WSRC-TR--90-263

DE92 015063

NRTSC
NUCLEAR REACTOR TECHNOLOGY
AND SCIENTIFIC COMPUTATIONS

KEYWORDS: LOCA
FLOW INSTABILITY
K REACTOR
TRAC

RETENTION: PERMANENT

UNCERTAINTIES IN TRAC PLENUM PRESSURES FOR THE FI PHASE OF A DEGB LOCA (U)

by

D. P. GRIGGS

ISSUED: MAY, 1991

J.P. Faraci 5/15/91

J. P. Faraci, Authorized Derivative Classifier Date

SRL SAVANNAH RIVER LABORATORY, AIKEN, SC 29808
Westinghouse Savannah River Company
Prepared for the U. S. Department of Energy under
Contract DE-AC09-88SR18035

PROJECT:
DOCUMENT: WSRC-TR-90-263
TITLE: UNCERTAINTIES IN TRAC PLENUM PRESSURES FOR THE FI PHASE OF A DEGB LOCA (U)
QA TASK NUMBER:
REVISION NUMBER: 0

APPROVALS

Mark L. Liebmann — 5-10-91

M. L. LIEBMANN, TECHNICAL REVIEWER — DATE

John D. Menna — 5-15-91

J. D. MENNA, RESEARCH SUPERVISOR — DATE

A. J. Garrett — 5/20/91

A. J. GARRETT, RESEARCH MANAGER — DATE

TABLE OF CONTENTS

UNCERTAINTIES IN TRAC PLENUM PRESSURES FOR THE FI PHASE OF A DEGB LOCA

SUMMARY

The TRAC-PF1/MOD1 code (TRAC) is used to perform best-estimate analyses of certain postulated Design Basis Accidents (DBAs) in SRS production reactors. Currently, the most limiting DBA in terms of reactor power level is an instantaneous double-ended guillotine break (DEGB) loss of coolant accident (LOCA). For this accident, TRAC is used to analyze only the first 5 seconds following the DEGB, which encompasses the Flow Instability (FI) phase of the LOCA. The TRAC analysis provides time-dependent plenum and tank bottom pressures for use as boundary conditions in the FLOWTRAN code.

The quantification of uncertainty is an important element of determining safe operating power levels for SRS reactors. This report presents estimates of the uncertainty in TRAC predictions of the time-dependent plenum pressures during a DEGB LOCA. The uncertainty was estimated by means of comparing TRAC results with steady-state data measured in L Reactor, and confirmed by comparisons with LOCA results calculated independently with the RELAP5 code.

The uncertainty estimate is based on steady-state plenum pressure measurements made during 3 forward flow and 3 backflow tests in L Reactor in 1985. The TRAC code was used to calculate cell average plenum pressures (using a 5 ring, 6 sector nodalization) for the same tests and the results were interpolated spatially to obtain pressures at the plenum locations where measurements were made. The relative (or fractional) differences between the measured and calculated (interpolated TRAC) plenum pressures for the 6 tests were combined into a single distribution; a mean and standard deviation of this distribution of relative differences was calculated. The resulting mean and standard deviation of the distribution of relative errors are 0.5% and 3.5%, respectively.

The standard deviation can then be used to estimate a "1-σ" uncertainty in the calculated absolute plenum pressure for K-14.1 during the time interval from 0.5s to 2.0s of a plenum inlet DEGB LOCA. This is done by multiplying the actual calculated average plenum pressure during the LOCA (using rings 1-4 only) by 3.5%.

The resulting estimated standard deviation for absolute plenum pressure during the period of interest is about 1.65 psi.

The actual uncertainty used in the LOCA-FI power limits for K-14.1 was 2.5 psi. The original source of the ± 2.5 psi uncertainty was an estimate by Los Alamos National Laboratory (LANL) personnel of a ± 10% accuracy for TRAC pressures. This presumes an adequate input model, which the comparison with reactor data establishes. For use in the limits methodology, this ± 10% uncertainty was interpreted as a "2-σ" uncertainty and conservatively translated to ± 5 psi for the LOCA. The "1-σ" value of ± 2.5 psi is 50% larger than the ± 1.65 psi uncertainty estimated from steady-state plenum pressure data comparisons.

The margin between the estimated plenum pressure uncertainty and the uncertainty used for limits provides an allowance for some additional contributors to transient plenum pressure uncertainty. The uncertainty estimate based on steady-state data comparisons does not account for transient effects or for the additional phenomena (e.g., break flow) involved in the K-14.1 LOCA. The quasi-steady nature of the pressures and flows over the period of interest during the LOCA suggests that purely transient effects will add little to the plenum pressure uncertainty. The break flowrate is modeled conservatively by assuming the worst break location and no friction loss at the break itself.

Some of the additional phenomena not present in the tests (e.g., different reactor and fuel charge; expected variations in operating plenum, process room, and blanket gas pressures; scram trip setpoint) and, hence, not accounted for in the resulting uncertainty estimate, are addressed as separate analyses and sensitivity studies in the limits methodology.

The TRAC code developers' estimate of the accuracy of TRAC plenum pressures was confirmed by means of a code-to-code comparison. A comparison of TRAC and RELAP5 plenum pressures during the LOCA in K-14.1 shows agreement within ± 10% throughout the time period of interest.

1.0 INTRODUCTION

The TRAC-PF1/MOD1 code (TRAC)[1] is used to perform best-estimate analyses of certain postulated Design Basis Accidents (DBAs) in SRS production reactors. Currently, the most limiting DBA in terms of reactor power level is an instantaneous double-ended guillotine break (DEGB) loss of coolant accident (LOCA). For this accident, TRAC is used to analyze only the first 5 seconds following the DEGB, which encompasses the Flow Instability (FI) phase of the DBA. The TRAC analysis provides time-dependent plenum and tank bottom pressures for use as boundary conditions in the FLOWTRAN code[2].

The quantification of uncertainty is an important element of determining safe operating power levels for SRS reactors. A detailed methodology for the determination of uncertainty for the FI phase of a DEGB LOCA has been developed[3,4]. In this methodology, uncertainties in the plenum and tank bottom pressures calculated by TRAC contribute to the overall uncertainty in the limits. Consequently, these TRAC uncertainties must be quantified as part of the limits methodology.

This report presents estimates of the uncertainty in the time-dependent plenum pressures for the DEGB LOCA calculated by TRAC. The uncertainty in the tank bottom pressure was estimated previously by Shadday[5] and Davis[6]. The plenum pressure uncertainty was estimated by means of comparing TRAC results with steady-state data measured in L Reactor, and confirmed by comparisons with transient LOCA results calculated by an independent group with the RELAP5[7] code.

Section 2 of this report gives an overview of the limits methodology and discusses the L Reactor data. The methodology for estimating the plenum pressure uncertainty is presented in Section 3, while the results are given in Section 4.

2.0 BACKGROUND

2.1 OVERVIEW OF LIMITS METHODOLOGY

The methodology for determining LOCA-FI limits[8] requires the estimation of the uncertainty in the time-dependent plenum pressures. The uncertainty estimation requires an understanding of the way both the plenum pressures and the plenum pressure uncertainties are used in determining the operating limits. Accordingly, an overview of this facet of the limits methodology is presented.

Limits are established to protect the fuel assemblies from damage under a variety of conditions ranging from normal operation to highly improbable postulated accidents. The DEGB LOCA falls into the latter category. For the DEGB LOCA, limits are implemented on an individual assembly basis as a maximum coolant exit, or effluent, temperature. These effluent temperature limits are actually functions of the cooling water temperature; these functions are programmed into the control computers. For normal operation, effluent temperature limits are implicitly power limits, given a balance between power produced in the assembly and power removed by the coolant.

Since the effluent temperature (and, hence, the power level) of every assembly is monitored, it is possible, in principle, to provide a separate operating limit for each assembly. However, the control computer presently cannot handle the 432 critical effluent temperature functions that K-14.1 would require. Consequently, groups of assemblies having similar power levels and flow rates are combined into a flowzone, for which an effluent temperature limit is established. Figure 1 shows the apportionment of fuel assembly positions into the six flowzones used in K-14.1. The flowzone effluent temperature limits are designed to provide a conservative operating condition for the most limiting assembly in the flowzone, thereby ensuring that all the assemblies are afforded conservative protection.

The transient plenum pressures are calculated with the TRAC code and a detailed K Reactor model[9]. Figure 1 shows the TRAC nodalization for the plenum superimposed on the K-14.1 facemap. The TRAC plenum model has 5 radial rings, 6 azimuthal sectors, and 1 axial level, for a total of 30 computational cells. TRAC calculates the time-dependent average absolute pressure for each of these 30 cells during the first 5 seconds following a postulated plenum inlet DEGB LOCA. These cell-averaged plenum pressures, as well as the corresponding calculated tank bottom pressures, provide boundary conditions for the FLOWTRAN code, which models a single fuel assembly in some detail.

As Figure 1 shows, each TRAC plenum cell encompasses all or part of a number (15-41) of permanent sleeve positions. For K-14.1, the 24 plenum cells comprising rings 1 through 4 (1 being the center ring) represent the region providing boundary conditions for the 6 fuel assembly flowzones. The positions associated with ring 5 are occupied by blanket assemblies, gas port sleeves, confinement heat removai instrument plugs, or long plenum plugs[10].

The TRAC transient plenum cell pressures are used two ways in the LOCA-FI limits methodology. First, they are used as boundary conditions for a transient FLOWTRAN analysis of an idealized (axisymmetric) assembly to calculate nominal flowzone power limits. The most limiting plenum pressure transient associated with any assembly in a flowzone is used to determine the nominal power limit for all assemblies in the flowzone. For example, while nearly all of the assembly positions comprising flowzone 1 are associated with TRAC ring 1, a small fraction of several positions extends into TRAC ring 2. During the FI phase of a DEGB LOCA, the plenum pressure transient is more severe in the break sector cells near the plenum edge. Therefore, the nominal power limits for flowzone 1 are based on the more severe pressure transient for ring 2 of the break sector. Similarly, the nominal power limits for assemblies in flowzone 2 are based on the pressure transient for ring 3 of the break sector. This conservative convention accounts for the uncertainty introduced by the averaging of the radial pressure gradient over the TRAC cells.

The second use of the TRAC transient plenum cell pressures is in determining the flowzone effluent temperature limits that incorporate all the important uncertainties to satisfy a core-wide probability of avoiding FI. Basically, the transient TRAC plenum cell pressures are assumed to represent the boundary conditions that would be experienced by an assembly placed (in the "r,θ" plane) at the center of the cell. The FLOWTRAN code is used to determine the limiting initial power and the corresponding limiting steady-state coolant temperature rise for an idealized assembly (e.g., perfectly symmetric power distribution, perfectly straight and concentric tubes) placed at the center of each of the 24 plenum cells. (The 6 cells in the outer ring do not provide boundary conditions for any fuel assemblies.)

The limiting temperature rises for idealized assemblies placed at actual assembly locations are calculated from these cell-centered results by an interpolation technique. First, a cubic spline interpolation is used to determine the assembly temperature rise limit as a function of radial position along the TRAC sector boundaries. Then a linear interpolation as a function of radial angle between the sector lines is performed to determine the temperature rise limits at each actual position. Corrections for cavitation and nonlinearities and the assumed inlet temperature are then added to these limiting temperature rises to give mean values for the critical effluent temperature at each position.

In order to determine limits that satisfy an overall (core-wide) probability of avoiding flow instability, the standard deviations of the critical effluent temperatures must also be estimated. The transient plenum pressure uncertainty is used in this part of the limits methodology. The transient plenum pressure uncertainty is one of a number of uncertainties that are combined to determine the largest standard deviation in the flowzone critical effluent temperatures. This maximum standard deviation is then used for all assemblies in flowzones 1-4. The effect of the plenum pressure uncertainty on the critical effluent temperature is assumed to be linear.

2.2 1985 L Reactor AC Flow Tests

Prior to the restart of L Reactor in 1985, a series of tests were performed to provide integral hydraulic data pertinent to various modes of reactor operation. One of these test series is referred to as the "AC tests" because the AC pump motors were used to drive the reactor coolant pumps during the tests. Eleven isothermal tests were performed with 3, 5, or 6 pumps operating under AC power, with the septifoil upflow cooling system on or off, with rotovalves open or closed, and at process water temperatures of approximately 22 or 60 °C. The tests were performed with a fresh Mark 16/31 mixed lattice charge at zero power. The tank level was maintained at overflow with no helium cover gas and the blanket gas space vented to atmosphere. Table 1 presents the basic configuration of the tests.

One of the primary goals of the 1985 AC Tests was to measure the plenum pressure distribution in some detail. Special pressure tap plenum plugs were used to measure pressures inside the permanent sleeve and universal sleeve housing (USH) at approximately 90 plenum locations. The location of these pressure measurements on a reactor facemap is shown in Figure 2. As the figure shows, the measurements were concentrated in a 120° sector, with fairly limited coverage elsewhere. Crowley and Hamm[11] give the accuracy of these measurements as ±1 foot of D_2O, which for these tests is about ± 0.5 psi. Koffman[12] converted the pressure measurements made inside the permanent sleeve and USH to average plenum pressures outside the permanent sleeve using data on pressure drop and flow rate measured in "A" tank. These converted plenum pressure measurements (referred to hereafter as "plenum data") have been used in the development and benchmarking of L Reactor models for the TRAC and RELAP5 system thermal-hydraulics codes[12-15] and are used in the current work as well. The measured data, plenum data, and data conversion are presented and discussed in Ref. 12.

3.0 UNCERTAINTY ESTIMATION METHODOLOGY

The methodology for estimating the transient plenum pressure uncertainty was developed to be consistent with the uncertainty methodology itself. The uncertainty required for the limits analysis is for the time interval 0.5 to 2.0 seconds during the LOCA. It is given as one standard deviation of a normal distribution in terms of absolute pressure in pounds per square inch (psi). The plenum pressure uncertainty to be estimated is an average over the portion of the plenum that provides boundary conditions to flowzones 1-4, since only these flowzones are considered in satisfying the core-wide probability of not exceeding the limits criterion.

The uncertainty associated with the use of TRAC plenum pressures in the limits methodology has two components. The first relates to the nodalization of the plenum in the TRAC model. TRAC calculates cell- or region-average pressures for a one-level, five-ring, six-sector representation of the plenum. As has been discussed, the FI limits analysis determines effluent temperature limits based on the pressure boundary conditions for individual fuel assemblies. The implicit averaging of pressure over plenum volumes encompassing from nine to more than twenty individual fuel assembly positions introduces an uncertainty associated with translating these TRAC results into the "fine structure" needed by the limits methodology. Data from the AC tests show that the actual pressure variations within the plenum regions corresponding to the TRAC cells can be significant. Hence, this component of uncertainty would exist even if the TRAC calculation produced "perfect" cell-averaged pressures, unless each plenum cell corresponded to a single assembly position. However, because of its "r,θ" vessel nodalization scheme, TRAC is not able to model one plenum cell per fuel position and requires assembly positions to be "lumped" together.

It is also important to point out that the uncertainty required is not simply that associated with the use of the average pressures calculated for a number of relatively large plenum regions; rather, it is the uncertainty associated with interpolating those calculated cell-averaged pressures to provide plenum pressure boundary conditions for fuel assemblies at specific locations within the reactor. Recall that in the limits methodology the TRAC cell pressures are assumed to represent the transient boundary conditions experienced by an assembly having its inlet at the geometric center of the TRAC cell. The corresponding critical effluent temperatures for all the relevant TRAC cells (i.e., those in rings 1-4) are then interpolated to give mean critical effluent temperatures at every assembly location in the core. The interpolation of the critical effluent temperatures is assumed to be equivalent to interpolating the pressure boundary conditions and then calculating the individual critical effluent temperatures with FLOWTRAN. Hence, the plenum pressure uncertainty must also account for the impact of the interpolation technique.

The second component of uncertainty deals with how well TRAC predicts the cell-averaged plenum pressures. This uncertainty is superimposed on the uncertainty caused by nodalization and interpolation. The net uncertainty is, in reality, time- and space-dependent, but is treated in the uncertainty analysis as constant in time and space. This component of uncertainty also does not account for variations in reactor operational (pre-transient) conditions. These are handled through separate analyses and sensitivity studies. To date, the operational uncertainties investigated include the effect of variations in atmospheric pressure[16], plenum pressure scram setpoint[17], transient power[18], and initial plenum centerline pressure[4]. The uncertainty in the steady-state plenum pressure is treated separately in the limits methodology as a plenum centerline pressure uncertainty and a plenum pressure gradient uncertainty[3,4].

The ideal way of estimating the uncertainty in a calculation is to have a direct comparison between the results and data. However, prototypic data for a LOCA in a production reactor does not exist.

Absent this, the next best approach is to use reactor data that tests the ability of the code to capture the basic phenomena involved in the postulated accident. This is the approach upon which this methodology is based.

The plenum pressure uncertainty was estimated by comparing plenum pressure measurements from steady-state, isothermal tests run in L Reactor in 1985 to TRAC analyses of the tests. Approximately ninety plenum pressure measurements were made for each of eleven tests. The tests were conducted at two different process water temperatures and with several different pumping configurations. Six of these tests were used to assess TRAC uncertainty. Three of the selected tests were performed with all six process pumps under both alternating current (AC) and direct current (DC) power as in normal operation. The remaining three tests were conducted with five process pumps under AC and DC power and the sixth pump inoperative. These three tests resulted in backflow through the loop containing the inoperative pump, thereby simulating some of the thermal-hydraulic conditions expected in the LOCA.

The use of steady-state tests to estimate the uncertainty in calculated plenum pressures during a DEGB LOCA is appropriate because of the timing of the period of interest relative to the progression of the accident. The instantaneous break produces a rapid system response during the first 0.5 seconds. The flow in the broken nozzle reverses and the plenum pressure distribution changes substantially. In the next 1.5 seconds, however, the overall plenum pressure and the spatial distribution of the pressure change much more slowly. Thus, steady-state tests that approximate the flow and pressure fields of a LOCA are adequate to estimate the uncertainty.

Since the measured plenum pressure distributions should ideally be as close as possible to the expected distribution during a LOCA, the rationale for the selection of tests requires some elaboration. Though the three tests conducted with one loop in backflow are closest to the LOCA in plenum boundary conditions and pressure distribution, an uncertainty estimate based on a combination of backflow and forward flow tests is preferable. This is because the combination of all 6 tests gives the best plenum pressure coverage and, hence, the best measure of core-wide uncertainty. The distribution of plenum instrumentation for the tests was heavily concentrated in 2 sectors.

For the backflow tests. one of these sectors was in front of the backflow loop and the other in front of an adjacent forward flow loop. The remaining scattered measurements were all in forward flow sectors. An estimation of plenum pressure uncertainty based on backflow tests only has an inherent imbalance in the ratio of forward flow to backflow sector measurements compared to the LOCA. Of course, an estimation of plenum pressure uncertainty based only on forward flow tests would involve no measurements taken in a backflow sector.

By contrast, the use of both forward flow and backflow tests in the estimation of plenum pressure uncertainty comes close to preserving the core-wide ratio of approximately 5 intact ("forward flow") sector fuel assembly positions for every break ("backflow") sector assembly position that would exist during the LOCA. The combination of 6 tests provides 3 backflow sectors and 9 forward flow sectors, all heavily instrumented, and a number of additional scattered measurements, all of which are in forward flow sectors. In addition, the use of all 6 tests increases the number of comparisons, thereby improving the statistics. Hence, the uncertainty estimation based upon both forward flow and backflow tests was preferred.

The TRAC L Reactor model has been benchmarked previously against the AC tests[15]. The TRAC plenum pressure results from the benchmark analyses of the six selected tests were compared to the data using an approach consistent with the uncertainty methodology. The TRAC cell-averaged pressures were interpolated spatially to give calculated values at the location of each measured plenum pressure. The interpolation scheme, which uses a linear method in the azimuthal direction and a spline fit in the radial direction, was taken from the uncertainty methodology. The program CINT[19] was modified for this purpose, resulting in a program called INTERP1. Appendix A contains a listing of INTERP1.

For a given AC test, INTERP1 performs the interpolation of TRAC plenum pressures to the locations where measurements were made and calculates the differences between the actual pressure data and the interpolated TRAC pressures. Both absolute and relative pressure differences are calculated, as well as the sum and sum of the squares of the differences. These are used to calculate the mean and standard deviation of all the differences between measured and interpolated TRAC plenum pressures for a number of tests. The mean and standard deviation of the distribution of the differences are calculated according to the following expressions:

$$\mu = (\Sigma\delta)/N \quad (1)$$

$$\sigma = \{[N\Sigma(\delta)^2 - (\Sigma\delta)^2]/[N(N-1)]\}^{0.5} \quad (2)$$

where,

μ = the mean of the distribution of differences;
σ = the standard deviation of the distribution of differences;
δ = the difference (absolute or relative) between the interpolated TRAC plenum pressure and the measured plenum pressure at a particular location; and
N = the total number of pressure differences in the distribution.

The derivation of Equation 2 is given in Appendix B.

Once the mean and standard deviation of the distribution of differences are determined, they are used to estimate the plenum pressure uncertainty. The mean is an indication of any systematic difference, or bias, between the data and the interpolated TRAC pressures. The standard deviation is a measure of the probability that an interpolated TRAC pressure will differ from the corresponding measurement by more than a specified amount. Since the plenum pressure uncertainty in the FI limits methodology is stated in terms of one standard deviation of a normal distribution, the standard deviation obtained with Equation 2 can be used as a direct estimate of the uncertainty (given that the mean is also taken into account).

4.0 UNCERTAINTY ESTIMATE RESULTS

The INTERP1 program was run for the six selected AC tests (i.e., H, B, C, D, E, and J). Three input files were required for each run. The first file, "interp.in", contains the TRAC plenum pressures for the given test, the radii of the TRAC rings, and the number of assembly positions to be compared. In this case, the 35 positions in flowzones 1 through 4 having plenum pressure measurements were considered. The pressures are given in psi absolute (psia) and the radii in inches. Appendix C contains the "interp.in" files for the 6 tests. The second input file, "rtheta.in", contains the On-Line Computer (OLC) number and "r,θ" location of each assembly position to be included. The radial positions are given in inches and the azimuthal positions given in radians, with the azimuthal origin taken to be the radius between TRAC sectors 1 and 6 and increasing angles in the counterclockwise direction. Since the same assembly positions were measured in all the tests, "rtheta.in" was the same for each INTERP1 run. Appendix D presents the file "rtheta.in". The final input file required by INTERP1 is "olcx.in", where the "x" is the test designator (e.g., b,c, etc.). This file contains the plenum pressure measurements by OLC number for a given test. To be consistent with the interpolated TRAC pressures, the pressure data are input in psia. Appendix E contains the files "olcx.in" for the 6 AC tests.

The output of the INTERP1 program is written to a file called "interp.out". This file contains the TRAC plenum cell pressures, the TRAC radii, and the total number of assembly positions considered. It also shows the interpolated TRAC pressures, the pressure measurements, and the absolute and relative differences between them for each position considered. Finally, the sum and sum of the squares of the differences (both absolute and relative) is given. The "interp.out" files for the six tests are given in Appendix F.

Table 2 presents a summary of the INTERP1 results for the 6 AC tests. Each test had 35 measurements in positions corresponding to K-14.1 flowzones 1-4, for a total of 210 comparisons. The totals of the sums and sums of the squares of the pressure differences (absolute and relative) for the 6 tests were used in Equations 1 and 2 to calculate means and standard deviations, as follows:

Absolute pressure differences (interpolated TRAC minus data) -

mean: 0.12 psia;
standard deviation: 2.81 psia;

Relative pressure differences (absolute differences divided by data) -

mean: 0.005
standard deviation: 0.035

As these results show, the mean of all the differences is positive and small. This suggests that there is no significant systematic error in using the interpolated TRAC plenum pressures as a predictor of the data. The fact that the mean is positive could suggest a slight nonconservatism in the interpolated TRAC results; however, since the magnitude is well within the measurement uncertainty (≅ 0.5 psi)[11], it may be neglected.

The standard deviation of the distribution of pressure differences provides an estimate of the uncertainty associated with using interpolated TRAC results to predict the AC tests. It can also be applied to estimate the plenum pressure uncertainty for the LOCA. One approach would be to use the standard deviation in the absolute pressure differences as the uncertainty. However, this would inflate the uncertainty appropriate for the LOCA because the pressure level during the LOCA is significantly lower than in the AC tests. The average calculated plenum pressure in rings 1-4 for the six tests is about 80 psia, while the average calculated LOCA plenum pressure over the time period of interest is about 47 psia. The developers of TRAC estimated the uncertainty in calculated pressures to be ± 10%[20]. Hence, the uncertainty should be roughly proportional to the value of the pressure. This suggests that the standard deviation of the relative pressure differences should be used to obtain a standard deviation in absolute terms appropriate for the LOCA. Table 3 shows the TRAC plenum pressures in rings 1-4 at 0.5s, 1.0s, 1.5s, and 2.0s during the LOCA. The average pressure at each time is also shown. Applying the relative standard deviation of 0.035 to the average plenum pressures at these times gives the following result:

time: 0.5s	standard deviation:	1.71 psia
time: 1.0s	standard deviation:	1.66 psia
time: 1.5s	standard deviation:	1.63 psia
time: 2.0s	standard deviation:	1.62 psia.

The average standard deviation over the time period of interest is approximately 1.65 psia.

This standard deviation incorporates the uncertainty associated with TRAC predictions of different gross steady-state plenum pressure distributions, including three that are "LOCA-like." It also includes the contribution to the uncertainty of the interpolation scheme used to convert the cell-average TRAC LOCA results to detailed fuel assembly boundary conditions. The data comparisons discussed above indicate a smaller uncertainty for steady-state predictions of plenum pressures than has been assumed for the LOCA analysis. As discussed below, the difference accounts for the transient uncertainty.

The standard deviation based on the data comparison does not account for all the sources of potential uncertainty in the LOCA plenum pressures. These sources of uncertainty include:

1. differences between charges (L-1.1 versus K-14.1);
2. expected variations in reactor operating conditions; and
3. transient effects involved in the K-14.1 LOCA.

As discussed previously,the first two categories are addressed through sensitivity studies and additional uncertainties included in the limits methodology. For the purpose of plenum pressure uncertainty, the main difference between the charges is in the hydraulic resistance of the charges and the attendant impact on plenum pressure. The uncertainty in the initial steady-state plenum pressure and its effect on the effluent temperature limits are addressed separately[3,4] from the transient plenum pressure uncertainty.

As previously discussed, the quasi-steady nature of the pressures and flows over the period of interest provides the rationale for not explicitly accounting for many of the transient effects. The obvious difference between the reactor configuration during the tests and during a LOCA is the presence of the break. While no plenum pressure data with a break exists, the backflow tests do provide data for a reactor configuration in which about 12,000 gallons per minute (gpm) of heavy water are flowing out of the plenum through one nozzle while the remaining six nozzles deliver 26,000 to 28,000 gpm to the plenum. This compares reasonably well to the TRAC calculated conditions for the LOCA, wherein the plenum side break flowrate is 24,200 to 25,000 gpm and the intact loops are delivering 26,300 to 27,700 gpm over the time period of interest[21].

The TRAC LOCA analysis "bounds" the break flowrate in the sense that the break itself is assumed to have no resistance to flow and the loop giving the highest break flowrate is assumed in the analysis. It is also important to note that for SRS reactors the break flowrate is determined by the overall system response rather than being controlled by phenomena occurring at the break itself as in commercial power reactors. This is because the escaping liquid is substantially subcooled and the velocities are substantially below the sonic velocity. Hence, the flow is not choked but simply controlled by the frictional losses and the pressure difference between the plenum and the process room. Thus, a higher break flowrate implies a higher pressure in the plenum sector nearest the break.

The remaining uncertainty associated with transient phenomena (e.g., break flow) is covered in the margin between the calculated plenum pressure standard deviation (i.e., 1.65 psia) and the actual uncertainty used in the limits analysis (i.e., 2.5 psia). The 50% increase over the estimated plenum pressure standard deviation provided by the 2.5 psia uncertainty is a reasonable allowance for these additional contributors to uncertainty. This will be confirmed by a code-to-code comparison in Section 5.

The original source of the ("1-σ") ± 2.5 psi uncertainty was an estimate by LANL personnel of ± 10% accuracy for TRAC pressures[20]. This was interpreted as a "2-σ" uncertainty and translated to ± 5 psi for the LOCA. Based on the average plenum pressure during the LOCA of about 47 psia, a "1-σ" uncertainty of ± 2.4 psia would be equivalent to ± 10%. Hence, the plenum pressure uncertainty used in the FI limits is conservative for both the original and the current estimates of uncertainty.

5.0 CONFIRMATION OF TRANSIENT PLENUM PRESSURE UNCERTAINTY

The uncertainty estimate obtained in Section 4 was based on data that was prototypic in kind and scale but not in scenario (i.e., not a LOCA). The additional uncertainty due to the unaddressed transient effects was assumed to increase the estimated uncertainty by no more than 50%. The purpose of this section is to provide some confirmation of the total uncertainty in plenum pressures for the LOCA. One approach used to compensate for the lack of fully prototypic system data involves comparing calculated results obtained from independent codes and models. This approach has the advantage of fidelity to the accident scenario, but does not address the basic uncertainty in the codes. The basic uncertainty can only be established by comparisons with data. As a result, this approach is best for confirmation of the overall predicted results and of uncertainty estimated from data comparisons. Hence, the current methodology uses a code-to-code comparison in this manner.

As previously discussed, the TRAC code developers estimated the accuracy of TRAC plenum pressures for LOCA analysis to be ± 10%[20]. The ± 2.5 psia uncertainty ("1-σ") used in the FI limits methodology is a conservative application of the ± 10% estimate ("2-σ") to the K-14.1 LOCA results. This estimate presumes an adequate basic representation of the reactor by the code and input model, which for the current application has been established by the comparisons with reactor data. A code-to-code comparison offers a means of confirming that the ± 10% estimate for transient plenum pressure uncertainty is reasonable. This is essentially a calculational analogue to an integral systems test, with the second code analyzing the same transient for the same reactor, but with an independently derived model. Given that the second code has proven capabilities comparable to TRAC, and that the basic adequacy of the code and input model to represent the reactor has been established, any differences seen in the transient results obtained with the second code can be used as a measure of uncertainty. In the case of the plenum pressure uncertainty, if the plenum pressures predicted by the second code differ from the TRAC plenum pressures by 10% or less, then original estimate of uncertainty would be supported.

The RELAP5 code is an industry-standard tool for performing analyses of nuclear reactor transients such as the LOCA. As part of the K Reactor Restart effort, a RELAP5 K Reactor model was developed and an analysis of the FI phase of a DEGB LOCA was performed and the results compared to TRAC results[6]. This TRAC/RELAP5 LOCA comparison was subsequently updated by Griggs and Liebmann[22]. The RELAP5 K Reactor model includes six process water loops and uses one-dimensional pipes with crossflow junctions to represent the plenum in two dimensions and the tank in three dimensions. The RELAP5 model has a three ring, six sector plenum and tank representation. The innermost ring (RELAP5 ring 1) corresponds to TRAC rings 1 and 2, and the middle ring (RELAP5 ring 2) corresponds to TRAC rings 3 and 4. The outer ring (RELAP5 ring 3) corresponds to TRAC ring 5.

The RELAP5 model was benchmarked against some of the 1985 AC tests[14] and produced good agreement with the data and, hence, results comparable to TRAC[15]. In particular, the codes (with their respective models) gave similar plenum pressure results (except in the outer ring) for 1985 AC tests I, H, and D. As discussed in Ref. 15, TRAC appears to predict pressures in the outer ring that are too high; this is not considered to be a serious problem because the outer ring pressures do not provide boundary conditions for any fuel assemblies. Also, the data available for the outer ring may not reflect a true average pressure for the region. RELAP5 showed good agreement with the outer ring pressures measured in the tests. These results demonstrate that the RELAP5 code and model is adequate to represent the reactor.

The comparison of TRAC and RELAP5 LOCA results showed overall good agreement. Table 4 shows the plenum pressures predicted by TRAC and RELAP5. This comparison is based on the averaging of TRAC plenum cell pressures to correspond to the larger RELAP5 plenum cells. As a result, there are 12 comparisons that can be made at any particular time during the LOCA. For these analyses, sector 3 is the break sector and sector 6 is "opposite" the break. Sectors 2 and 4 and sectors 1 and 5 are symmetric and thus have (nominally) the same pressures. The transient times shown are 0.5s, 1.0s, 1.5s, and 2.0s. At each of these times, all (12 out of 12) of the RELAP5 plenum pressures are within ± 10% of the averaged TRAC pressures. The average difference in TRAC and RELAP5 plenum pressures at these times is about 5%. Thus, the RELAP5 plenum pressure predictions fall within the ("2-σ") uncertainty assumed for the TRAC plenum pressure predictions.

The comparison of TRAC and RELAP5 LOCA results supports the original estimate of ± 10% accuracy, though it cannot be used to support or refute the "2-σ" interpretation. A single code-to-code comparison does not lend itself to a statistical interpretation. It is worth noting, however, that the calculated break sector (i.e., sector 3) plenum pressures agree within ± 3% at the times considered. The break sector plenum pressures play the biggest role in the determination of FI limits, so it is important that the uncertainty used is clearly adequate there.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The quantification of uncertainty is an important element of determining safe operating power levels for SRS reactors. Estimates of the uncertainty in TRAC predictions of the time-dependent plenum pressures during a DEGB LOCA have been made. The uncertainty was estimated by means of comparing TRAC results with steady-state data measured in L Reactor, and confirmed by comparisons with LOCA results calculated independently with the RELAP5 code.

The primary uncertainty estimate is based on a comparison of steady-state plenum pressure measurements made in L Reactor in 1985 with interpolated TRAC results for the same tests. This uncertainty estimate is based on 3 forward flow and three backflow tests at two temperatures (tests were isothermal). The uncertainty estimates use only those measurements made at positions included in Flowzones 1-4 in K-14.1, since the uncertainty in the pressures for the other flowzones is not used in the limits methodology; as a result, only the results for TRAC rings 1-3 are used in the analysis. The relative (or fractional) differences between the measured and calculated (interpolated TRAC) plenum pressures for the 6 tests were combined into a single distribution; a mean and standard deviation of this distribution of relative differences is calculated. The resulting mean and standard deviation of the distribution of relative errors are 0.5% and 3.5%, respectively.

The standard deviation can then be used to estimate a "1-σ" uncertainty in the calculated absolute plenum pressure for K-14.1 during the time interval from 0.5 s to 2.0s of a plenum inlet DEGB LOCA. This is done by multiplying the actual calculated average plenum pressure during the LOCA (using rings 1-3 only) by 3.5%. The resulting estimated standard deviation for absolute plenum pressure during the period of interest is about 1.65 psi.

The estimated plenum pressure uncertainty is less than the ± 2.5 psi transient uncertainty used for the FI limits, providing additional margin. The uncertainty estimate based on steady-state data comparisons (± 1.65 psia) does not account for transient effects or for the additional phenomena involved in the K-14.1 LOCA. However, the quasi-steady nature of the pressures and flows over the period of interest during the LOCA suggests that purely transient effects will add little to the plenum pressure uncertainty. A number of additional uncertainties, such as steady-state plenum pressure uncertainties and operational variations, are addressed separately in the limits methodology. The remaining plenum pressure uncertainty associated with additional LOCA phenomena, such as the break flow, is judged to be small since break flow rate is modelled conservatively by assuming worst leak location and no friction loss at the break itself.

The TRAC code developers' estimate of ± 10% accuracy for TRAC plenum pressures, upon which the original ± 2.5 psi uncertainty was based, was confirmed by means of a code-to-code comparison. A comparison of TRAC and RELAP5 plenum pressures during the LOCA in K-14.1 showed agreement within ± 10% throughout the time period of interest. Agreement in the break sector was within ± 3% during the time period of interest.

6.2 Recommendations

As a result of the completion of the 1989 L Reactor Hydraulics Tests[23], additional plenum pressure data exist that can be used to estimate TRAC uncertainty. These tests have the advantage of being more prototypic than the 1985 data because they were performed with a Mark 22 charge. They have the disadvantage of fewer plenum pressure measurements per test. Nevertheless, the use of this test data could make an important contribution to the technical basis for the TRAC uncertainty.

7.0 REFERENCES

1. Safety Code Development Group, "TRAC-PF1/MOD1: An Advanced Best-Estimate Computer Program for Pressurized Water Reactor Thermal-Hydraulic Analysis," Los Alamos National Laboratory report LA-10157-MS (NUREG/CR-3858), July 1986.

2. S. E. Aleman, *et al.*, "FLOWTRAN: An Algorithm for Describing the Thermal-Hydraulic Behavior of SRP Assemblies," DPSTM-140, September 1989.

3. B. J. Hardy and A. M. White, "A Probabilistic Method for Determining Effluent Temperature Limits for Flow Instability for SRS Reactors," WSRC-TM-90-5 (DPSTM-160), June 1990.

4. B. J. Hardy, "Addendum to: A Probabilistic Method for Determining Effluent Temperature Limits for Flow Instability for SRS Reactors (U)," WSRC-TM-90-5 (DPSTM-160), Addendum 1, Westinghouse Savannah River Company, February 1991.

5. M. A. Shadday, Jr., "The Impact of Cavitation During a DEGB LOCA, With Uncertainties," WSRC-RP-89-1313, December 1989.

6. C. B. Davis, "A Comparison of RELAP5 and TRAC LOCA Calculations for the K-14.1 Charge at SRS," EGG-EAST-8608, EG&G Idaho, Inc., August 1989.

7. V. H. Ransom, *et al.*, "RELAP5/MOD2 Code Manual Volume 1: Code Structure, System Models, and Solution Methods," NUREG/CR-3412, U. S. Nuclear Regulatory Commission, EGG-2396, EG&G Idaho, Inc., August 1985.

8. W. M. Massey, *et al.*, "LOCA FI Limits Methodology," WSRC-TM-90-4, June 1990.

9. E. G. Schaub, "TRAC Calculations of the Initial Flow Decay in K-14.1," DPST-89-326, June 1990.

10. R. F. Swingle, "K-14.1 Mark 22 Charge Flow Design Revision 1," RTM-5036, Rev. 1, WSRC-TR-90-00218, June 1990.

11. D. A. Crowley and L. L. Hamm, "Improved Plenum Pressure Gradient Facemaps for PKL Reactors," DPST-88-527, May 1988.

12. L. D. Koffman, R. E. Pevey, and A. M. White, "TRAC Calculations of the Initial Flow Decay in L-1.1," DPST-87-737, December 1987.

13. C. B. Davis, C. D. Fletcher, and S. B. Rodriquez, "Benchmarking the RELAP5 L-Reactor Model with Savannah River Reactor Test Data," EGG-EAST-8336, EG&G Idaho, Inc., April 1989.

14. M. A. Bolander and C. B. Davis, "Benchmarking the Six-Loop, Three-Dimensional RELAP5 L-Reactor Model with Savannah River Reactor Test Data," EGG-EAST-8556, EG&G Idaho, Inc., August 1989.

15. D. P. Griggs and J. M. Cozzuol, "TRAC L Reactor Model: Geometry Review and Benchmarking," WSRC-TR-90-32, August 1990.

16. M. L. Liebmann, "TRAC LOCA Atmospheric Pressure Study," NES-ART-900189, Memorandum to J. D. Menna, Westinghouse Savannah River Company, October 2, 1989.

17. M. L. Liebmann, "LOCA Low Plenum Pressure Trip Setpoint," NES-ART-900259, Memorandum to N. H. Kuehn, Westinghouse Savannah River Company, November 14, 1990.

18. M. L. Liebmann, "TRAC K14.1 LOCA w/Revised Power Table & 80% Trip Setpoint(CP)," NES-ART-900319, Memorandum to J. D. Menna, Westinghouse Savannah River Company, December 31, 1990.

19. B. J. Hardy, "Documentation for Computer Code CINT," Westinghouse Savannah River Company Inter-Office Memorandum NES-RFI-890134, FIU-89-67, November 7, 1989.

20. W. L. Kubic, Jr., "Source of the Initial Estimates of the Uncertainty in Transient Plenum Pressure and Transient Tank Bottom Pressure," WSRC Inter-Office Memorandum NES-ART-900274, April 30, 1990.

21. D. P. Griggs, "E. I. du Pont de Nemours & Company Laboratory Notebook E51803," DPSTN-4680, Savannah River Laboratory, issued July 13, 1988.

22. D. P. Griggs and M. L. Liebmann, "Comparison of TRAC and RELAP5 Reactor System Calculations for a DEGB LOCA in K-14.1," WSRC-TR-90-393, September 1990.

23. J. D. Menna, *et al.*, "Steady State Data Report of Tests DC-4, DC-9, AC-4 (modified), and AC-10, NEDE-89-165, Westinghouse Savannah River Company, Savannah River Laboratory, November 3, 1989.

Figure 1
TRAC Plenum Grid on Facemap with K-14.1 Flowzones

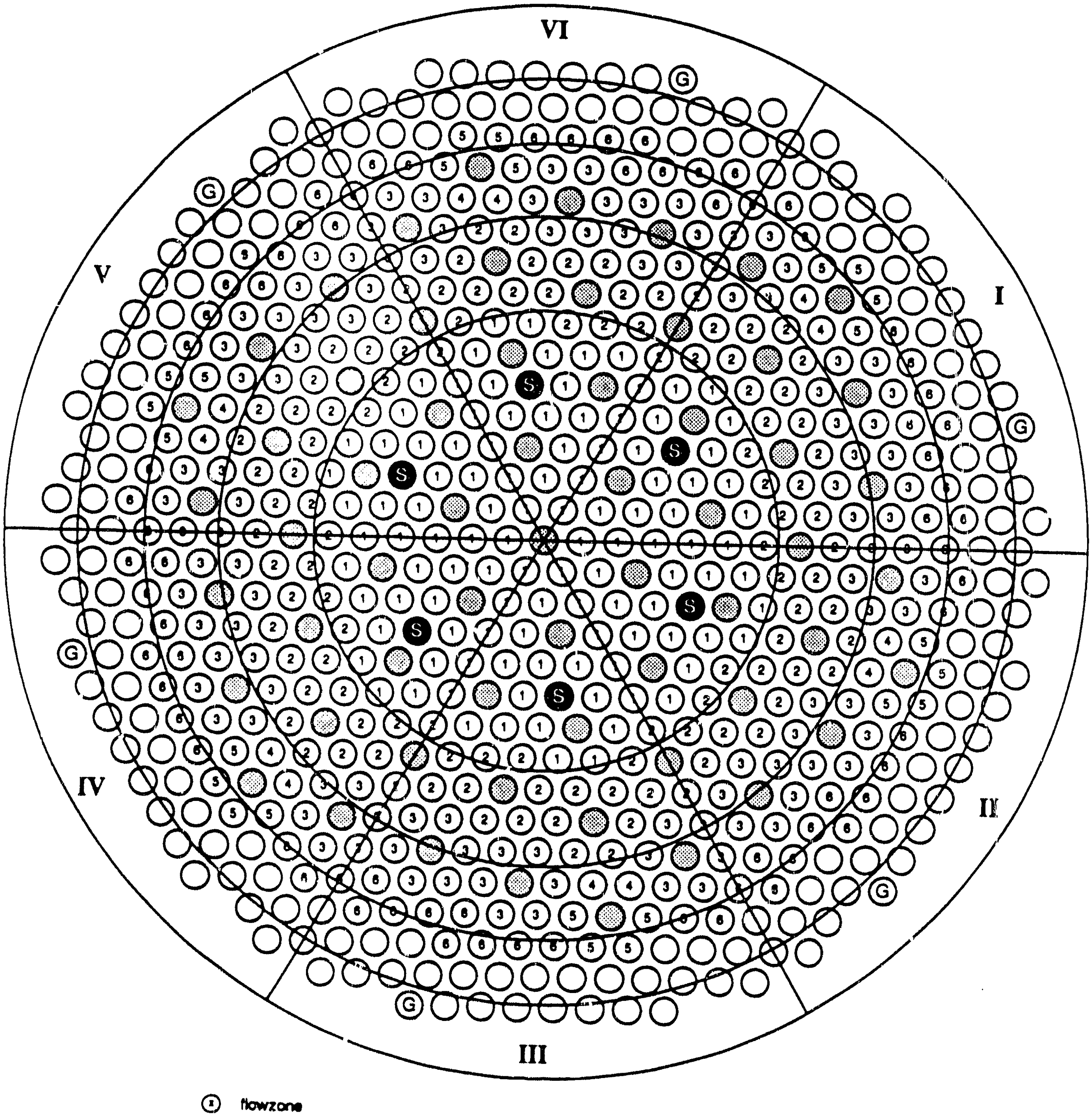

Figure 2
1985 L Area Tests Plenum Pressure Measurement Locations

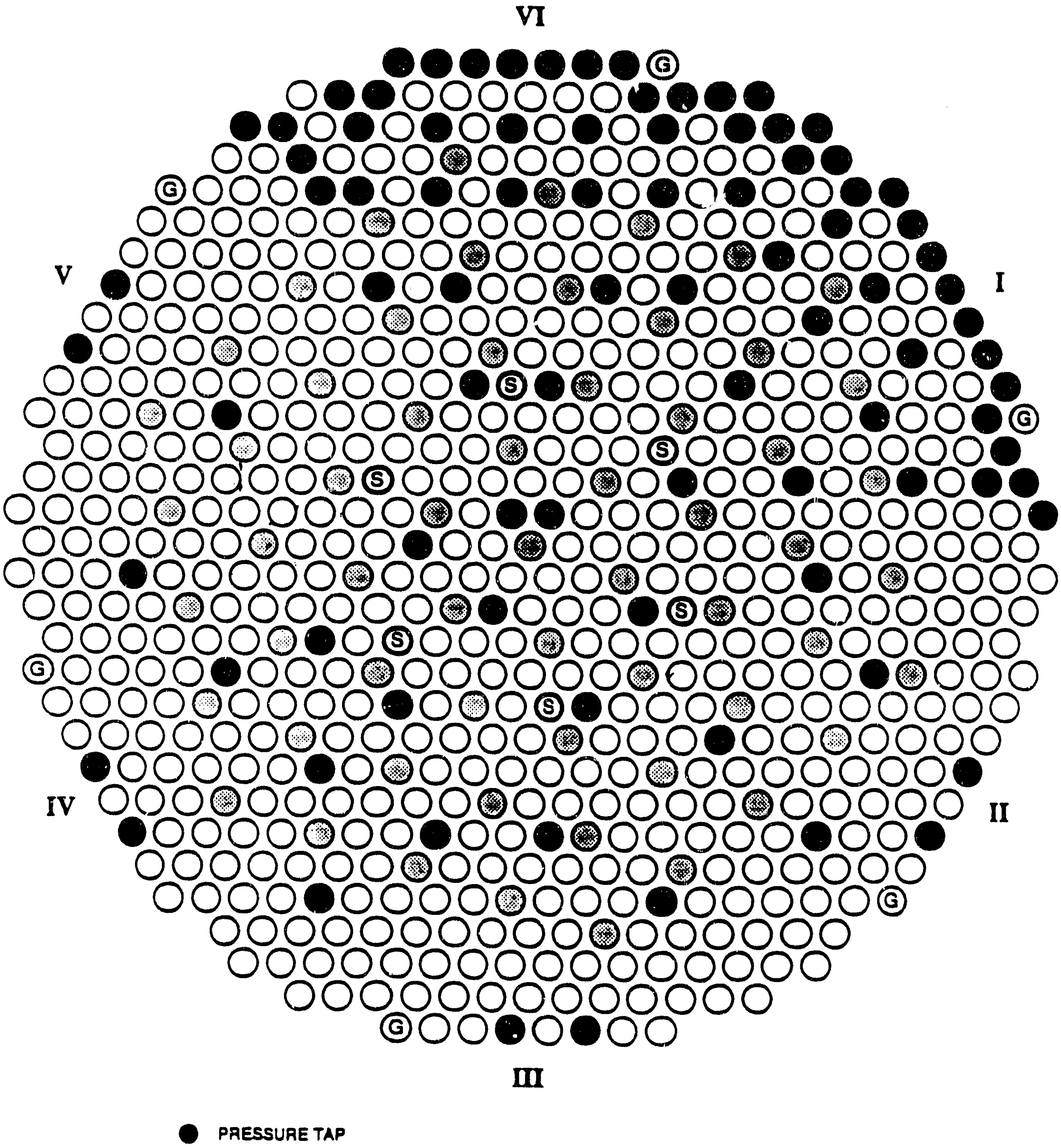

Table 1
1985 L Area AC Flow Test Configurations

Test	Pumps on	Septifoil	Rotovalves open[1]	Temperature, °C
A	1 - 6	off	A only	22.01
B	1 - 6	off	A and B	25.10
C	1 - 6	on	A and B	22.46
D	1 - 5	off	A and B	22.35
E	2 - 6	off	A and B	22.28
F	1, 3, 5	off	A and B	22.89
G	1 - 6	off	A only	60.59
H	1 - 6	off	A and B	60.17
I	1 - 6	on	A and B	59.94
J	2 - 6	off	A and B	59.49
K	1, 3, 6	off	A and B	58.40

1. Each loop has two rotovalves, designated A and B. Tests with only one rotovalve open (A and G) were not analyzed.

TABLE 2

SUMMARY OF INTERP1 RESULTS FOR 6 AC TESTS

Test	N	Absolute Differences		Relative Differences	
		$\Sigma\delta$	$\Sigma(\delta^2)$	$\Sigma\delta$	$\Sigma(\delta^2)$
B	35	-46.53	371.78	-0.469	0.040
C	35	-36.56	318.06	-0.378	0.037
H	35	-8.81	337.52	-0.059	0.038
D	35	19.98	165.04	0.340	0.039
E	35	43.87	203.00	0.703	0.047
J	35	53.16	257.28	0.858	0.061
Total	210	25.11	1652.68	0.995	0.262

TABLE 3

TRAC LOCA PLENUM PRESSURES

TRAC Plenum Cell Number	Plenum Pressure (psia) at:			
	0.5s	1.0s	1.5s	2.0s
1	44.84	43.15	42.24	42.03
2	42.31	40.83	39.99	39.81
3	42.49	41.24	40.49	40.32
4	43.13	41.67	40.82	40.63
5	45.21	43.54	42.62	42.41
6	45.82	44.09	43.16	42.95
7	49.19	47.45	46.47	46.25
8	45.69	44.07	43.14	42.92
9	40.23	39.14	38.41	38.23
10	45.84	44.32	43.39	43.18
11	49.18	47.42	46.45	46.23
12	50.77	48.93	47.92	47.70
13	52.92	51.21	50.27	50.02
14	48.90	47.31	46.36	46.16
15	38.55	37.50	36.79	36.62
16	48.57	47.13	46.17	45.98
17	52.94	51.17	50.19	49.99
18	54.31	52.49	51.49	51.29
19	60.47	58.86	57.89	57.71
20	55.73	54.28	53.35	53.17
21	36.70	35.84	35.22	35.08
22	54.97	53.72	52.79	52.61
23	60.53	58.85	57.88	57.71
24	61.90	60.16	59.18	59.01
Average	48.80	47.27	46.36	46.17

TABLE 4
Comparison of TRAC and RELAP5 LOCA Plenum Pressures

SECTOR	RELAP5 RING	TIME, S	PLENUM PRESSURE, psia TRAC*(T)	RELAP5 (R)	R-T, psia	(R-T)/T
3	1	0.5	41.34	40.92	-1.42	-0.01
3	2	0.5	37.61	38.92	1.31	0.03
2 (4)	1	0.5	43.98	43.09	-0.89	-0.02
2 (4)	2	0.5	52.30	49.47	-2.83	-0.05
1 (5)	1	0.5	47.00	44.20	-2.80	-0.06
1 (5)	2	0.5	56.68	52.45	-4.23	-0.07
6	1	0.5	48.28	44.31	-3.97	-0.08
6	2	0.5	58.08	52.78	-5.30	-0.09
3	1	1.0	40.13	39.25	-0.88	-0.02
3	2	1.0	36.61	37.57	0.96	0.03
2 (4)	1	1.0	42.37	41.31	-1.06	-0.03
2 (4)	2	1.0	50.71	47.81	-2.90	-0.06
1 (5)	1	1.0	45.22	42.37	-2.85	-0.06
1 (5)	2	1.0	54.95	50.78	-4.17	-0.08
6	1	1.0	46.34	42.50	-3.84	-0.08
6	2	1.0	56.24	51.10	-5.14	-0.09
3	1	1.5	39.44	38.45	-0.99	-0.03
3	2	1.5	36.00	36.89	0.89	0.02
2 (4)	1	1.5	41.56	40.84	-0.72	-0.02
2 (4)	2	1.5	49.85	46.99	-2.86	-0.06
1 (5)	1	1.5	44.35	41.53	-2.82	-0.06
1 (5)	2	1.5	54.05	49.92	-4.13	-0.08
6	1	1.5	45.54	41.64	-3.90	-0.09
6	2	1.5	55.33	50.24	-5.09	-0.09
3	1	2.0	39.26	38.38	-0.88	-0.02
3	2	2.0	35.84	36.82	0.98	0.03
2 (4)	1	2.0	41.35	40.40	-0.95	-0.02
2 (4)	2	2.0	49.64	46.91	-2.73	-0.06
1 (5)	1	2.0	44.13	41.44	-2.69	-0.06
1 (5)	2	2.0	53.85	49.84	-4.01	-0.07
6	1	2.0	45.31	41.57	-3.74	-0.08
6	2	2.0	55.13	50.16	-4.97	-0.09

*average of two TRAC cells corresponding to one RELAP5 cell

APPENDIX A

INTERP1 Program Listing

```
c       this program interpolates among TRAC cell pressures
c       (using a cubic spline interpolation scheme
c       to create three curves along each of the sector lines
c       followed by a linear weighting of the values on the
c       lines by the angle from each line ) to determine
c       calculated plenum pressures that can be compared
c       directly with measured plenum pressures
      dimension nolc(90),nolc2(90),ttot(90),press(90)
      dimension p(24),x11(8),y1(8,3),fdp(8,3)
      dimension r(90),theta(90),diff(90),rdiff(90)
      open(unit=11,file='interp.in',status='old')
      open(unit=12,file='rtheta.in',status='old')
      open(unit=13,file='olcp.in',status='old')
      open(unit=6,file='interp.out',status='new')
      nin=11
      read(nin,107) (p(i),i=1,24)
  107 format(f6.2)
      write(6,108) ((i,p(i)),i=1,24)
  108 format(' The TRAC pressures for the different cells are:',
     1/24(4x,i3,1x,f10.2/))
      read(nin,100) r1,r2,r3,r4
  100 format(1x,f7.2,1x,f7.2,1x,f7.2,1x,f7.2)
      write(6,101) r1,r2,r3,r4
  101 format(1x,'the inner and outer radii are',4(1x,f10.2))
c
c      this code is taken from Numerical Methods in
c      Engineering by Ferziger, p.17,18
c
      nd=8
      x11(1)=-(r4+r3)/2.
      x11(2)=-(r3+r2)/2.
      x11(3)=-(r2+r1)/2.
      x11(4)=-(r1/2.)
      x11(5)=r1/2.
      x11(6)=(r1+r2)/2.
      x11(7)=(r2+r3)/2.
      x11(8)=(r3+r4)/2.
      do 200 kki=1,3
      y1(1,kki)=p(21+kki)
      y1(2,kki)=p(15+kki)
      y1(3,kki)=p(9+kki)
      y1(4,kki)=p(3+kki)
      y1(5,kki)=p(kki)
      y1(6,kki)=p(6+kki)
      y1(7,kki)=p(12+kki)
      y1(8,kki)=p(18+kki)
c
c      the next step sets up the spline function
c
      call spline(nd,x11,y1(1,kki),fdp(1,kki))
  200 continue
c
c       we now set up a loop that interpolates among the press.
c
      read(nin,102) nass,avg,ravg
  102 format(1x,i3,2(f8.4))
      write(6,103) nass,avg,ravg
  103 format(1x,' The number of assemblies considered is ',i3/
     1' Average residual:',f8.4,5x,'Average relative residual:',
     2f8.4)
      write(6,109)
  109 format(/3x,'n',5x,'olc',4x,'radius',6x,'theta',4x,
     1'p, interp',2x,'p, L data',3x,'(I - L)',2x,'(I - L)/L')
```

```
      do 1 i = 1,nass
      read(12,104) nolc(i),r(i),theta(i)
  104 format(5x,i3,2(5x,f6.3))
      read(13,105) nolc2(i),press(i)
  105 format(2x,i3,3x,f6.2)
      if(nolc(i).ne.nolc2(i))then
      write(6,106) i,nolc(i),nolc2(i)
  106 format(1x,'WARNING - OLCs for record ',i3,'  did not match'/
     1' rtheta: ',i3,5x,'olcp:',i3)
      stop
      end if
c
c      convert to degrees from radians
c
      theta(i)=theta(i)*360./2./3.14159265358
    1 continue
c
c     loop over all assemblies to find the two lines it is between
c
      var=0.0
      rvar=0.0
      do 205 i=1,nass
      if(theta(i).lt.30.or.theta(i).ge.330.)then
c
c      interpolate between line 1+ and line 3-
c
      call speval(nd,x11,y1(1,1),fdp(1,1),r(i),tt1)
      r2=-r(i)
      call speval(nd,x11,y1(1,3),fdp(1,3),r2,tt2)
      the=theta(i)
      if(the.lt.31.)the=the+360.
      ttot(i)=tt2*(390.-the)/60.+tt1*(the-330.)/60.
      go to 204
      end if
      if(theta(i).lt.90.and.theta(i).ge.30.)then
c
c      interpolate between line 1+ and 2+
c
      call speval(nd,x11,y1(1,1),fdp(1,1),r(i),tt1)
      call speval(nd,x11,y1(1,2),fdp(1,2),r(i),tt2)
      the=theta(i)
      ttot(i)=tt2*(the-30.)/60.+tt1*(90.-the)/60.
      go to 204
      end if
      if(theta(i).lt.150.and.theta(i).ge.90.) then
c
c      interpolate between lines 2+ and 3+
c
      call speval(nd,x11,y1(1,2),fdp(1,2),r(i),tt1)
      call speval(nd,x11,y1(1,3),fdp(1,3),r(i),tt2)
      the=theta(i)
      ttot(i)=tt2*(the-90.)/60.+tt1*(150.-the)/60.
      go to 204
      end if
      if(theta(i).lt.210.and.theta(i).ge.150.) then
c
c      interpolate between lines 3+ and 1-
c
      call speval(nd,x11,y1(1,3),fdp(1,3),r(i),tt1)
      r2=-r(i)
      call speval(nd,x11,y1(1,1),fdp(1,1),r2,tt2)
      the=theta(i)
      ttot(i)=tt2*(the-150.)/60.+tt1*(210.-the)/60.
```

```
      go to 204
      end if
      if(theta(i).lt.270.and.theta(i).ge.210.) then
c
c      interpolate between lines 1- and 2-
c
      r2=-r(i)
      call speval(nd,x11,y1(1,1),fdp(1,1),r2,tt1)
      call speval(nd,x11,y1(1,2),fdp(1,2),r2,tt2)
      the=theta(i)
      ttot(i)=tt2*(the-210.)/60.+tt1*(270.-the)/60.
      go to 204
      end if
c
c      interpolate between lines 2- and 3-
c
      r2=-r(i)
      call speval(nd,x11,y1(1,2),fdp(1,2),r2,tt1)
      call speval(nd,x11,y1(1,3),fdp(1,3),r2,tt2)
      the=theta(i)
      ttot(i)=tt2*(the-270.)/60.+tt1*(330.-the)/60.
  204 diff(i)=ttot(i)-press(i)
      rdiff(i)=diff(i)/press(i)
      sum=sum + diff(i)
      rsum=rsum + rdiff(i)
      var=var + (abs(avg-diff(i)))**2
      rvar=rvar + (abs(ravg-rdiff(i)))**2
      write(6,150) i,nolc(i),r(i),theta(i),ttot(i),press(i),
     1diff(i),rdiff(i)
  150 format(1x,2(i4,2x),2(f9.3,2x),3(f9.2,2x),f7.3)
  205 continue
      write(6,152) sum,var
      write(6,151) rsum,rvar
  151 format(/1x,'Sum of relative errors:',f7.3/
     11x,'Sum squared relative errors:',f7.3)
  152 format(/1x,'Sum of pressure errors:',f9.2,3x,'psia'/
     11x,'Sum squared pressure errors:',f9.2,3x,'psia')
      stop
      end
      subroutine spline(n,x,y,fdp)
      dimension x(8),y(8),a(8),b(8),c(8),r(8),fdp(8)
      alamda=1.
      nm2=n-2
      nm1=n-1
      c(1)=x(2)-x(1)
      do 1 i=2,nm1
      c(i)=x(i+1)-x(i)
      a(i)=c(i-1)
      b(i)=2.*(a(i)+c(i))
      r(i)=6.*((y(i+1)-y(i))/c(i)-(y(i)-y(i-1))/c(i-1))
    1 continue
      b(2)=b(2)+alamda*c(1)
      b(nm1)=b(nm1)+alamda*c(nm1)
      do 2 i=3,nm1
      t=a(i)/b(i-1)
      b(i)=b(i)-t*c(i-1)
      r(i)=r(i)-t*r(i-1)
    2 continue
      fdp(nm1)=r(nm1)/b(nm1)
      do 3 i=2,nm2
      nmi=n-i
      fdp(nmi)=(r(nmi)-c(nmi)*fdp(nmi+1))/b(nmi)
    3 continue
```

```
      fdp(1)=alamda*fdp(2)
      fdp(n)=alamda*fdp(nm1)
      return
      end
      subroutine speval(n,x,y,fdp,xx,f)
      dimension x(8),y(8),fdp(8)
      nm1=n-1
      do 1 i=1,nm1
      if(xx.le.x(i+1)) go to 10
    1 continue
   10 dxm=xx-x(i)
      dxp=x(i+1)-xx
      del=x(i+1)-x(i)
      f=fdp(i)*dxp*(dxp**2/del-del)/6.+fdp(i+1)*dxm*(dxm**2/del-
     1del)/6.+y(i)*dxp/del+y(i+1)*dxm/del
      return
      end
```

APPENDIX B

Derivation of Standard Deviation Equation

This derivation takes the standard equations for the variance of a distribution and converts it to a form that does not require the mean to be known. In this case, the distribution to be characterized is one of differences in measured and calculated plenum pressures.

Definitions:

μ = the mean of the distribution of differences;
σ^2 = the variance of the distribution of differences;
σ = the standard deviation of the distribution of differences;
δ = the difference (absolute or relative) between the interpolated TRAC plenum pressure and the measured plenum pressure at a particular location; and
N = the total number of pressure differences in the distribution.

The standard expressions for mean and variance are as follows:

$$\mu = (\Sigma\delta)/N \quad (1)$$
$$\sigma^2 = [\Sigma(\delta-\mu)^2]/(N-1) \quad (2)$$

Expand Equation (2):

$$\sigma^2 = [\Sigma(\delta^2-2\delta\mu+\mu^2)]/(N-1) \quad (3)$$
$$\sigma^2 = (\Sigma\delta^2-2\mu\Sigma\delta+N\mu^2)/(N-1) \quad (4)$$

Substitute Equation (1) into Equation (4):

$$\sigma^2 = [\Sigma\delta^2-2(\Sigma\delta)^2/N + (\Sigma\delta)^2/N]/(N-1) \quad (5)$$

Rearranging Equation (5) and taking the square root gives the expression for the standard deviation:

$$\sigma = \{[N\Sigma\delta^2-(\Sigma\delta)^2]/[N(N-1)]\}^{0.5} \quad (6)$$

APPENDIX C

"Interp.in" Files for AC Tests H, B, C, D, E, and J

<u>AC Test H</u>

```
 89.32
 88.75
 89.44
 89.64
 89.68
 89.52
 90.13
 90.12
 90.27
 90.63
 90.23
 90.48
 93.92
 93.71
 94.08
 94.07
 93.93
 93.90
100.13
100.02
100.26
100.30
100.08
100.15
   44.88    63.47    77.73    90.39
 35  0.0000  0.0000
```

AC Test B

89.64
89.07
89.75
89.94
90.00
89.83
90.47
90.46
90.61
90.95
90.57
90.82
94.17
93.96
94.33
94.31
94.19
94.16
100.16
100.06
100.29
100.32
100.12
100.18

	44.88	63.47	77.73	90.39
35	0.0000	0.0000		

AC Test C

86.34
85.80
86.44
86.63
86.68
86.52
87.14
87.14
87.27
87.60
87.23
87.47
90.67
90.48
90.83
90.80
90.69
90.66
96.38
96.29
96.50
96.52
96.34
96.40

	44.88		63.47		77.73	90.39
35		0.0000		0.0000		

AC Test D

64.61
65.16
64.56
65.06
65.50
65.16
65.96
64.32
65.85
67.70
68.34
67.86
68.94
64.62
68.76
71.12
72.17
71.35
73.86
65.50
73.60
76.49
77.58
76.78

	44.88	63.47	77.73	90.39
35	0.0000	0.0000		

AC Test E

65.93
64.50
65.34
65.77
65.72
65.20
64.81
66.05
67.82
68.84
67.88
66.47
65.05
69.03
71.53
72.30
71.62
69.13
65.79
74.13
76.84
77.67
76.99
74.03

44.88 63.47 77.73 90.39

35 0.0000 0.0000

AC Test J

65.72
64.22
65.05
65.48
65.44
64.93
64.54
65.78
67.54
68.60
67.62
66.20
64.81
68.85
71.35
72.15
71.46
68.94
65.59
74.15
76.87
77.74
77.04
74.04

	44.88	63.47	77.73	90.39
35	0.0000	0.0000		

APPENDIX D

"Rtheta.in" File

280	71.042	5.064
161	54.672	4.776
295	57.297	4.402
177	57.297	3.976
148	50.478	5.479
71	32.078	5.046
83	38.974	4.033
313	61.025	3.550
263	67.506	5.916
182	42.579	3.583
26	14.000	4.189
15	24.249	5.760
135	52.849	6.168
34	21.000	3.142
1	7.000	1.047
6	7.000	2.094
59	30.512	0.409
129	50.478	0.243
248	71.042	0.172
243	67.506	0.367
198	61.025	2.733
106	32.078	1.904
47	30.512	1.456
124	49.000	0.667
238	67.506	0.680
115	56.000	1.047
110	50.478	1.290
214	50.478	1.852
210	56.000	2.094
230	71.042	0.876
354	73.750	2.012
358	68.942	1.827
221	66.776	1.623
218	67.506	1.415
223	71.042	1.219

APPENDIX E

"Olcpx.in" Files for AC Tests H, B, C, D, E, and J

AC Test H

280	99.70
161	92.52
295	90.13
177	89.43
148	90.82
71	90.05
83	89.11
313	96.33
263	91.63
182	88.33
26	90.04
15	90.05
135	89.25
34	89.75
1	90.51
6	89.77
59	90.34
129	89.90
248	88.23
243	90.93
198	93.96
106	88.13
47	89.42
124	89.12
238	89.60
115	94.89
110	92.26
214	87.68
210	86.75
230	100.40
354	88.73
358	88.94
221	92.13
218	94.69
223	101.84

AC Test B

280	100.66
161	93.59
295	91.56
177	90.96
148	92.28
71	91.45
83	90.24
313	97.41
263	94.08
182	89.99
26	91.81
15	91.38
135	90.67
34	90.85
1	91.78
6	91.25
59	91.76
129	91.10
248	89.61
243	92.01
198	94.27
106	89.44
47	90.64
124	90.45
238	90.47
115	96.39
110	94.22
214	89.24
210	88.44
230	101.35
354	90.23
358	90.97
221	93.60
218	97.04
223	102.63

AC Test C

280	96.83
161	89.91
295	88.00
177	87.32
148	88.90
71	87.70
83	86.70
313	93.37
263	90.32
182	86.67
26	87.87
15	87.65
135	87.15
34	87.47
1	88.10
6	87.65
59	88.18
129	87.50
248	86.14
243	88.31
198	90.73
106	85.82
47	87.07
124	86.88
238	87.05
115	92.49
110	90.44
214	85.97
210	85.06
230	97.35
354	86.66
358	87.20
221	89.96
218	92.99
223	98.45

AC Test D

280	77.07
161	69.56
295	67.32
177	66.56
148	69.56
71	66.87
83	64.33
313	70.73
263	70.91
182	63.87
26	65.27
15	65.50
135	66.21
34	64.05
1	64.78
6	64.38
59	63.90
129	64.56
248	65.25
243	65.93
198	69.65
106	64.93
47	65.06
124	62.34
238	60.64
115	63.93
110	65.27
214	64.67
210	65.10
230	64.29
354	65.71
358	64.33
221	64.27
218	65.73
223	65.62

AC Test E

280	74.44
161	67.17
295	66.32
177	67.92
148	65.04
71	63.80
83	65.12
313	73.97
263	68.50
182	67.19
26	64.34
15	64.42
135	64.92
34	65.40
1	64.26
6	64.37
59	64.97
129	64.32
248	64.29
243	64.24
198	71.70
106	63.58
47	64.24
124	64.41
238	64.91
115	63.95
110	62.93
214	63.25
210	63.91
230	66.05
354	65.06
358	64.26
221	65.38
218	62.03
223	64.98

AC Test J

280	74.63
161	66.82
295	65.80
177	67.33
148	64.14
71	63.16
83	64.49
313	74.06
263	68.18
182	66.21
26	63.75
15	64.05
135	64.74
34	64.88
1	63.87
6	63.82
59	64.50
129	63.86
248	63.36
243	63.64
198	71.78
106	63.01
47	63.82
124	63.68
238	63.90
115	63.66
110	62.35
214	62.35
210	63.19
230	65.94
354	64.50
358	63.49
221	64.64
218	61.30
223	64.80

APPENDIX F

"Interp.out" Files for AC Tests H, B, C, D, E, and J

AC Test H

The TRAC pressures for the different cells are:

1	89.32
2	88.75
3	89.44
4	89.64
5	89.68
6	89.52
7	90.13
8	90.12
9	90.27
10	90.63
11	90.23
12	90.48
13	93.92
14	93.71
15	94.08
16	94.07
17	93.93
18	93.90
19	100.13
20	100.02
21	100.26
22	100.30
23	100.08
24	100.15

the inner and outer radii are 44.88 63.47 77.73 90.39
The number of assemblies considered is 35
Average residual: 0.000 Average relative residual: 0.000

n	olc	radius	theta	p, interp	p, L data	(I - L)	(I - L)/L
1	280	71.042	290.146	94.07	99.70	-5.63	-0.056
2	161	54.672	273.645	90.31	92.52	-2.21	-0.024
3	295	57.297	252.216	90.77	90.13	0.64	0.007
4	177	57.297	227.808	90.92	89.43	1.49	0.017
5	148	50.478	313.924	90.05	90.82	-0.77	-0.009
6	71	32.078	289.115	89.50	90.05	-0.55	-0.006
7	83	38.974	231.074	89.59	89.11	0.48	0.005
8	313	61.025	203.400	91.61	96.33	-4.72	-0.049
9	263	67.506	338.962	92.95	91.63	1.32	0.014
10	182	42.579	205.291	89.75	88.33	1.42	0.016
11	26	14.000	240.012	89.67	90.04	-0.37	-0.004
12	15	24.249	330.024	89.50	90.05	-0.55	-0.006
13	135	52.849	353.400	90.19	89.25	0.94	0.011
14	34	21.000	180.023	89.56	89.75	-0.19	-0.002
15	1	7.000	59.989	89.35	90.51	-1.16	-0.013
16	6	7.000	119.977	89.37	89.77	-0.40	-0.004
17	59	30.512	23.434	89.19	90.34	-1.15	-0.013
18	129	50.478	13.923	89.82	89.90	-0.08	-0.001
19	248	71.042	9.855	94.07	88.23	5.84	0.066
20	243	67.506	21.028	92.92	90.93	1.99	0.022
21	198	61.025	156.589	91.45	93.96	-2.51	-0.027
22	106	32.078	109.091	88.90	88.13	0.77	0.009
23	47	30.512	83.423	88.76	89.42	-0.66	-0.007
24	124	49.000	38.216	89.58	89.12	0.46	0.005
25	238	67.506	38.961	92.89	89.60	3.29	0.037
26	115	56.000	59.989	90.38	94.89	-4.51	-0.048
27	110	50.478	73.912	89.70	92.26	-2.56	-0.028
28	214	50.478	106.112	89.74	87.68	2.06	0.023
29	210	56.000	119.977	90.45	86.75	3.70	0.043
30	230	71.042	50.191	94.00	100.40	-6.40	-0.064
31	354	73.750	115.279	95.04	88.73	6.31	0.071
32	358	68.942	104.679	93.26	88.94	4.32	0.049
33	221	66.776	92.991	92.55	92.13	0.42	0.005
34	218	67.506	81.074	92.77	94.69	-1.92	-0.020
35	223	71.042	69.844	93.93	101.84	-7.91	-0.078

Sum of pressure errors: -8.81 psia
Sum squared pressure errors: 337.52 psia

Sum of relative errors: -0.059
Sum squared relative errors: 0.038

AC Test B

The TRAC pressures for the different cells are:

1	89.64
2	89.07
3	89.75
4	89.94
5	90.00
6	89.83
7	90.47
8	90.46
9	90.61
10	90.95
11	90.57
12	90.82
13	94.17
14	93.96
15	94.33
16	94.31
17	94.19
18	94.16
19	100.16
20	100.06
21	100.29
22	100.32
23	100.12
24	100.18

the inner and outer radii are 44.88 63.47 77.73 90.39
The number of assemblies considered is 35
Average residual: 0.000 Average relative residual: 0.000

n	olc	radius	theta	p, interp	p, L data	(I - L)	(I - L)/L
1	280	71.042	290.146	94.33	100.66	-6.33	-0.063
2	161	54.672	273.645	90.64	93.59	-2.95	-0.031
3	295	57.297	252.216	91.10	91.56	-0.46	-0.005
4	177	57.297	227.808	91.24	90.96	0.28	0.003
5	148	50.478	313.924	90.39	92.28	-1.89	-0.020
6	71	32.078	289.115	89.83	91.45	-1.62	-0.018
7	83	38.974	231.074	89.92	90.24	-0.32	-0.004
8	313	61.025	203.400	91.92	97.41	-5.49	-0.056
9	263	67.506	338.962	93.23	94.08	-0.85	-0.009
10	182	42.579	205.291	90.08	89.99	0.09	0.001
11	26	14.000	240.012	89.97	91.81	-1.84	-0.020
12	15	24.249	330.024	89.82	91.38	-1.56	-0.017
13	135	52.849	353.400	90.53	90.67	-0.14	-0.001
14	34	21.000	180.023	89.86	90.85	-0.99	-0.011
15	1	7.000	59.989	89.66	91.78	-2.12	-0.023
16	6	7.000	119.977	89.68	91.25	-1.57	-0.017
17	59	30.512	23.434	89.52	91.76	-2.24	-0.024
18	129	50.478	13.923	90.17	91.10	-0.93	-0.010
19	248	71.042	9.855	94.32	89.61	4.71	0.053
20	243	67.506	21.028	93.20	92.01	1.19	0.013
21	198	61.025	156.589	91.77	94.27	-2.50	-0.027
22	106	32.078	109.091	89.23	89.44	-0.21	-0.002
23	47	30.512	83.423	89.09	90.64	-1.55	-0.017
24	124	49.000	38.216	89.93	90.45	-0.52	-0.006
25	238	67.506	38.961	93.17	90.47	2.70	0.030
26	115	56.000	59.989	90.71	96.39	-5.68	-0.059
27	110	50.478	73.912	90.05	94.22	-4.17	-0.044
28	214	50.478	106.112	90.08	89.24	0.84	0.009
29	210	56.000	119.977	90.78	88.44	2.34	0.026
30	230	71.042	50.191	94.25	101.35	-7.10	-0.070
31	354	73.750	115.279	95.25	90.23	5.02	0.056
32	358	68.942	104.679	93.52	90.97	2.55	0.028
33	221	66.776	92.991	92.84	93.60	-0.76	-0.008
34	218	67.506	81.074	93.05	97.04	-3.99	-0.041
35	223	71.042	69.844	94.18	102.63	-8.45	-0.082

Sum of pressure errors: -46.53 psia
Sum squared pressure errors: 371.78 psia

Sum of relative errors: -0.469
Sum squared relative errors: 0.040

AC Test C

The TRAC pressures for the different cells are:

1	86.34
2	85.80
3	86.44
4	86.63
5	86.68
6	86.52
7	87.14
8	87.14
9	87.27
10	87.60
11	87.23
12	87.47
13	90.67
14	90.48
15	90.83
16	90.80
17	90.69
18	90.66
19	96.38
20	96.29
21	96.50
22	96.52
23	96.34
24	96.40

the inner and outer radii are 44.88 63.47 77.73 90.39
The number of assemblies considered is 35
Average residual: 0.000 Average relative residual: 0.000

n	olc	radius	theta	p, interp	p, L data	(I - L)	(I - L)/L
1	280	71.042	290.146	90.82	96.83	-6.01	-0.062
2	161	54.672	273.645	87.30	89.91	-2.61	-0.029
3	295	57.297	252.216	87.74	88.00	-0.26	-0.003
4	177	57.297	227.808	87.87	87.32	0.55	0.006
5	148	50.478	313.924	87.06	88.90	-1.84	-0.021
6	71	32.078	289.115	86.52	87.70	-1.18	-0.014
7	83	38.974	231.074	86.61	86.70	-0.09	-0.001
8	313	61.025	203.400	88.52	93.37	-4.85	-0.052
9	263	67.506	338.962	89.78	90.32	-0.54	-0.006
10	182	42.579	205.291	86.76	86.67	0.09	0.001
11	26	14.000	240.012	86.66	87.87	-1.21	-0.014
12	15	24.249	330.024	86.51	87.65	-1.14	-0.013
13	135	52.849	353.400	87.20	87.15	0.05	0.001
14	34	21.000	180.023	86.55	87.47	-0.92	-0.011
15	1	7.000	59.989	86.35	88.10	-1.75	-0.020
16	6	7.000	119.977	86.37	87.65	-1.28	-0.015
17	59	30.512	23.434	86.23	88.18	-1.95	-0.022
18	129	50.478	13.923	86.85	87.50	-0.65	-0.007
19	248	71.042	9.855	90.81	86.14	4.67	0.054
20	243	67.506	21.028	89.75	88.31	1.44	0.016
21	198	61.025	156.589	88.38	90.73	-2.35	-0.026
22	106	32.078	109.091	85.95	85.82	0.13	0.002
23	47	30.512	83.423	85.82	87.07	-1.25	-0.014
24	124	49.000	38.216	86.62	86.88	-0.26	-0.003
25	238	67.506	38.961	89.72	87.05	2.67	0.031
26	115	56.000	59.989	87.38	92.49	-5.11	-0.055
27	110	50.478	73.912	86.74	90.44	-3.70	-0.041
28	214	50.478	106.112	86.77	85.97	0.80	0.009
29	210	56.000	119.977	87.44	85.06	2.38	0.028
30	230	71.042	50.191	90.75	97.35	-6.60	-0.068
31	354	73.750	115.279	91.71	86.66	5.05	0.058
32	358	68.942	104.679	90.06	87.20	2.86	0.033
33	221	66.776	92.991	89.41	89.96	-0.55	-0.006
34	218	67.506	81.074	89.61	92.99	-3.38	-0.036
35	223	71.042	69.844	90.69	98.45	-7.76	-0.079

Sum of pressure errors: -36.56 psia
Sum squared pressure errors: 318.06 psia

Sum of relative errors: -0.378
Sum squared relative errors: 0.037

AC Test D

The TRAC pressures for the different cells are:

1	64.61
2	65.16
3	64.56
4	65.06
5	65.50
6	65.16
7	65.96
8	64.32
9	65.85
10	67.70
11	68.34
12	67.86
13	68.94
14	64.62
15	68.76
16	71.12
17	72.17
18	71.35
19	73.86
20	65.50
21	73.60
22	76.49
23	77.58
24	76.78

the inner and outer radii are 44.88 63.47 77.73 90.39
The number of assemblies considered is 35
Average residual: 0.000 Average relative residual: 0.000

n	olc	radius	theta	p, interp	p, L data	(I - L)	(I - L)/L
1	280	71.042	290.146	72.03	77.07	-5.04	-0.065
2	161	54.672	273.645	68.39	69.56	-1.17	-0.017
3	295	57.297	252.216	68.68	67.32	1.36	0.020
4	177	57.297	227.808	68.38	66.56	1.82	0.027
5	148	50.478	313.924	67.46	69.56	-2.10	-0.030
6	71	32.078	289.115	65.84	66.87	-1.03	-0.015
7	83	38.974	231.074	66.17	64.33	1.84	0.029
8	313	61.025	203.400	68.59	70.73	-2.14	-0.030
9	263	67.506	338.962	70.13	70.91	-0.78	-0.011
10	182	42.579	205.291	66.23	63.87	2.36	0.037
11	26	14.000	240.012	65.06	65.27	-0.21	-0.003
12	15	24.249	330.024	65.24	65.50	-0.26	-0.004
13	135	52.849	353.400	66.95	66.21	0.74	0.011
14	34	21.000	180.023	64.78	64.05	0.73	0.011
15	1	7.000	59.989	64.91	64.78	0.13	0.002
16	6	7.000	119.977	64.91	64.38	0.53	0.008
17	59	30.512	23.434	64.79	63.90	0.89	0.014
18	129	50.478	13.923	66.07	64.56	1.51	0.023
19	248	71.042	9.855	69.88	65.25	4.63	0.071
20	243	67.506	21.028	68.50	65.93	2.57	0.039
21	198	61.025	156.589	66.98	69.65	-2.67	-0.038
22	106	32.078	109.091	64.82	64.93	-0.11	-0.002
23	47	30.512	83.423	64.92	65.06	-0.14	-0.002
24	124	49.000	38.216	65.32	62.34	2.98	0.048
25	238	67.506	38.961	67.61	60.64	6.97	0.115
26	115	56.000	59.989	65.24	63.93	1.31	0.021
27	110	50.478	73.912	64.69	65.27	-0.58	-0.009
28	214	50.478	106.112	64.67	64.67	0.00	0.000
29	210	56.000	119.977	65.18	65.10	0.08	0.001
30	230	71.042	50.191	67.57	64.29	3.28	0.051
31	354	73.750	115.279	66.84	65.71	1.13	0.017
32	358	68.942	104.679	65.48	64.33	1.15	0.018
33	221	66.776	92.991	64.64	64.27	0.37	0.006
34	218	67.506	81.074	65.04	65.73	-0.69	-0.010
35	223	71.042	69.844	66.13	65.62	0.51	0.008

Sum of pressure errors: 19.98 psia
Sum squared pressure errors: 165.04 psia

Sum of relative errors: 0.340
Sum squared relative errors: 0.039

AC Test E

The TRAC pressures for the different cells are:

1	65.93
2	64.50
3	65.34
4	65.77
5	65.72
6	65.20
7	64.81
8	66.05
9	67.82
10	68.84
11	67.88
12	66.47
13	65.05
14	69.03
15	71.53
16	72.30
17	71.62
18	69.13
19	65.79
20	74.13
21	76.84
22	77.67
23	76.99
24	74.03

the inner and outer radii are 44.88 63.47 77.73 90.39
The number of assemblies considered is 35
Average residual: 0.000 Average relative residual: 0.000

n	olc	radius	theta	p, interp	p, L data	(I - L)	(I - L)/L
1	280	71.042	290.146	70.92	74.44	-3.52	-0.047
2	161	54.672	273.645	67.87	67.17	0.70	0.010
3	295	57.297	252.216	68.67	66.32	2.35	0.035
4	177	57.297	227.808	69.06	67.92	1.14	0.017
5	148	50.478	313.924	66.49	65.04	1.45	0.022
6	71	32.078	289.115	65.82	63.80	2.02	0.032
7	83	38.974	231.074	66.72	65.12	1.60	0.024
8	313	61.025	203.400	69.90	73.97	-4.07	-0.055
9	263	67.506	338.962	67.88	68.50	-0.62	-0.009
10	182	42.579	205.291	67.22	67.19	0.03	0.000
11	26	14.000	240.012	65.52	64.34	1.18	0.018
12	15	24.249	330.024	65.22	64.42	0.80	0.012
13	135	52.849	353.400	65.76	64.92	0.84	0.013
14	34	21.000	180.023	65.51	65.40	0.11	0.002
15	1	7.000	59.989	65.30	64.26	1.04	0.016
16	6	7.000	119.977	64.90	64.37	0.53	0.008
17	59	30.512	23.434	65.65	64.97	0.68	0.010
18	129	50.478	13.923	65.23	64.32	0.91	0.014
19	248	71.042	9.855	66.47	64.29	2.18	0.034
20	243	67.506	21.028	65.46	64.24	1.22	0.019
21	198	61.025	156.589	69.16	71.70	-2.54	-0.035
22	106	32.078	109.091	64.96	63.58	1.38	0.022
23	47	30.512	83.423	64.70	64.24	0.46	0.007
24	124	49.000	38.216	65.01	64.41	0.60	0.009
25	238	67.506	38.961	65.44	64.91	0.53	0.008
26	115	56.000	59.989	65.53	63.95	1.58	0.025
27	110	50.478	73.912	65.46	62.93	2.53	0.040
28	214	50.478	106.112	66.10	63.25	2.85	0.045
29	210	56.000	119.977	67.19	63.91	3.28	0.051
30	230	71.042	50.191	66.44	66.05	0.39	0.006
31	354	73.750	115.279	71.07	65.06	6.01	0.092
32	358	68.942	104.679	69.19	64.26	4.93	0.077
33	221	66.776	92.991	68.19	65.38	2.81	0.043
34	218	67.506	81.074	67.75	62.03	5.72	0.092
35	223	71.042	69.844	67.78	64.98	2.80	0.043

Sum of pressure errors: 43.87 psia
Sum squared pressure errors: 203.00 psia

Sum of relative errors: 0.703
Sum squared relative errors: 0.047

AC Test J

The TRAC pressures for the different cells are:

1	65.72
2	64.22
3	65.05
4	65.48
5	65.44
6	64.93
7	64.54
8	65.78
9	67.54
10	68.60
11	67.62
12	66.20
13	64.81
14	68.85
15	71.35
16	72.15
17	71.46
18	68.94
19	65.59
20	74.15
21	76.87
22	77.74
23	77.04
24	74.04

the inner and outer radii are 44.88 63.47 77.73 90.39
The number of assemblies considered is 35
Average residual: 0.000 Average relative residual: 0.000

n	olc	radius	theta	p, interp	p, L data	(I - L)	(I - L)/L
1	280	71.042	290.146	70.75	74.63	-3.88	-0.052
2	161	54.672	273.645	67.61	66.82	0.79	0.012
3	295	57.297	252.216	68.43	65.80	2.63	0.040
4	177	57.297	227.808	68.82	67.33	1.49	0.022
5	148	50.478	313.924	66.21	64.14	2.07	0.032
6	71	32.078	289.115	65.54	63.16	2.38	0.038
7	83	38.974	231.074	66.44	64.49	1.95	0.030
8	313	61.025	203.400	69.68	74.06	-4.38	-0.059
9	263	67.506	338.962	67.66	68.18	-0.52	-0.008
10	182	42.579	205.291	66.95	66.21	0.74	0.011
11	26	14.000	240.012	65.24	63.75	1.49	0.023
12	15	24.249	330.024	64.95	64.05	0.90	0.014
13	135	52.849	353.400	65.49	64.74	0.75	0.012
14	34	21.000	180.023	65.23	64.88	0.35	0.005
15	1	7.000	59.989	65.05	63.87	1.18	0.019
16	6	7.000	119.977	64.62	63.82	0.80	0.013
17	59	30.512	23.434	65.42	64.50	0.92	0.014
18	129	50.478	13.923	64.96	63.86	1.10	0.017
19	248	71.042	9.855	66.25	63.36	2.89	0.046
20	243	67.506	21.028	65.22	63.64	1.58	0.025
21	198	61.025	156.589	68.92	71.78	-2.86	-0.040
22	106	32.078	109.091	64.67	63.01	1.66	0.026
23	47	30.512	83.423	64.42	63.82	0.60	0.009
24	124	49.000	38.216	64.74	63.68	1.06	0.017
25	238	67.506	38.961	65.19	63.90	1.29	0.020
26	115	56.000	59.989	65.26	63.66	1.60	0.025
27	110	50.478	73.912	65.18	62.35	2.83	0.045
28	214	50.478	106.112	65.82	62.35	3.47	0.056
29	210	56.000	119.977	66.92	63.19	3.73	0.059
30	230	71.042	50.191	66.23	65.94	0.29	0.004
31	354	73.750	115.279	70.93	64.50	6.43	0.100
32	358	68.942	104.679	68.99	63.49	5.50	0.087
33	221	66.776	92.991	67.98	64.64	3.34	0.052
34	218	67.506	81.074	67.54	61.30	6.24	0.102
35	223	71.042	69.844	67.58	64.80	2.78	0.043

Sum of pressure errors: 53.16 psia
Sum squared pressure errors: 257.28 psia

Sum of relative errors: 0.858
Sum squared relative errors: 0.061

END

DATE
FILMED
8 / 11 / 92