a large temperature transient with no resulting change in calculated dry air mass. This is due to the containment pressure changing in response to the temperature change.

The dry air mass containment stabilization method eliminates any specific minimum time interval, while at the same time imposing physically meaningful criteria. The time savings is encouragement for the licensee to improve the Type A test instrumentation system, containment modeling, and pump-up techniques.

B9.6.2.1 Test for the Rate of Change of Dry Air Mass

If the calculated leakage rate is not close to being constant, the Type A test should not start. A changing leakage rate may indicate unstable containment atmospheric conditions or suggest specific types of leakage (leaks through airlock shaft seals are known to be nonsteady). This test requires the rate of change of the leakage rate to be less than a value which would result in as 0.01 La change in one hour.

It is believed that a valid Least Squares fit cannot be performed without utilizing at least 20 data sets. In order to accomplish this while not requiring an inordinate length of time for data collection, the sample interval must be decreased. Intervals as short as two minutes are allowed. This interval is long enough to accommodate the transient response characteristics of most RTDs. The leakage rates for two overlapping 20 data set intervals are calculated. The difference between these two leakage rates divided by the time between intervals, is the rate of change of leakage rate.

B9.6.2.2 Test for Dry Air Mass Point Scatter

An excessive amount of scatter in dry air mass data points may indicate unstable containment conditions or instrument problems. In either case,t he test should not begin until the scatter is within reasonable limits. The UCL is calculated from the average of the deviation of mass points from the least squares calculated leakage rate. The difference between the UCL and the Least Squares line of leakage rate may be used as an indicator of the amount of data scatter.

The amount of data scatter is considered acceptable for determining containment stabilization if the difference between the UCL and the Least Squares leakage rate is less than 0.25 La for the 30 data sets used. The 0.25 La value was chosen to be consistent with the acceptance criteria used for the verification test.

B9.6.3 Appendix J Method

This method is consistent with the requirements of Section III.A.1.(c) of Reference 8. Unlike the method described above, there are no specific checks on the allowable rates of change or scatter.

The decision of when to start the test is left tot he judgement of the licensee. If that judgement proves to be flawed, then the result would be either an extended Type A Test, a Type A test restart, or failure of the Verification Test. In no case would this result in the passing of a bad Type A test.

B9.7 CALCULATION OF CONTAINMENT DRY AIR MASS

The determination of the overall dry air mass for containment at any point in time is based on the application of the fundamental idea gas equation PV = NRT.

Thus, the overall dry air mass at time t can be determined using the total containment average values for pressure, vapor pressure, temperature, and free air volume. For the thermodynamic conditions present during the CILRT, the assumption that the containment air will behave as an ideal gas is valid.

B9.8.1 Mass Point Method

This method is based upon the assumption that the true leakage rate is constant during the text period. If this assumption is true and if there was perfect containment modeling and instrumentation, a plot of the measured containment dry air mass versus time would yield a straight line with a negative slope. The leakage rate is proportional to the slope of this line. In a real case, the mass points are scattered about any straight line drawn through them. The Mass Point Method calls for performing a Least Squares Fit of the mass points. This fit determines the Slope and Y-Intercept of the line that minimizes the total amount of scatter of these points along its path. The methodology for calculation of this leakage rate and its 95 percent upper confidence limit is presented here.

Each time a data set is collected during the Type A test, the time of collection and the Total Containment Dry Air Mass at that time are calculated and stored. A collection of K such times/mass pairs are shown below.

t_1., M_1 t_2,M.$_2$ t_3,M_3. _ _ _ t_{K-1},$M_{K\cdot-1}$ t_K,M_K .

where

t_i = Time (hours at which data set i was collected. By definition, the time at t_1 equals zero.

M_i = Total Containment Dry Air Mass (Lbm) at time t_i.

Let

ST = Starting data set number of the calculational range.
SP = Ending data set number of the calculational range.
N = Number of data sets to be Least Squares Fit.

N = SP - ST + 1

For the above set of data points when containment mass M=At+B, A and B for the range of points starting from ST and extending to SP are calculated as shown below.

$$A = \frac{N\sum_{i=ST}^{SP} t_i M_i - \sum_{i=ST}^{SP} t_i \sum_{i=ST}^{SP} M_i}{N\sum_{i=ST}^{SP} (t_i)^2 - \left(\sum_{i=ST}^{SP} t_i\right)^2}$$

$$B = \frac{\sum_{i=ST}^{SP} M_i - A\sum_{i=ST}^{SP} t_i}{N}$$

substituting for A,

$$B = \frac{\sum_{i+ST}^{SP} M_i \sum_{i=ST}^{SP} (t_i)^2 - \sum_{i=ST}^{SP} t_i \sum_{i=ST}^{SP} M_i t_i}{N\sum_{i=ST}^{SP} (t_i)^2 - \left(\sum_{i=ST}^{SP} t_i\right)^2}$$

where

A = Rate of change of Total Containment Dry Air Mass, the slope of the straight line discussed above (lbm/hr).

B = Calculated value of Total Containment Dry Air Mass (lbm) at t_i.

The leakage rate of dry air from containment at t_i, L_i, expressed in units of percent per day is shown below.

$$L_i = \frac{-2400A}{B + At_{st}}$$

Let T be the Student's distribution function at the 95th percentile, expressed as a function of N.

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

Ignoring negligible terms, the 95 percent Upper Confident Limit (UCL) of the true leakage rate in units of percent per day is given below.

$$F = \left[\frac{1}{(N-2)} \left(\frac{N \sum_{i=ST}^{SP} M_i^2 - \left(\sum_{i=ST}^{SP} M_i \right)^2}{N \sum_{i=ST}^{SP} t_i^2 - \left(\sum_{i=ST}^{SP} t_i \right)^2} - A^2 \right) \right]^{1/2} \frac{(2400)}{B + At_{ST}} \frac{(weight\%}{perday)}$$

B9.8.2 Point-to-Point Method

The point-to-point method is not recommended for use in determining overall leakage rate acceptance criteria for Type A tests. However, this method can be useful in providing quick assessments of leakage rate changes during the test.

This method is based upon the assumption that the rate of change of leakage rate is constant during the testing period. If this is true, and if there was perfect containment modeling and instrumentation,a plot of containment leakage rates versus time would be a straight line with a negative slope. The mass out of containment leakage rate of dry air is proportional to the equation of the line. In a real case, the leakage rates are scattered about any straight line drawn through them.

The point-to-point method calls for performing a Least Squares Fit of the leakage rates determined from each data point interval. This fit determines the slope and the Y-intercept of the line that minimizes the total amount of scatter of these points along its path. The methodology for calculation of this leakage rate is presented here.

Each time a data set is collected during the Type A test, the time of collection, the Total Containment Dry Air Mass, and the point-to-point leakage rate for the last two data sets are calculated and stored.

A collection of K such points are shown below.

t_1,M_1 t_2,M_2 t_3,M_3 • • • t_{K-1},M_{K-1} t_K,M_K

• •   • •   • • •   • •   • •

$M_{P,2}$ $M_{P,3}$ $M_{P,K-1}$ $M_{P,K}$

where

t_i = Time (hours) at which data set i was collected. By definition, the time at t_1 equals zero.

M_i = Total Containment Dry Air Mass (Lbm) at time t_i.

$\dot{M}_{P,i}$ = Point-to-point leakage rate for the interval of T_{i-1} to t_i (weight percent per day).

The point-to-point leakage rate at time i is calculated as

$$\dot{M}_{P,i} = \frac{2400}{t_i - t_{i-1}}\left(1 - \frac{M_i}{M_{i-1}}\right)$$

The leakage rate of dry air from containment at t_i, L_i, expressed in units of percent per day is shown below.

$L_i = -(B + At_i)$

where

A = Rate of change of Point to Point leakage rates, (%/day/hr).

B = Calculated value of Point to Point leakage rate at t_1 (%/day).

Let

ST = Starting data set number of the calculation range.

SP = Ending data set number of the calculation range.

N = Number of Point to Point Leakage rates to be Least Squares Fit.

N = SP - ST

For the above set of point-to-point leakage rates, A and B for the range of internal leakage rates starting from ST+1 and extending to SP are calculated as shown below:

$$B = \frac{N \sum_{i=ST+1}^{SP} t_i \overset{0}{M}_{P,i} - \sum_{i=ST+1}^{SP} t_i \sum_{i=ST+1}^{SP} \overset{0}{M}_{P,i}}{N \sum_{i=ST+1}^{SP} (t_1)^2 - \left(\sum_{i=ST+1}^{SP} t_i \right)^2}$$

$$A = \frac{\sum_{i=ST+1}^{SP} \overset{0}{M}_{P,i} \sum_{i=ST+1}^{SP} (t_i)^2 - \sum_{i=ST+1}^{SP} t_i \sum_{i=ST+1}^{SP} \overset{0}{M}_{P,i} t_i}{N \sum_{i=ST+1}^{SP} (t_i)^2 - \left(\sum_{i=ST+1}^{SP} t_i \right)^2}$$

B9.8.3 Total Time Method

This method is based upon on the assumption that the rate of change of leakage rate is constant during the testing period. If this is true, and if there was perfect containment modeling and instrumentation, a plot of containment leakage rates versus time would be a straight line with a negative slope. The leakage rate of dry air mass out of containment is proportional to the equation of the line. In a real case, the leakage rates are scattered about any straight line drawn through them.

The Total Time Method calls for performing a Lease Squares Fit of the total time leakage calculations. This fit determines the slope and the Y-Intercept of the line that minimizes the total amount of scatter of these points along its path.

Each time a data set is collected during the Type A test, the time of collection, the total containment dry air mass, and the total time leakage rate at that time are calculated and stored.

A collection of K such points are shown below.

$t_1, M_1 \quad t_2, M_2 \quad t_3, M_3 \quad \bullet \; \bullet \; \bullet \quad t_{K-1}, M_{K-1} \quad t_K, M_K$

$\bullet\,\bullet \quad \bullet\,\bullet \quad \bullet \; \bullet \; \bullet \quad \bullet\,\bullet \quad \bullet\,\bullet$

$\dot{M}_{T,2} \quad \dot{M}_{T,3} \qquad\qquad \dot{M}_{T,K-1} \quad \dot{M}_{T,K}$

where

t_i = Time (hours) at which data set i was collected. By definition, the time at t_1 equals zero.

M_i = Total Containment Dry Air Mass (Lbm) at time t_i.

$\dot{M}_{T,i}$ = Total Time Leakage Rate at time t_i (weight percent per day).

The total time leakage rate at time t_i is calculated as shown below.

$$\dot{M}_{T,i} = \frac{2400}{t_i - t_{ST}} \left(1 - \frac{M_i}{M_{ST}} \right)$$

Let

ST = Starting data set number of the calculation range.

SP = Ending data set number of the calculation range.

N = Number of Total Time Leakage rates to be Least Squares Fit.

N = SP - ST

For the above set of total time leakage rates, A and B for the range of mass points starting from ST and extending to SP are calculated as shown below.

$$A = \frac{N \sum_{i=ST+1}^{SP} t_i M_{T,i} - \sum_{i=ST+1}^{SP} t_i \sum_{i=ST+1}^{SP} M_{T,i}}{N \sum_{i=ST+1}^{SP} (t_i)^2 - \left(\sum_{i=ST+1}^{SP} t_i \right)^2}$$

$$B = \frac{\sum_{i=ST+1}^{SP} M_{T,i} \sum_{i=ST+1}^{SP} (t_i)^2 - \sum_{i=ST+1}^{SP} t_i \sum_{i=ST+1}^{SP} M_{T,i} t_i}{N \sum_{i=ST+1}^{SP} (t_1)^2 - \left(\sum_{i=ST+1}^{SP} t_i \right)^2}$$

where

A = Rate of change of Total Time Leakage Rates, (%/day/hr).

B = Calculated value of Total Time Leakage Rates at t_{ST} (%/day).

The leakage rate of dry air from containment at t_i, L^i, expressed in units of percent per day is shown below.

$L_i = -(B + A_{ti})$

Let T be the student's t distribution function at the 95th percentile, expressed as a function of N.

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

Ignoring negligible terms, the 95% Upper Confidence Limit (UCL) of the true Leakage Rate is given below in units of percent per day.

UCL = L + TF

Let

Then

$$F = \frac{1}{N-1} + \frac{\left(t_P - \frac{1}{N-2} \sum_{i=ST+3}^{SP} t_i \right)^2}{\sum_{i=ST+3}^{SP} t_i^2 - \frac{1}{N-2} \left(\sum_{i=ST+3}^{SP} t_i \right)^2}$$

$$F = \left[\frac{1}{(N-2)} \left(\sum_{i=ST+3}^{SP} (M_{t,I})^2 - B \sum_{i=ST+3}^{SP} M_{T,i} - A \sum_{i=ST+3}^{SP} M_{T,i}\, t_i \right) \right]^{1/2}$$

B9.8.4 BN-TOP-1 Method

This method calculates total time leakage rates and the statistical leakage rate in a manner identical to that specified in Section B9.8.3. Only the Upper Confidence Limit (UCL) is calculated differently, and that methodology is described here.

The student's t distribution used for the BN-TOP-1 Method is a double sided distribution at the 97.5 percentile.

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

Ignoring negligible terms, the 97.5% Upper Confidence Limit of the leakage rate is given below in units of percent per day.

UCL = L + TF

L was given in Section 9.8.3.

Let

Then

$$F = 1 + \frac{1}{N-2} + \frac{\left(t_P - \frac{1}{(N-2)} \sum_{i=ST+3}^{SP} t_i \right)^2}{\sum_{i=ST+3}^{SP} t_i^2 - \frac{1}{(N-2)} \left(\sum_{i=ST+3}^{SP} t_i \right)^2}$$

$$F = \left[\frac{F}{(N-2)} \left(\sum_{i=ST+3}^{SP} (M_{T,i})^2 - B \sum_{i=ST+3}^{SP} M_{T,i} - A \sum_{i=ST+3}^{SP} M_{T,i}\, t_i \right) \right]^{1/2}$$

B9.9 VERIFICATION TEST

B9.9.1 General Requirements

The same calculational methods, time steps, and instrumentation should be used for both the type A test and the verification test, because the purpose of the verification test is to qualify the instruments used for the Type A test. Any changes to the calculational methods, time steps, or instrumentation might change the calculated leakage rate and nullify the verification process.

B9.9.2 Test Start Time

The verification test procedure is based on the assumption that the actual containment leakage rate is constant. The error resulting from any small rate of change in leakage rate may become large over a long time period.

Data must continue to be collected during the interim period in case the start of the verification test is unexpectedly delayed long enough to result in a significant difference between leakage rates at the end of the Type A test and the start of the verification test. Then the data is used as part of the Type A test, and the error is eliminated by sliding the Type A test end time forward to the start of the verification test. A difference of less than 0.1 La was chosen as the criteria. In most cases, this much error in the Type A test will still allow passage of the verification test within the ±0.25 La band.

B9.9.3 Stabilization Period

BN-TOP-1, Section 2.3.C.1, states that containment atmospheric conditions shall be allowed to stabilize for about one hour after superimposing a known leakage rate.

Although starting the verification test stabilization period too soon or extending the period too long will result in an unnecessary extension in the time required to verify the Type A test results, it will not result in verification of an invalid Type A test.

B9.9.4 Measurement of Induced Leakage Rate/Verification Test

The verification test compares a known leakage rate against the measured containment leakage rate. Any flow measurement instrument that meets the specifications listed in Section 8.2.4 is sufficiently accurate to quantify the induced leakage relative to the known acceptance criteria for the measured leakage rate.

The verification test methodology is based upon the assumption that the induced leakage is constant, therefore it should not be intentionally varied. Since the differential pressure across the flow measurement device is essentially constant over the duration of the verification test, no manual adjustments should be required in order to maintain this constant flow rate. In some cases, however, the measured value of induced leakage rate may drift a small amount. Readings of the leakage rate should be periodically taken in order to verify that the amount of drift has not become excessive, and to alert the licensee to make corrections if needed. Typically, a drift of less than 0.05 La should not adversely affect results, and therefore no correction would be required.

B9.9.5 Calculation of Target Leakage Rate

Once the final value of the LSLR is known from the Type A test, a known additional leakage is induced from the containment. The new containment leakage rate is expected to equal the LSLR plus this induced leakage rate. It should be noted that the above statement is based upon the assumption that the LSLR remains constant during the course of the induced leakage rate test.

The acceptable range of induced leakage rates was chosen to be between 0.75 La and 1.25 La. This is due to the fact that this range commonly appears in many plant's existing Technical Specifications. Also, use of induced leakages in this range for many CILRTs has proven to be both practical and acceptable.

Flow meters commonly measure the induced leakage rate in units of scfm or sccm. since these volumetric flow rates are specified at a standard temperature and pressure, the density of the air is known. Thus, the mass flow rate is specified.

Plant Technical Specifications list acceptance criteria in units of %/day. An equation must be used to relate leakage in %/day to scfm.

Percent/day implies the percent of the total containment inventory per day that is leaking out of containment. The fact that the inventory is changing during the verification test is ignored, and the containment dry air mass present at the start of the verification test is used at all future times.

Many different values of standard temperature and pressure are listed in various references. One pair was specified here for the sake of uniformity.

The mass flow rate M_{ind} of the induced leakage rate equals $Q_{scfm}F_{std}$.

Substituting,

$$F_{std} = \frac{P_{st}}{RT_{st}}$$

$$M_{ind} = \frac{Q_{scfm}P_{st}(144)}{R(T_{st}+459.69)}\ lbm/\min$$

The total dry air mass of containment at the start of the verification test M_o is

$$M_o = \frac{144P_cV_c}{R(T_{av}+459.69)}$$

The leakage rate Q in percent/day is

$$Q = \frac{M_{ind}}{M_o}(100)(1440)\%/day$$

Substituting,

$$\overset{0}{Q}_{\%/day} = \frac{\overset{0}{Q}_{scfm} P_{st} (144) R (T_{av} + 459.69)(144,000)}{V_c P_c (T_{st} + 459.69)}$$

$$\overset{0}{Q}_{scfm} = \overset{0}{Q}_{\%/day} \left(\frac{R (T_{st} + 459.69) P_c V_c (144)}{144,000 P_{st} (T_{av} + 459.69)} \right)$$

B9.9.6 Test Duration

BN-TOP-1, Section 2.3.C.2, states that the verification test duration shall be approximately equal to half of the integrated leak rate test duration.

If a method other than BN-TOP-1 is used, no minimum duration for the verification test is required. However, for the verification test to be declared successful, the LSLR measured during the verification test must be stable and within he acceptance band described in Section 9.9.7(2). Continuation of the test after these two conditions are met will only serve to unnecessarily extend the time to perform the verification test and will not result in verification of an invalid Type A test.

B9.9.7 Acceptance Criteria

The accuracy of the Type A test measuring system and the leakage rate test results are verified provided the difference between the induced leakage rate and the Type A test leakage rate is within 0.25 L_a. The acceptance band specified in Section 9.9.7 is consistent with Reference 8.

B9.10 DEPRESSURIZATION

Like Section 9.5, Section 9.10 only provides awareness of the potential for equipment damage. Each plant must determine the appropriate depressurization rate to avoid equipment damage due to outgassing.

B10.1 GENERAL

This section provides acceptable Type B and C test methodology. ANSI N45.4 and 10CFR50 Appendix J do not provide specific test methods (only test parameters). ANSI/ANS 56.8 (which has yet to be endorsed by the NRC) does provide pressure decay, flow rate, water collection, and vacuum retention as acceptable test methods. All these methods are outlined in Section 10.0. In addition water displacement and bubble testing are included.

B10.2 TEST METHODS

B10.2.1 Pressure Decay Method

Pressure decay is probably the most frequently used test method. This method employs the ideal gas law to measure the change in volume with respect to changes in temperature and pressure. The methodology and leak rate equation in Section 10.2.1 is consistent with ANSI/ANS 56.8. The derivation for the pressure decay formula is provided below.

From the ideal gas law

$$n - \frac{PV}{RT}$$

Leakage is obtained by taking the derivative with respect to time

$$L' = \frac{dn}{dt} = \frac{V}{R}\frac{d(P/T)}{dt} = \frac{V}{R}\left[\frac{1}{T}\frac{dP}{dt} - \frac{P}{T^2}\frac{dT}{dt}\right]$$

If we assume that P and T are linear functions of time

$$L' = \frac{V}{R\bar{T}\Delta t}\left[\Delta P - \frac{\bar{P}\Delta T}{\bar{T}}\right]$$

where

$$\bar{T} = Average\,temperature = \frac{T_1 + T_2}{2}$$

$$\bar{P} = Average\,temperature = \frac{P_1 + P_2}{2}$$

$$\Delta P = P_1 - P_2$$

$$\Delta T = T_1 - T_2$$

Substituting,

$$L' = \frac{V}{R\Delta t}\left[\frac{P_1 - P_2}{(T_1 + T_2)/2} - \frac{[(P_1 - P_2)/2](T_1 - T_2)}{(T_1 + T_2)^2/4}\right]$$

$$L' = \frac{V}{R\Delta t}\left[\frac{4P_1T_2 - 4P_2T_1}{T_1^2 + 2T_1T_2 + T_2^2}\right]$$

If $T_1 = T_2$, then $(T_1 + T_2)^2 = 4T_1T_2$

$$L' = \frac{V}{R\Delta t}\left[\frac{P_1T_2 - P_2T_1}{T_1T_2}\right]$$

$$L' = \frac{V}{R\Delta t}\left[\frac{P_1}{T_1} - \frac{P_2}{T_2}\right] in\ lbm\ mole/hr$$

$$L' = \frac{V}{R\Delta t}\left[\frac{P_1}{T_1} - \frac{P_2}{T_2}\right]\bar{V} ft^3/hr$$

where

V = molar volume of air at 14.696 psia and temperature T.

Since

$$\frac{\bar{V}}{R} = \frac{T}{14.696}$$

$$L' = \frac{V}{\Delta t}\left[\frac{P_1}{T_1} - \frac{P_2}{T_2}\right]\frac{T}{14.696} ft^{3/hr}$$

If T = T_{st}, standard temperature (68^{o}F) L is in Standard Cubic Feet per Hour.

$$L^{/} = \frac{V}{)t}\left[\frac{P_1}{T_1} - \frac{P_2}{T_2}\right]\frac{T_{st}}{14.696}\,scfh$$

where

V is in ft^3
P is in psia
T is in ^{o}R
)t is in hr
T_s is in ^{o}R

$$L^{/} = \frac{V}{)t}\left[\frac{P_1}{T_1} - \frac{P_2}{T_2}\right]35.9\,scfh$$

To conservatively correct the leakage rate to what it would have been if the test volume had been maintained above P_a:

L = L' (CF)

where

$$CF = \frac{P - \frac{1}{P}}{P_{AVE} - \frac{1}{P_{AVE}}}$$

$$P_{AVE} = \frac{\frac{P_1 + P_2}{2} + 14.696}{14.696} = \frac{P_1 + P_2}{2\ x\ 14.696} + 1$$

L = Corrected leak rate (SCFH)
V = Total test volume (ft^3)
)t = Elapsed time (hr)
P_1 = Initial pressure (psia)
P_2 = Final pressure (psia)
P_{AVE} = Average test pressure of the test (atmospheres)
P = Peak accident pressure (atmosphere)
T_1 = Initial temperature (^oR)
T_2 = Final temperature (^oR)
L' = Measured leakage rate (SCFH)

In some cases, when the pressure decay method is used, the pressure int he test volume drops below P_a. Reference 11, page 26, Equation 39 can be used to correct the measured leakage rates for this drop in pressure. A short derivation of this correction factor is shown below.

Fully developed, isothermal viscous gas flow through a circular channel is described by the Hagen-Poiseville equation.

$$P_a - P_c = \frac{32\ MVl}{g_c D^2}$$

where
M = Air's viscosity
V = Average velocity
l = Channels's length
D = Channel's diameter
g_c = Gravitational constant

P_a = Pressure (psi)
PF = Ambient pressure (psi)

The mass flow rate of the air (W_a) at test pressure P_a is equal to Q Favg, where Q is the air's volumetric flow rate and Favg is the air's average density. The channel cross sectional area, A is equal to $BD^2/4$. Also, V = Q/A.

From the above equations, it can be seen that

$$W_a = \frac{g_c BD^4}{128\ Ml}(F_{avg})(Pa - PF)$$

For a perfect gas, Favg is equivalent to $P_{avg}/R\ T_a$.

where

P_{avg} = Average pressure
T_a = Average temperature
R = Appropriate gas constant

For isothermal conditions, this flow's Favg may be approximated by

$$F_{avg} = \frac{P_a + P_F}{2}\frac{1}{R\ T_a}$$

$$W_a = \frac{g_c BD^4}{256\ Ml}\frac{1}{R\ T_a}(P_a^2 - P_F^2)$$

Let

$$\frac{g_c BD^4}{256\ Ml}\frac{1}{R\ T_a} = a\ constant\ K$$

$$W_a = K(P_a^2 - P_F^2)$$

Let

$$\overline{P_a} = \frac{P_a}{P_F},$$

$$P_a^2 = \overline{P_a}^2 P_F^2$$

$$W_a = K(\overline{P_a}^2 P_F^2 - P_F^2) = K\ P_F^2(\overline{P_a}^2 - 1)$$

The correction factor CF = $\frac{L_a}{L_t}$

where

L_a = Leakage rate expected if the test were conducted at P_a

L_t = Leakage rate at the actual test pressure

W_a = Mass flow rate at the test pressure P_a

W_t = Mass flow rate at the actual test pressure

P_t = Final test pressure (atmospheres)

P_a = Peak accident pressure (atmospheres)

Converting mass to volume (leakage rate),

$$La = \frac{W_a}{F_a} \text{ and } L_t = \frac{W_t}{F_t}$$

where F_a and F_t are the densities of the gas at P_a and P_t, respectively.

$$CF = \frac{W_a}{W_t}\,\frac{\frac{RT}{P_a}}{\frac{RT}{P_t}}$$

$$CF = \frac{W_a}{W_t}\,\frac{P_t}{P_a}$$

$$CF = \frac{K(P_a^2-1)P_t}{K(P_t^2-1)P_a}$$

$$CF = \frac{P_a - 1/P_a}{P_t - 1/P_t}$$

B10.2.2 Flowmeter Makeup Method

The use of rotameters or mass flow meters is useful in measuring large leak rates where a pressure decay test is not practical, or when the test volume is unknown, therefore not allowing the use of the pressure decay method. The test methodology is consistent with ANSI/ANS 56.8.

B10.2.3 Water Displacement Method

The water displacement method is an easy leak test to perform. Typically water displacement tests are conducted on systems normally filled with water, thereby saving time. The water displacement method assumes any loss from the test container is a direct measurement of component leakage. As long as the water source has been vented or disconnected, it is a safe assumption. The test methodology and leak rate equation in Section 10.2.3 is not addressed in ANSI/ANS 56.8, ANSI

N45.4 or 10CFR50 Appendix J.

B10.2.4 Vacuum Testing Method

The vacuum testing method is basically the same as the flowmeter method. To use this method it has to be proven that all the leakage is passing through the flowmeter.

B10.2.5 Bubble Testing Method

B10.2.5.1 Immersion

Immersion testing is seldom used due to the need to immerse the test component. Immersion testing is typically used in locating leaks rather than quantifying leak rates.

B10.2.5.2 Liquid Application Method

This method is usually used in conjunction with other methods. Quantifying leak rates with method is not practical. To use this method the acceptance criteria must be zero leakage.

B10.2.5.3 Bubbler Column

This method is useful in detecting very small leaks, but quantification of the leak is not possible.

B10.2.6 Continuous Monitoring

This section requires that penetrations served by continuous leakage monitoring systems must be leak rate tested, as required by Paragraph II.D.2(a) of 10CFR50 Appendix J. The method of determining the leakage rates must be technically justifiable. Both pressure decay and makeup volume are accepted methods for determining leakage rate.

B10.2.7 Reference Vessel Method

The reference vessel method may be used to measure the leak rate of a test volume when its volume is unknown. This is basically a pressure decay test using an additional test tank of known volume. The leakage rate equation is the same as that developed in Section 10.2.1.

APPENDIX
REPORTING REQUIREMENTS

REPORTING FORMAT

The following format shall be used in reporting Type A, B and C test results. Each format section has editorial comments delineating the required information. If a Type A test is not performed, these sections shall be marked "N/A."

REACTOR CONTAINMENT BUILDING INTEGRATED LEAKAGE RATE TEST

TABLE OF CONTENTS

DEFINITION OF SYMBOLS AND ABBREVIATIONS

Provide a listing of all symbols and abbreviations used in test of report. Symbols and abbreviations used in attachments should not be included here.

1.0 ABSTRACT

Identify plant, plant docket number, plant owner, plant location, outage cycle, date of test completion, a description of primary containment, and test results. This section should be short and concise.

2.0 INTRODUCTION

2.1 TYPE A TEST (as applicable)

2.1.1 Test Summary

Identify test instruction and technical data, such as design temperature and pressure, peak accident temperature and pressure, test duration, containment volume, and allowable leakage rate.

2.1.2 Conclusion

Provide comparison of test results, both total time and mass point for as-found and as-left conditions. Provide a positive statement as to whether the test passed or failed as-found and as-left criteria.

2.2 TYPE B AND C TESTS

2.2.1 Test Summary

Identify test instructions and types of tests.

2.2.2 Conclusion

Provide minimum and maximum pathway leakage rates for as-found and as-left conditions. Provide positive statement as to whether accumulation of path leakage rates passed failed criteria. Do not discuss individual components in this section.

3.0 CONTAINMENT INTEGRATED LEAK RATE TEST (as applicable)

3.1 GENERAL TEST DESCRIPTION

3.1.1 Containment Inspection

Briefly discuss how primary containment was inspected and any findings and corrective action.

3.1.2 Equipment and Instrumentation

Briefly discuss pressurization equipment, types and quantities of instrumentation, verification test equipment, and depressurization equipment.

3.1.3 Data Acquisition System

Provide a description of the data acquisition system. This section should be detailed enough so that it stands alone. No other portion of the report discusses the data acquisition system.

3.1.4 Systems and Penetrations Not Tested

Provide a list and explanation of all systems and penetrations that were in service or isolated during the test.

3.2 EDITED LOG OF EVENTS

Provide an edited version of the log maintained during the performance of the CILRT.

3.3 TEST RESULTS

3.3.1 Mass Point Analysis

Provide a detailed description of Type A test results using the mass point analysis. Provide figures in Attachment 1 (see Paragraph

6.1) as aids for clarification. Do not provide equations if a standard or technical report can be referenced. Provide justification for rejected data, as applicable.

3.3.2 Total Time Analysis

Provide the same information as in 3.3.1 using total time analysis. Refer to Attachment 2 (see Paragraph 6.2) for clarification of results.

3.3.3 Instrument Selection Guide

Provide the results of the instrument error analysis.

3.3.4 Verification Test

Provide the amount of imposed leakage and the measured leakage by the CILRT measurement system.

3.3.5 Leakage Penalties Added to the Calculated Type A Leakage Rate

Identify all penalties added to the calculated Type A leakage rate as a result of systems in service and penetrations isolated.

4.0 TYPE B AND C TESTS

4.1 COMPONENTS NOT TESTED

Provide a list of components/pathways not subjected to Type B or C testing and a brief description of the reason why they were not tested.

4.2 AS-FOUND LLRTs

4.2.1 MXPLRs and MNPLRs

Provide the totals for the MXPLRs and MNPLRs. Refer to Attachment 3 (see Paragraph 6.3) for list of individual MXPLRs and MNPLRs.

4.3 REPAIRS AND ADJUSTMENTS

Provide a description of any repairs or adjustments made as a result of the as-found testing. Use the following format. Do not include components on which no repairs or adjustments were made.

Penetration	Component	Repair Description
X-10	2-FCV-71-2	Replaced valve seat and increased torque switch setting from 2.25 to 2.5.

4.4 AS-LEFT LLRTs

4.4.1 MXPLRs and MNPLRs

Provide the totals for the MXPLRs and MNPLRs. Refer to Attachment 3 for list of individual MXPLRs and MNPLRs.

4.4.2 Type B and C Running Total

Provide the as-left Type B and C Running Total Containment Leakage Rate (RTCLR) and the Total Containment MXPLR.

5.0 CORRECTIVE ACTION PLAN (as applicable)

Provide a detailed corrective action plan in lieu of increased CILRT testing frequency.

6.0 ATTACHMENTS

6.1 ATTACHMENT 1, PRIMARY CONTAINMENT LEAKAGE RATE AND UCL vs. TIME, MASS POINT ANALYSIS

This is to be used on conjunction with Section 3.3.1 to explain analysis of test results.

6.2 ATTACHMENT 2, PRIMARY CONTAINMENT LEAKAGE RATE AND UCL vs. TIME, TOTAL TIME ANALYSIS

This is to be used on conjunction with Section 3.3.2 to explain analysis of test results.

6.3 ATTACHMENT 3, TYPE B AND C TEST RESULTS

Provide a list of as-found and as-left LLRTs in tabular form. Use the format of Table 1 on the following page. This table should include all containment penetrations tested. The tables prepared per Section 4.3 will be a subset of this table.

Table 1

Penetration Number	Description	Test Procedure No. & Rev. Date	Test Date	Test Method	Leakage (SCFH) As-Found / As-Left	MXPLR As-Found / As-Left	MNPLR As-Found / As-Left	MNPLR Reduction
X-10	2-FCV-71-2	2-S1-4.7-71a 2/11/79	3/16/89 3/20/89	A	100 10			
	2-FCV-71-3	2-S1-4.7-7lb 2/11/79	3/16/89 3/20/89	B	50 5	100 10	50 5	45
X-11								

The column labeled "Test Method" shall be used to delineate how the component was tested. Use the following codes:

A - Inboard component tested separately.
B - Outboard component tested separately.
C - Inboard component tested simultaneously with other components.
D - Outboard component tested simultaneously with other components.
E - Inboard and outboard component(s) tested simultaneously.