South Carolina Electric and Gas Company

# V.C. SUMMER NUCLEAR PLANT

## Primary Reactor Containment Integrated Leakage Rate Test

Final Report
October 1984

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Bechtel Power Corporation

SOUTH CAROLINA ELECTRIC AND GAS COMPANY

VIRGIL C. SUMMER NUCLEAR STATION

UNIT 1

# FIRST PERIODIC

# REACTOR CONTAINMENT BUILDING

# INTEGRATED LEAKAGE RATE TEST

# FINAL REPORT

Prepared by

Bechtel Power Corporation

SU-072

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## 1. SUMMARY

This report presents data, analyses, and conclusions pertaining to the V. C. Summer Nuclear Station (VCSNS), Unit 1, first periodic Integrated Leakage Rate Test (ILRT) performed in October 1984. Included in the report is a presentation of the Local Leakage Rate Test Results required by the U.S. Code of Federal Regulations, 10CFR50, Appendix J, for adjustment of the ILRT results.

A 24-hour ILRT was successfully performed at the beginning of the VCSNS first refueling outage from 2145 on October 7, to 2145 on October 8, 1984. The ILRT was followed by a successful verification (imposed leakage) test to ensure satisfactory instrument performance. The following is a summary of test results expressed in weight percent per day:

| | Test Result | Acceptance Criteria |
|---|---|---|
| Total Time Method | | |
| ILRT Lam | 0.087 | 0.150 |
| ILRT UCL* | 0.094 | 0.150 |
| Verification Lam | 0.287 | 0.233 to 0.333 |
| Mass Point Method | | |
| ILRT Lam | 0.089 | 0.150 |
| ILRT UCL* | 0.091 | 0.150 |
| Verification Lam | 0.268 | 0.235 to 0.335 |

A chronological summary of events, a summary of plant technical data, and a discussion of test results are included in subsequent portions of this report.

Although the test was performed over a 24-hour period, satisfactory results were obtained after the initial eight hours from 2145 October 7, to 0545 on October 8. Results of the 8-hour test period are included in this report also.

* UCL = 95 percent Upper Confidence Level

## 2. TEST SYNOPSIS

The reactor containment building Integrated Leakage Rate Test (Type A) is performed to demonstrate that leakage through the primary reactor containment and systems or components penetrating primary containment does not exceed the allowable leakage rate specified in the V.C. Summer Nuclear Station, Unit 1, Final Safety Analysis Report.

The successful periodic Type A and supplemental verification tests were performed according to the requirements of the V.C. Summer Nuclear Station, Unit 1, Final Safety Analysis Report and 10CFR50, Appendix J. The Type A test method used is the absolute method described in ANSI N45.4-1972, "Leakage Rate Testing of Containment Structures for Nuclear Reactors." The leakage rate was calculated using formulas from the above ANSI standard and BN-TOP-1, Rev 1, "Testing Criteria for Integrated Leakage Rate Testing of Primary Containment Structures for Nuclear Power Plants." Type A and verification test durations were in accordance with 10CFR50, Appendix J, and BN-TOP-1.

The test results are reported in accordance with the requirements of 10CFR50, Appendix J, Section V.

The containment leakage rate testing method applied was the Absolute Method as described in References 5 and 6. This is a direct application of the ideal gas law: $PV = WRT$. The Total Time and Mass Point techniques (References 5 and 6) were used to calculate the leakage rate. The Total Time Analysis technique measures leakage rate based on the most recent data point and the data point taken at the start of the test. The overall calculated leakage rate is determined by applying linear regression analysis to all measured leakage rate data at the end of the test period. The Mass Point technique calculates the containment air mass at each data point. The leakage rate is then determined by applying linear regression analysis to the measured air masses.

Ninety-five percent confidence levels were calculated for leakage rate data as required by References 5 and 6. This is to ensure a 95% probability that the calculated leakage rate value is within the acceptance limits. All calculations were done with Bechtel's ILRT computer program described in Appendix A.

The temperature and pressure history, containment air mass, and total time leakage rate were plotted by the computer program. These plots are in Appendix B.

Pressurization started at 1035 on October 6, 1984. Test pressure was reached at 2145 on October 6, 1984, and the required stabilization period was started. During the next 24 hours leakage paths were discovered that did not permit a successful test. Penetration 212, containment blowdown, was isolated with a blind flange. This penetration is closed with flanges during normal operation. Valves were relied upon for isolation during the ILRT for convenience. Although a drop in leakage rate was noticed, additional leakage still

existed. After a thorough walkdown of the containment penetrations, the remaining leakage was suspected to be steam generator in-leakage.

Consequently, the steam generators were filled with water. Subsequent measurements confirmed an acceptable leakage rate. Following the successful test, the manual isolation valve on each steam generator sample line (penetrations 220, 225, and 411) was found to be open. The leakage path on each line was through the open vent between the automatic sample line isolation valve and the containment liner, through the closed automatic isolation valve, through the open manual valve which was to be closed in accordance with the ILRT valve lineup, and into the steam generator. The automatic isolation valves seat with pressure on the steam generator side of the valve. Pressure on the downstream (containment liner) side of the valve will tend to unseat the valve. An investigation into the sample lines showed the lines to be seismic category one, safety class 2, and missile protected. In other words, these lines are extensions of the containment boundary. The vent valves should have been closed to achieve a correct isolation of the containment for the ILRT. These valves are closed during normal operation and were opened only for the ILRT. (See sketch in Appendix J).

The difference in leakage rates prior to filling the steam generators with water and after filling was approximately 14 scfm. Following the ILRT the steam generators' water levels were re-established at their levels which existed prior to filling. Local leakage rates for each sample line were measured through the vent path which existed during the ILRT. The sum of the three local leakage rates was approximately 13.5 scfm. Considering measurement uncertainty, the leakage is considered to be due to the improperly aligned manual sample isolation valves.

Other penetrations either blocked or not aligned for the test were the RCP seal injection and return line, penetrations 221, 229, 408 and 410; RHR hot leg suction, penetration 226; RHR cold leg injection, penetration 227; component cooling water, penetrations 312 and 330; nuclear gas sample system, penetration 405; breathing air, penetration 324; and service air, penetration 310.

Results of post ILRT local testing on these penetrations are presented in Section 3 of this report, TEST DATA SUMMARY. Section 4, ANALYSIS AND INTERPRETATION, incorporates the local test results into the ILRT calculated and 95 percent UCL values.

The Residual Heat Removal (RHR) system was required to be in service during the ILRT. Local leakage rate test results on RHR penetrations are reported in Appendix I. Safety injection accumulators were pressurized during the ILRT. Pressure was monitored; no decrease was detected, so containment leakage was not masked by accumulator leakage. Similarly, one of the two power-operated relief valves' accumulators was pressurized. No pressure loss was observed. An analysis was done to quantify the pressure drop required to mask a failed test. Results showed that the pressure drop required was

discernable (See Appendix K) on permanent plant instrumentation. Finally, the breathing air system was isolated from the containment, but not depressurized. Local leakage rate testing post-ILRT showed no in-leakage through the containment isolation valves.

The 24-hour test period ended at 2145 on October 8. The calculated Total Time leakage rate was 0.087%/day with an upper confidence limit of 0.094%/day. Corresponding Mass Point leakage rate values were 0.089%/day and 0.091%/day. With a maximum post test leakage based on maximum penetration leakage values following repair to isolation valves of 0.014%/day for blocked mechanical penetrations, all leakage rate acceptance criteria were satisfied. The upper confidence limit (UCL) of the leakage rate calculated at the 95% level, plus post test local leakage test results for blocked systems, was less than 0.75La (0.75 x 0.2%/day = 0.150%/day). Also, the Instrument Selection Guide (ISG) was less than 0.25 La (see Appendix G). When considering minimum penetration leakage values before repair to isolation valves, Type C results added to the Type A results give Mass Point leakage of 0.1195%/day and Total Time leakage of 0.1225%/day.

In order to verify the leakage rate measurement system, a 10.8 scfm leak was imposed. A 4.75 hour verification test was run from 0130 to 0615 on October 9. The Total Time calculated leakage rate was 0.287%/day, which satisfied the acceptance criterion of being in the range 0.233 to 0.333%/day. The Mass Point calculated leakage rate was 0.268%/day, which satisfied the acceptance criterion of being in the range of 0.235 to 0.335%/day.

Leakage rates were calculated during the entire 24 hour test period. SCE&G had petitioned the NRC for permission to perform a short duration test in accordance with BN-TOP-1. Permission was granted. Just prior to the test, SCE&G decided to perform a 24-hour test. Data would also be analyzed to show that a short duration test could be performed, demonstrating containment integrity while reducing outage duration for future tests. After 8 hours of testing, all acceptance criteria were satisfied. Results are reported in Appendix H.

A description of the computer program used to calculate the leakage rates is given in Appendix A. Test summary data, leakage rate reports, and plots are given in Appendices B through F. Local leakage rate test results are given in Appendix I.

## 3. TEST DATA SUMMARY

### A. Plant Information

| | |
|---|---|
| Owner: | South Carolina Electric and Gas Company |
| Plant: | Virgil C. Summer Nuclear Station Unit 1 |
| Location: | Jenkinsville, SC |
| Containment Type: | Reinforced, Post Tensioned Concrete |
| Date Test Completed: | October 9, 1984 |
| Docket Number: | 50-395 |

### B. Technical Data

| | | |
|---|---|---|
| 1. | Containment Net Free Air Volume | 1,840,000 cu. ft. |
| 2. | Design Pressure | 57 psig |
| 3. | Calculated Peak Accident Pressure, Pa | 47.1 psig |
| 4. | Containment ILRT Average Temperature Limits | 55-120°F |

### C. Test Results - Type A Test

| | | |
|---|---|---|
| 1. | Test Method | Absolute |
| 2. | Data Analysis Techniques | Total Time and Mass Point |
| 3. | Test Pressure | 47.1 psig + 3.0 - 0.0 |
| 4. | Maximum Allowable Leakage Rate, La | 0.2%/day |
| 5. | 75% of La | 0.150%/day |

6. Integrated Leakage Rate Test Results

| | Leakage Rate, %/day | |
|---|---|---|
| | From Regression Line (Lam) | At Upper 95% Confidence Level |
| Total Time Analysis | 0.087 | 0.094 |
| Mass Point Analysis | 0.089 | 0.091 |

| | | |
|---|---|---|
| 7. | Verification Test Imposed Leakage Rate, Li%/day | 10.8 scfm<br>0.196%/day |

8. Verification Test Results

| | Leakage Rate, %/day |
|---|---|
| Total Time Analysis | 0.287 |
| Mass Point Analysis | 0.268 |

9. Verification Test Limits — Test Limit, %/day

| | Total Time Analysis | Mass Point Analysis |
|---|---|---|
| (1) Upper Limit (Li + Lam + 0.25 La) | 0.333 | 0.335 |
| (2) Lower Limit (Li + Lam - 0.25 La) | 0.233 | 0.235 |

10. Report Printouts

The Report Printouts of the Type A and Verification Test calculations are provided for the Total Time and Mass Point Analyses (Appendices C through F). Stabilization data are also provided (Appendix B).

D. Local Leakage Rate Test Results - Type B and C Tests (see also Appendix I)

1. LLRT Results

LLRT Subtotal of Type B and C Tests: 0.0666%/day

0.6 La = 0.12%/day

Therefore, total type B and C leakage < 0.6 La

2. Leakage of penetrations not in post-LOCA lineup during ILRT:

| Penetration | Description | As Left (%/day) |
|---|---|---|
| 221 | RCP Seal Water | 0.000525 |
| 229 | RCP Seal Water | 0.000669 |
| 408 | RCP Seal Water | 0.000467 |
| 410 | RCP Seal Water | 0.000967 |
| 226 | RHR 'B' | 0.002983 |
| 227 | RHR 'B' | 0.002657 |
| 310 | Service Air | 0.001312 |
| 324 | Breathing Air | 0.000461 |
| 312 | Component Cooling | 0.003983 |
| 330 | Component Cooling | 0.004848 |
| 405 | Sample System | 0.000434 |

E. Integrated Leakage Rate Measurement System

The following instrument system was used:

| No. Required | Description | Date | |
|---|---|---|---|
| 1. Absolute Pressure | | | |
| 2 | Mensor Precision Pressure Gauge | Range: | 0-100 psia |
| | | Accuracy: | ± 0.05% F.S. |
| | | Resolution: | 0.001 psia |
| | | Repeatability: | 0.001 psia |
| 2. Drybulb Temperature | | | |
| 24 | 100 Ohm Temperature Sensors | Range: | 0-125°F |
| | | Accuracy: | 0.2°F |
| | | Resolution: | 0.001°F |
| | | Repeatability: | 0.01°F |
| 3. Dewpoint Temperature | | | |
| 5* | Chilled Mirror Dewpoint | Range: | 0-120°F |
| | | Accuracy: | 0.1% FS |
| * 1 failed, 4 used during the test. | | Resolution: | 0.001 |
| | | Repeatability: | ± 0.01°F |
| 4. Flow | | | |
| 1 | Mass Flow Meter | Range: | 0-12 scfm |
| | | Accuracy: | ± 1% F.S. |
| | | Sensitivity: | NA |
| | | Repeatability: | 0.2% F.S. |

5. Overall Instrumentation Selection Guide (ISG) Value (from ANSI/ANS 56.8-1981, Appendix G) based on ILRT instrumentation, and a 24-hour test duration = 0.0052%/day.
   8-hour ISG = 3x0.0052 = 0.0156%/day.

6. For Drybulb and Dewpoint Temperature Sensor Locations and Volume Fractions, see Table 1.

F. Information Retained at Plant

The following information is available for review at the Facility:

1. A listing of all containment penetrations, including the total number of like penetrations, penetration size and function.

2. A listing of normal operations instrumentation used for the leakage rate test.

3. A system lineup (at time of test), showing required valve positions and status of piping systems.

4. A continuous, sequential log of events from initial survey of containment to restoration of all tested systems.

5. Documentation of instrumentation calibrations and standards, including an error analysis of instrumentation (Appendix G).

6. Data to verify temperature stabilization criteria as established by test procedure (Appendix B).

7. The working copy of test procedure that includes signature signoff of procedural steps.

8. The procedure and all data that would verify completion of penetrations and valve testing (Type B & C tests).

9. Computer printouts of Integrated Leakage Rate Test Data along with a summary description of the computer program (Appendix A).

10. The Quality Assurance audit plan or checkout that was used to monitor ILRT with proper signoffs.

11. A listing of all test exceptions instituted by licensee to conclude successful testing.

12. Descriptions of sensor malfunctions, repairs, and methods used to redistribute volume fractions to operating instrumentation (Table 1 and Appendix d).

13. A review of confidence limits of test results with accompanying computer printouts where applicable.

14. Description of method of leak rate verification of instrument measuring system (superimposed leakage), with calibration information on flowmeters along with calculations that were used to measure the verification leakage rate.

15. Plots presenting ILRT data obtained during the test (Appendix E).

16. The P&IDs of pertinent systems.

## 4. ANALYSIS AND INTERPRETATION

During the ILRT, 11 mechanical penetrations were not in post-LOCA lineup. The penetrations together with their post ILRT Type C leakage rates are given below:

| Penetration | Post ILRT Leakage Rate | |
|---|---|---|
| | SCCM | %/day |
| RCP Seal Water (221) | 799.9 | 0.000525 |
| RCP Seal Water (229) | 1018.8 | 0.000669 |
| RCP Seal Water (408) | 711.5 | 0.000467 |
| RCP Seal Water (410) | 1473.5 | 0.000967 |
| RHR 'B' (226) | 4546.8 | 0.002983* |
| RHR 'B' (227) | 4050.00 | 0.002657* |
| Service Air (310) | 6070.8 | 0.001312 |
| Breathing Air (324) | 7388.5 | 0.000461 |
| Component Cooling (312) | 660.9 | 0.003983 |
| Component Cooling (330) | 1999.7 | 0.004848 |
| Sample System (405) | 703.0 | 0.000434 |

* Leakage rates reported but not added to the ILRT Leakage Rate - see RHR Penetration discussion, Section 4.

The total leakage rate for the nine penetrations expressed in %/day of containment air mass is 0.014.

The calculated Mass Point leakage rate during the ILRT was 0.089 %/day. The calculated 95% upper confidence level was 0.091 %/day. The calculated Total Time leakage rate during the ILRT was 0.087%/day. The corresponding 95% upper confidence level was 0.094%/day. Adding the total Type C leakage for systems not in post-LOCA lineup during the test yields the corrected leakage rates as follows:

| | Leakage Rate, %/day | | | |
|---|---|---|---|---|
| | Mass Point | | Total Time | |
| | Leakage Rate | 95% UCL | Leakage Rate | 95% UCL |
| Calculated | 0.089 | 0.091 | 0.087 | 0.094 |
| Type C | 0.014 | 0.014 | 0.014 | 0.014 |
| Corrected | 0.103 | 0.105 | 0.101 | 0.108 |

Since the corrected 95% upper confidence levels for the Mass Point and Total Time leakage rates are less than 0.75 La, the test results demonstrate that leakage through the primary reactor containment and systems and components penetrating primary containment do not exceed the allowable leakage rate specified in the V. C. Summer Nuclear Station Final Safety Analysis Report, Reference 1.

RHR Penetration

Train "B" was in operation during the ILRT in accordance with Technical Specifications. Difficulties were encountered while testing the Containment Isolation valves associated with penetrations 226 and 227.

Penetration 226

This penetration serves the train "B" RHR hot leg suction. This penetration has two motor-operated valves inside containment, with the valve farthest from the RCS and outside the primary shield wall being the Containment Isolation valve. Actuator problems on the containment isolation valve (XVG-87013-RH) prevented a successful local leak rate test. The as found leakage rate was greater than the capacity of the test equipment ( > 20 l/m). The motor operator was replaced and the subsequent leakage test indicated a leakage rate of 1080 cc/min or 0.002983%/day.

Penetration 227

This penetration serves the low head cold leg injection piping from RHR. Relief request has been submitted to NRR from Type C testing. The as found leakage was 12,650 cc/min. After valve repair, the leakage was reduced to 962 cc/min or 0.002657%/day.

The leakage rates of these two penetrations (226 and 227) are hereby reported to the Commission in accordance with 10CFR50, Appendix J, Section III.A.1.(d), but are not included in the overall Type "A" leakage rate.

## 5. REFERENCES


1. V. C. Summer Nuclear Station Final Safety Analysis Report

2. V. C. Summer Nuclear Station Surveillance Test Procedure STP-206.001 Integrated Leak Rate Test.

3. 10CFR50, Appendix J, Reactor Containment Leakage Test for Water Cooled Power Reactors.

4. ANSI N45.4-1972, Leakage Rate Testing of Containment Structures for Nuclear Reactors.

5. ANSI/ANS 56.8-1981, Containment System Leakage Testing Requirements.

6. Bechtel Topical Report BN-TOP-1, Testing Criteria for Integrated Leakage Rate Testing of Primary Containment Structures for Nuclear Power Plants.

TABLE 1

DRYBULB AND DEWPOINT TEMPERATURE SENSOR LOCATIONS

| Sensor Number | Elevation (ft) | Azimuth (degrees) | Chanel Number | Volume Fractions/ Sensor |
|---|---|---|---|---|
| 7307A | 569 | 248 | 11 | 0.1005 |
| 7307B | 569 | 63 | 12 | 0.1005 |
| 7307C | 533 | 17 | 13 | 0.1413 |
| 7307D | 533 | 191 | 14 | 0.1413 |
| 7307E | 412 | 293 | 15 | 0.0200 |
| 7307F | 514 | 352 | 16 | 0.0345 |
| 7307G | 514 | 166 | 17 | 0.0346 |
| 7307H | 463 | 133 | 18 | 0.0345 |
| 7307I | 463 | 307 | 19 | 0.0346 |
| 7307J | 463 | 40 | 20 | 0.0345 |
| 7307K | 463 | 48 | 21 | 0.0346 |
| 7307L | 463 | 193 | 22 | 0.0345 |
| 7307M | 463 | 200 | 23 | 0.0345 |
| 7307N | 436 | 290 | 24 | 0.0200 |
| 7307O | 436 | 302 | 25 | 0.0200 |
| 7307P | 436 | 38 | 26 | 0.0200 |
| 7307Q | 436 | 73 | 27 | 0.0200 |
| 7307R | 436 | 160 | 28 | 0.0200 |
| 7307S | 436 | 207 | 29 | 0.0200 |
| 7307T | 412 | 298 | 30 | 0.0200 |
| 7307U | 412 | 45 | 31 | 0.0200 |
| 7307V | 412 | 68 | 32 | 0.0200 |
| 7307W | 412 | 156 | 33 | 0.0200 |
| 7307X | 412 | 200 | 34 | 0.0200 |
| | | | | 1.0000 |
| 7306A | 552 | 17 | 1 | 0.4837 |
| *7306B | 514 | 352 | 2 | 0.0000 |
| 7306C | 463 | 133 | 3 | 0.2582 |
| 7306D | 463 | 207 | 4 | 0.1291 |
| 7306E | 412 | 298 | 5 | 0.1290 |
| | | | | 1.0000 |

* Dewcell B failed early in the test. It's volume fraction was added to dewcell C for the test calculations.

Appendix A

# DESCRIPTION OF BECHTEL ILRT COMPUTER PROGRAM

# APPENDIX A

## DESCRIPTION OF BECHTEL ILRT COMPUTER PROGRAM

### A. PROGRAM AND REPORT DESCRIPTION

1. The Bechtel ILRT computer program is used to determine the integrated leakage rate of a nuclear primary containment structure. The program is used to compute leakage rate based on input values of time, free air volume, containment atmosphere total pressure, drybulb temperature, and dewpoint temperature (water vapor pressure). Leakage rate is computed using the Absolute Method as defined in ANSI/ANS 56.8-1981, "Containment System Leakage Testing Requirements" and BN-TOP-1, Rev 1, "Testing Criteria for Integrated Leakage Rate Testing of Primary Containment Structures for Nuclear Power Plants." The program is designed to allow the user to evaluate containment leakage rate test results at the jobsite during containment leakage testing. Current leakage rate values may be obtained at any time during the testing period using one of two computational methods, yielding three different report printouts.

2. In the first printout, the Total Time Report, leakage rate is computed from initial values of free air volume, containment atmosphere drybulb temperature and partial pressure of dry air, the latest values of the same parameters, and elapsed time. These individually computed leakage rates are statistically averaged using linear regression by the method of least squares. The Total Time Method is the computational technique upon which the short duration test criteria of BN-TOP-1, Rev 1, "Testing Criteria for Integrated Leakage Rate Testing of Primary Containment Structures for Nuclear Power Plant," are based.

3. The second printout is the Mass Point Report and is based on the Mass Point Analysis Technique described in ANSI/ANS 56.8-1981, "Containment System Leakage Testing Requirements." The mass of dry air in the containment is computed at each data point (time) using the Equation of State, from current values of containment atmosphere drybulb temperature and partial pressure of dry air. Contained mass is "plotted" versus time and a regression line is fit to the data using the method of least squares. Leakage rate is determined from the statistically derived slope and intercept of the regression line.

4. The third printout, the Trend Report, is a summary of leakage rate values based on Total Time and Mass Point computations presented as a function of number of data points and elapsed time (test duration). The Trend Report provides all leakage rate values required for comparision to the acceptance criteria of BN-TOP-1 for conduct of a short duration test.

5. The program is written in a high level language and is designed for use on a micro-computer. Brief descriptions of progrm use, formulae used for leakage rate computations, and program logic are provided in the following paragraphs.

B. EXPLANATION OF PROGRAM

1. The Bechtel ILRT computer program is written, for use by experienced ILRT personnel, to determine containment integrated leakage rates based on the Absolute Method described in ANSI/ANS 56.8-1981 and BN-TOP-1.

2. Information loaded into the program prior to or at the start of the test:

   a. Number of containment atmosphere drybulb temperature sensors, dewpoint temperature (water vapor pressure) sensors and pressure gages to be used in leakage rate computations for the specific test

   b. Volume fractions assigned to each of the above sensors

   c. Calibration data for above sensors

   d. Test title

   e. Test pressure

   f. Maximum allowable leakage rate at test pressure.

3. Data received from the data acquistion system during the test, and used to compute leakage rate:

   a. Time and date

   b. Containment atmosphere drybulb temperatures

   c. Containment atmosphere pressure (s)

   d. Containment atmosphere dewpoint temperatures

   e. Containment free air volume.

4. After all data at a given time are received, a Summary of Measured Data Report (refer to "Program Logic," Paragraph D, "Data" option command) is printed.

5. If drybulb and dewpoint temperature sensors should fail during the tests, the data from the sensor(s) are not used. The volume fractions for the remaining sensors are recomputed and reloaded into the program for use in ensuing leakage rate computations.

## C. LEAKAGE RATE FORMULAE

### 1. Computation using the Total Time Method

#### a. Measured leakage rate from data:

$$P_1V_1 = W_1RT_1 \quad (1)$$

$$P_iV_i = W_iRT_i \quad (2)$$

$$L_i = \frac{2400\ (W_i - W_1)}{\Delta t_i\ W_1} \quad (3)$$

Solving for $W_1$ and $W_i$ and substituting equations (1) and (2) into (3) yields:

$$L_i = \frac{2400}{\Delta t_i}\left(1 - \frac{T_1P_iV_i}{T_iP_1V_1}\right) \quad (4)$$

where:

$W_1$, $W_i$ = Weight of contained mass of dry air at times $t_1$ and $t_i$ respectively, lbm.

$T_1$, $T_i$ = Containment atmosphere drybulb temperature at times $t_1$ and $t_i$ respectively, °R.

$P_1$, $P_i$ = Partial pressure of the dry air component of the containment atmosphere at times $t_1$ and $t_i$ respectively, psia.

$V_1$, $V_i$ = Containment free air volume at times $t_1$ and $t_i$ respectively, (constant or variable during the test), $ft^3$.

$t_1$, $t_i$ = Time at $1^{st}$ and $i^{th}$ data points respectively, hours.

$\Delta t_i$ = Elapsed time from $t_1$ to $t_i$, hours.

$R$ = Specific gas constant for air = 53.35 ft.lbf/lbm.°R.

$L_i$ = Measured leakage rate computed during time interval $t_1$ to $t_i$, wt%/day.

To reduce truncation error, the computer program uses the following equivalent formulation:

$$L_i = \frac{-2400}{\Delta t_i}\left(\frac{\Delta W_i}{W_1}\right)$$

where:

$$\frac{\Delta W_i}{W_1} = \frac{W_i - W_1}{W_1}$$

$$= -\frac{\frac{\Delta P_i}{P_1} + \frac{\Delta V_i}{V_1} + \frac{\Delta P_i V_i}{P_1 V_1} - \frac{\Delta T_i}{T_1}}{1 + \frac{\Delta T_i}{T_i}}$$

$$\Delta P_i = P_i - P_1$$

$$\Delta V_i = V_i - V_1$$

$$\Delta T_i = T_i - T_1$$

b. Calculated leakage rate from regression analysis:

$$\bar{L} = a + b\,\Delta t_N$$

where:

$\bar{L}$ = Calculated leakage rate, wt%/day, as determined from the regression line.

$$a = (\Sigma L_i - b\Sigma\Delta t_i)/N \qquad (6)$$

$$b = \frac{N(\Sigma L_i \Delta t_i) - (\Sigma L_i)(\Sigma \Delta t_i)}{N(\Sigma t_i^2) - (\Sigma \Delta t_i)^2} \qquad (7)$$

N = Number of data points

$$\Sigma = \sum_{i=1}^{N}$$

c. Calculated leakage rate at the 95% confidence level.

$$\bar{L}_{95} = a + b\,\Delta t_N + S_{\bar{L}}$$

where:

$\bar{L}_{95}$ = Calculated leakage rate at the 95% confidence level, at elapsed time $\Delta t_N$.

For $\Delta t_N \quad 24$

$$S_{\bar{L}} = t_{0.025;N-2}[(\Sigma L_i^2 - a\Sigma L_i - b\Sigma L_i \Delta t_i)/(N-2)]^{1/2} \times$$

$$[1 + \frac{1}{N} + (\Delta t_N - \overline{\Delta t})^2 / (\Sigma \Delta t_i^2 - (\Sigma \Delta t_i)^2/N)]^{1/2} \qquad (9a)$$

where:

$$t_{0.025;N-2} = 1.95996 + \frac{2.37226}{N-2} + \frac{2.82250}{(N-2)^2}$$

For $\Delta tN _ \quad 24$

$$S_{\bar{L}} = t_{0.025;N-2}[(\Sigma L_i^2 - a\Sigma L_i - b\Sigma L_i \Delta t_i)/(N-2)]^{1/2} \times$$

$$[\frac{1}{N} + (\Delta t_N - \overline{\Delta t})^2 / (\Sigma \Delta t_i^2 - (\Sigma \Delta t_i)^2/N)]^{1/2} \qquad (9b)$$

where:

$$t_{0.025;N-2} = \frac{1.6449(N-2)^2 + 3.5283(N-2) + 0.85602}{(N-2)^2 + 1.2209(N-2) - 1.5162}$$

$$\overline{\Delta t} = \frac{\Sigma \Delta t_i}{N}$$

2. Computation using the Mass Point Method

   a. Contained mass of dry air from data:

$$W_i = 144 \frac{P_i V_i}{R T_i} \qquad (10)$$

where:

All symbols as previously defined.

b. Calculated leakage rate from regression analysis, $W = a + b\ t$:

$$\overline{L} = -2400\ \frac{b}{a} \tag{11}$$

where:

$\overline{L}$ = Calculated leakage rate, wt%/day, as determined from the regression line

$$a = (\Sigma W_i - b\Sigma\Delta t_i)/N \tag{12}$$

$$b = \frac{N(\Sigma W_i \Delta t_i) - (\Sigma W_i)(\Sigma \Delta t_i)}{N(\Sigma \Delta t_i^2) - (\Sigma \Delta t_i)^2} \tag{13}$$

$\Delta t_i$ = Total elapsed time at time $i^{th}$ data point, hours

$N$ = Number of data points

$W_i$ = Contained mass of dry air at $i^{th}$ data point, lbm, as computed from equation (10)

$$\Sigma = \sum_{i=1}^{N}$$

In order to reduce truncation error, the computer program uses the following equivalent formulation:

$$a = W_1 \left[ 1 + (\Sigma \frac{\Delta W_i}{W_1} - \frac{b}{W_1} \Sigma \Delta t_i)/N \right]$$

$$b = W_1 \left[ \frac{N\ (\Sigma \frac{\Delta W_i}{W_1}\ \Delta t_i) - \Sigma\ \frac{\Delta W_i}{W_1}\ \Sigma\ \Delta t_i}{N(\Sigma \Delta\ t_i^2) - (\Sigma \Delta\ t_i)^2} \right]$$

where, $\frac{\Delta W_i}{W_1}$ is as previously defined.

c. Calculated leakage rate at the 95% confidence level.

$$\bar{L}_{95} = \frac{-2400}{a} (b - S_b) \qquad (14)$$

where:

$\bar{L}_{95}$ = Calculated leakage rate at the 95% confidence level, wt.%/day.

$$S_b = t_{0}.025;N-2 \; \frac{SN^{1/2}}{[N\Sigma\Delta t_i^{\,2} - (\Sigma\Delta t_i)^2\,]^{1/2}} \qquad (15)$$

where, $t_{0}.025;N-2 = \dfrac{1.6449(N-2)^2 + 3.5283(N-2)^2 + 0.85602}{(N-2)^2 + 1.2209(N-2) - 1.5162}$

$$S = \left( \frac{[W_i - (a + b\,\Delta t_i)]^2}{N-2} \right)^{1/2}$$

$$S = W_1 \left[ \frac{1}{N-2} \left( \Sigma(\Delta W_i/W_1)^2 - [\,\Sigma(\Delta W_i/W_1)]^2/N - \frac{[\,\Sigma(\Delta W_i/W_1)\,\Delta t_i - \Sigma(\Delta W_i/W_1)(\Sigma\Delta t_i)/N\,]^2}{\Sigma(\Delta t_i^{\,2}) - (\Sigma\Delta t_i)^2/N} \right) \right]^{1/2}$$

## D. PROGRAM LOGIC

1. The Bechtel ILRT computer program logic flow is controlled by a set of user options. The user options and a brief descripton of their associated function are presented below.

| OPTION COMMAND | FUNCTION |
|---|---|
| | After starting the program execution, the user either enters the name of the file containing previously entered data or initializes a new data file. |
| DATA | Enables user to enter raw data. When the system requested values of time, volume, temperature, pressure and vapor pressure, the user enters the appropriate data. After completing the data entry, a summary is printed out. The user then verifies that the data were entered correctly. If errors are detected, the user will then be given the opportunity to correct the errors. After the user verifies that the data were entered correctly, a Corrected Data Summary Report of time, data, average temperature, partial pressure of dry air, and water vapor pressure is printed. |
| TREND | A Trend Report is printed. |
| TOTAL | A Total Time Report is printed. |
| MASS | A Mass Point Report is printed. |
| TERM | Enables user to sign-off temporarily or permanently. All data is saved on a file for restarting. |
| CORR | Enables user to correct previously entered data. |
| LIST | A Summary Data Report is printed. |
| PLOT | Enables user to plot summary data, individual sensor data, air mass or leakage rate versus time. |
| DELETE | Enables user to delete a data point. |
| INSERT | Enables user to reinstate a previously deleted data point. |
| VOLFRA | Enables user to change volume fractions. |
| TIME | Enables the user to specify the time interval for a report or plot. |
| VERF | Enables the user to input imposed leakage rate and calculated ILRT leakage rates at start of verification test. |

Appendix B

STABILIZATION SUMMARY DATA

V. C. SUMMER ILRT
TEMPERATURE STABILIZATION

FROM A STARTING TIME AND DATE OF: 1730 1007 1984

| TIME (HOURS) | TEMP ( R) | AVE ΔT (4HRS) | ANSI AVE ΔT (1HR) | DIFF | BN-TOP-1 AVE ΔT (2HRS) |
|---|---|---|---|---|---|
| .00 | 552.62 | | | | |
| .25 | 552.60 | | | | |
| .50 | 552.58 | | | | |
| .75 | 552.55 | | | | |
| 1.00 | 552.53 | | | | |
| 1.25 | 552.50 | | | | |
| 1.50 | 552.48 | | | | |
| 1.75 | 552.45 | | | | |
| 2.00 | 552.42 | | | | -.103* |
| 2.25 | 552.38 | | | | -.110* |
| 2.50 | 552.36 | | | | -.109* |
| 2.75 | 552.33 | | | | -.108* |
| 3.00 | 552.30 | | | | -.111* |
| 3.25 | 552.28 | | | | -.111* |
| 3.50 | 552.26 | | | | -.111* |
| 3.75 | 552.24 | | | | -.105* |
| 4.00 | 552.21 | -.103 | -.093 | -.01* | -.051* |

* INDICATES TEMPERATURE STABILIZATION HAS BEEN SATISFIED

Appendix C

ILRT TREND REPORT

V. C. SUMMER ILRT
TREND REPORT

TIME AND DATE AT START OF TEST: 2145 1007 1984

| NO. PTS | END TIME | TOTAL TIME ANALYSIS MEAS. | CALCULATED | UCL | MASS POINT ANALYSIS CALCULATED | UCL |
|---|---|---|---|---|---|---|
| 4 | 2230 | -.030 | -.022 | .152 | -.025 | .207 |
| 5 | 2245 | .016 | -.029 | .271 | -.016 | .092 |
| 6 | 2300 | .143 | .047 | .436 | .083 | .219 |
| 7 | 2315 | .047 | .038 | .332 | .062 | .157 |
| 8 | 2330 | .090 | .053 | .303 | .077 | .147 |
| 9 | 2345 | .108 | .071 | .293 | .095 | .151 |
| 10 | 0 | .068 | .067 | .263 | .085 | .130 |
| 11 | 15 | .099 | .075 | .255 | .093 | .130 |
| 12 | 30 | .049 | .066 | .231 | .077 | .112 |
| 13 | 45 | .075 | .066 | .220 | .076 | .106 |
| 14 | 100 | .064 | .064 | .207 | .072 | .097 |
| 15 | 115 | .053 | .059 | .194 | .065 | .088 |
| 16 | 130 | .055 | .056 | .184 | .060 | .081 |
| 17 | 145 | .056 | .054 | .175 | .058 | .076 |
| 18 | 200 | .053 | .051 | .168 | .055 | .071 |
| 19 | 215 | .071 | .053 | .165 | .058 | .073 |
| 20 | 230 | .063 | .053 | .161 | .058 | .072 |
| 21 | 245 | .071 | .055 | .159 | .061 | .073 |
| 22 | 300 | .079 | .058 | .159 | .064 | .076 |
| 23 | 315 | .079 | .060 | .159 | .067 | .078 |
| 24 | 330 | .054 | .058 | .154 | .064 | .075 |
| 25 | 345 | .061 | .057 | .151 | .063 | .073 |
| 26 | 400 | .078 | .059 | .150 | .066 | .075 |
| 27 | 415 | .080 | .061 | .151 | .069 | .078 |
| 28 | 430 | .060 | .060 | .148 | .067 | .075 |
| 29 | 445 | .063 | .060 | .145 | .066 | .074 |
| 30 | 500 | .064 | .060 | .143 | .065 | .073 |
| 31 | 515 | .072 | .061 | .142 | .066 | .074 |
| 32 | 530 | .070 | .061 | .141 | .067 | .074 |
| 33 | 545 | .065 | .061 | .139 | .066 | .073 |
| 34 | 600 | .073 | .062 | .139 | .068 | .073 |
| 35 | 615 | .079 | .063 | .139 | .069 | .075 |
| 36 | 630 | .071 | .063 | .138 | .070 | .075 |
| 37 | 645 | .072 | .064 | .137 | .070 | .075 |
| 38 | 700 | .065 | .064 | .136 | .069 | .074 |
| 39 | 715 | .072 | .064 | .135 | .070 | .074 |
| 40 | 730 | .067 | .064 | .134 | .069 | .074 |
| 41 | 745 | .060 | .063 | .132 | .068 | .073 |
| 42 | 800 | .067 | .063 | .131 | .068 | .072 |
| 43 | 815 | .077 | .064 | .131 | .069 | .073 |
| 44 | 830 | .072 | .065 | .131 | .069 | .074 |
| 45 | 845 | .085 | .066 | .132 | .071 | .076 |
| 46 | 900 | .082 | .067 | .132 | .073 | .077 |
| 47 | 915 | .085 | .069 | .133 | .075 | .079 |
| 48 | 930 | .073 | .069 | .132 | .075 | .079 |
| 49 | 945 | .076 | .069 | .132 | .075 | .079 |

V. C. SUMMER ILRT
TREND REPORT

TIME AND DATE AT START OF TEST: 2145 1007 1984

| NO. PTS | END TIME | TOTAL TIME ANALYSIS MEAS. | CALCULATED | UCL | MASS POINT ANALYSIS CALCULATED | UCL |
|---|---|---|---|---|---|---|
| 50 | 1000 | .082 | .070 | .132 | .076 | .080 |
| 51 | 1015 | .070 | .070 | .132 | .076 | .080 |
| 52 | 1030 | .073 | .070 | .131 | .076 | .079 |
| 53 | 1045 | .076 | .071 | .131 | .076 | .079 |
| 54 | 1100 | .081 | .071 | .131 | .077 | .080 |
| 55 | 1115 | .080 | .072 | .131 | .077 | .081 |
| 56 | 1130 | .084 | .073 | .131 | .078 | .082 |
| 57 | 1145 | .083 | .073 | .131 | .079 | .082 |
| 58 | 1200 | .079 | .074 | .131 | .079 | .083 |
| 59 | 1215 | .083 | .075 | .131 | .080 | .083 |
| 60 | 1230 | .082 | .075 | .131 | .080 | .084 |
| 61 | 1245 | .079 | .075 | .131 | .081 | .084 |
| 62 | 1300 | .084 | .076 | .131 | .081 | .084 |
| 63 | 1315 | .078 | .076 | .131 | .081 | .084 |
| 64 | 1330 | .083 | .077 | .131 | .082 | .085 |
| 65 | 1345 | .082 | .077 | .131 | .082 | .085 |
| 66 | 1400 | .084 | .078 | .131 | .082 | .085 |
| 67 | 1415 | .080 | .078 | .131 | .083 | .085 |
| 68 | 1430 | .088 | .079 | .131 | .083 | .086 |
| 69 | 1445 | .081 | .079 | .131 | .083 | .086 |
| 70 | 1500 | .086 | .079 | .131 | .084 | .087 |
| 71 | 1515 | .088 | .080 | .131 | .085 | .087 |
| 72 | 1530 | .087 | .080 | .131 | .085 | .088 |
| 73 | 1545 | .083 | .081 | .131 | .085 | .088 |
| 74 | 1600 | .091 | .081 | .132 | .086 | .089 |
| 75 | 1615 | .087 | .082 | .132 | .086 | .089 |
| 76 | 1630 | .089 | .082 | .132 | .087 | .089 |
| 77 | 1645 | .088 | .083 | .132 | .087 | .090 |
| 78 | 1700 | .084 | .083 | .132 | .087 | .090 |
| 79 | 1715 | .082 | .083 | .132 | .087 | .090 |
| 80 | 1730 | .081 | .083 | .132 | .087 | .090 |
| 81 | 1745 | .087 | .084 | .132 | .088 | .090 |
| 82 | 1800 | .084 | .084 | .131 | .088 | .090 |
| 83 | 1815 | .084 | .084 | .131 | .088 | .090 |
| 84 | 1830 | .083 | .084 | .131 | .088 | .090 |
| 85 | 1845 | .086 | .084 | .131 | .088 | .090 |
| 86 | 1900 | .088 | .085 | .131 | .088 | .090 |
| 87 | 1915 | .083 | .085 | .131 | .088 | .090 |
| 88 | 1930 | .088 | .085 | .131 | .088 | .090 |
| 89 | 1945 | .085 | .085 | .131 | .088 | .090 |
| 90 | 2000 | .085 | .086 | .131 | .088 | .090 |
| 91 | 2015 | .090 | .086 | .131 | .089 | .091 |
| 92 | 2030 | .089 | .086 | .131 | .089 | .091 |
| 93 | 2045 | .090 | .087 | .131 | .089 | .091 |
| 94 | 2100 | .083 | .087 | .131 | .089 | .091 |
| 95 | 2115 | .085 | .087 | .131 | .089 | .091 |
| 96 | 2130 | .083 | .087 | .130 | .089 | .091 |
| 97 | 2145 | .082 | .087 | .094 | .089 | .091 |

Appendix D

ILRT SUMMARY DATA, MASS POINT AND TOTAL TIME REPORTS

V. C. SUMMER ILRT
SUMMARY DATA

ALMAX = .200 VOLUME = 1840000.
VRATET = .287 VRATEM = .289

| TIME | DATE | TEMP | PRESSURE | VPRS | VOLUME |
|---|---|---|---|---|---|
| 2145 | 1007 | 552.195 | 62.9479 | .3756 | 1840000. |
| 2200 | 1007 | 552.169 | 62.9437 | .3768 | 1840000. |
| 2215 | 1007 | 552.152 | 62.9417 | .3768 | 1840000. |
| 2230 | 1007 | 552.128 | 62.9409 | .3751 | 1840000. |
| 2245 | 1007 | 552.117 | 62.9386 | .3754 | 1840000. |
| 2300 | 1007 | 552.108 | 62.9333 | .3787 | 1840000. |
| 2315 | 1007 | 552.083 | 62.9333 | .3762 | 1840000. |
| 2330 | 1007 | 552.071 | 62.9297 | .3773 | 1840000. |
| 2345 | 1007 | 552.059 | 62.9268 | .3792 | 1840000. |
| 0 | 1008 | 552.042 | 62.9264 | .3771 | 1840000. |
| 15 | 1008 | 552.022 | 62.9217 | .3798 | 1840000. |
| 30 | 1008 | 552.012 | 62.9235 | .3765 | 1840000. |
| 45 | 1008 | 551.999 | 62.9196 | .3784 | 1840000. |
| 100 | 1008 | 551.985 | 62.9186 | .3784 | 1840000. |
| 115 | 1008 | 551.977 | 62.9182 | .3768 | 1840000. |
| 130 | 1008 | 551.955 | 62.9152 | .3778 | 1840000. |
| 145 | 1008 | 551.946 | 62.9136 | .3769 | 1840000. |
| 200 | 1008 | 551.932 | 62.9120 | .3770 | 1840000. |
| 215 | 1008 | 551.927 | 62.9090 | .3790 | 1840000. |
| 230 | 1008 | 551.914 | 62.9080 | .3780 | 1840000. |
| 245 | 1008 | 551.899 | 62.9048 | .3792 | 1840000. |
| 300 | 1008 | 551.887 | 62.9020 | .3810 | 1840000. |
| 315 | 1008 | 551.872 | 62.8997 | .3803 | 1840000. |
| 330 | 1008 | 551.862 | 62.9018 | .3772 | 1840000. |
| 345 | 1008 | 551.859 | 62.9000 | .3770 | 1840000. |
| 400 | 1008 | 551.843 | 62.8951 | .3804 | 1840000. |
| 415 | 1008 | 551.835 | 62.8932 | .3803 | 1840000. |
| 430 | 1008 | 551.823 | 62.8949 | .3781 | 1840000. |
| 445 | 1008 | 551.818 | 62.8933 | .3787 | 1840000. |
| 500 | 1008 | 551.802 | 62.8910 | .3790 | 1840000. |
| 515 | 1008 | 551.785 | 62.8871 | .3809 | 1840000. |
| 530 | 1008 | 551.782 | 62.8867 | .3803 | 1840000. |
| 545 | 1008 | 551.772 | 62.8861 | .3789 | 1840000. |
| 600 | 1008 | 551.768 | 62.8834 | .3796 | 1840000. |
| 615 | 1008 | 551.762 | 62.8811 | .3809 | 1840000. |
| 630 | 1008 | 551.745 | 62.8804 | .3801 | 1840000. |
| 645 | 1008 | 551.743 | 62.8795 | .3795 | 1840000. |
| 700 | 1008 | 551.735 | 62.8797 | .3783 | 1840000. |
| 715 | 1008 | 551.725 | 62.8764 | .3807 | 1840000. |
| 730 | 1008 | 551.724 | 62.8772 | .3788 | 1840000. |
| 745 | 1008 | 551.705 | 62.8763 | .3787 | 1840000. |
| 800 | 1008 | 551.697 | 62.8731 | .3809 | 1840000. |
| 815 | 1008 | 551.701 | 62.8705 | .3815 | 1840000. |
| 830 | 1008 | 551.698 | 62.8710 | .3795 | 1840000. |
| 845 | 1008 | 551.699 | 62.8669 | .3821 | 1840000. |
| 900 | 1008 | 551.697 | 62.8669 | .3811 | 1840000. |
| 915 | 1008 | 551.690 | 62.8647 | .3823 | 1840000. |
| 930 | 1008 | 551.681 | 62.8669 | .3786 | 1840000. |
| 945 | 1008 | 551.672 | 62.8642 | .3798 | 1840000. |

V. C. SUMMER ILRT
SUMMARY DATA

ALMAX = .200 VOLUME = 1840000.
VRATET = .287 VRATEM = .289

| TIME | DATE | TEMP | PRESSURE | VPRS | VOLUME |
|---|---|---|---|---|---|
| 1000 | 1008 | 551.660 | 62.8604 | .3826 | 1840000. |
| 1015 | 1008 | 551.651 | 62.8631 | .3789 | 1840000. |
| 1030 | 1008 | 551.651 | 62.8616 | .3794 | 1840000. |
| 1045 | 1008 | 551.646 | 62.8595 | .3800 | 1840000. |
| 1100 | 1008 | 551.638 | 62.8564 | .3821 | 1840000. |
| 1115 | 1008 | 551.640 | 62.8564 | .3811 | 1840000. |
| 1130 | 1008 | 551.659 | 62.8563 | .3807 | 1840000. |
| 1145 | 1008 | 551.651 | 62.8555 | .3805 | 1840000. |
| 1200 | 1008 | 551.634 | 62.8546 | .3809 | 1840000. |
| 1215 | 1008 | 551.632 | 62.8520 | .3820 | 1840000. |
| 1230 | 1008 | 551.625 | 62.8512 | .3818 | 1840000. |
| 1245 | 1008 | 551.626 | 62.8519 | .3801 | 1840000. |
| 1300 | 1008 | 551.617 | 62.8485 | .3830 | 1840000. |
| 1315 | 1008 | 551.611 | 62.8494 | .3811 | 1840000. |
| 1330 | 1008 | 551.601 | 62.8458 | .3837 | 1840000. |
| 1345 | 1008 | 551.606 | 62.8465 | .3825 | 1840000. |
| 1400 | 1008 | 551.597 | 62.8442 | .3833 | 1840000. |
| 1415 | 1008 | 551.589 | 62.8442 | .3818 | 1840000. |
| 1430 | 1008 | 551.609 | 62.8427 | .3833 | 1840000. |
| 1445 | 1008 | 551.594 | 62.8435 | .3815 | 1840000. |
| 1500 | 1008 | 551.616 | 62.8428 | .3817 | 1840000. |
| 1515 | 1008 | 551.608 | 62.8408 | .3827 | 1840000. |
| 1530 | 1008 | 551.607 | 62.8404 | .3821 | 1840000. |
| 1545 | 1008 | 551.598 | 62.8408 | .3807 | 1840000. |
| 1600 | 1008 | 551.599 | 62.8366 | .3839 | 1840000. |
| 1615 | 1008 | 551.588 | 62.8365 | .3830 | 1840000. |
| 1630 | 1008 | 551.590 | 62.8352 | .3833 | 1840000. |
| 1645 | 1008 | 551.579 | 62.8337 | .3838 | 1840000. |
| 1700 | 1008 | 551.576 | 62.8350 | .3815 | 1840000. |
| 1715 | 1008 | 551.573 | 62.8351 | .3804 | 1840000. |
| 1730 | 1008 | 551.571 | 62.8347 | .3808 | 1840000. |
| 1745 | 1008 | 551.574 | 62.8314 | .3831 | 1840000. |
| 1800 | 1008 | 551.571 | 62.8320 | .3815 | 1840000. |
| 1815 | 1008 | 551.566 | 62.8311 | .3814 | 1840000. |
| 1830 | 1008 | 551.568 | 62.8313 | .3812 | 1840000. |
| 1845 | 1008 | 551.557 | 62.8280 | .3835 | 1840000. |
| 1900 | 1008 | 551.557 | 62.8265 | .3841 | 1840000. |
| 1915 | 1008 | 551.558 | 62.8285 | .3810 | 1840000. |
| 1930 | 1008 | 551.559 | 62.8252 | .3833 | 1840000. |
| 1945 | 1008 | 551.559 | 62.8263 | .3812 | 1840000. |
| 2000 | 1008 | 551.545 | 62.8243 | .3827 | 1840000. |
| 2015 | 1008 | 551.549 | 62.8214 | .3846 | 1840000. |
| 2030 | 1008 | 551.549 | 62.8209 | .3841 | 1840000. |
| 2045 | 1008 | 551.539 | 62.8191 | .3849 | 1840000. |
| 2100 | 1008 | 551.531 | 62.8215 | .3815 | 1840000. |
| 2115 | 1008 | 551.534 | 62.8203 | .3817 | 1840000. |
| 2130 | 1008 | 551.519 | 62.8190 | .3820 | 1840000. |
| 2145 | 1008 | 551.510 | 62.8183 | .3822 | 1840000. |

V. C. SUMMER ILRT
LEAKAGE RATE (WEIGHT PERCENT/DAY)
MASS POINT ANALYSIS

TIME AND DATE AT START OF TEST: 2145 1007 1984
TEST DURATION: 24.00 HOURS

| TIME | TEMP (R) | PRESSURE (PSIA) | CTMT. AIR MASS (LBM) | MASS LOSS (LBM) | AVERAGE MASS LOSS (LBM/HR) |
|---|---|---|---|---|---|
| 2145 | 552.195 | 62.9479 | 566155. | | |
| 2200 | 552.169 | 62.9437 | 566143. | 11.5 | 46.2 |
| 2215 | 552.152 | 62.9417 | 566143. | .9 | 24.8 |
| 2230 | 552.128 | 62.9409 | 566160. | -17.6 | -7.0 |
| 2245 | 552.117 | 62.9386 | 566151. | 9.0 | 3.8 |
| 2300 | 552.108 | 62.9333 | 566113. | 38.5 | 33.8 |
| 2315 | 552.083 | 62.9333 | 566138. | -25.6 | 11.1 |
| 2330 | 552.071 | 62.9297 | 566118. | 20.4 | 21.2 |
| 2345 | 552.059 | 62.9268 | 566104. | 13.8 | 25.5 |
| 0 | 552.042 | 62.9264 | 566119. | -14.9 | 16.0 |
| 15 | 552.022 | 62.9217 | 566097. | 22.3 | 23.3 |
| 30 | 552.012 | 62.9235 | 566123. | -26.2 | 11.7 |
| 45 | 551.999 | 62.9196 | 566102. | 20.9 | 17.7 |
| 100 | 551.985 | 62.9186 | 566106. | -3.9 | 15.1 |
| 115 | 551.977 | 62.9182 | 566111. | -5.4 | 12.5 |
| 130 | 551.955 | 62.9152 | 566106. | 4.9 | 13.0 |
| 145 | 551.946 | 62.9136 | 566102. | 4.5 | 13.3 |
| 200 | 551.932 | 62.9120 | 566102. | -.5 | 12.4 |
| 215 | 551.927 | 62.9090 | 566080. | 22.8 | 16.8 |
| 230 | 551.914 | 62.9080 | 566084. | -4.4 | 15.0 |
| 245 | 551.899 | 62.9048 | 566071. | 12.7 | 16.8 |
| 300 | 551.887 | 62.9020 | 566058. | 13.5 | 18.5 |
| 315 | 551.872 | 62.8997 | 566053. | 4.6 | 18.5 |
| 330 | 551.862 | 62.9018 | 566081. | -28.2 | 12.8 |
| 345 | 551.859 | 62.9000 | 566069. | 12.6 | 14.4 |
| 400 | 551.843 | 62.8951 | 566041. | 28.1 | 18.3 |
| 415 | 551.835 | 62.8932 | 566032. | 8.6 | 18.9 |
| 430 | 551.823 | 62.8949 | 566059. | -27.3 | 14.2 |
| 445 | 551.818 | 62.8933 | 566051. | 8.4 | 14.9 |
| 500 | 551.802 | 62.8910 | 566046. | 5.0 | 15.0 |
| 515 | 551.785 | 62.8871 | 566027. | 18.6 | 17.0 |
| 530 | 551.782 | 62.8867 | 566027. | .4 | 16.5 |
| 545 | 551.772 | 62.8861 | 566033. | -5.9 | 15.3 |
| 600 | 551.768 | 62.8834 | 566012. | 20.5 | 17.3 |
| 615 | 551.762 | 62.8811 | 565998. | 15.0 | 18.5 |
| 630 | 551.745 | 62.8804 | 566009. | -11.8 | 16.6 |
| 645 | 551.743 | 62.8795 | 566003. | 6.3 | 16.9 |
| 700 | 551.735 | 62.8797 | 566013. | -10.2 | 15.3 |
| 715 | 551.725 | 62.8764 | 565993. | 20.2 | 17.0 |
| 730 | 551.724 | 62.8772 | 566002. | -8.7 | 15.7 |
| 745 | 551.705 | 62.8763 | 566013. | -11.2 | 14.2 |

V. C. SUMMER ILRT
LEAKAGE RATE (WEIGHT PERCENT/DAY)
MASS POINT ANALYSIS

TIME AND DATE AT START OF TEST: 2145 1007 1984
TEST DURATION: 24.00 HOURS

| TIME | TEMP (R) | PRESSURE (PSIA) | CTMT. AIR MASS (LBM) | MASS LOSS (LBM) | AVERAGE MASS LOSS (LBM/HR) |
|---|---|---|---|---|---|
| 800 | 551.697 | 62.8731 | 565993. | 19.6 | 15.8 |
| 815 | 551.701 | 62.8705 | 565965. | 28.1 | 18.1 |
| 830 | 551.698 | 62.8710 | 565972. | -6.5 | 17.0 |
| 845 | 551.699 | 62.8669 | 565935. | 36.4 | 20.0 |
| 900 | 551.697 | 62.8669 | 565937. | -1.4 | 19.4 |
| 915 | 551.690 | 62.8647 | 565923. | 13.3 | 20.1 |
| 930 | 551.681 | 62.8669 | 565954. | -30.1 | 17.1 |
| 945 | 551.672 | 62.8642 | 565930. | 15.1 | 18.0 |
| 1000 | 551.660 | 62.8604 | 565917. | 21.6 | 19.4 |
| 1015 | 551.651 | 62.8631 | 565950. | -32.8 | 16.4 |
| 1030 | 551.651 | 62.8616 | 565937. | 12.8 | 17.1 |
| 1045 | 551.646 | 62.8595 | 565922. | 15.1 | 18.0 |
| 1100 | 551.638 | 62.8564 | 565903. | 19.1 | 19.1 |
| 1115 | 551.640 | 62.8564 | 565900. | 2.3 | 18.9 |
| 1130 | 551.659 | 62.8563 | 565881. | 19.3 | 19.3 |
| 1145 | 551.651 | 62.8555 | 565881. | -.2 | 19.6 |
| 1200 | 551.634 | 62.8546 | 565891. | -9.8 | 18.5 |
| 1215 | 551.632 | 62.8520 | 565870. | 21.0 | 19.7 |
| 1230 | 551.625 | 62.8512 | 565869. | .8 | 19.4 |
| 1245 | 551.626 | 62.8519 | 565875. | -6.0 | 18.7 |
| 1300 | 551.617 | 62.8485 | 565853. | 22.2 | 19.8 |
| 1315 | 551.611 | 62.8494 | 565868. | -15.1 | 18.5 |
| 1330 | 551.601 | 62.8458 | 565845. | 23.1 | 19.7 |
| 1345 | 551.606 | 62.8465 | 565846. | -1.6 | 19.3 |
| 1400 | 551.597 | 62.8442 | 565834. | 12.0 | 19.7 |
| 1415 | 551.589 | 62.8442 | 565843. | -8.5 | 18.9 |
| 1430 | 551.609 | 62.8427 | 565809. | 33.8 | 20.6 |
| 1445 | 551.594 | 62.8435 | 565831. | -22.3 | 19.0 |
| 1500 | 551.616 | 62.8428 | 565803. | 28.1 | 20.4 |
| 1515 | 551.608 | 62.8408 | 565793. | 10.1 | 20.7 |
| 1530 | 551.607 | 62.8404 | 565790. | 2.8 | 20.5 |
| 1545 | 551.598 | 62.8408 | 565804. | -13.5 | 19.5 |
| 1600 | 551.599 | 62.8366 | 565764. | 39.6 | 21.4 |
| 1615 | 551.588 | 62.8365 | 565775. | -10.5 | 20.6 |
| 1630 | 551.590 | 62.8352 | 565762. | 12.8 | 21.0 |
| 1645 | 551.579 | 62.8337 | 565759. | 3.0 | 20.8 |
| 1700 | 551.576 | 62.8350 | 565774. | -15.0 | 19.8 |
| 1715 | 551.573 | 62.8351 | 565778. | -3.9 | 19.3 |
| 1730 | 551.571 | 62.8347 | 565776. | 1.9 | 19.2 |
| 1745 | 551.574 | 62.8314 | 565744. | 32.1 | 20.6 |
| 1800 | 551.571 | 62.8320 | 565752. | -8.6 | 19.9 |

V. C. SUMMER ILRT
LEAKAGE RATE (WEIGHT PERCENT/DAY)
MASS POINT ANALYSIS

TIME AND DATE AT START OF TEST: 2145 1007 1984
TEST DURATION: 24.00 HOURS

| TIME | TEMP (R) | PRESSURE (PSIA) | CTMT. AIR MASS (LBM) | MASS LOSS (LBM) | AVERAGE MASS LOSS (LBM/HR) |
|---|---|---|---|---|---|
| 1815 | 551.566 | 62.8311 | 565749. | 3.1 | 19.8 |
| 1830 | 551.568 | 62.8313 | 565749. | .7 | 19.6 |
| 1845 | 551.557 | 62.8280 | 565730. | 19.0 | 20.3 |
| 1900 | 551.557 | 62.8265 | 565716. | 13.9 | 20.7 |
| 1915 | 551.558 | 62.8285 | 565734. | -17.8 | 19.6 |
| 1930 | 551.559 | 62.8252 | 565702. | 31.5 | 20.8 |
| 1945 | 551.559 | 62.8263 | 565713. | -10.7 | 20.1 |
| 2000 | 551.545 | 62.8243 | 565710. | 3.2 | 20.0 |
| 2015 | 551.549 | 62.8214 | 565678. | 31.2 | 21.2 |
| 2030 | 551.549 | 62.8209 | 565675. | 3.4 | 21.1 |
| 2045 | 551.539 | 62.8191 | 565668. | 6.8 | 21.2 |
| 2100 | 551.531 | 62.8215 | 565698. | -29.7 | 19.7 |
| 2115 | 551.534 | 62.8203 | 565684. | 14.0 | 20.0 |
| 2130 | 551.519 | 62.8190 | 565688. | -3.8 | 19.7 |
| 2145 | 551.510 | 62.8183 | 565691. | -3.2 | 19.3 |

| | |
|---|---|
| FREE AIR VOLUME USED (CU. FT.) | =1840000. |
| REGRESSION LINE | |
| INTERCEPT (LBM) | = 566178. |
| SLOPE (LBM/HR) | = -21.0 |
| MAXIMUM ALLOWABLE LEAKAGE RATE | = .200 |
| 75% OF MAXIMUM ALLOWABLE LEAKAGE RATE | = .150 |
| THE UPPER 95% CONFIDENCE LIMIT | = .091 |
| THE CALCULATED LEAKAGE RATE | = .089 |

V. C. SUMMER ILRT
LEAKAGE RATE (WEIGHT PERCENT/DAY)
TOTAL TIME ANALYSIS

TIME AND DATE AT START OF TEST: 2145 1007 1984
TEST DURATION: 24.00 HOURS

| TIME | TEMP (R) | PRESSURE (PSIA) | MEASURED LEAKAGE RATE |
|---|---|---|---|
| 2145 | 552.195 | 62.9479 | |
| 2200 | 552.169 | 62.9437 | .196 |
| 2215 | 552.152 | 62.9417 | .105 |
| 2230 | 552.128 | 62.9409 | -.030 |
| 2245 | 552.117 | 62.9386 | .016 |
| 2300 | 552.106 | 62.9333 | .143 |
| 2315 | 552.083 | 62.9333 | .047 |
| 2330 | 552.071 | 62.9297 | .090 |
| 2345 | 552.059 | 62.9268 | .108 |
| 0 | 552.042 | 62.9264 | .068 |
| 15 | 552.022 | 62.9217 | .099 |
| 30 | 552.012 | 62.9235 | .049 |
| 45 | 551.999 | 62.9196 | .075 |
| 100 | 551.985 | 62.9186 | .064 |
| 115 | 551.977 | 62.9182 | .053 |
| 130 | 551.955 | 62.9152 | .055 |
| 145 | 551.946 | 62.9136 | .056 |
| 200 | 551.932 | 62.9120 | .053 |
| 215 | 551.927 | 62.9090 | .071 |
| 230 | 551.914 | 62.9080 | .063 |
| 245 | 551.899 | 62.9048 | .071 |
| 300 | 551.887 | 62.9020 | .079 |
| 315 | 551.872 | 62.8997 | .079 |
| 330 | 551.862 | 62.9018 | .054 |
| 345 | 551.859 | 62.9000 | .061 |
| 400 | 551.843 | 62.8951 | .078 |
| 415 | 551.835 | 62.8932 | .080 |
| 430 | 551.823 | 62.8949 | .060 |
| 445 | 551.818 | 62.8933 | .063 |
| 500 | 551.802 | 62.8910 | .064 |
| 515 | 551.785 | 62.8871 | .072 |
| 530 | 551.782 | 62.8867 | .070 |
| 545 | 551.772 | 62.8861 | .065 |
| 600 | 551.768 | 62.8834 | .073 |
| 615 | 551.762 | 62.8811 | .079 |
| 630 | 551.745 | 62.8804 | .071 |
| 645 | 551.743 | 62.8795 | .072 |
| 700 | 551.735 | 62.8797 | .065 |
| 715 | 551.725 | 62.8764 | .072 |
| 730 | 551.724 | 62.8772 | .067 |
| 745 | 551.705 | 62.8763 | .060 |
| 800 | 551.697 | 62.8731 | .067 |

V. C. SUMMER ILRT
LEAKAGE RATE (WEIGHT PERCENT/DAY)
TOTAL TIME ANALYSIS

TIME AND DATE AT START OF TEST: 2145 1007 1984
TEST DURATION: 24.00 HOURS

| TIME | TEMP (R) | PRESSURE (PSIA) | MEASURED LEAKAGE RATE |
|---|---|---|---|
| 815 | 551.701 | 62.8705 | .077 |
| 830 | 551.698 | 62.8710 | .072 |
| 845 | 551.699 | 62.8669 | .085 |
| 900 | 551.697 | 62.8669 | .082 |
| 915 | 551.690 | 62.8647 | .085 |
| 930 | 551.681 | 62.8669 | .073 |
| 945 | 551.672 | 62.8642 | .076 |
| 1000 | 551.660 | 62.8604 | .082 |
| 1015 | 551.651 | 62.8631 | .070 |
| 1030 | 551.651 | 62.8616 | .073 |
| 1045 | 551.646 | 62.8595 | .076 |
| 1100 | 551.638 | 62.8564 | .081 |
| 1115 | 551.640 | 62.8564 | .080 |
| 1130 | 551.659 | 62.8563 | .084 |
| 1145 | 551.651 | 62.8555 | .083 |
| 1200 | 551.634 | 62.8546 | .079 |
| 1215 | 551.632 | 62.8520 | .083 |
| 1230 | 551.625 | 62.8512 | .082 |
| 1245 | 551.626 | 62.8519 | .079 |
| 1300 | 551.617 | 62.8485 | .084 |
| 1315 | 551.611 | 62.8494 | .078 |
| 1330 | 551.601 | 62.8458 | .083 |
| 1345 | 551.606 | 62.8465 | .082 |
| 1400 | 551.597 | 62.8442 | .084 |
| 1415 | 551.589 | 62.8442 | .080 |
| 1430 | 551.609 | 62.8427 | .088 |
| 1445 | 551.594 | 62.8435 | .081 |
| 1500 | 551.616 | 62.8428 | .086 |
| 1515 | 551.608 | 62.8408 | .088 |
| 1530 | 551.607 | 62.8404 | .087 |
| 1545 | 551.598 | 62.8408 | .083 |
| 1600 | 551.599 | 62.8366 | .091 |
| 1615 | 551.588 | 62.8365 | .087 |
| 1630 | 551.590 | 62.8352 | .089 |
| 1645 | 551.579 | 62.8337 | .088 |
| 1700 | 551.576 | 62.8350 | .084 |
| 1715 | 551.573 | 62.8351 | .082 |
| 1730 | 551.571 | 62.8347 | .081 |
| 1745 | 551.574 | 62.8314 | .087 |
| 1800 | 551.571 | 62.8320 | .084 |
| 1815 | 551.566 | 62.8311 | .084 |
| 1830 | 551.568 | 62.8313 | .083 |

V. C. SUMMER ILRT
LEAKAGE RATE (WEIGHT PERCENT/DAY)
TOTAL TIME ANALYSIS

TIME AND DATE AT START OF TEST: 2145 1007 1984
TEST DURATION: 24.00 HOURS

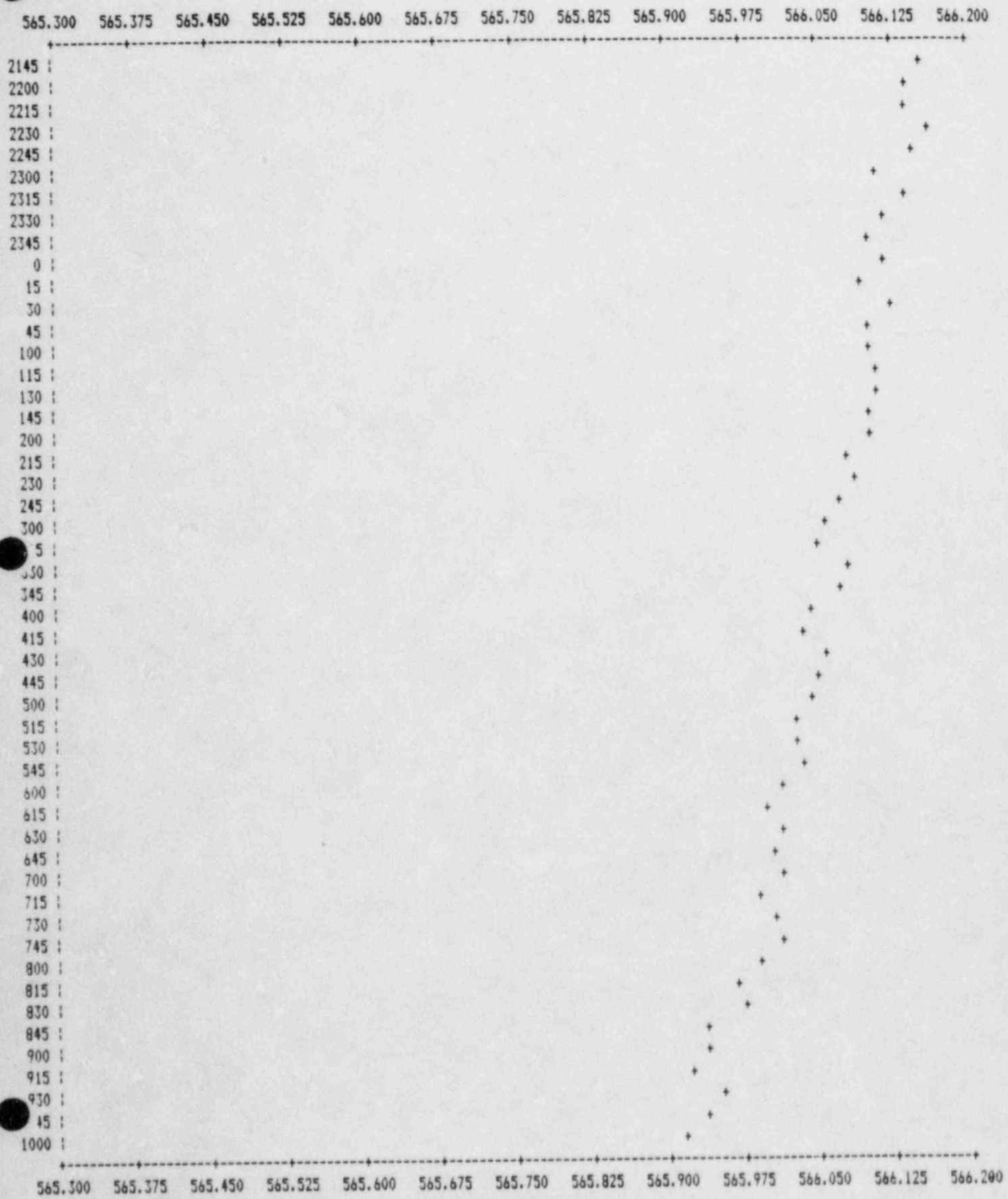
| TIME | TEMP (R) | PRESSURE (PSIA) | MEASURED LEAKAGE RATE |
|---|---|---|---|
| 1845 | 551.557 | 62.8280 | .086 |
| 1900 | 551.557 | 62.8265 | .088 |
| 1915 | 551.558 | 62.8285 | .083 |
| 1930 | 551.559 | 62.8252 | .088 |
| 1945 | 551.559 | 62.8263 | .085 |
| 2000 | 551.545 | 62.8243 | .085 |
| 2015 | 551.549 | 62.8214 | .090 |
| 2030 | 551.549 | 62.8209 | .089 |
| 2045 | 551.539 | 62.8191 | .090 |
| 2100 | 551.531 | 62.8215 | .083 |
| 2115 | 551.534 | 62.8203 | .085 |
| 2130 | 551.519 | 62.8190 | .083 |
| 2145 | 551.510 | 62.8183 | .082 |

| | | |
|---|---|---|
| MEAN OF THE MEASURED LEAKAGE RATES | = | .078 |
| MAXIMUM ALLOWABLE LEAKAGE RATE | = | .200 |
| 75% OF MAXIMUM ALLOWABLE LEAKAGE RATE | = | .150 |
| THE UPPER 95% CONFIDENCE LIMIT | = | .094 |
| THE CALCULATED LEAKAGE RATE | = | .087 |

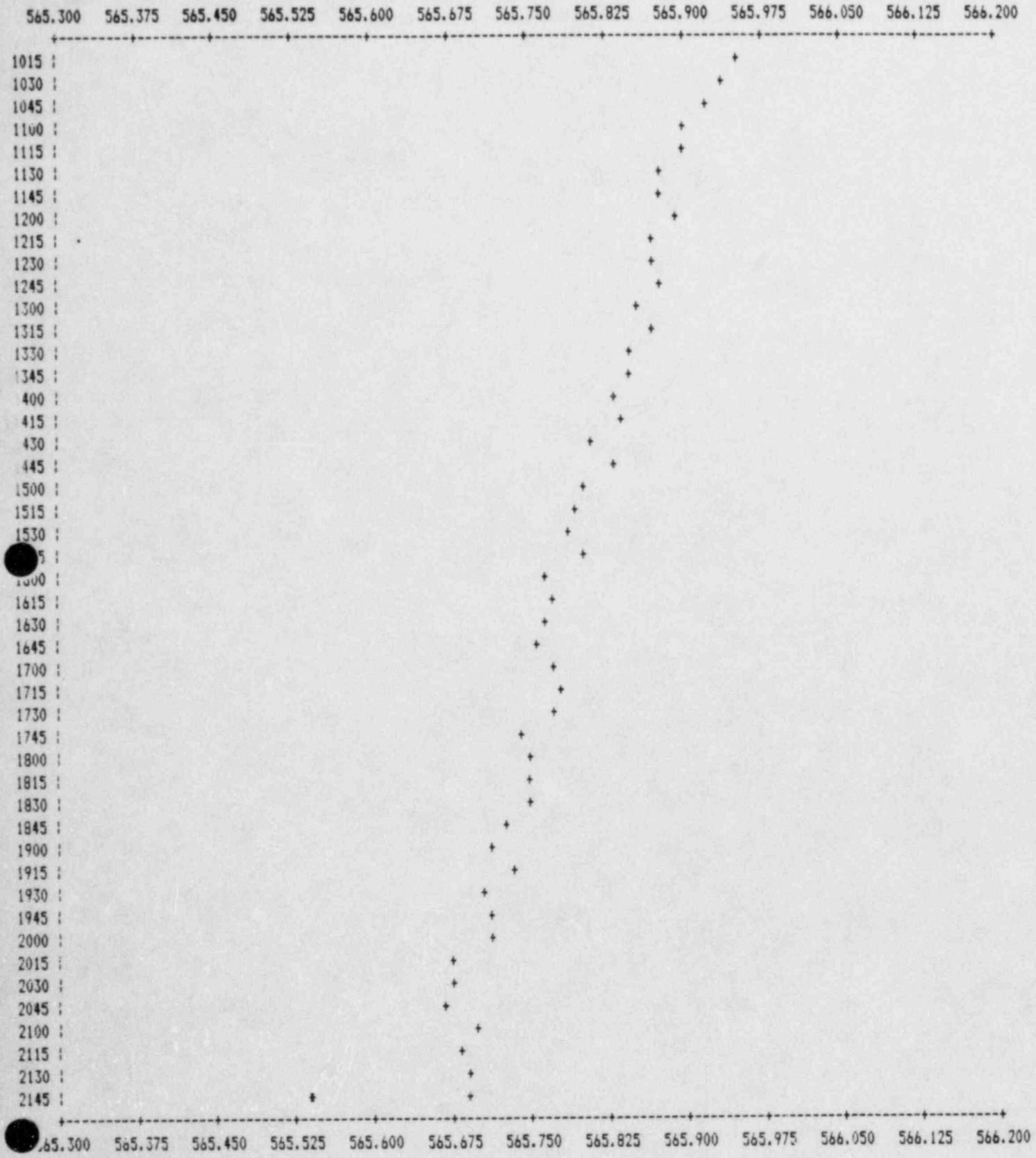
Appendix E

ILRT AND VERIFICATION PLOTS, AIRMASS, TEMPERATURE, PRESSURE, VAPOR PRESSURE, AND LEAKAGE RATE

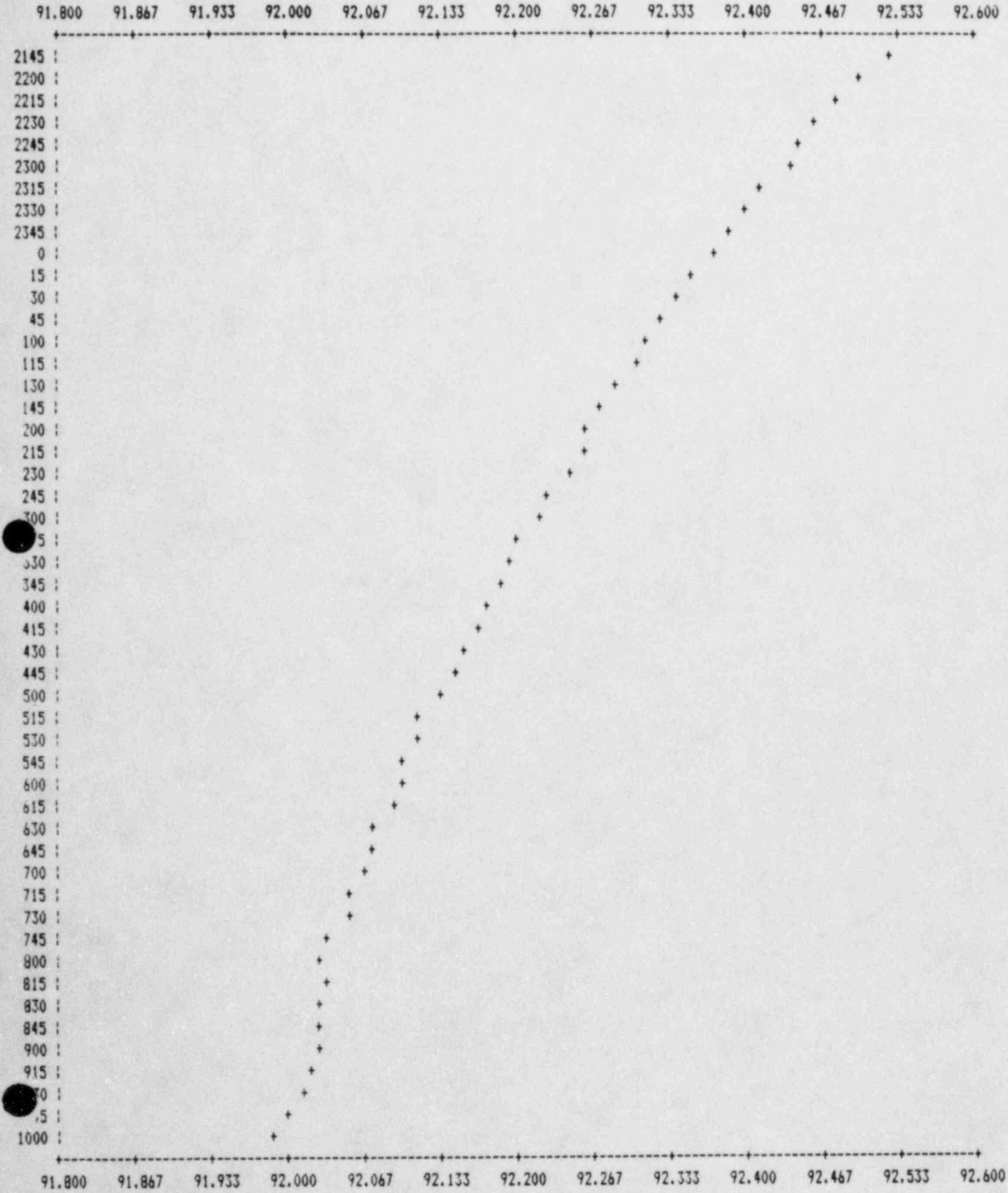
V. C. SUMMER ILRT
AIRMASS LBM X 1000



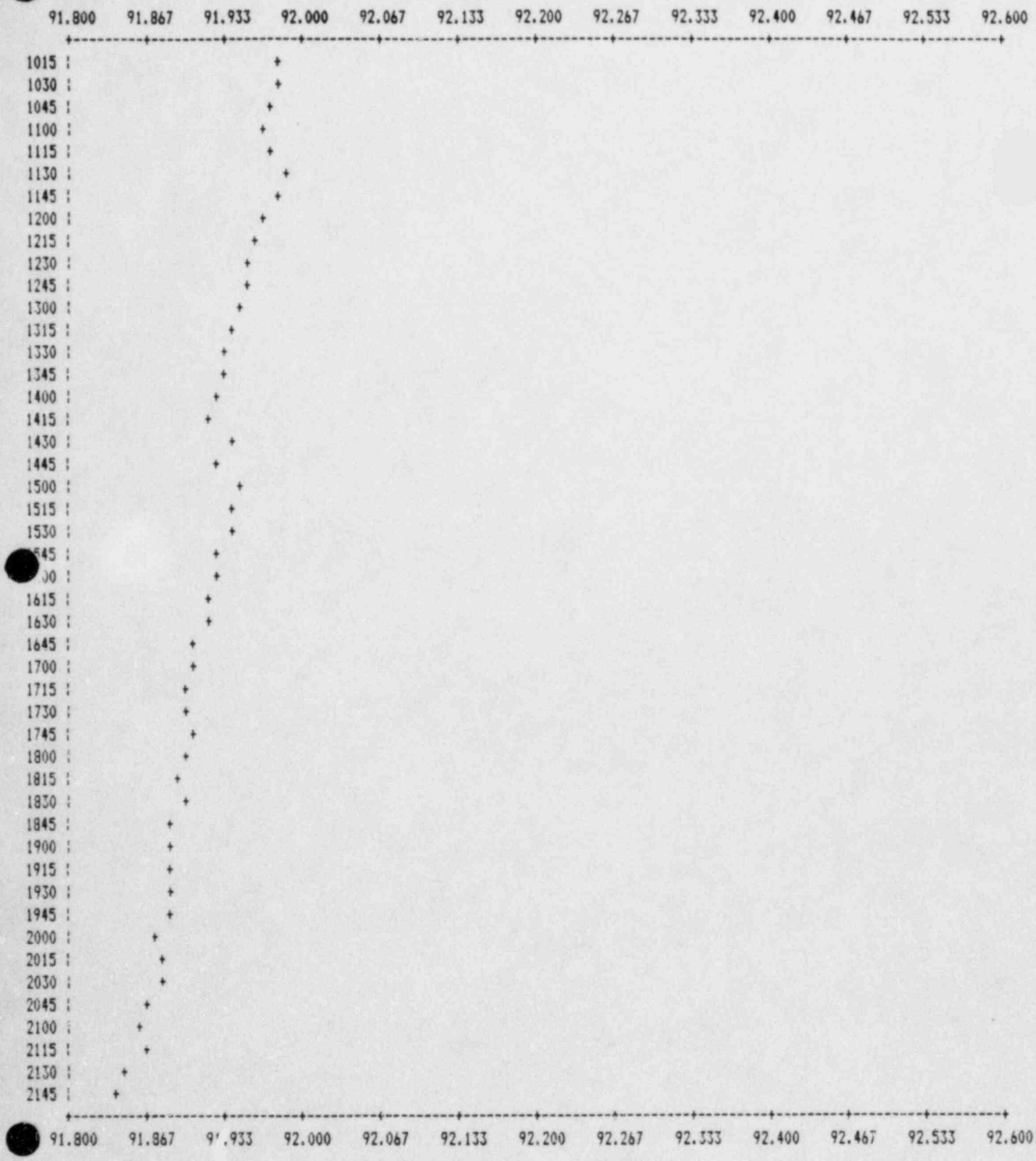
V. C. SUMMER ILRT
AIRMASS LBM X 1000



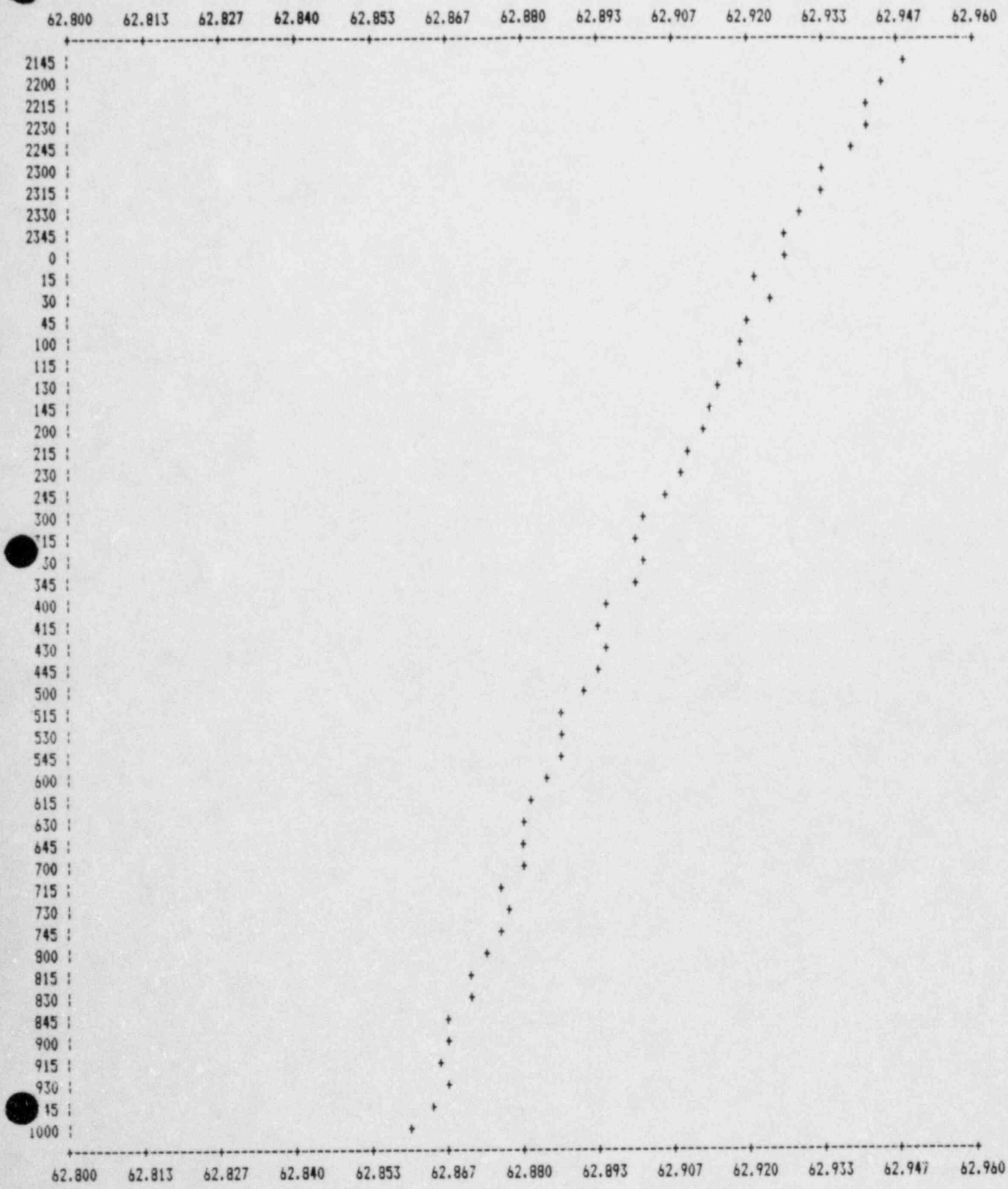
V. C. SUMMER ILRT
TEMPERATURE DEGREES F



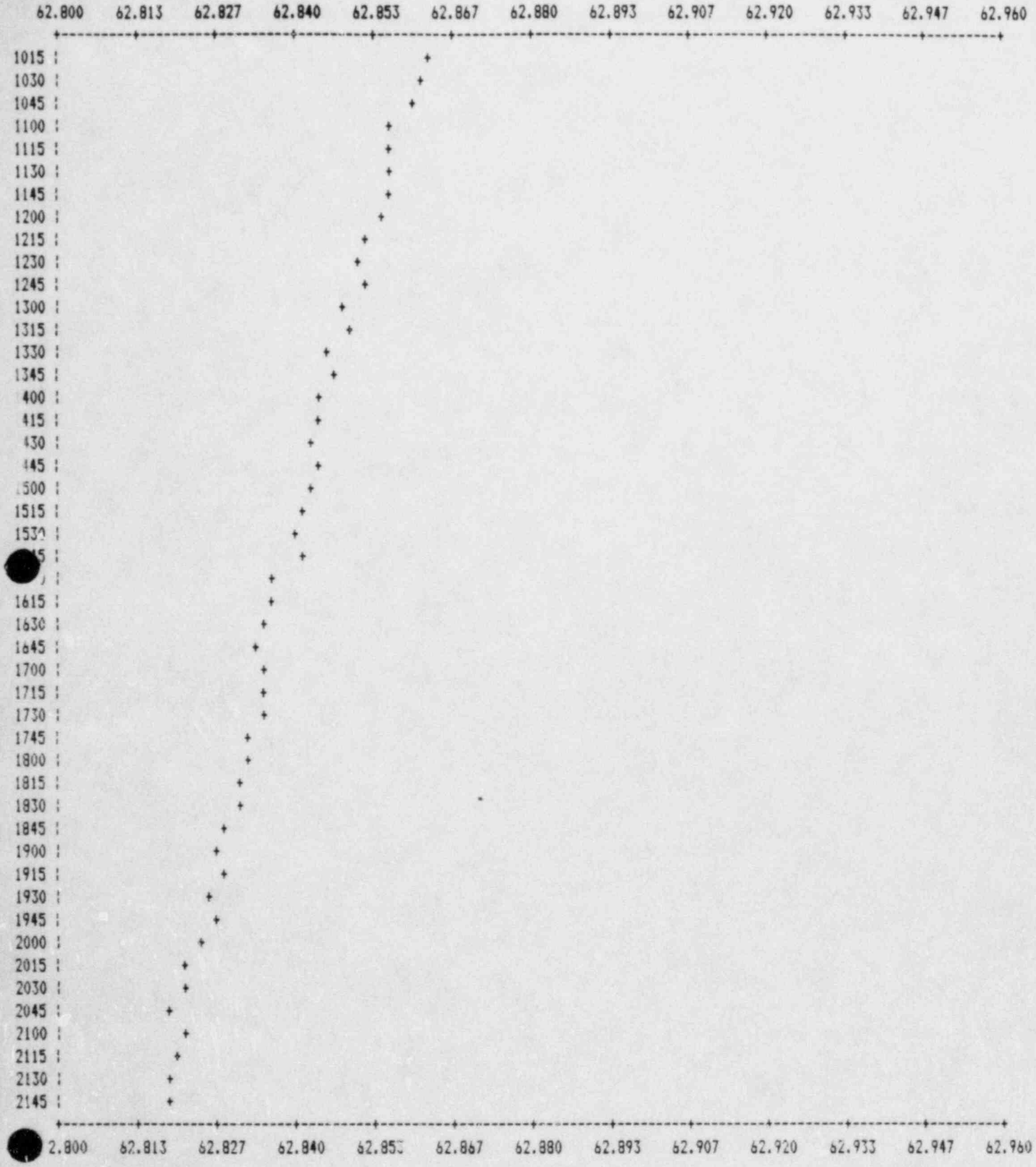
V. C. SUMMER ILRT
TEMPERATURE DEGREES F



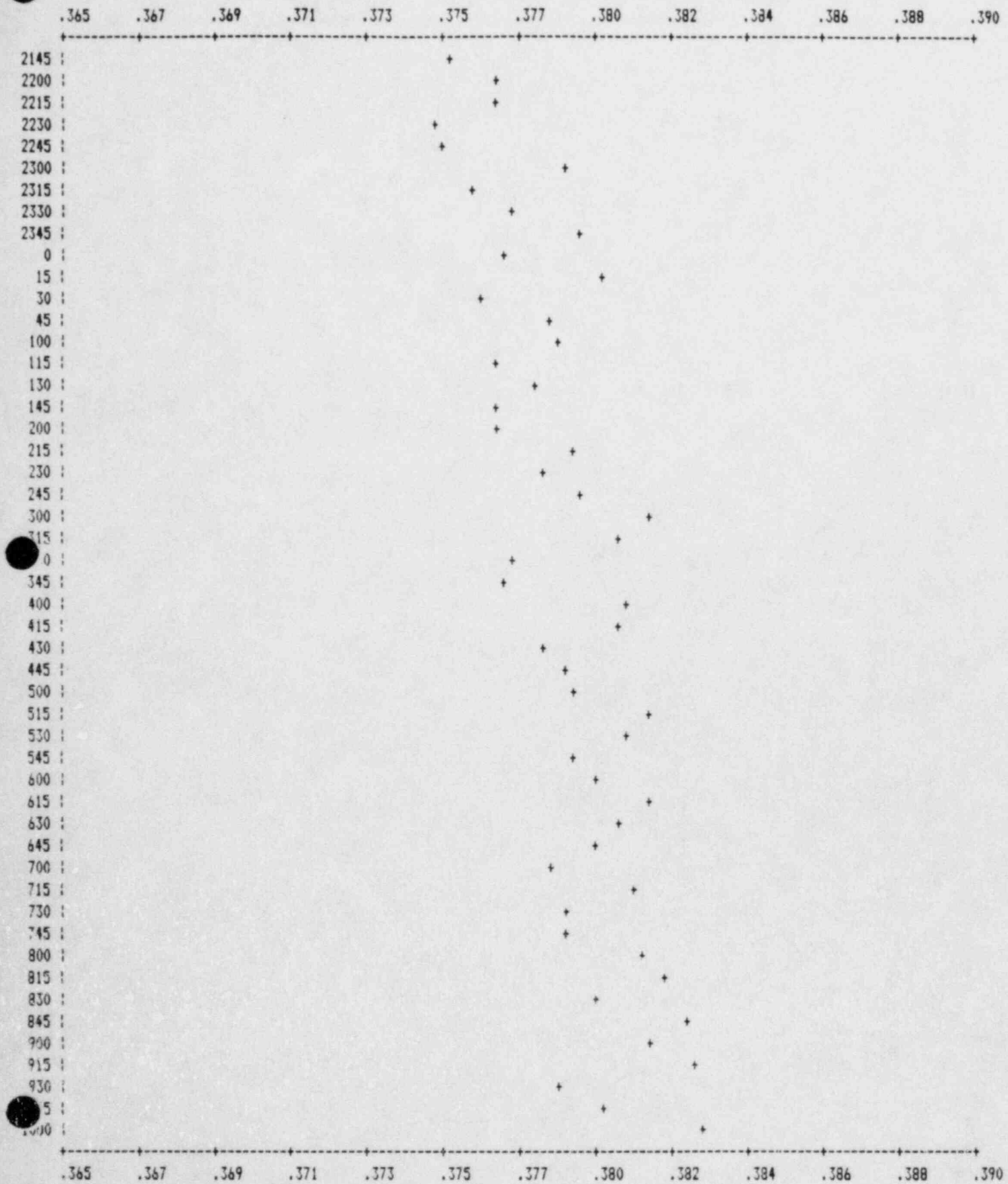
V. C. SUMMER ILRT
PRESSURE PSIA



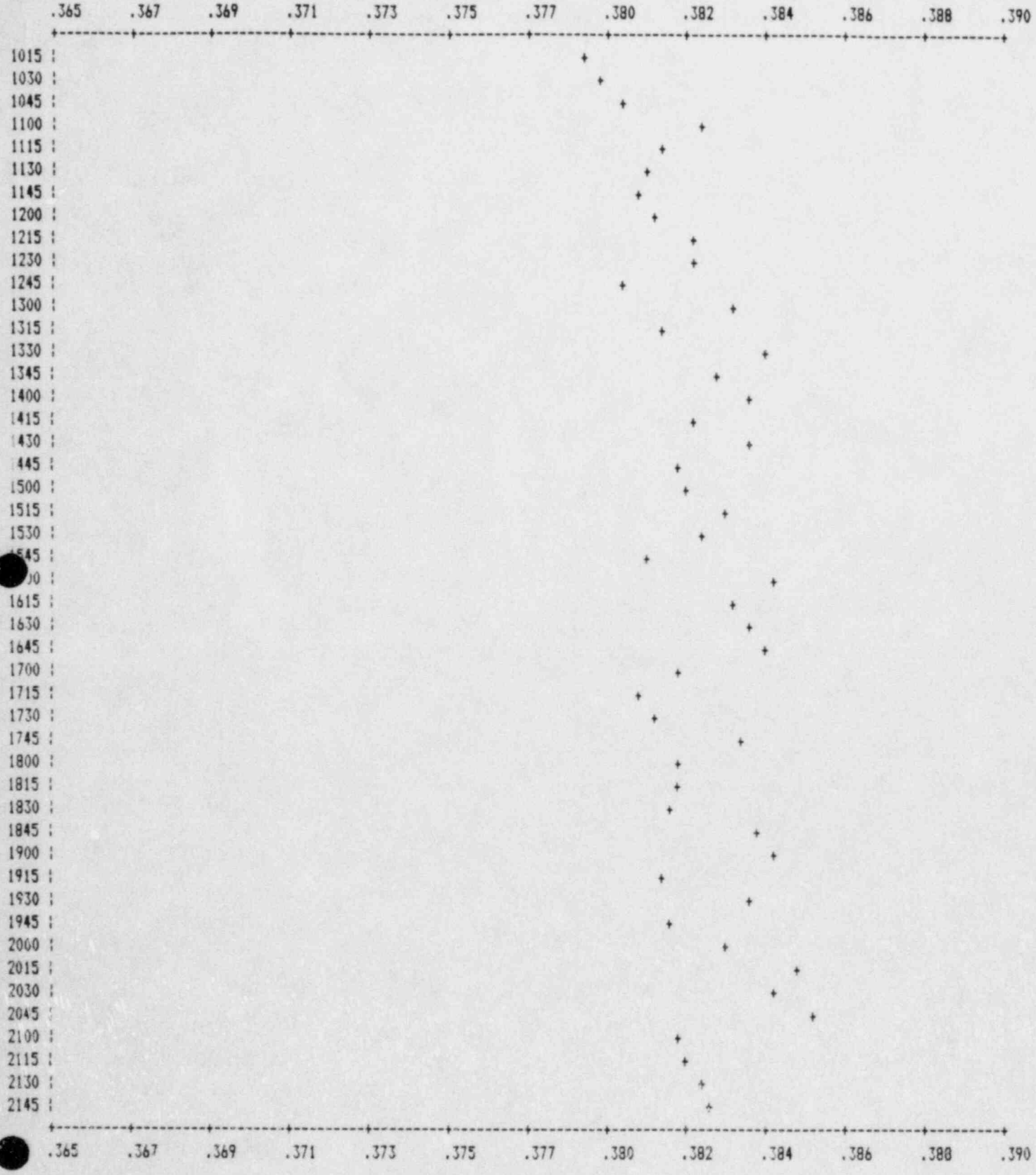
V. C. SUMMER ILRT
PRESSURE PSIA



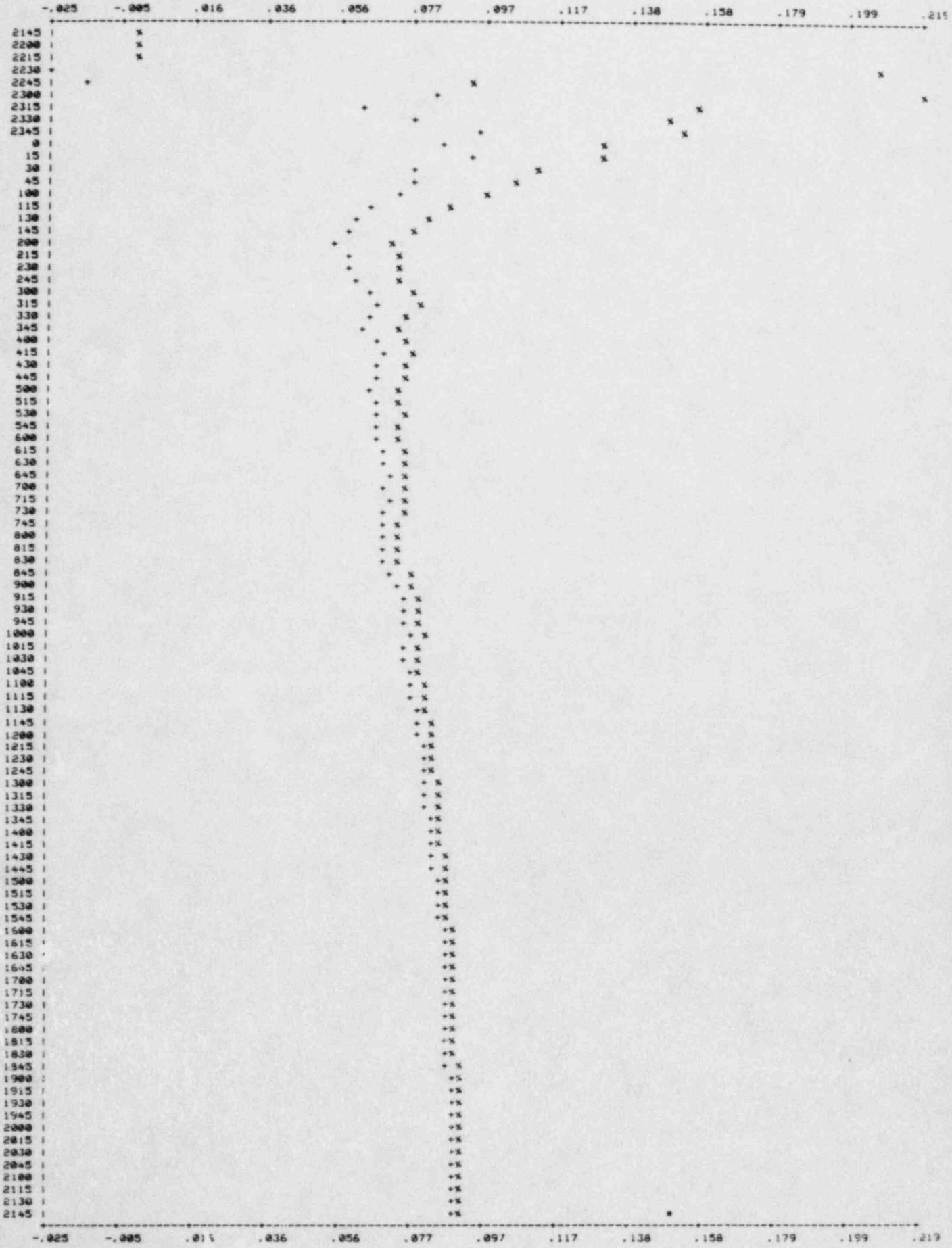
V. C. SUMMER ILRT
VAPOR PRESSURE PSIA

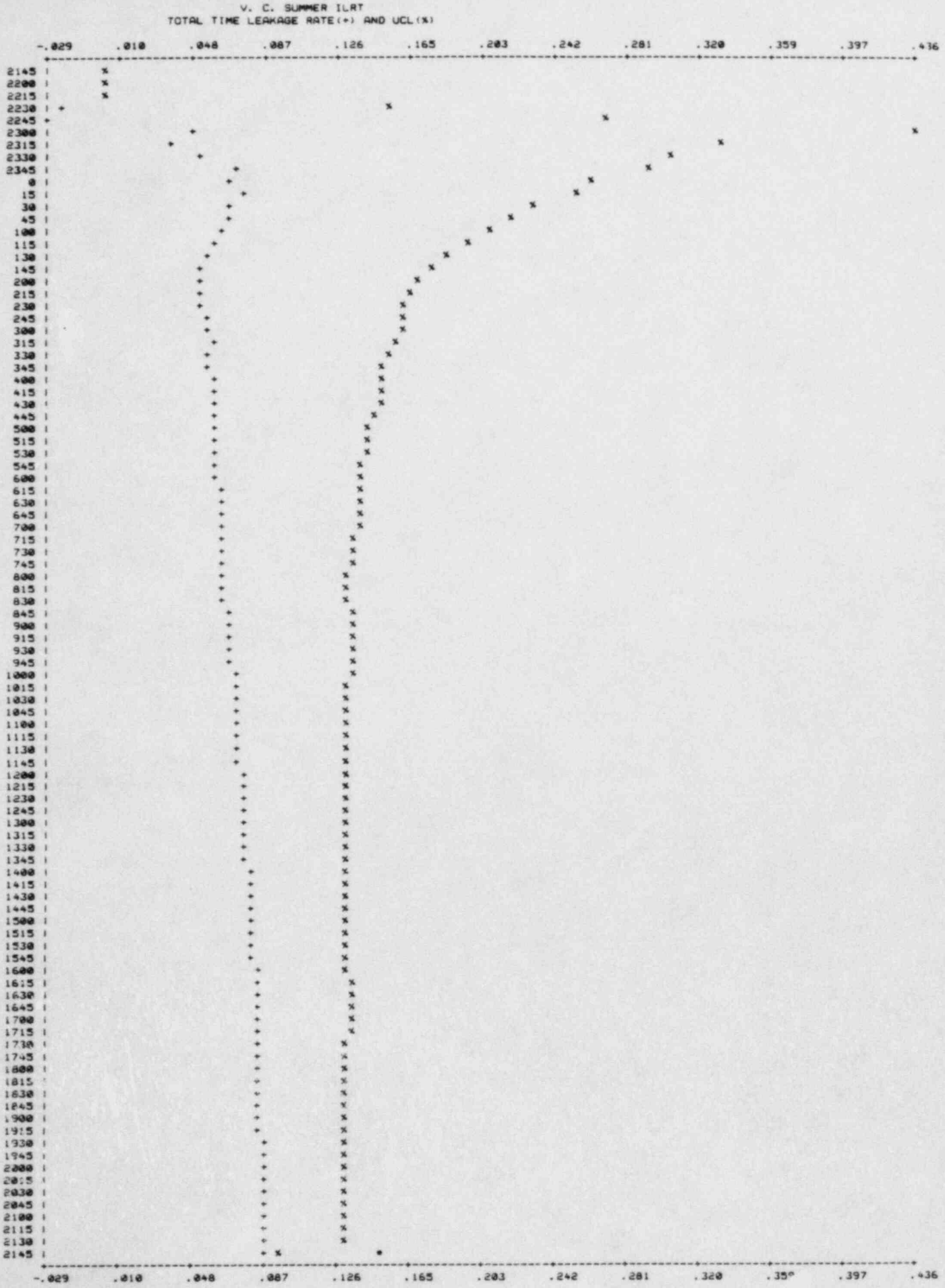


V. C. SUMMER ILRT
VAPOR PRESSURE PSIA

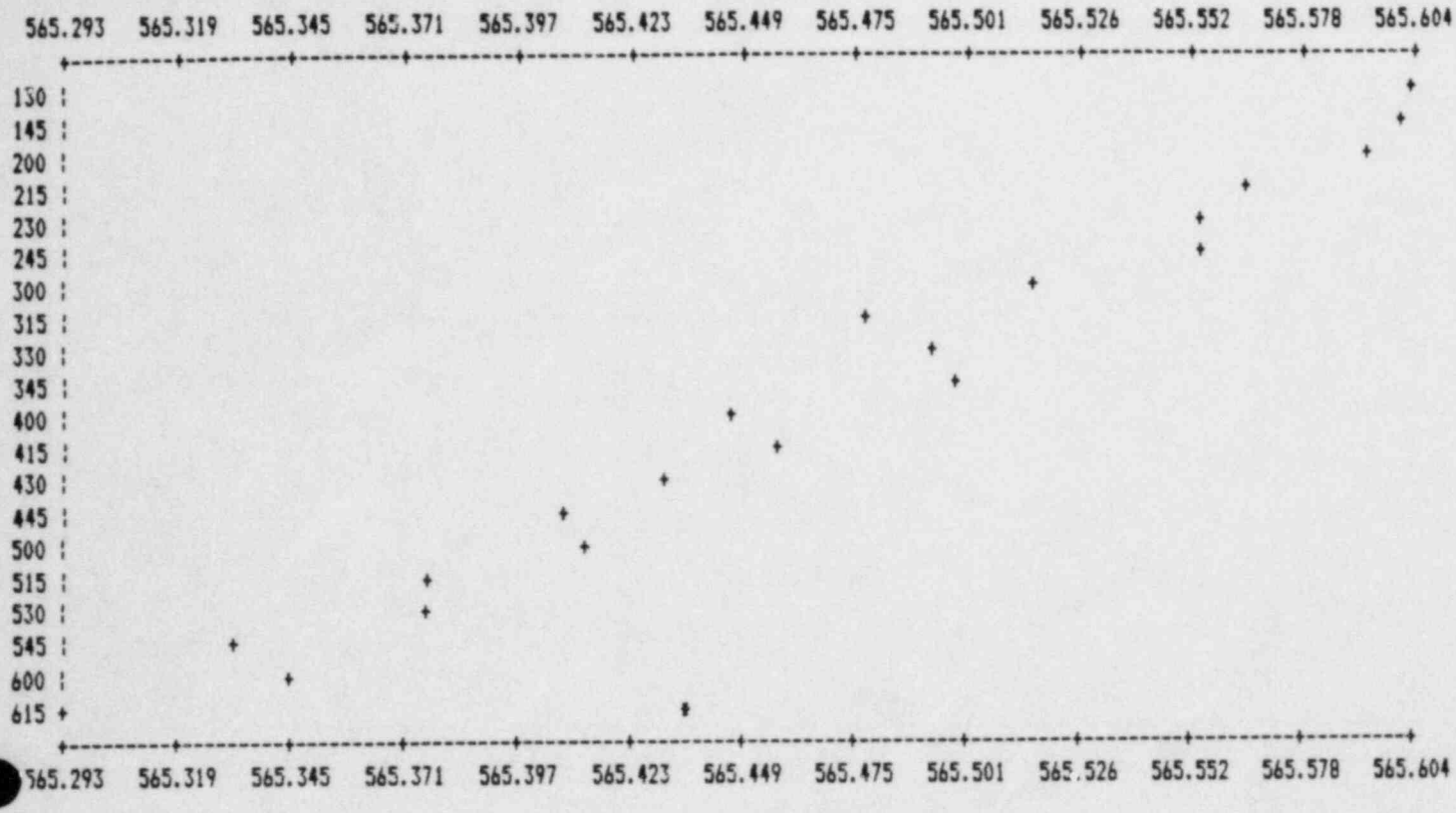


V. C. SUMMER ILRT
MASS POINT LEAKAGE RATE(+) AND UCL(%)

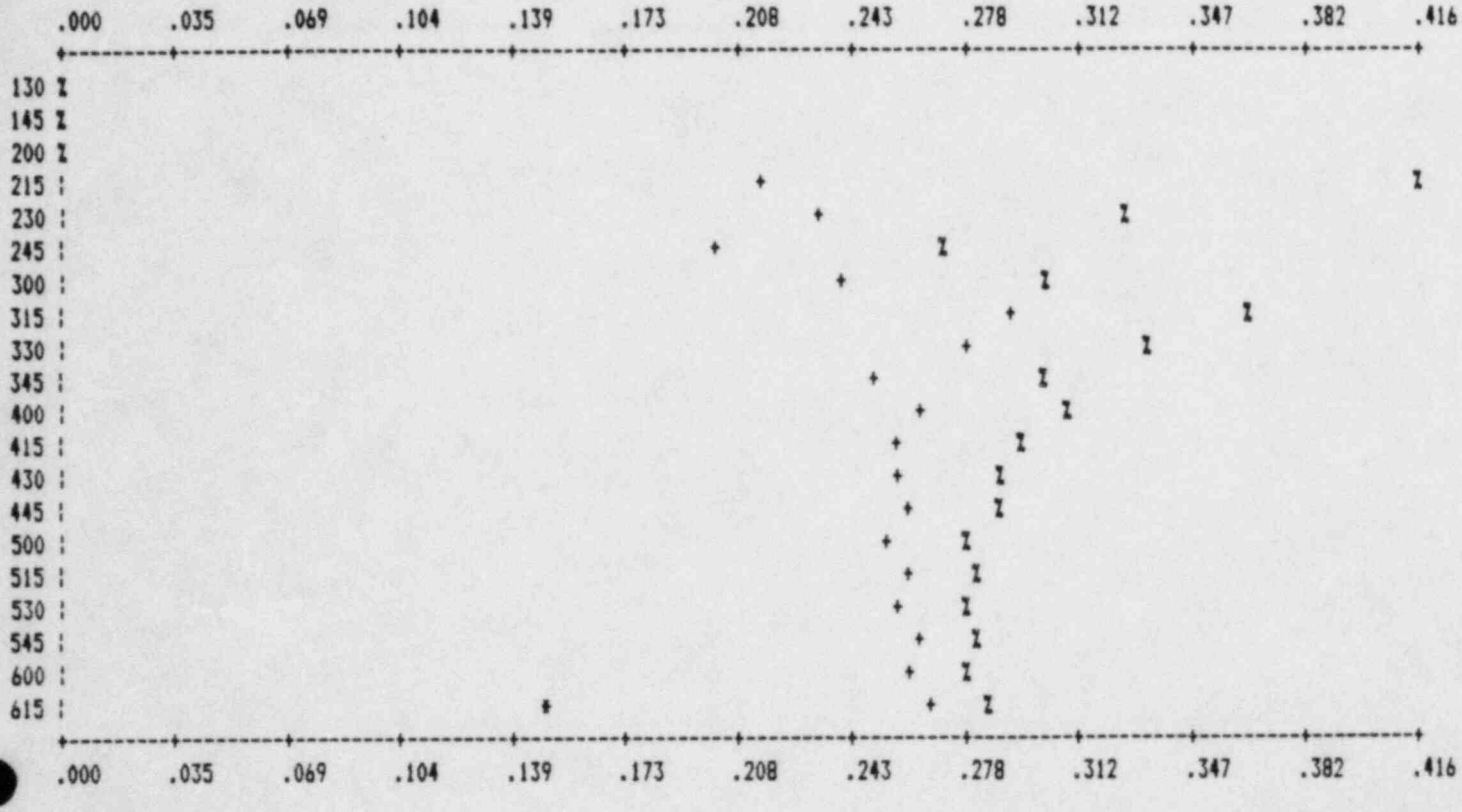



V. C. SUMMER ILRT
TOTAL TIME LEAKAGE RATE(+) AND UCL(%)
-.029
.010
.048
.087
.126
.165
.203
.242
.281
.320
.359
.397
.436

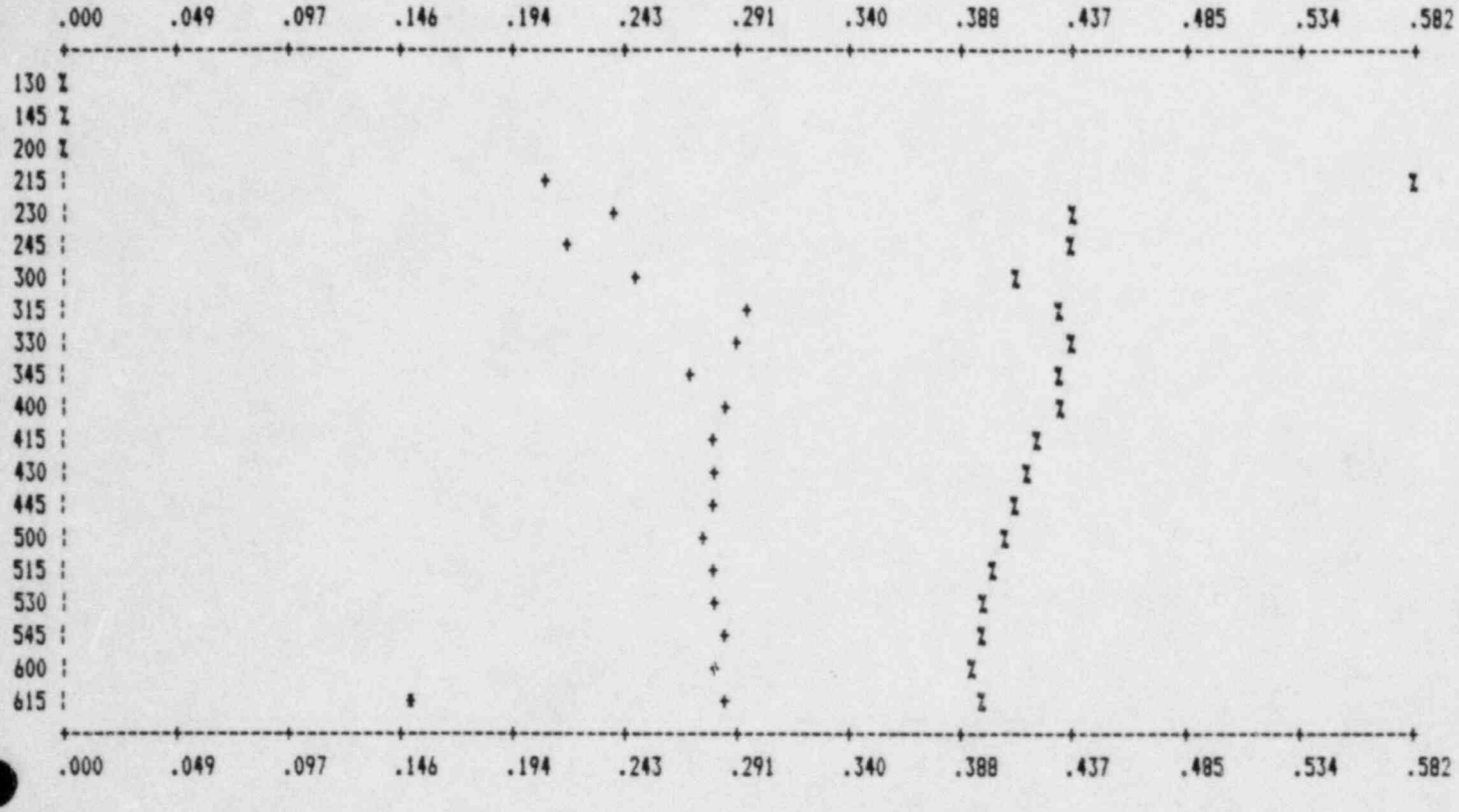
V. C. SUMMER ILRT
AIRMASS LBM X 1000



V. C. SUMMER ILRT
MASS POINT LEAKAGE RATE(+) AND UCL(%)



V. C. SUMMER ILRT
TOTAL TIME LEAKAGE RATE(+) AND UCL(%)



Appendix F

VERIFICATION FLOW SUMMARY DATA, MASS POINT

AND TOTAL TIME REPORTS

# V. C. SUMMER ILRT
## SUMMARY DATA

ALMAX = .200 VOLUME = 1840000.
VRATET = .283 VRATEM = .285

| TIME | DATE | TEMP | PRESSURE | VPRS | VOLUME |
|---|---|---|---|---|---|
| 130 | 1009 | 551.441 | 62.8008 | .3867 | 1840000. |
| 145 | 1009 | 551.444 | 62.8007 | .3853 | 1840000. |
| 200 | 1009 | 551.439 | 62.7993 | .3847 | 1840000. |
| 215 | 1009 | 551.432 | 62.7954 | .3861 | 1840000. |
| 230 | 1009 | 551.427 | 62.7937 | .3853 | 1840000. |
| 245 | 1009 | 551.424 | 62.7934 | .3836 | 1840000. |
| 300 | 1009 | 551.425 | 62.7892 | .3858 | 1840000. |
| 315 | 1009 | 551.432 | 62.7856 | .3874 | 1840000. |
| 330 | 1009 | 551.434 | 62.7876 | .3834 | 1840000. |
| 345 | 1009 | 551.418 | 62.7864 | .3836 | 1840000. |
| 400 | 1009 | 551.422 | 62.7810 | .3870 | 1840000. |
| 415 | 1009 | 551.425 | 62.7825 | .3835 | 1840000. |
| 430 | 1009 | 551.417 | 62.7789 | .3851 | 1840000. |
| 445 | 1009 | 551.413 | 62.7759 | .3856 | 1840000. |
| 500 | 1009 | 551.406 | 62.7756 | .3844 | 1840000. |
| 515 | 1009 | 551.401 | 62.7708 | .3867 | 1840000. |
| 530 | 1009 | 551.397 | 62.7705 | .3860 | 1840000. |
| 545 | 1009 | 551.402 | 62.7662 | .3873 | 1840000. |
| 600 | 1009 | 551.384 | 62.7655 | .3860 | 1840000. |
| 615 | 1009 | 551.403 | 62.7619 | .3876 | 1840000. |

V. C. SUMMER ILRT
LEAKAGE RATE (WEIGHT PERCENT/DAY)
MASS POINT ANALYSIS

TIME AND DATE AT START OF TEST: 130 1009 1984
TEST DURATION: 4.75 HOURS

| TIME | TEMP (R) | PRESSURE (PSIA) | CTMT. AIR MASS (LBM) | MASS LOSS (LBM) | AVERAGE MASS LOSS (LBM/HR) |
|---|---|---|---|---|---|
| 130 | 551.441 | 62.8008 | 565604. | | |
| 145 | 551.444 | 62.8007 | 565601. | 3.7 | 14.8 |
| 200 | 551.439 | 62.7993 | 565593. | 7.6 | 22.6 |
| 215 | 551.432 | 62.7954 | 565565. | 28.2 | 52.7 |
| 230 | 551.427 | 62.7937 | 565554. | 10.7 | 50.2 |
| 245 | 551.424 | 62.7934 | 565555. | -.7 | 39.6 |
| 300 | 551.425 | 62.7892 | 565516. | 38.4 | 58.6 |
| 315 | 551.432 | 62.7856 | 565477. | 39.3 | 72.7 |
| 330 | 551.434 | 62.7876 | 565493. | -15.9 | 55.7 |
| 345 | 551.418 | 62.7864 | 565498. | -5.2 | 47.2 |
| 400 | 551.422 | 62.7810 | 565446. | 52.4 | 63.4 |
| 415 | 551.425 | 62.7825 | 565456. | -10.1 | 54.0 |
| 430 | 551.417 | 62.7789 | 565431. | 24.5 | 57.7 |
| 445 | 551.413 | 62.7759 | 565408. | 22.9 | 60.3 |
| 500 | 551.406 | 62.7756 | 565413. | -5.0 | 54.5 |
| 515 | 551.401 | 62.7708 | 565375. | 38.0 | 61.0 |
| 530 | 551.397 | 62.7705 | 565376. | -.7 | 57.0 |
| 545 | 551.402 | 62.7662 | 565332. | 43.6 | 64.0 |
| 600 | 551.384 | 62.7655 | 565344. | -12.0 | 57.7 |
| 615 | 551.403 | 62.7619 | 565293. | 50.9 | 65.4 |

FREE AIR VOLUME USED (CU. FT.) =1840000.
REGRESSION LINE
INTERCEPT (LBM) = 565617.
SLOPE (LBM/HR) = -63.2
VERIFICATION TEST LEAKAGE RATE UPPER LIMIT = .335
VERIFICATION TEST LEAKAGE RATE LOWER LIMIT = .235
THE CALCULATED LEAKAGE RATE = .268

V. C. SUMMER ILRT
LEAKAGE RATE (WEIGHT PERCENT/DAY)
TOTAL TIME ANALYSIS

TIME AND DATE AT START OF TEST: 130 1009 1984
TEST DURATION: 4.75 HOURS

| TIME | TEMP (R) | PRESSURE (PSIA) | MEASURED LEAKAGE RATE |
|---|---|---|---|
| 130 | 551.441 | 62.8008 | |
| 145 | 551.444 | 62.8007 | .063 |
| 200 | 551.439 | 62.7993 | .096 |
| 215 | 551.432 | 62.7954 | .224 |
| 230 | 551.427 | 62.7937 | .213 |
| 245 | 551.424 | 62.7934 | .168 |
| 300 | 551.425 | 62.7892 | .249 |
| 315 | 551.432 | 62.7856 | .309 |
| 330 | 551.434 | 62.7876 | .236 |
| 345 | 551.418 | 62.7864 | .200 |
| 400 | 551.422 | 62.7810 | .269 |
| 415 | 551.425 | 62.7825 | .229 |
| 430 | 551.417 | 62.7789 | .245 |
| 445 | 551.413 | 62.7759 | .256 |
| 500 | 551.406 | 62.7756 | .231 |
| 515 | 551.401 | 62.7708 | .259 |
| 530 | 551.397 | 62.7705 | .242 |
| 545 | 551.402 | 62.7662 | .271 |
| 600 | 551.384 | 62.7655 | .245 |
| 615 | 551.403 | 62.7619 | .278 |

| | | |
|---|---|---|
| MEAN OF THE MEASURED LEAKAGE RATES | = | .225 |
| VERIFICATION TEST LEAKAGE RATE UPPER LIMIT | = | .333 |
| VERIFICATION TEST LEAKAGE RATE LOWER LIMIT | = | .233 |
| THE CALCULATED LEAKAGE RATE | = | .287 |

Appendix G

ISG CALCULATIONS

## ISG CALCULATION

## 24 HOUR TEST

La = 0.2%/day

P = 63.15 psia

T = 551.4

Vap Pres = 0.3875 psia, @70°F, $\Delta$1°F = 0.0125 psia change VPRS

t = 24 hours

Pressure $e_p = \frac{0.003}{\sqrt{2}} = 0.002121$

Vapor Pressure $C_{v_p} = \frac{(0.01)\ (0.0125)}{\sqrt{4}} = 0.0000625$

Temperature $C_T = \frac{0.04}{\sqrt{24}} = 0.0081648$

$$ISG = \frac{2400}{24}\left[2\left(\frac{0.002121}{63.15}\right)^2 + 2\left(\frac{0.0000625}{63.15}\right)^2 + 2\left(\frac{0.0081649}{551.4}\right)^2\right]^{1/2}$$

ISG = 0.0052

Appendix H

8-HOUR TEST RESULTS

V. C. SUMMER ILRT
LEAKAGE RATE (WEIGHT PERCENT/DAY)
TOTAL TIME ANALYSIS

TIME AND DATE AT START OF TEST: 2145 1007 1984
TEST DURATION: 8.00 HOURS

| TIME | TEMP (R) | PRESSURE (PSIA) | MEASURED LEAKAGE RATE |
|---|---|---|---|
| 2145 | 552.195 | 62.9479 | |
| 2200 | 552.169 | 62.9437 | .196 |
| 2215 | 552.152 | 62.9417 | .105 |
| 2230 | 552.128 | 62.9409 | -.030 |
| 2245 | 552.117 | 62.9386 | .016 |
| 2300 | 552.108 | 62.9333 | .143 |
| 2315 | 552.083 | 62.9333 | .047 |
| 2330 | 552.071 | 62.9297 | .090 |
| 2345 | 552.059 | 62.9268 | .108 |
| 0 | 552.042 | 62.9264 | .068 |
| 15 | 552.022 | 62.9217 | .099 |
| 30 | 552.012 | 62.9235 | .043 |
| 45 | 551.999 | 62.9196 | .075 |
| 100 | 551.985 | 62.9186 | .064 |
| 115 | 551.977 | 62.9182 | .053 |
| 130 | 551.955 | 62.9152 | .055 |
| 145 | 551.946 | 62.9136 | .056 |
| 200 | 551.932 | 62.9120 | .053 |
| 215 | 551.927 | 62.9090 | .071 |
| 230 | 551.914 | 62.9080 | .063 |
| 245 | 551.899 | 62.9048 | .071 |
| 300 | 551.887 | 62.9020 | .079 |
| 315 | 551.872 | 62.8997 | .079 |
| 330 | 551.862 | 62.9018 | .054 |
| 345 | 551.859 | 62.9000 | .061 |
| 400 | 551.843 | 62.8951 | .078 |
| 415 | 551.835 | 62.8932 | .080 |
| 430 | 551.823 | 62.8949 | .060 |
| 445 | 551.818 | 62.8933 | .063 |
| 500 | 551.802 | 62.8910 | .064 |
| 515 | 551.785 | 62.8871 | .072 |
| 530 | 551.782 | 62.8867 | .070 |
| 545 | 551.772 | 62.8861 | .065 |

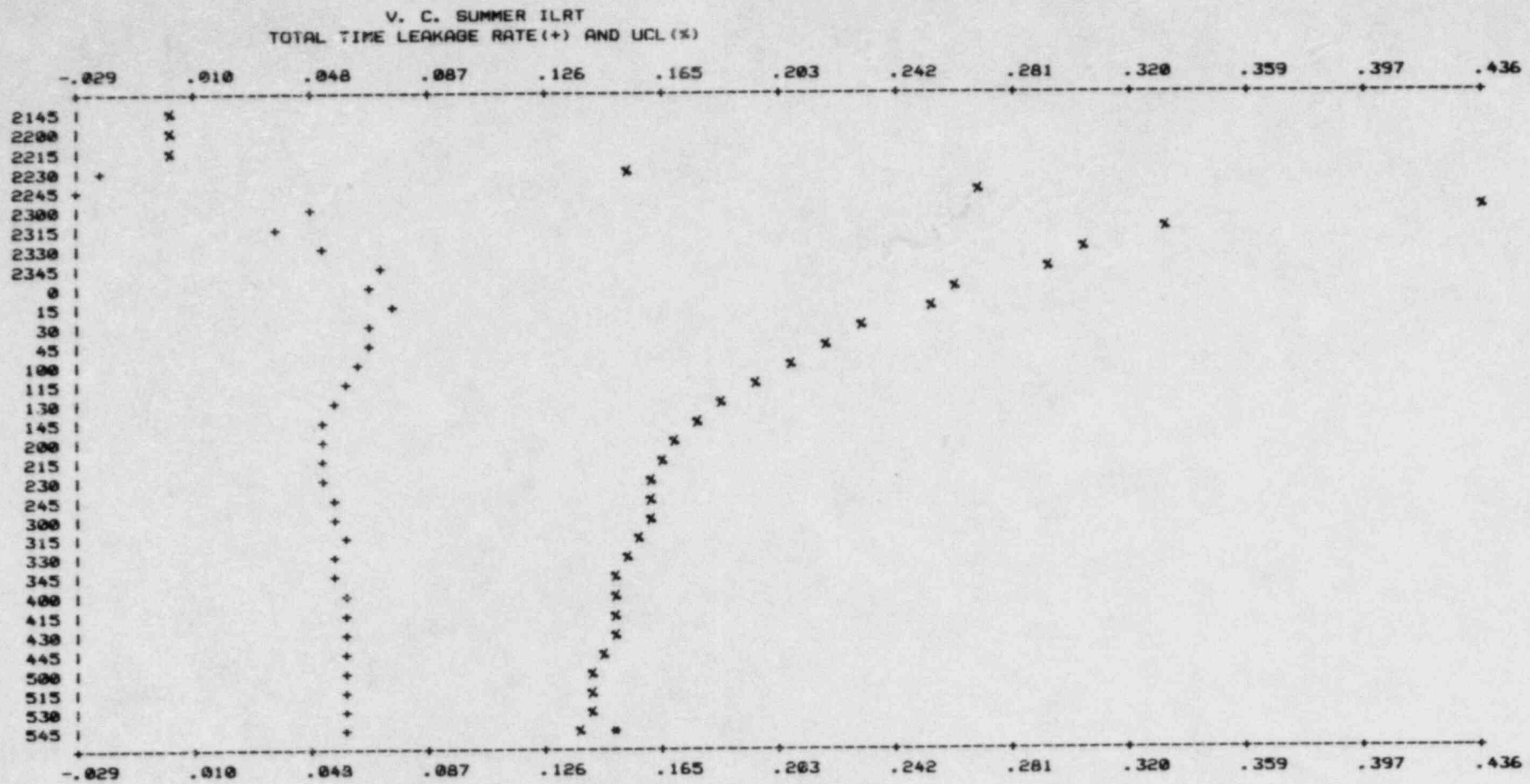
| | | |
|---|---|---|
| MEAN OF THE MEASURED LEAKAGE RATES | = | .071 |
| MAXIMUM ALLOWABLE LEAKAGE RATE | = | .200 |
| 75% OF MAXIMUM ALLOWABLE LEAKAGE RATE | = | .150 |
| THE UPPER 95% CONFIDENCE LIMIT | = | .139 |
| THE CALCULATED LEAKAGE RATE | = | .061 |

V. C. SUMMER ILRT
LEAKAGE RATE (WEIGHT PERCENT/DAY)
MASS POINT ANALYSIS

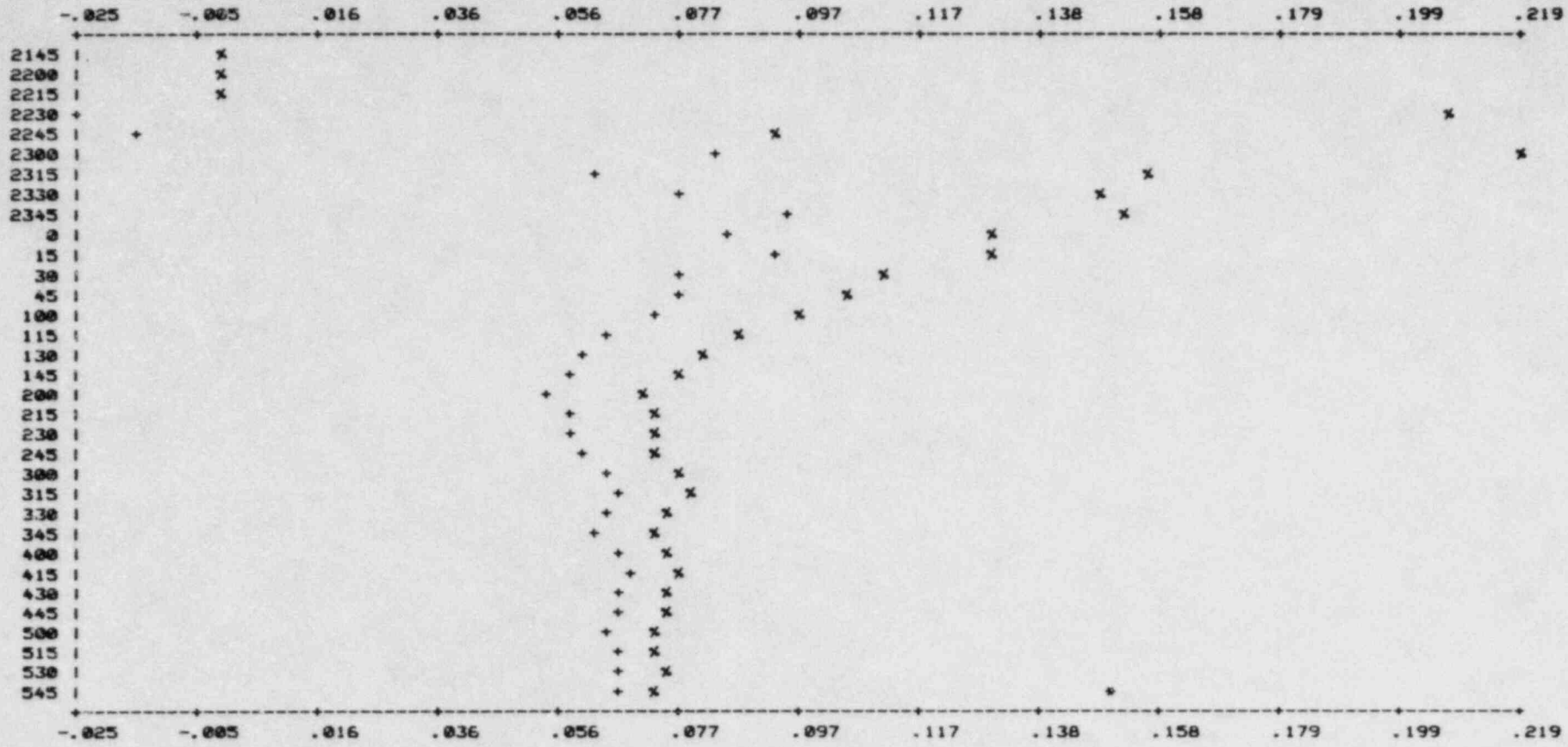
TIME AND DATE AT START OF TEST: 2145 1007 1984
TEST DURATION: 8.00 HOURS

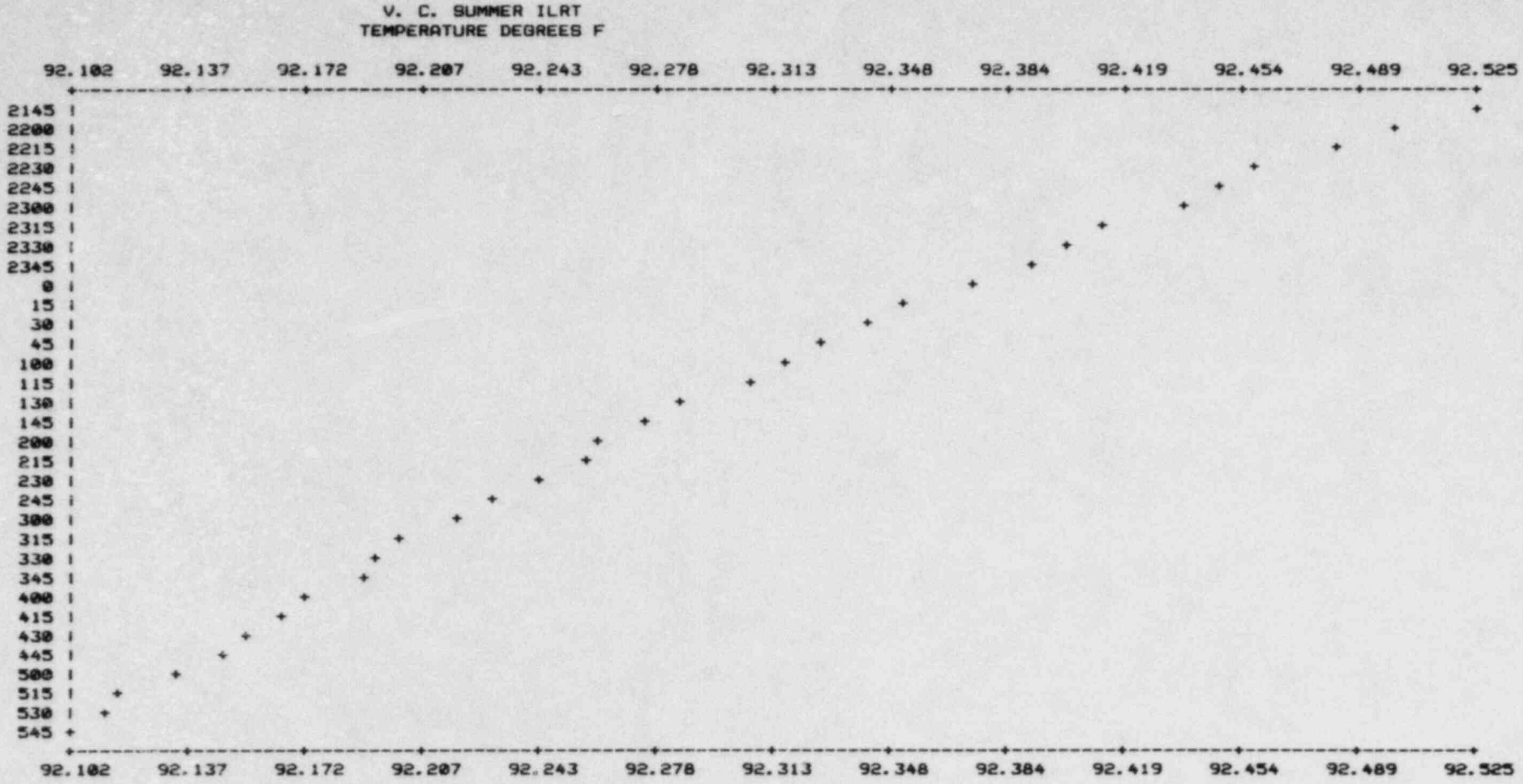
| TIME | TEMP (R) | PRESSURE (PSIA) | CTMT. AIR MASS (LBM) | MASS LOSS (LBM) | AVERAGE MASS LOSS (LBM/HR) |
|---|---|---|---|---|---|
| 2145 | 552.195 | 62.9479 | 566155. | | |
| 2200 | 552.169 | 62.9437 | 566143. | 11.5 | 46.2 |
| 2215 | 552.152 | 62.9417 | 566143. | .9 | 24.8 |
| 2230 | 552.128 | 62.9409 | 566160. | -17.6 | -7.0 |
| 2245 | 552.117 | 62.9386 | 566151. | 9.0 | 3.8 |
| 2300 | 552.108 | 62.9333 | 566113. | 38.5 | 33.8 |
| 2315 | 552.083 | 62.9333 | 566138. | -25.6 | 11.1 |
| 2330 | 552.071 | 62.9297 | 566118. | 20.4 | 21.2 |
| 2345 | 552.059 | 62.9268 | 566104. | 13.8 | 25.5 |
| 0 | 552.042 | 62.9264 | 566119. | -14.9 | 16.0 |
| 15 | 552.022 | 62.9217 | 566097. | 22.3 | 23.3 |
| 30 | 552.012 | 62.9235 | 566123. | -26.2 | 11.7 |
| 45 | 551.999 | 62.9196 | 566102. | 20.9 | 17.7 |
| 100 | 551.985 | 62.9186 | 566106. | -3.9 | 15.1 |
| 115 | 551.977 | 62.9182 | 566111. | -5.4 | 12.5 |
| 130 | 551.955 | 62.9152 | 566106. | 4.9 | 13.0 |
| 145 | 551.946 | 62.9136 | 566102. | 4.5 | 13.3 |
| 200 | 551.932 | 62.9120 | 566102. | -.5 | 12.4 |
| 215 | 551.927 | 62.9090 | 566080. | 22.8 | 16.8 |
| 230 | 551.914 | 62.9080 | 566084. | -4.4 | 15.0 |
| 245 | 551.899 | 62.9048 | 566071. | 12.7 | 16.8 |
| 300 | 551.887 | 62.9020 | 566058. | 13.5 | 18.5 |
| 315 | 551.872 | 62.8997 | 566053. | 4.6 | 18.5 |
| 330 | 551.862 | 62.9018 | 566081. | -28.2 | 12.8 |
| 345 | 551.859 | 62.9000 | 566069. | 12.6 | 14.4 |
| 400 | 551.843 | 62.8951 | 566041. | 28.1 | 18.3 |
| 415 | 551.835 | 62.8932 | 566032. | 8.6 | 18.9 |
| 430 | 551.823 | 62.8949 | 566059. | -27.3 | 14.2 |
| 445 | 551.818 | 62.8933 | 566051. | 8.4 | 14.9 |
| 500 | 551.802 | 62.8910 | 566046. | 5.0 | 15.0 |
| 515 | 551.785 | 62.8871 | 566027. | 18.6 | 17.0 |
| 530 | 551.782 | 62.8867 | 566027. | .4 | 16.5 |
| 545 | 551.772 | 62.8861 | 566033. | -5.9 | 15.3 |

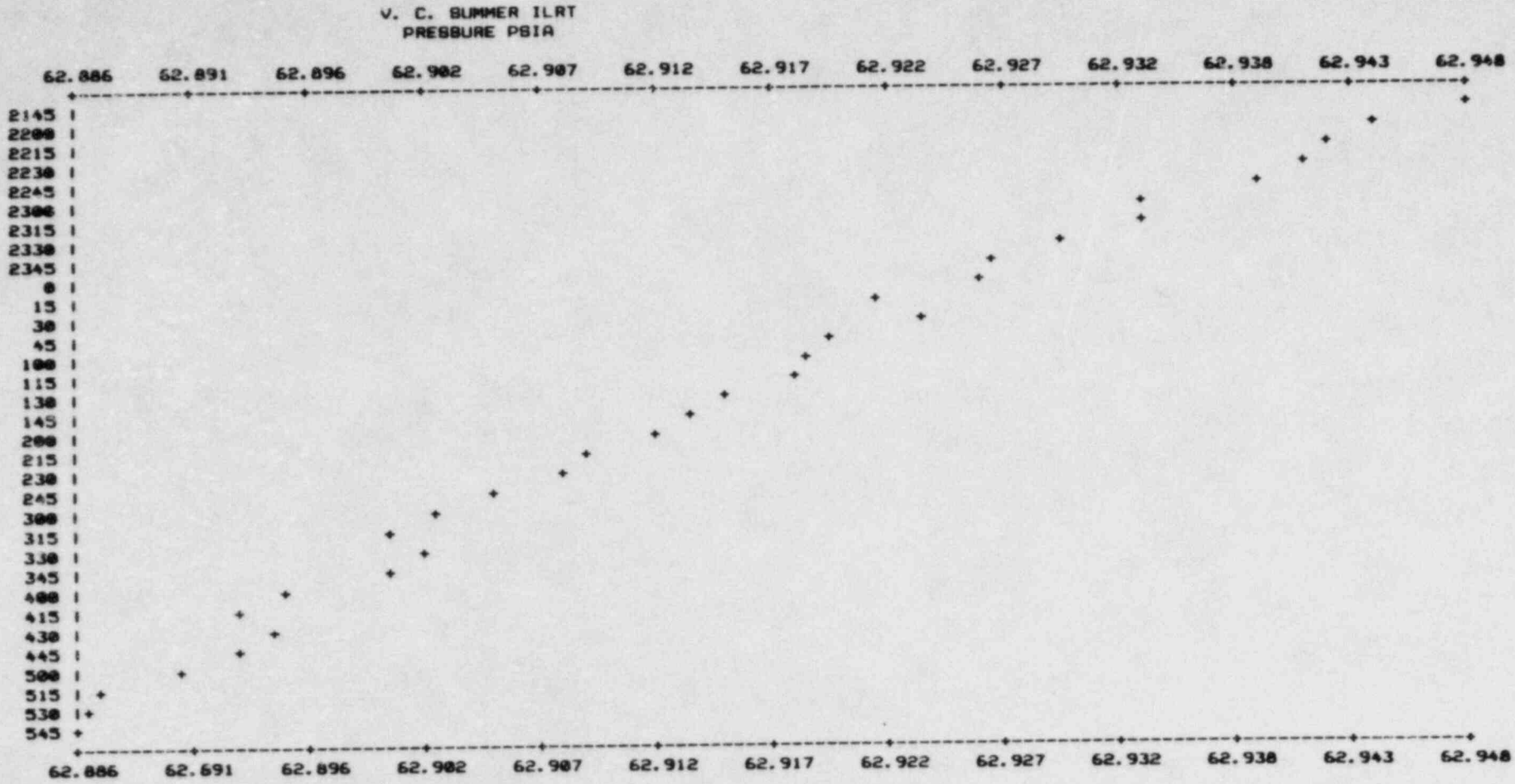
| | |
|---|---|
| FREE AIR VOLUME USED (CU. FT.) | =1840000. |
| REGRESSION LINE | |
| INTERCEPT (LBM) | = 566154. |
| SLOPE (LBM/HR) | = -15.7 |
| MAXIMUM ALLOWABLE LEAKAGE RATE | = .200 |
| 75% OF MAXIMUM ALLOWABLE LEAKAGE RATE | = .150 |
| THE UPPER 95% CONFIDENCE LIMIT | = .073 |
| THE CALCULATED LEAKAGE RATE | = .066 |

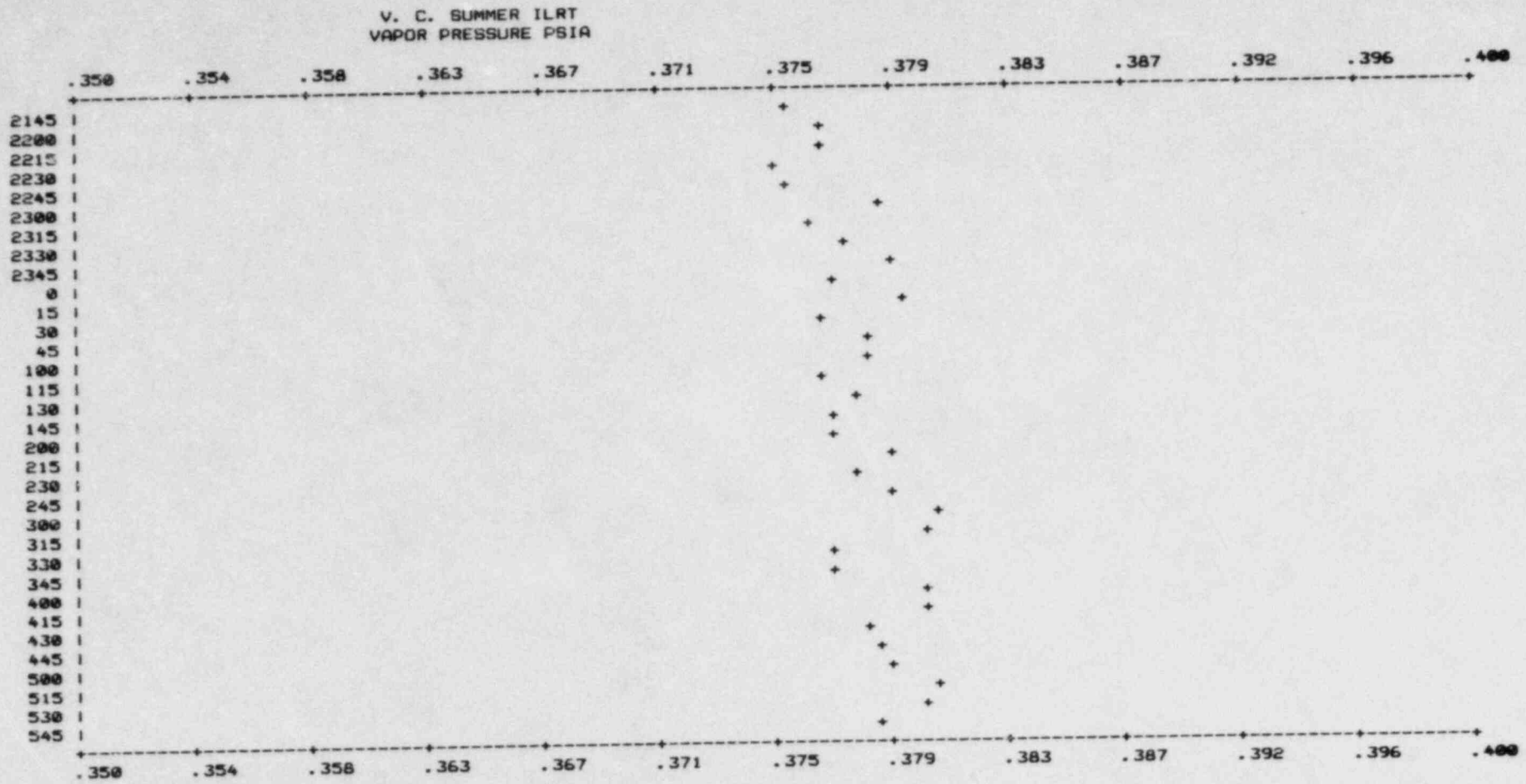

V. C. SUMMER ILRT
TOTAL TIME LEAKAGE RATE(+) AND UCL(x)
-.029
.010
.048
.087
.126
.165
.203
.242
.281
.320
.359
.397
.436
2145
2200
2215
2230
2245
2300
2315
2330
2345
0
15
30
45
100
115
130
145
200
215
230
245
300
315
330
345
400
415
430
445
500
515
530
545

V. C. SUMMER ILRT
MASS POINT LEAKAGE RATE(+) AND UCL(x)

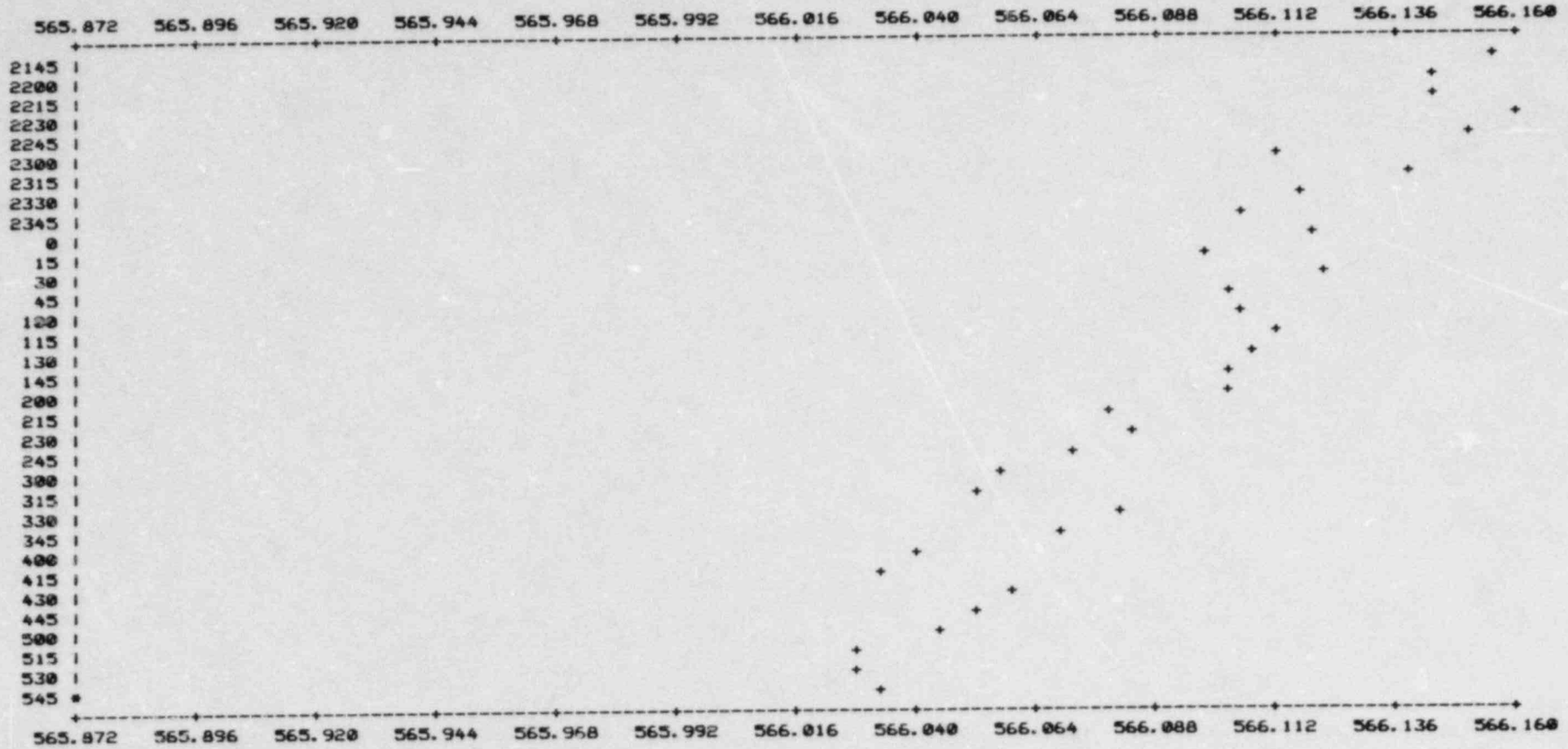



V. C. SUMMER ILRT
TEMPERATURE DEGREES F
92.102
92.137
92.172
92.207
92.243
92.278
92.313
92.348
92.384
92.419
92.454
92.489
92.525
2145
2200
2215
2230
2245
2300
2315
2330
2345
0
15
30
45
100
115
130
145
200
215
230
245
300
315
330
345
400
415
430
445
500
515
530
545


V. C. SUMMER ILRT
PRESSURE PSIA
62.886
62.891
62.896
62.902
62.907
62.912
62.917
62.922
62.927
62.932
62.938
62.943
62.948
2145
2200
2215
2230
2245
2300
2315
2330
2345
0
15
30
45
100
115
130
145
200
215
230
245
300
315
330
345
400
415
430
445
500
515
530
545


V. C. SUMMER ILRT
VAPOR PRESSURE PSIA
.350
.354
.358
.363
.367
.371
.375
.379
.383
.387
.392
.396
.400
2145
2200
2215
2230
2245
2300
2315
2330
2345
0
15
30
45
100
115
130
145
200
215
230
245
300
315
330
345
400
415
430
445
500
515
530
545

V. C. SUMMER ILRT
AIRMASS LBM X 1000



Appendix I

LOCAL LEAKAGE RATE TEST RESULTS

LLRT (TYPE B & C) TEST SUMMARY

1. TYPE B TEST

| Pene # | Description | cc/min. As Left Leak Rate |
|---|---|---|
| 107 | Fuel Transfer Tube | 0 |
| 201 | L.R. System Blind Flanges (2) | 0 |
| 210 | L.R. System Blind Flanges (2) | 0 |
| 211 | L.R. System Blind Flanges (2) | 0 |
| 212 | L.R. System Blind Flanges (2) | 0 |
| 216 | L.R. System Blind Flanges (2) | 0 |
| 327 | SP Sys. Mini-Containment (valve enclosure) | 0 |
| 328 | SP Sys. Mini-Containment (valve enclosure) | 0 |
| 329 | RH Sys. Mini-Containment (valve enclosure) | 0 |
| 425 | RH Sys. Mini-Containment (valve enclosure) | 0 |
| 501 | PT 951 | 0 |
| 502 | Elect. Pene. | 0 |
| 503 | Elect. Pene. | 0 |
| 504 | Elect. Pene. | 0 |
| 505 | Spare Pene. | |
| 600 | Elect. Pene. | 0 |
| 601 | Elect. Pene. | 0 |
| 602 | Elect. Pene. | 0 |
| 603 | Elect. Pene. | 0 |
| 604 | Elect. Pene. | 0 |
| 605 | Elect. Pene. | 0 |
| 606 | Elect. Pene. | 0 |
| 607 | Elect. Pene. | 0 |
| 700 | Elect. Pene. | 0 |
| 701 | Elect. Pene. | 0 |
| 702 | Elect. Pene. | 0 |
| 703 | PT 950 | 0 |
| 704 | Elect. Pene. | 0 |
| 705 | Elect. Pene. | 0 |
| 706 | Elect. Pene. | 0 |
| 707 | Elect. Pene. | 0 |
| 708 | Elect. Pene. | 0 |
| 709 | Elect. Pene. | 0 |
| 710 | Elect. Pene. | 0 |
| 711 | Elect. Pene. | 0 |
| 712 | Elect. Pene. | 0 |
| 713 | Spare Pene. | |
| 714 | Elect. Pene. | 0 |
| 715 | Elect. Pene. | 0 |
| 716 | Elect. Pene. | 0 |
| 717 | Elect. Pene. | 0 |
| 718 | Elect. Pene. | |

LLRT (TYPE B & C) TEST SUMMARY

1. TYPE B TEST

| Pene # | Description | cc/min. As Left Leak Rate |
|---|---|---|
| 719 | Spare Pene. | |
| 720 | Elect. Pene. | 0 |
| 721 | Elect. Pene. | 0 |
| 722 | Elect. Pene. | 0 |
| 723 | Elect. Pene. | 0 |
| 724 | Spare Pene. | |
| 725 | Elect. Pene. | 0 |
| 726 | Elect. Pene. | 0 |
| 727 | Elect. Pene. | 0 |
| 728 | Elect. Pene. | 0 |
| 800 | Elect. Pene. | 0 |
| 801 | Spare Pene. | |
| 802 | Elect. Pene. | 0 |
| 803 | Elect. Pene. | 0 |
| 804 | Elect. Pene. | 0 |
| 805 | Elect. Pene. | 0 |
| 806 | Elect. Pene. | 0 |
| 807 | Spare Pene. | |
| 808 | Elect. Pene. | 0 |
| 809 | Elect. Pene. | 0 |
| 810 | Elect. Pene. | 0 |
| 811 | Spare Pene. | |
| 812 | Spare Pene. | |
| 813 | Elect. Pene. | 0 |
| 814 | Elect. Pene. | 0 |
| 815 | Elect. Pene. | 0 |
| | Personnel Air Lock | 0 |
| | Emergency Air Lock | 370 |
| | Equipment Hatch | 80 |

LLRT (TYPE B & C) TEST SUMMARY

2. TYPE C TEST

| Pene# | Description | cc/min. As Left Leak Rate |
|---|---|---|
| 101 | R.B. Purge Exhaust | 1160 |
| 102 | R.B. Cool Unit "B" Return | 985 |
| 103 | Post Acc. $H_2$ Purge Line | 970 |
| 104 | Spare | |
| 105A | $H_2$ Analyzer Supply | 2 |
| 105B | $H_2$ Analyzer Return | 2 |
| 106 | Spare | |
| 108 | Spare | |
| 204 | C.C.W. to Reactor Cool Pumps | 245 |
| 208 | To CRDM CLR 150L | 76 |
| 209 | From CRDM CLR 150L | 32.8 |
| 214 | Spare | |
| 215 | Spare | |
| 217 | PT 953 | |
| 218 | Spare | |
| 221 | Seal Inj. to RCP-C | 190 |
| 222 | Hi.Hd. S.I. to RCS | 30 |
| 223 | Sample from RCS-C | 140 |
| 226 | RHR Suction from RCS-C | 1080 |
| 227 | Lo. Hd. S.I. to RCS | 962 |
| 228 | Spare Pene. | |
| 229 | Seal Inj. to RCP-B | 242 |
| 230 | Spare Pene. | |
| 231 | Demin. Water | 3.5 |
| 232 | Spare Pene. | |
| 301A | $H_2$ Analyzer Supply | 41.8 |
| 301B | $H_2$ Analyzer Return | 1 |
| 302 | Purge Press. Blower Suction | 738 |
| 303 | R.B. Spray Nozzles - Train "B" | 350 |
| 304 | S.W. to R.B. Cool Unit "A" | 562 |
| 305 | S.W. from R.B. Cool Unit "A" | 0 |
| 307 | Spare Pene. | |
| 309 | R.B. Hi Range Area Monitor Support | |
| 310 | R.B. Station Air | 475 |
| 311 | R.B. Instrument Air | 85.8 |
| 312 | CCW to RCP Bearings | 1442 |
| 313 | $N_2$ to F.W. Lines | 510 |
| 314 | Sample from RCS-B | 168 |
| 315 | Spare Pene. | |
| 316 | RHR Pump Suction RCS-A | 395 |
| 317 | Fill Line to Accumulator | 311 |
| 318 | RCS Letdown Heat Exchanger | 700 |
| 319 | R.B. Instrument Air Comp. Suction | 144.3 |
| 320 | $N_2$ to Accumulator | 500 |
| 321 | Accumulator Test Line | 430 |
| 322 | Lo. Hd. S.I. to RCS - Hot Legs | 0 |

LLRT (TYPE B & C) TEST SUMMARY

2. TYPE C TEST

| Pene# | Description | cc/min. As Left Leak Rate |
|---|---|---|
| 323 | Accumulator Sample | 250 |
| 324 | Breathing Air | 167 |
| 325 | Lo. Hd. S.I. to RCS - Hot Legs | 620 |
| 327 | Spray Pump "A" Suction From R.B. Sump | 96.7 |
| 328 | Spray Pump "B" Suction From R.B. Sump | 1000 |
| 329 | S.I. Pp. A Suction From R.B. Sump | 300 |
| 330 | CCW From RCP Bearings | 1755 |
| 401 | Supply to RB Spray Nozzle - Train "A" | 97.5 |
| 402 | R.B. Cooling Supply | 1015 |
| 403 | R.B. Cooling Unit B Supply | 551 |
| 404 | Fire Service Hose Reel Supply | 4 |
| 405 | Sample Line from Prez. | 157 |
| 406A | Dead Weight Tester | 0 |
| 407A | Radiation Monitor Supply | 330 |
| 407B | Radiation Monitor Return | 399 |
| 408 | Seal Inj. to RCP-A | 169 |
| 409 | Charging to Regen. Heat XR | 55 |
| 410 | RCP Seal Water Return | 350 |
| 412 | Hi. Hd. S.I. to RCS | 570 |
| 413 | Spare Pene. | |
| 414 | Spare Pene. | |
| 415 | Hi. Hd. S.I. to RCS | 377 |
| 416 | Spare Pene. | |
| 417D | Nuclear Sample | 168 |
| 418 | RCDT to Vent Hdr. & $H_2$ | 141 |
| 419 | Refuel Cavity Dr. Line | 24 |
| 420 | Prez. Relief Tk. | 1 |
| 421 | Refuel Cavity Fill Line | 404 |
| 422 | PRT Makeup | 745 |
| 423 | RCDT | 129 |
| 424 | R.B. Sump Dr. | 5.5 |
| 425 | S.I. Pp "B" From R.B. Sump | 421 |
| 426 | Boron Inj. to RCS | 100 |
| 427 | Fire Service Deluge | 298 |

The total local leakage rate for both Type B & C Tests is:

24123.9 cc/min
or .333 La

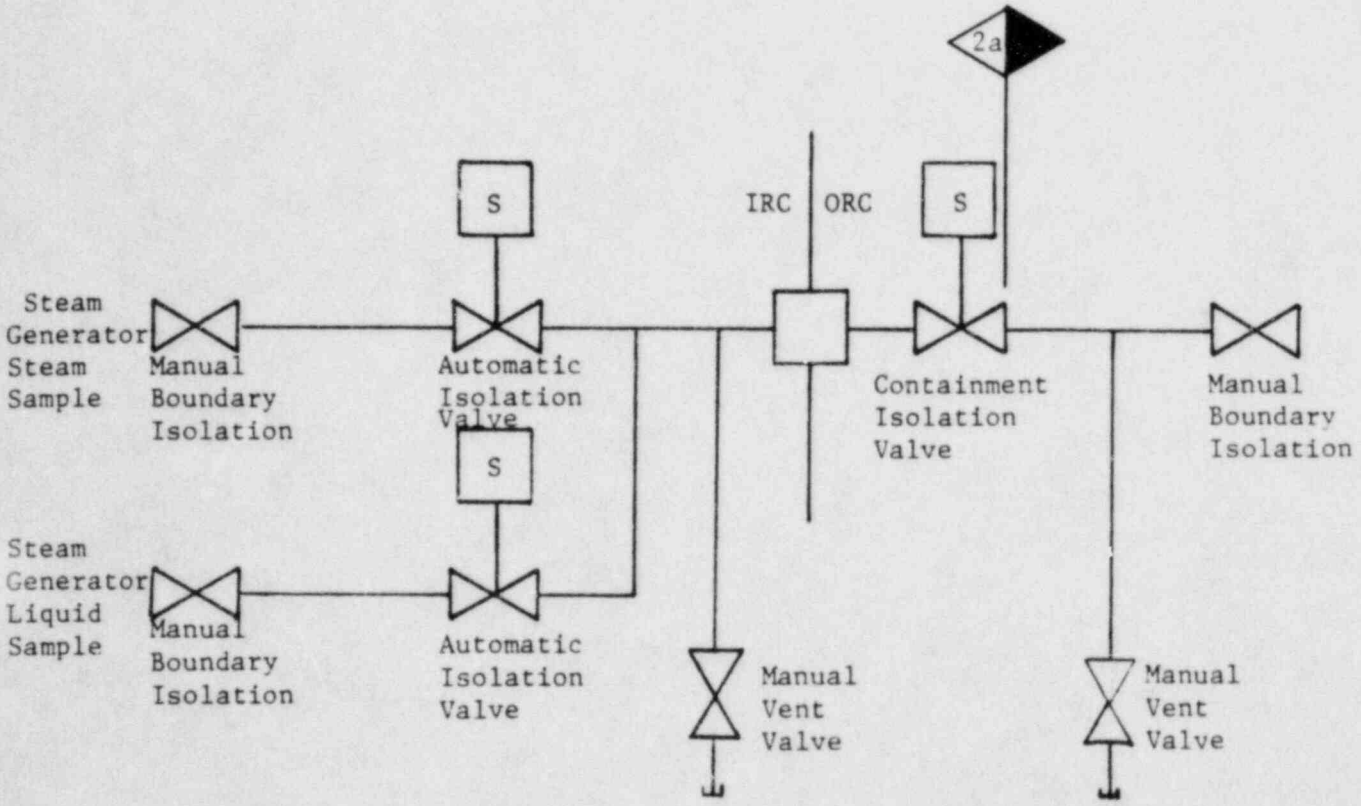
Appendix J

TYPICAL STEAM GENERATOR SAMPLE LINE DRAWING

APPENDIX J

STEAM GENERATOR SAMPLE

(Typical of all 3
penetrations: 220, 225, 411)



Appendix K

PRESSURIZED VESSEL LEAKAGE CALCULATION

## Analysis of Pressurized Sources in Containment

### Initial Conditions

Accumulator level (minimum or worst case) = 57% or 7416.12 gals.
Accumulator pressure (maximum or w.c.) = 555 lbs.

"A" Accumulator Temperature = 89.7
"B" Accumulator Temperature = 89.1
"C" Accumulator Temperature = 90.2
} Using appropriate ILRT temperature sensors

Accumulator Gas($N_2$) Volume = 1450 ft.$^3$ (Total) - (7416.12 gals.)(.1337 ft.$^3$/gal.)

or

458.46 ft.$^3$ gas space per Accumulator

Minimum Leak to mask an actual failed test 0.15%/day - 0.1%/day = 0.05%/day
= .002083%/hr

Mass Leak/Hr = .002083%/hr x 566154.9 lbm. (Actual Mass)
= 11.79 lbm./hr

$\Delta P/hr$ per Accumulator assuming leak of 11.79 lbm./hr

Use R=55.2 for nitrogen

Accumulator

$$A\ \Delta P/hr = \frac{(\Delta M/hr.)\ RT}{Volume} = \frac{(11.79)(55.2)(460 + 89.7)}{458.46} = 780.33 \text{ psf/hr} = 5.42 \text{ psi/hr}$$

$$B\ \Delta P/hr = \frac{(11.79)(55.2)(460 + 89.1)}{458.46} = 779.48 \text{ psf/hr} = 5.41 \text{ psi/hr}$$

$$C\ \Delta P/hr = \frac{(11.79)(55.2)(460 + 90.2)}{458.46} = 781.04 \text{ psf/hr} = 5.42 \text{ psi/hr}$$

Accumulator pressures were observed for a period of 12 hrs. during the 24 hour test period with no change in pressure.

Worst case (min.) pressure change in any one accumulator:

5.41 psi/hr x 12hr = 64.92 psi

Worst case pressure change if all accumulators are leaking:

64.92 psi ÷ 3 = 21.64 psi

Indicators for Accumulator pressure are in 20 psi increments. A change of 21.64 psi is well within the range of detectable pressure change for accumulator pressure channels.

$N_2$ Reservoir for Pressurizer PORV (PCV-444B)

$N_2$ Reservoir Volume = 16 $ft^3$ $N_2$ Reservoir Pressure = 82.0 psi

$N_2$ Reservoir Temperature = 92.8 $^oF$

$$\Delta P/hr = \frac{(\Delta M/hr)(R)(T)}{V} = \frac{(14.39)(55.2)(460 + 92.8)}{16} = 27444 \text{ psf/hr}$$
$$= 190.58 \text{ psi/hr}$$

Since the reservoir pressure was only 82 psi, any significant leakage would have been detectable. Indicator scale for PI 8090 is in 10 psi increments.