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2CAN060502

June 11, 2005

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

SUBJECT: ANO-2 Cycle 18 Startup Report
Arkansas Nuclear One, Unit 2
Docket No. 50-368
License No. NPF-6

Dear Sir or Madam:

Attached is the Arkansas Nuclear One, Unit 2 (ANO-2) Cycle 18 Startup report pursuant to ANO-2 Technical Requirements Manual Section 6.9.1.1. This section requires submittal of such a report following installation of fuel that has a different design. Cycle 18 is the first cycle at ANO-2 to be refueled with zirconium diboride (ZrB_2) as the burnable poison in the fuel assemblies. The unit achieved criticality on April 10, 2005, following the 2R17 refueling outage. Should you have any questions, please contact David Bice at 479-858-5338.

Sincerely,

DEJ/dbb

Attachment: ANO-2 Cycle 18 Startup Report

IE26

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Attachment to

2CAN060502

ANO-2 Cycle 18 Startup Report

ANO-2 Cycle 18 Startup Report

ABSTRACT

This report summarizes the results of the startup physics test program. Results of these activities verify the Cycle 18 nuclear design calculations and demonstrate adequate conservatism in core performance with respect to the Arkansas Nuclear One, Unit 2 (ANO-2) Safety Analysis Report (SAR), Technical Specifications (TSs), Technical Requirements Manual (TRM), and the Cycle 18 Reload Safety Evaluation. Cycle 18 achieved initial criticality on April 10, 2005.

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1.0 INTRODUCTION

This report summarizes the results of the ANO-2 Cycle 18 startup physics test program. The startup physics test program consisted of a series of tests performed at various stages, including prior to initial criticality, low power physics testing (LPPT), and during power ascension.

The objective of these tests were (a) to demonstrate that during reactor operation the measured core physics parameters would be within the assumptions of the SAR accident analyses (Reference 7.1), within the limitations of the plant TSs (Reference 7.2), and within the limitations of the Cycle 18 reload safety evaluation (References 7.3 and 7.4), (b) to verify the nuclear design calculations, and (c) to provide the bases for validation of database and addressable constants in the core protection calculators (CPCs) and the core operating limit supervisory system (COLSS). *Specifically, shape annealing matrix (SAM) elements installed in each* channel of the CPCs are determined and the all rods out (ARO) planar radial peaking factor (RPF) is verified and conservatively adjusted in the CPCs and COLSS during power ascension.

Section 2 of this report provides a brief description of the reactor core. Section 3 discusses the pre-critical control element assembly (CEA) drop time test. In section 4, initial criticality and the low power physics tests are presented. Section 5 describes the power ascension tests, which include a reactor coolant system (RCS) flow rate determination, core power distribution measurements, the SAM determination, planar RPF verification, azimuthal power tilt verification, and a temperature reactivity coefficient measurement. The conclusions of this report are given in Section 6. Section 7 lists the references cited in this report.

2.0 REACTOR CORE DESCRIPTION

The design of the ANO-2 Cycle 18 core includes using zirconium diboride (ZrB_2) as an integral fuel burnable absorber (IFBA). Zirconium diboride pellet coating replaces Erbia as the poison in the fuel assemblies. The ZrB_2 rods have an eight (8) inch axial blanket (e.g., poison cutback) consisting of fully enriched annular pellets. The term "fully enriched" means that the annular pellets have the same enrichment as the solid pellets in that rod. All fresh rods utilize ZIRLO fuel cladding material.

The 84 new fuel assemblies designated as Batch X were loaded with fuel rod enrichments as high as 4.21 w/o U-235 and a nominal B-10 loading of 3.14 mg/in in the ZrB_2 IFBA rods. In addition, 5 Batch U and 88 Batch W assemblies were loaded into the Cycle 18 core (Reference 7.3).

The mechanical design bases have not changed since the original fuel design. The designs and manufacturing processes for the grid cages and the upper end fitting were modified for the Batch X fuel bundle assembly design. This is a manufacturing process change and does not impact the mechanical design bases. All Batch X fuel rods use ZIRLO cladding material instead of Zircaloy-4 cladding (Reference 7.3).

2.1 Loading Pattern and Assembly Burnup

Attached Figures 1 through 4, taken from the ANO-2 Cycle 18 Reload Analysis Report (RAR), give the loading pattern and beginning of cycle (BOC) assembly average design burnups.

2.2 In-core Instrumentation (ICI) Locations

The ICI design consists of 42 fixed ICI assemblies inserted into the center guide tube of 42 fuel assemblies. ICI locations are identified in Figure 5. Each ICI assembly contains 5 self-powered rhodium detectors and one core exit thermocouple (CET). None of the 42 ICI assemblies were replaced during 2R17 prior to the Cycle 18 startup. During power ascension, at least 190 of 210 possible detectors were operable.

2.3 Verification of Core Loading

After the reactor core was loaded, core mapping was performed using an underwater television camera and monitor. This core mapping operation verified that the core was correctly loaded. Core mapping was performed by the reactor engineering organization. The core mapping operation included a comparison of the identification numbers on the fuel assemblies, CEA configuration, and fuel assembly orientation against the design configuration.

3.0 PRECRITICAL TESTS

3.1 Control Element Assembly (CEA) Drop Time Testing

This testing verifies that the drop time of all CEAs are in accordance with the surveillance requirements of ANO-2 TS 3.1.3.4. The method used by this test involves special control element assembly calculator (CEAC) software (CEA Drop Time Test, or CDTT software), which allows the measurement of all CEAs simultaneously. After the establishment of hot, full flow RCS conditions (i.e., greater than 525 °F with four reactor coolant pumps operating) and with the RCS boron concentration at a sufficient level to keep the reactor adequately shutdown during the test, all CEAs are withdrawn to the full out position. The CDTT software is then loaded into one of the CEAC channels and initiated. The software transmits a large penalty factor to each of the CPC channels, thereby initiating a reactor trip. The CDTT software records CEA positions every 50 milliseconds (msec) during the drop. Data output from the CDTT software is adjusted for holding coil delay time and used to verify that drop time limits are satisfied.

From TS 3.1.3.4, the maximum individual and average 90% insertion times required for all CEAs are:

Individual Limit	=	3.5 seconds
Average Limit	=	3.2 seconds

A 50 msec allowance is used for measurement uncertainty.

All CEAs passed a limit of 3.45 seconds (TS limit minus 0.05 seconds). The slowest drop time was 3.350 seconds (CEA #80). The average CEA drop time was 2.956 seconds, which passed an average limit of 3.15 seconds (TS average limit minus 0.05 seconds).

In addition, ANO-2 utilizes the CEA drop time testing data as a CEA coupling check. If measured and expected drop times differ by more than 0.1 seconds for a CEA, then an additional review of drop characteristics (i.e., slowdown in the dashpot region, presence or absence of "bounce") is performed to determine the condition of the CEA. Expected drop times are obtained from historical data. If CEAs remain suspect after this further review, additional CEA coupling data may be taken during low power physics testing by exercising the suspect CEAs individually and monitoring the reactivity trace behavior on a reactimeter. This provides a final confirmation that any suspect CEA is coupled. For Cycle 18, all CEAs were determined to be coupled based on meeting expected drop times or review of drop characteristics.

4.0 LOW POWER PHYSICS TESTING

4.1 Initial Criticality

ANO-2 normally withdraws CEAs to criticality. Shutdown Banks A and B are withdrawn and the RCS is then diluted to an estimated critical boron concentration corresponding to the desired critical CEA position. For Cycle 18, the estimated critical position was Group P at 138.4 inches withdrawn based on a measured RCS boron concentration of 1541 parts-per-million (ppm) prior to starting the approach to criticality. For Cycle 18, actual criticality was achieved with Group P at 100 inches withdrawn.

4.2 Critical Boron Concentration

This test procedure specifies that the controlling group (Group P) be withdrawn from near fully withdrawn (< 75 pcm inserted reactivity) to fully withdrawn. As a pre-requisite, multiple RCS boron samples are obtained and compared to average to verify reactivity equilibrium. The residual worth of Group P is determined using a reactimeter. The average RCS boron sample is corrected for the residual Group P worth to determine the ARO critical boron concentration (CBC). For Cycle 18, the ARO CBC was predicted to be 1575.0 ppm (per Westinghouse, fuel vendor). The measured ARO CBC was 1591.8 ppm. The acceptance criteria is ± 100 ppm difference between measured and predicted. Therefore, the -16.8 ppm difference for Cycle 18 was well within the acceptance criteria limit.

Using the measured ARO CBC, a shutdown margin calculation is performed assuming CEAs at the Zero Power Insertion Limits (ZPIL). The calculated shutdown margin is verified to be within the TS 3.1.1.1 / Core Operating Limits Report (COLR) limit. For Cycle 18, the calculated shutdown margin assuming CEAs at the ZPIL is -6.529 %Δk/k. This satisfies the TS 3.1.1.1 / COLR requirement to have at least -5.5 %Δk/k shutdown margin.

4.3 CEA Reactivity Worth

ANO-2 utilizes the CEA exchange method to determine the CEA reactivity worth. For Cycle 18, Shutdown Bank B was used as the Reference Group. The worth of the Reference Group is obtained by exchanging CEA insertion with dilution of the RCS at a continuous dilution rate of approximately 88 gpm. This provides both a total worth and an integral worth curve for the Reference Group. The measured worth of Bank B was 1708.98 pcm versus a predicted worth of 1793.90 pcm. The acceptance criteria is ± 10%. Therefore, the 5.0% difference for Cycle 18 was well within the acceptance criteria.

The remaining CEA banks (or groups) are combined into test groups. These test groups are exchanged with the Reference Group. The final position of the Reference Group with the test group fully inserted and the Reference Group integral worth curve are used to determine the test group worth. For Cycle 18, the four test groups were Banks 2+6, Banks P+4, Banks A+5, and Banks 1+3. The results are listed below in Table 4.3-1. All test groups were well within the acceptance criteria limits.

The total measured CEA worth was 5893.62 pcm versus a total predicted worth of 6067.90 pcm. The acceptance criterion for total CEA worth is ± 10%. Therefore, the 2.96% difference for Cycle 18 was well within the acceptance criteria limit.

TABLE 4.3-1

Test Group	Measured pcm	Predicted pcm	Acceptance Criteria	%(P-M)/M
Banks 2+6	955.72	984.10	± 15%	2.97
Banks P+4	967.61	1022.20	± 15%	5.64
Banks A+5	1128.50	1127.60	± 15%	-0.08
Banks 1+3	1132.81	1140.10	± 15%	0.64

4.4 <u>Temperature Reactivity Coefficient</u>

The isothermal temperature coefficient (ITC) is measured at approximately the ARO configuration. The average RCS temperature is varied by first increasing and then decreasing temperature by about 5 °F. The change in reactivity is determined using the reactimeter. The acceptance criterion states that the measured value shall not differ from the predicted value by more than $\pm 0.3 \times 10^{-2}$ %Δk/k/°F.

The moderator temperature coefficient (MTC) of reactivity is calculated in conjunction with the ITC measurement. After the ITC has been measured, a predicted value of fuel temperature coefficient (FTC) of reactivity is subtracted to obtain the MTC. The MTC value must be less positive than $+ 0.5 \times 10^{-2}$ %Δk/k/°F when power is ≤ 70% and less positive than 0.0 %Δk/k/°F when power is > 70% (Reference 7.2). The MTC must also be within the limits of the COLR for the current cycle (Reference 7.4). The measured MTC shall be extrapolated as necessary for comparison with the COLR. The extrapolated value shall be within the limits of the COLR for the current cycle.

For Cycle 18, the zero power MTC positive limit is $+ 0.50 \times 10^{-2}$ %Δk/k/°F which decreases linearly with power to $+ 0.05 \times 10^{-2}$ %Δk/k/°F at 50% power. The limit decreases linearly with power to 0.0×10^{-2} %Δk/k/°F at 60% power. At 100% power, the MTC upper limit is $- 0.2 \times 10^{-2}$ %Δk/k/°F. The lower MTC limit (i.e., most negative) for all power levels is $- 3.8 \times 10^{-2}$ %Δk/k/°F (Reference 7.4).

During low power physics testing for Cycle 18, the measured ITC was $- 0.2940 \times 10^{-2}$ %Δk/k/°F versus a predicted ITC value of $- 0.2903 \times 10^{-2}$ %Δk/k/°F. Therefore, the 0.0037×10^{-2} %Δk/k/°F difference was well within the $\pm 0.3 \times 10^{-2}$ %Δk/k/°F acceptance criteria limit.

The measured MTC at zero power was extrapolated to 50% power in order to compare to the COLR limit. The measured MTC is linearly extrapolated using predicted MTCs at zero and 100% power. The extrapolated MTC at 50% power was - 0.8886 x 10^{-2} %Δk/k/°F versus an upper (or positive) COLR limit of + 0.05 x 10^{-2} %Δk/k/°F at 50% power. The measured MTC at zero power was extrapolated to 100% power to compare to the COLR limit. The extrapolated MTC at 100% power was - 1.6531 x 10^{-2} %Δk/k/°F versus an upper (or positive) COLR limit of - 0.2 x 10^{-2} %Δk/k/°F and a negative COLR limit of - 3.8 x 10^{-2} %Δk/k/°F at 100% power. Therefore, the extrapolated MTC was in compliance with the COLR limits.

5.0 POWER ASCENSION TESTING

5.1 Reactor Coolant System (RCS) Flow Rate

At the 65% power test plateau, the RCS flow rate was determined by calorimetric methods at steady state conditions in accordance with ANO-2 TS Table 4.3-1, Item 10, Note 8. The acceptance criterion requires the measured RCS flow rate to be at least 3% greater than the design flow rate of 120.4 x 10^6 lbm/hr to account for measurement uncertainties. The RCS flow rate determined calorimetrically was 6.58% greater than the required design flow rate, which satisfies the acceptance criteria for Cycle 18. The COLSS & CPC calculated RCS flow rates were verified to be conservative with respect to the calorimetric flow rate and the CPCs were verified conservative with respect to COLSS. No adjustments to COLSS and CPC calculated flow were made.

5.2 Core Power Distribution

5.2.1 29% Power Test Plateau Results

Core power distribution data using fixed in-core neutron detectors is used to verify proper core loading and consistency between as-built and engineering design models. The first power distribution measurement is performed after the turbine is synchronized and prior to exceeding 30% power. The objective of this measurement is primarily to identify any fuel misloading that results in asymmetries or deviations from the reactor physics design. Because of the decreased signal-to-noise ratio at low powers and the absence of xenon stability requirements, radial and azimuthal symmetry criteria are emphasized, whereas pointwise absolute statistical acceptance criteria are relaxed. A core power distribution map at 29% power is given in Figure 6. The acceptance criteria at 29% follow:

a. For a predicted relative power density (RPD) < 0.9, the measured and predicted relative power density values shall agree within ± 0.1 RPD units.

b. For a predicted RPD ≥ 0.9, the measured and predicted RPD values shall agree within ± 10%.

c. The power in each operable detector shall be within ± 10% of the average power in its symmetric detector group.

d. The vector tilt shall be less than 3%.

The acceptance criteria stated in a, b, and c above were met for all 177 locations and all operable detectors (195 operable out of a possible 210). From Figure 6, the maximum percent difference for a predicted RPD ≥ 0.9 was -3.96% (predicted RPD of 1.261 versus measured RPD of 1.211). The largest percent difference for an operable in-core detector relative to the average power in its symmetric group was 9.13%. The vector tilt was measured to be 2.13%; therefore, the acceptance criterion stated in item d above was met.

5.2.2 65% Power Test Plateau Results

At the intermediate power plateau of approximately 65% power, a core power distribution analysis is performed to again verify proper fuel loading and consistency with design predictions. The acceptance criteria at the intermediate power analysis follow:

a. The measured radial power distribution is compared to the predicted power distribution by calculating the root mean square (RMS) deviation from predictions of the RPD for each of the 177 fuel assemblies. This RMS error may not exceed 5%.

b. The measured radial power distribution is additionally compared to the predicted power distribution using a box-by-box comparison of the RPD for each of the 177 fuel assemblies. For a predicted RPD ≥ 0.9, the measured and predicted RPD values shall agree within ± 10%.

c. For a predicted RPD < 0.9, the measured and predicted RPD values shall agree within ± 15%.

d. The measured axial power distribution is also compared to the predicted axial power distribution. The acceptance criterion states the RMS error between the measured axial power distribution and the predicted axial power distribution shall not exceed 5%.

e. The measured values of total planar RPF (F_{xy}), total integrated RPF (F_r), core average axial peak (F_z), and 3-D power peak (F_q) are compared to predicted values.. The acceptance criteria state that the measured values:

F_{xy}, F_r, F_z, F_q shall be within ± 10% of the predicted values, and that COLSS and CPC constants shall be adjusted to appropriately reflect the measured values.

All of the acceptance criteria stated in a through e above were met for Cycle 18.

TABLE 5.2.2-1

PEAKING PARAMETER COMPARISON			
PARAMETER	MEASURED	PREDICTED	% DIFFERENCE*
F_{xy}	1.5551	1.4800	5.07
F_r	1.4263	1.4100	1.15
F_z	1.1395	1.1100	2.66
F_q	1.6446	1.6000	2.79

* % Difference = %(M-P)/P obtained from GETARP output (Figure 7)

Calculated RMS values were:

RADIAL = 2.0236
AXIAL = 4.0553

A RPD map for the 65% power test plateau is given in Figure 7. The maximum percent difference for a predicted RPD ≥ 0.9 was 4.00% (predicted RPD of 1.160 versus measured RPD of 1.206).

5.2.3 <u>100% Power Test Plateau Results</u>

The final core power distribution analysis is performed with equilibrium xenon at approximately 100% power. At this plateau, axial and radial power distributions are compared to design predictions as a final verification that the core is operating in a manner consistent with its design within the associated design uncertainties. The acceptance criteria are the same as those for the intermediate power distribution analysis stated in 5.2.2.a through 5.2.2.e above. The acceptance criteria stated in 5.2.2.a through 5.2.2.e for the 100% power test plateau were met for Cycle 18.

The measured F_q was 10.11% greater than predictions. Per Section 4.5.4 of Reference 7.1, an evaluation of this condition was performed by the fuel vendor. The evaluation concluded that the applicable neutronics model, as well as the safety and setpoints analyses for the cycle, remained valid with the larger than normal F_q deviation. This evaluation was presented to the On-Site Safety Review Committee (OSRC). The OSRC concurred with the results of the evaluation.

TABLE 5.2.3-1

PEAKING PARAMETER COMPARISON			
PARAMETER	MEASURED	PREDICTED	% DIFFERENCE*
F_{xy}	1.5244	1.4700	3.70
F_r	1.4078	1.3900	1.28
F_z	1.1053	1.0700	3.30
F_q	1.7067	1.5500	10.11

* % Difference = %(M-P)/P obtained from GETARP output (Figure 8)

Calculated RMS values were:

RADIAL = 2.3774
AXIAL = 4.7633

A relative power density (RPD) map for the 100% power test plateau is given in Figure 8. The maximum % difference for a predicted RPD ≥ 0.9 was 4.99% (predicted RPD of 1.195 versus measured RPD of 1.255).

5.3 Shape Annealing Matrix (SAM) and Boundary Point Power Correlation Coefficient (BPPCC) Measurement

The CPCs, part of the reactor protection system, use excore neutron flux detector signals to infer the axial distribution of reactor power. The algorithm, which infers the core power distribution from the excore signals, includes an adjustment for the non-uniform transport of neutrons between the core and the excore detectors. This adjustment is provided by the SAM. The ANO-2 TSs require measurement and installation of appropriate SAM elements and associated BPPCCs after each refueling or verification of cycle independent SAM (CISAM) elements for each channel of the CPCs prior to exceeding 70% power. For Cycle 18, new SAM and BPPCC elements were measured.

There were minor complications with the SAM measurement. Specifically, the test matrix values for some of the CPC channels were not within acceptance criteria. The primary purpose of comparing a test matrix value (TMV) to acceptance criteria is to identify inconsistencies in data used to calculate the SAM and BPPCC elements. The ultimate criteria for judging the acceptability of SAM and BPPCC elements is the criteria on RMS error, which was satisfied for all four CPC channels at 65% full power. The TMV acceptance criterion was based on early analyses (circa 1975) of the sensitivity of CPC power measurement uncertainties to varying TMVs. In accordance with Section 4.5.4 of Reference 7.1, an evaluation of the failure to satisfy the TMV criteria was performed with the assistance of the fuel vendor. The evaluation concluded that the acceptance criteria for the TMV should be revised and that the measured SAM and BPPCC elements were acceptable as long as an additional penalty was applied to CPC addressable uncertainty constants BERR1 and BERR3 (power measurement uncertainty factors used in the Departure from Nucleate Boiling Ratio and Local Power Density calculations, respectively). The evaluation also recommended raising power to approximately 90% while collecting additional data for further evaluation. The evaluation was presented to the OSRC and they concurred with the resolution. The SAM elements and BPPCCs were installed and power was raised from ~65% to 90%. Following power ascension to 90%, further evaluations concluded that the additional penalties applied to CPC addressable constants BERR1 and BERR3 were no longer necessary. This further evaluation was also presented to the OSRC and concurred with. The additional penalties applied to BERR1 and BERR3 were subsequently removed.

5.4 Planar Radial Peaking Factor (RPF) Verification

At the 65% power test plateau, the RPF for the ARO configuration was measured using in-core detector data and the CECOR computer code. The measured ARO F_{xy} was 1.5577. The planar RPF multiplier corresponding to the ARO condition in CPCs (ARM1) addressable constant and the similar addressable constant (AB1(01)) in COLSS were appropriately and conservatively adjusted as a result of this measurement prior to the plant increasing power above 70%. For Cycle 18, adjustments for other CEA configurations were not required.

For ANO-2, the CEA shadowing factors are not measured. The CPC database and addressable constants include allowances for using predicted CEA shadowing factors.

5.5 Temperature Reactivity Coefficient

A moderator and isothermal temperature coefficient measurement was performed at 100%. During the ITC and MTC measurement, turbine load is used to increase RCS average temperature, which decreases reactor power, and then to decrease RCS average temperature, which increases reactor power. This manipulation yields a ratio of RCS temperature change to reactor power change. Using a predicted power coefficient (PC) with the measured average ratio, an ITC is inferred. Using a predicted FTC with the inferred ITC yields an MTC.

Acceptance criteria state that the difference between the predicted and inferred ITC shall be less than 0.3×10^{-4} Δk/k/°F. For Cycle 18, the MTC shall be less negative than -3.8×10^{-4} Δk/k/°F but less positive than the curve in the Cycle 18 COLR.

For Cycle 18, the ITC and MTC passed the acceptance criteria. The measured ITC was -1.20×10^{-4} Δk/k/°F versus a predicted ITC of -1.34×10^{-4} Δk/k/°F. The difference was 0.14×10^{-4} Δk/k/°F which was within the ± 0.3 acceptance criteria. The measured MTC was -1.04×10^{-4} Δk/k/°F and within COLR limits.

In addition, the measured MTC was extrapolated to 100% power and predicted peak boron concentration to verify the MTC remains less than 0.0 Δk/k/°F and within COLR limits. The extrapolated value is -0.89×10^{-4} Δk/k/°F. For Cycle 18 only, the MTC will be measured at the peak boron concentration to confirm the predictions.

The measured MTC was also extrapolated using predicted ΔITC/ΔPPM to 100% power and through end of cycle conditions. This extrapolation indicated that the limiting boron concentration for maintaining COLR compliance can not be physically achieved (i.e., negative boron concentration) during the cycle, verifying that the negative MTC limit of -3.8×10^{-4} Δk/k/°F will not be exceeded during Cycle 18.

6.0 CONCLUSIONS

Based upon analysis of the startup physics test results, it is concluded that the measured core parameters verify the Cycle 18 nuclear design calculations and the proper loading of the core. All test values were found to be acceptable with respect to limits and requirements contained within the ANO-2 SAR and TSs. These results include:

- CEA Drop Times
- Critical Boron Concentrations
- CEA Reactivity Worths
- Temperature Reactivity Coefficients (during LPPT and at power)
- RCS Flow Rate by calorimetric measurement
- Core Power Distributions at 29%, 65%, and 100% power test plateaus
- SAM Measurement
- Planar RPF Verification

The above test results demonstrate adequate conservatism in the Cycle 18 core performance with respect to the ANO-2 SAR, TSs, TRM, Cycle 18 COLR, Cycle 18 RAR, and Cycle 18 reload safety evaluations.

7.0 REFERENCES

7.1 ANO-2 Safety Analysis Report (SAR), Section 4.5, Startup Program and Section 15, Accident Analysis

7.2 ANO-2 Technical Specifications

7.3 ANO-2 Cycle 18 Reload Analysis Report (RAR), CALC-A2-NE-2004-000

7.4 ANO-2 Cycle 18 Core Operating Limits Report (COLR), CALC-A2-NE-2004-001

7.5 ANO-2 Procedure 2302.003, Change 011-02-0, Determination of CEA Group Worths by Exchange, 4/10/2005

7.6 ANO-2 Procedure 2302.009, Change 022-00-0, Moderator Temperature Coefficient at Power, 4/28/2005

7.7 ANO-2 Procedure 2302.021, Change 021-00-0, Sequence for Low Power Physics Testing Following Refueling, 4/10/2005

7.8 ANO-2 Procedure 2302.022, Change 013-01-0, Initial Criticality Following Refueling, 4/10/2005

7.9 ANO-2 Procedure 2302.023, Change 009-00-0, Low Power Physics Base Power Level Determination, 4/10/2005

7.10 ANO-2 Procedure 2302.026, Change 012-00-0, Isothermal Temperature Coefficient Measurement, 4/10/2005

7.11 ANO-2 Procedure 2302.028, Change 011-00-0, Determination of Critical Boron Concentration and Inverse Boron Worth, 4/10/2005

7.12 ANO-2 Procedure 2302.034, Change 019-00-0, Power Ascension Testing Controlling Procedure, 5/6/2005

7.13 ANO-2 Procedure 2302.039, Change 012-01-0, Core Power Distribution Following Refueling, 4/12/2005, 4/13/2005 & 4/22/2005

7.14 ANO-2 Procedure 2302.046, Change 008-05-0, CEA Drop Time Test, 4/9/2005

7.15 ANO-2 Procedure 2302.057, Change 003-00-0, RCS Calorimetric Flowrate Calibration Using RCSFLOW Program, 4/13/2005 & 4/18/2005

FIGURE 1

Cycle 18 Core Loading

Assembly Designation	Number of Assemblies	Fuel Rods per Assy (not including ZrB_2 Rods)	Nominal Enrichment (wt% U-235)	ZrB_2 Rods per Assy	Shim Loading (ZrB_2)	Number of Fuel Rods (Including ZrB_2 Rods)	Number of ZrB_2 Rods
X1	16	184 28	4.21 3.81	0 24	– 2x	2944 832	0 384
X2	8	176 12	4.21 3.81	8 40	2x 2x	1472 416	64 320
X3	12	164 12	4.21 3.81	20 40	2x 2x	2208 624	240 480
X4	36	136 0	4.21 3.81	48 52	2x 2x	6624 1872	1728 1872
X5	12	112 0	4.21 3.81	72 52	2x 2x	2208 624	864 624
Total	84					19824	6576

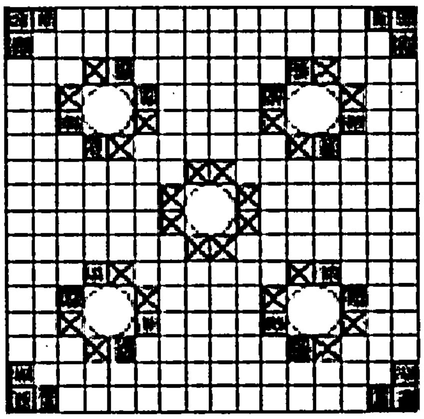
Assembly Designation	Number of Assemblies	Fuel Rods per Assy (not including Erbia Rods)	Nominal Enrichment (wt% U-235)	Erbia Rods per Assy	Shim Loading (wt% Er203)	Number of Fuel Rods (Including Erbia Rods)	Number of Erbia Rods
W1	16	152 60	4.54 4.24	0 24	– 2.1	2432 1344	384
W2	20	152 36	4.54 4.24	0 48	– 2.1	3040 1680	960
W3	8	136 12	4.54 4.24	0 88	– 2.1	10888 800	704
W4	44	128 8	4.54 4.24	0 100	– 2.1	5632 4752	4400
Total	88					20768	6448

U3	4	136 12	4.17 3.87	0 88	– 2.1	5448 400	352
U4	1	128 8	4.17 3.87	0 100	– 2.1	128 108	100
Total	5					1180	452

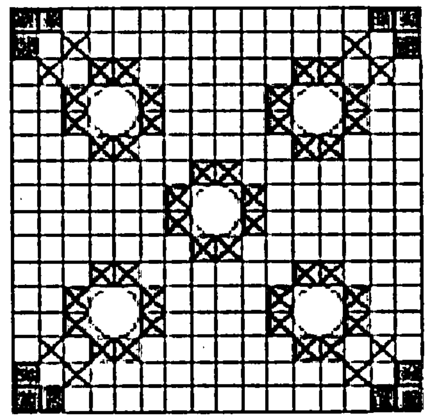
GRAND TOTAL	177		41772	<u>ZrB_2</u> 6576 <u>Erbia</u> 6900

FIGURE 2

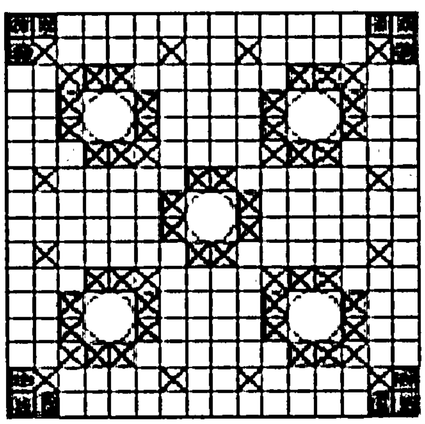
Integral Burnable Poison Shim and Enrichment Zoning Patterns for Batch X Fuel Assemblies



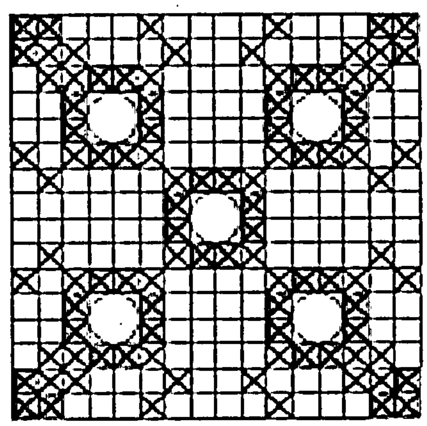
X1 (24 ZrB_2 Pins)



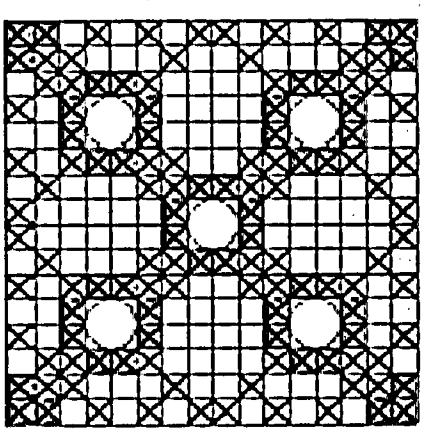
X2 (48 ZrB_2 Pins)



X3 (60 ZrB_2 Pins)



X4 (100 ZrB_2 Pins)



X5 (124 ZrB_2 Pins)

FIGURE 3

Cycle 18 Fuel Management Scheme

nn BB xxx - yyy	nn = Quarter Core Location (Current Cy) BB = Fuel Batch Identifier xxx = Quarter Core Location (Previous Cy) yyy = Number of 90° Rotations

					1 W2 11-2	2 W4 44-0	3 W4 14-2
			4 W2 07-2	5 W4 35-3	6 X1	7 X2	8 X3
		9 U3 04-2	10 X1	11 X3	12 X4	13 W4 20-2	14 X4
	15 W2 38-2	16 X1	17 W1 16-0	18 X4	19 W3 12-2	20 X4	21 W4 26-1
	22 W4 42-1	23 X3	24 X4	25 W4 33-0	26 X5	27 W1 06-3	28 X5
29 W2 23-2	30 X1	31 X4	32 W3 31-2	33 X5	34 W4 18-0	35 X4	36 W1 10-3
37 W4 24-1	38 X2	39 W4 40-2	40 X4	41 W1 30-1	42 X4	43 W2 08-2	44 W4 28-0
45 W4 47-2	46 X3	47 X4	48 W4 26-0	49 X5	50 W1 10-2	51 W4 49-0	52 U4(1) 28-0

(1) U4 assembly reinserted from the spent fuel pool, discharged at the end of Cycle 16

FIGURE 4

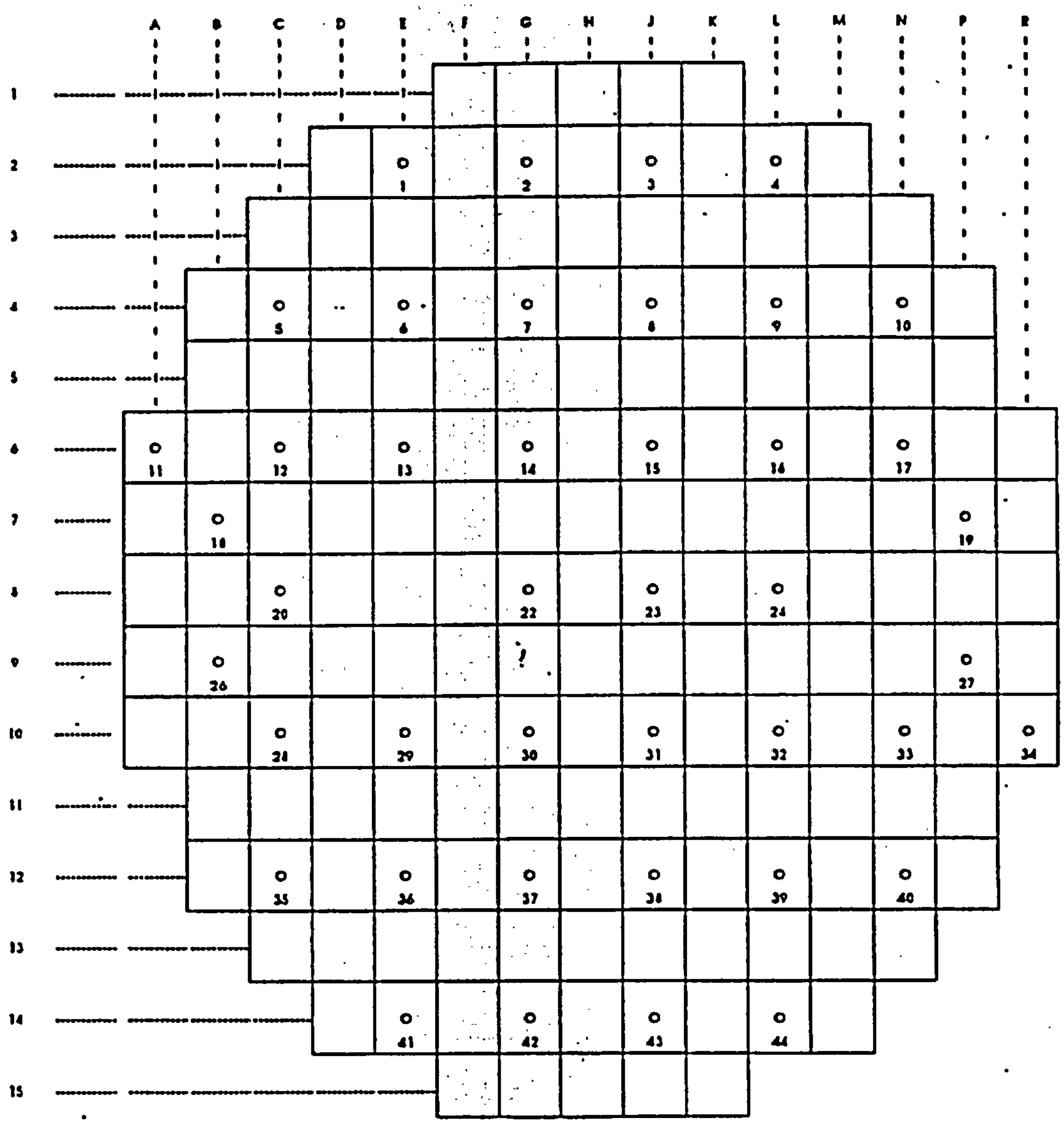
BOC Assembly Average Burnup and Initial Enrichment Distribution

nn BB XXXXX	BB = Batch Identifier for Assembly nn Assembly Average Burnup (MWD/T)						
					1 W2 22500	2 W4 24600	3 W4 24800
			4 W2 21600	5 W4 25100	6 X1 0 4.21 / 3.81	7 X2 0 4.21 / 3.81	8 X3 0 4.21 / 3.81
		9 U3 32600	10 X1 0 4.21 / 3.81	11 X3 0 4.21 / 3.81	12 X4 0 4.21 / 3.81	13 W4 25100	14 X4 0 4.21 / 3.81
	15 W2 21600	16 X1 0 4.21 / 3.81	17 W1 17600	18 X4 0 4.21 / 3.81	19 W3 24200	20 X4 0 4.21 / 3.81	21 W4 24900
	22 W4 25100	23 X3 0 4.21 / 3.81	24 X4 0 4.21 / 3.81	25 W4 24900	26 X5 0 4.21 / 3.81	27 W1 19500	28 X5 0 4.21 / 3.81
29 W2 22500	30 X1 0 4.21 / 3.81	31 X4 0 4.21 / 3.81	32 W3 24200	33 X5 0 4.21 / 3.81	34 W4 24000	35 X4 0 4.21 / 3.81	36 W1 17600
37 W4 24000	38 X2 0 4.21 / 3.81	39 W4 25100	40 X4 0 4.21 / 3.81	41 W1 19500	42 X4 0 4.21 / 3.81	43 W2 22300	44 W4 25300
45 W4 24800	46 X3 0 4.21 / 3.81	47 X4 0 4.21 / 3.81	48 W4 24900	49 X5 0 4.21 / 3.81	50 W1 17600	51 W4 25300	52 U4 25800

Batch X ZrB_2 rods have annular pellets in top & bottom 8" of rod at the rod's nominal enrichment

FIGURE 5

ICI Locations



DETECTOR AXIAL LEVEL LOCATIONS: J = 1 BOTTOM OF CORE
J = 3 MIDDLE OF CORE
J = 5 TOP OF CORE

FIGURE 6

GETARP Output for the 29% Power Plateau

Step 9.6A..
2302.039
KSA 4-12-0

```
GGGGGGGGGG  EEEEEEEEEE  TTTTTTTTTTT     AAAA      RRRRRRRRR    PPPPPPPPP
GGGGGGGGGG  EEEEEEEEEE  TTTTTTTTTTT    AAAAAA     RRRRRRRRRR   PPPPPPPPPP
GGG         EEE             TTT       AAA  AAA    RRR      RRR PPP      PPP
GGG  GGGGG  EEEEEE          TTT      AAAAAAAAAA   RRRRRRRRRR   PPPPPPPPPP
GGG  GGGGG  EEEEEE          TTT      AAAAAAAAAA   RRRRRRRRR    PPPPPPPPP
GGG    GGG  EEE             TTT      AAA     AAA  RRR RRR      PPP
GGGGGGGGGG  EEEEEEEEEE      TTT      AAA     AAA  RRR  RRR     PPP
GGGGGGGGGG  EEEEEEEEEE      TTT      AAA     AAA  RRR     RRR  PPP      (FPA)
A PROGRAM TO EXTRACT DATA FROM CECOR SUMMARY FILES FOR COMPARISON OF
AXIAL AND RADIAL POWER DISTRIBUTIONS.
GETRNP01 - GETARP FOR NT REVISION 1
MEASURED DATA EXTRACTED FROM: a2154x6.s01
PREDICTED DATA EXTRACTED FROM: a2pred.029
```

RELATIVE RADIAL POWER DISTRIBUTION COMPARISON

Key
PREDICTED
MEASURED
% DIFFER

% DIFFERENCE = (MEAS.-PREDICTED) / PREDICTED X 100.0

					.439	.530	.541	.538	.442					
					.448	.535	.549	.545	.444					
					2.14	.92	1.48	1.38	.44					
			.453	.677	1.105	1.157	1.130	1.161	1.108	.678	.453			
			.473	.650	1.083	1.151	1.120	1.149	1.074	.646	.464			
			4.37	-4.05	-1.97	-.51	-.90	-1.06	-3.06	-4.72	2.40			
		.477	1.122	1.201	1.167	1.093	1.155	1.094	1.168	1.202	1.123	.477		
		.508	1.131	1.186	1.162	1.079	1.155	1.065	1.144	1.161	1.097	.486		
		6.55	.82	-1.24	-.44	-1.25	-.04	-2.65	-2.10	-3.40	-2.36	1.82		
	.453	1.123	1.261	1.194	1.082	1.136	1.061	1.135	1.082	1.194	1.261	1.122	.453	
	.500	1.167	1.261	1.214	1.088	1.142	1.060	1.149	1.067	1.183	1.211	1.109	.470	
	10.31	3.90	-.03	1.68	.57	.50	-.05	1.26	-1.40	-.92	-3.96	-1.16	3.74	
	.678	1.202	1.194	1.051	1.067	1.164	1.117	1.162	1.067	1.051	1.194	1.201	.677	
	.704	1.227	1.222	1.065	1.104	1.171	1.139	1.168	1.082	1.029	1.172	1.169	.667	
	3.77	2.11	2.32	1.29	3.46	.60	1.96	.49	1.39	-2.08	-1.86	-2.69	-1.48	
.442	1.108	1.168	1.082	1.067	1.074	1.200	1.248	1.197	1.074	1.067	1.082	1.167	1.105	.439
.448	1.132	1.209	1.102	1.095	1.093	1.231	1.245	1.212	1.064	1.051	1.053	1.148	1.071	.437
1.30	2.18	3.52	1.83	2.66	1.81	2.58	-.26	1.21	-.89	-1.52	-2.70	-1.67	-3.05	-.45
.538	1.161	1.094	1.135	1.162	1.197	1.170	1.119	1.170	1.200	1.164	1.136	1.093	1.157	.530
.563	1.204	1.114	1.177	1.185	1.239	1.193	1.127	1.159	1.198	1.139	1.129	1.057	1.122	.522
4.59	3.67	1.80	3.72	1.99	3.50	2.00	.75	-.98	-.17	-2.14	-.64	-3.27	-3.02	-1.60
.541	1.130	1.155	1.061	1.117	1.248	1.119	1.031	1.119	1.248	1.117	1.061	1.155	1.130	.541
.565	1.149	1.171	1.077	1.159	1.278	1.145	1.047	1.083	1.219	1.106	1.044	1.137	1.097	.533
4.41	1.72	1.35	1.49	3.80	2.38	2.33	1.57	-3.25	-2.30	-.99	-1.60	-1.53	-2.89	-1.55
.530	1.157	1.093	1.136	1.164	1.200	1.170	1.119	1.170	1.197	1.162	1.135	1.094	1.161	.538
.547	1.169	1.096	1.169	1.188	1.240	1.192	1.126	1.154	1.198	1.146	1.133	1.062	1.131	.524
3.23	1.06	.32	2.93	2.02	3.31	1.92	.65	-1.41	.05	-1.42	-.22	-2.93	-2.62	-2.65
.439	1.105	1.167	1.082	1.067	1.074	1.197	1.248	1.200	1.074	1.067	1.082	1.168	1.108	.442
.459	1.116	1.183	1.085	1.077	1.083	1.220	1.239	1.199	1.073	1.064	1.057	1.159	1.072	.410
4.49	1.00	1.37	.32	.91	.81	1.95	-.71	-.10	-.11	-.24	-2.33	-.76	-3.28	-7.23
	.677	1.201	1.194	1.051	1.067	1.162	1.117	1.164	1.067	1.051	1.194	1.202	.678	
	.702	1.215	1.207	1.048	1.092	1.162	1.131	1.159	1.087	1.049	1.186	1.183	.674	
	3.69	1.12	1.11	-.25	2.32	.02	1.29	-.40	1.90	-.18	-.68	-1.55	-.59	
	.453	1.122	1.261	1.194	1.082	1.135	1.061	1.136	1.082	1.194	1.261	1.123	.453	
	.497	1.163	1.247	1.206	1.074	1.146	1.053	1.137	1.069	1.200	1.229	1.128	.479	
	9.61	3.66	-1.08	.97	-.73	.99	-.80	.11	-1.21	.52	-2.55	.44	5.83	
		.477	1.123	1.202	1.168	1.094	1.155	1.093	1.167	1.201	1.122	.477		
		.500	1.120	1.176	1.149	1.065	1.144	1.060	1.141	1.166	1.105	.493		
		4.84	-.24	-2.15	-1.61	-2.67	-.98	-2.98	-2.20	-2.93	-1.51	3.42		
			.453	.678	1.108	1.161	1.130	1.157	1.105	.677	.453			
			.469	.646	1.073	1.140	1.106	1.130	1.063	.639	.461			
			3.60	-4.66	-3.14	-1.83	-2.11	-2.33	-3.77	-5.68	1.79			
					.442	.538	.541	.530	.439					
					.444	.539	.540	.527	.438					
					.34	.22	-.11	-.57	-.19					

FIGURE 6

GETARP Output for the 29% Power Plateau (continued)

RELATIVE AXIAL POWER DISTRIBUTION COMPARISON

NODE	PREDICTED	MEAS.	% DIFFERENCE
1	.5540	.5542	.0429
2	.6790	.6317	-6.9607
3	.7910	.6994	-11.5784
4	.8270	.7570	-8.4690
5	.8430	.8045	-4.5726
6	.8550	.8423	-1.4819
7	.8660	.8714	.6180
8	.8740	.8925	2.1214
9	.8800	.9071	3.0804
10	.8840	.9164	3.6626
11	.8880	.9217	3.7963
12	.8910	.9244	3.7520
13	.8950	.9257	3.4354
14	.8990	.9267	3.0826
15	.9030	.9282	2.7873
16	.9080	.9307	2.5040
17	.9140	.9348	2.2750
18	.9200	.9405	2.2280
19	.9280	.9478	2.1346
20	.9360	.9565	2.1929
21	.9440	.9663	2.3661
22	.9540	.9769	2.3971
23	.9650	.9877	2.3572
24	.9760	.9986	2.3197
25	.9900	1.0093	1.9495
26	1.0050	1.0196	1.4521
27	1.0210	1.0295	.8343
28	1.0350	1.0392	.4061
29	1.0480	1.0489	.0849
30	1.0590	1.0589	-.0093
31	1.0700	1.0696	-.0367
32	1.0810	1.0814	.0334
33	1.0920	1.0944	.2241
34	1.1040	1.1090	.4553
35	1.1150	1.1251	.9035
36	1.1250	1.1423	1.5411
37	1.1360	1.1603	2.1394
38	1.1470	1.1782	2.7188
39	1.1580	1.1949	3.1876
40	1.1680	1.2092	3.5245
41	1.1790	1.2194	3.4281
42	1.1880	1.2240	3.0286
43	1.1950	1.2211	2.1834
44	1.1980	1.2090	.9183
45	1.1970	1.1861	-.9142
46	1.1910	1.1508	-3.3747
47	1.1790	1.1021	-6.5236
48	1.1590	1.0391	-10.3451
49	1.1100	.9615	-13.3796
50	.9570	.8694	-9.1577
51	.7860	.7633	-2.8820

PEAKING PARAMETER COMPARISON

PARAMETER	MEAS.	PREDICTED	% DIFFERENCE
FXY	1.5689	1.5100	3.9025 %
FR	1.4392	1.4300	.6426 %
FZ	1.2240	1.2000	1.9983 %
FQ	1.7827	1.7700	.7190 %

CALCULATED RMS VALUES
RADIAL = 2.2059
AXIAL = 4.1986
MEASURED ASI = -.1046
PREDICTED ASI = -.1132

ACCEPTANCE CRITERIA REPORT

MEASURED FXY WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
MEASURED FR WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
MEASURED FZ WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
MEASURED FQ WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
RMS ERROR ON AXIAL DISTRIBUTION WAS LESS THAN OR EQUAL TO 5.000 %.
RMS ERROR ON RADIAL DISTRIBUTION WAS LESS THAN OR EQUAL TO 5.000 %.
ALL PREDICTED RADIAL POWERS LESS THAN 0.9
WERE WITHIN PLUS OR MINUS 15.000 % OF MEASURED.
ALL PREDICTED RADIAL POWERS GREATER THAN OR EQUAL TO 0.9
WERE WITHIN PLUS OR MINUS 10.000 % OF MEASURED.

*** ALL ACCEPTANCE CRITERIA WERE MET ***

FIGURE 7

GETARP Output for the 65% Power Plateau

```
GGGGGGGGGG  EEEEEEEEEE  TTTTTTTTTT     AAAA      RRRRRRRRR   PPPPPPPPP
GGGGGGGGGG  EEEEEEEEEE  TTTTTTTTTT    AAAAAA     RRRRRRRRRR  PPPPPPPPPP
GGG         EEE             TTT      AAA  AAA    RRR     RRR PPP     PPP
GGG  GGGGG  EEEEEE          TTT     AAAAAAAAAA   RRRRRRRRRR  PPPPPPPPPP
GGG  GGGGG  EEEEEE          TTT     AAAAAAAAAA   RRRRRRRRR   PPPPPPPPP
GGG    GGG  EEE             TTT     AAA     AAA  RRR RRR     PPP
GGGGGGGGGG  EEEEEEEEEE      TTT     AAA     AAA  RRR  RRR    PPP
GGGGGGGGGG  EEEEEEEEEE      TTT     AAA     AAA  RRR    RRR  PPP      (FPA)
A PROGRAM TO EXTRACT DATA FROM CECOR SUMMARY FILES FOR COMPARISON OF
AXIAL AND RADIAL POWER DISTRIBUTIONS.
GETRNP01 - GETARP FOR NT REVISION 1
MEASURED DATA EXTRACTED FROM: a2155rp.s01
PREDICTED DATA EXTRACTED FROM: A2PRED.068
```

RELATIVE RADIAL POWER DISTRIBUTION COMPARISON

Legend
PREDICTED
MEASURED
% DIFFER

% DIFFERENCE = (MEAS.-PREDICTED) / PREDICTED X 100.0

					.451	.544	.554	.551	.454					
					.448	.534	.548	.544	.443					
					-.72	-1.88	-1.17	-1.35	-2.32					
			.462	.685	1.106	1.156	1.131	1.160	1.108	.686	.462			
			.471	.652	1.085	1.152	1.120	1.146	1.077	.653	.466			
			2.00	-4.75	-1.91	-.38	-.98	-1.19	-2.77	-4.80	.91			
		.484	1.114	1.192	1.162	1.092	1.154	1.092	1.163	1.193	1.115	.484		
		.503	1.126	1.183	1.162	1.080	1.157	1.066	1.147	1.165	1.101	.486		
		3.92	1.06	-.72	-.02	-1.09	.23	-2.34	-1.39	-2.33	-1.29	.45		
	.462	1.115	1.243	1.186	1.080	1.136	1.062	1.136	1.080	1.185	1.243	1.114	.462	
	.493	1.152	1.251	1.205	1.086	1.146	1.063	1.155	1.069	1.181	1.214	1.111	.470	
	6.71	3.34	.62	1.60	.53	.88	.13	1.71	-1.06	-.37	-2.34	-.28	1.81	
	.686	1.193	1.185	1.050	1.070	1.161	1.117	1.159	1.069	1.050	1.186	1.192	.685	
	.696	1.214	1.213	1.060	1.103	1.172	1.142	1.172	1.086	1.033	1.178	1.176	.669	
	1.44	1.75	2.37	.96	3.09	.96	2.23	1.11	1.60	-1.63	-.67	-1.35	-2.26	
.454	1.108	1.163	1.080	1.069	1.074	1.196	1.240	1.193	1.074	1.070	1.080	1.162	1.106	.451
.448	1.126	1.190	1.094	1.099	1.093	1.232	1.247	1.217	1.070	1.063	1.060	1.160	1.078	.438
-1.21	1.59	2.31	1.31	2.78	1.79	3.00	.57	2.01	-.39	-.69	-1.82	-.18	-2.56	-2.89
.551	1.160	1.092	1.136	1.159	1.193	1.166	1.117	1.166	1.196	1.161	1.136	1.092	1.156	.544
.563	1.206	1.108	1.174	1.185	1.240	1.193	1.127	1.159	1.203	1.147	1.136	1.062	1.124	.521
2.13	4.00	1.46	3.34	2.25	3.94	2.35	.94	-.59	.60	-1.21	-.01	-2.74	-2.76	-4.14
.554	1.131	1.154	1.062	1.117	1.240	1.117	1.035	1.117	1.240	1.117	1.062	1.154	1.131	.554
.564	1.150	1.170	1.075	1.160	1.279	1.145	1.046	1.077	1.222	1.115	1.048	1.141	1.098	.532
1.80	1.70	1.35	1.21	3.84	3.11	2.49	1.02	-3.61	-1.42	-.22	-1.32	-1.17	-2.89	-3.94
.544	1.156	1.092	1.136	1.161	1.196	1.166	1.117	1.166	1.193	1.159	1.136	1.092	1.160	.551
.546	1.169	1.094	1.169	1.189	1.242	1.194	1.126	1.153	1.201	1.150	1.135	1.061	1.128	.524
.35	1.16	.20	2.88	2.39	3.84	2.37	.85	-1.09	.65	-.77	-.08	-2.83	-2.75	-4.84
.451	1.106	1.162	1.080	1.070	1.074	1.193	1.240	1.196	1.074	1.069	1.080	1.163	1.108	.454
.457	1.114	1.178	1.083	1.081	1.084	1.225	1.242	1.202	1.075	1.069	1.056	1.156	1.072	.418
1.33	.69	1.41	.32	1.05	.97	2.68	.17	.53	.05	.00	-2.23	-.61	-3.22	-7.88
	.685	1.192	1.186	1.050	1.069	1.159	1.117	1.161	1.070	1.050	1.185	1.193	.686	
	.698	1.209	1.204	1.047	1.093	1.165	1.134	1.162	1.088	1.047	1.183	1.179	.671	
	1.86	1.39	1.54	-.27	2.24	-.49	1.55	.07	1.67	-.32	-.18	-1.18	-2.14	
	.462	1.114	1.243	1.185	1.080	1.136	1.062	1.136	1.080	1.186	1.243	1.115	.462	
	.492	1.152	1.242	1.201	1.074	1.150	1.055	1.142	1.067	1.192	1.223	1.129	.475	
	6.42	3.41	-.05	1.38	-.59	1.24	-.69	.53	-1.17	.53	-1.65	.33	2.91	
		.484	1.115	1.193	1.163	1.092	1.154	1.092	1.162	1.192	1.114	.484		
		.497	1.119	1.177	1.151	1.065	1.145	1.061	1.142	1.165	1.102	.490		
		2.60	.35	-1.34	-1.07	-2.45	-.76	-2.84	-1.74	-2.29	-1.06	1.20		
			.462	.686	1.108	1.160	1.131	1.156	1.106	.685	.462			
			.470	.652	1.075	1.138	1.106	1.129	1.065	.643	.461			
			1.66	-5.02	-2.95	-1.89	-2.24	-2.34	-3.71	-6.20	-.31			
					.454	.551	.554	.544	.451					
					.443	.538	.539	.526	.437					
					-2.43	-2.44	-2.75	-3.40	-3.01					

FIGURE 7

GETARP Output for the 65% Power Plateau (continued)

RELATIVE AXIAL POWER DISTRIBUTION COMPARISON

NODE	PREDICTED	MEAS.	% DIFFERENCE
1	.6200	.6135	-1.0465
2	.7550	.6986	-7.4762
3	.8770	.7724	-11.9320
4	.9110	.8345	-8.3944
5	.9240	.8851	-4.2085
6	.9330	.9246	-.9028
7	.9410	.9537	1.3545
8	.9460	.9738	2.9334
9	.9490	.9859	3.8935
10	.9500	.9918	4.4045
11	.9510	.9930	4.4149
12	.9510	.9909	4.1963
13	.9520	.9870	3.6788
14	.9530	.9826	3.1040
15	.9540	.9786	2.5794
16	.9560	.9759	2.0791
17	.9580	.9749	1.7633
18	.9610	.9759	1.5509
19	.9650	.9789	1.4428
20	.9700	.9838	1.4189
21	.9750	.9901	1.5478
22	.9810	.9975	1.6798
23	.9880	1.0055	1.7677
24	.9950	1.0136	1.8704
25	1.0040	1.0215	1.7475
26	1.0160	1.0290	1.2798
27	1.0270	1.0359	.8620
28	1.0350	1.0421	.6860
29	1.0420	1.0479	.5645
30	1.0480	1.0534	.5195
31	1.0550	1.0591	.3887
32	1.0610	1.0652	.3950
33	1.0670	1.0720	.4703
34	1.0720	1.0798	.7278
35	1.0780	1.0886	.9844
36	1.0830	1.0983	1.4155
37	1.0880	1.1086	1.8938
38	1.0930	1.1188	2.3640
39	1.0970	1.1282	2.8417
40	1.1020	1.1355	3.0410
41	1.1070	1.1395	2.9402
42	1.1100	1.1388	2.5965
43	1.1110	1.1318	1.8700
44	1.1090	1.1168	.7076
45	1.1030	1.0925	-.9480
46	1.0920	1.0575	-3.1559
47	1.0770	1.0107	-6.1518
48	1.0550	.9514	-9.8192
49	1.0120	.8792	-13.1271
50	.8800	.7940	-9.7679
51	.7360	.6966	-5.3544

PEAKING PARAMETER COMPARISON

PARAMETER	MEAS.	PREDICTED	% DIFFERENCE
FXY	1.5551	1.4800	5.0717 %
FR	1.4263	1.4100	1.1538 %
FZ	1.1395	1.1100	2.6620 %
FQ	1.6446	1.6000	2.7893 %

CALCULATED RMS VALUES
RADIAL = 2.0236
AXIAL = 4.0553
MEASURED ASI = -.0523
PREDICTED ASI = -.0596

ACCEPTANCE CRITERIA REPORT

MEASURED FXY WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
MEASURED FR WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
MEASURED FZ WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
MEASURED FQ WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
RMS ERROR ON AXIAL DISTRIBUTION WAS LESS THAN OR EQUAL TO 5.000 %.
RMS ERROR ON RADIAL DISTRIBUTION WAS LESS THAN OR EQUAL TO 5.000 %.
ALL PREDICTED RADIAL POWERS LESS THAN 0.9
WERE WITHIN PLUS OR MINUS 15.000 % OF MEASURED.
ALL PREDICTED RADIAL POWERS GREATER THAN OR EQUAL TO 0.9
WERE WITHIN PLUS OR MINUS 10.000 % OF MEASURED.

*** ALL ACCEPTANCE CRITERIA WERE MET ***

FIGURE 8

GETARP Output for the 100% Power Plateau

```
GGGGGGGGGG EEEEEEEEEE TTTTTTTTTT    AAAA     RRRRRRRRR  PPPPPPPPP
GGGGGGGGGG EEEEEEEEEE TTTTTTTTTT   AAAAAA    RRRRRRRRRR PPPPPPPPPP
GGG        EEE           TTT      AAA  AAA   RRR    RRR PPP    PPP
GGG  GGGGG EEEEEE        TTT      AAAAAAAAA  RRRRRRRRRR PPPPPPPPPP
GGG  GGGGG EEEEEE        TTT      AAAAAAAAAA RRRRRRRRR  PPPPPPPPP
GGG    GGG EEE           TTT      AAA    AAA RRR RRR    PPP
GGGGGGGGGG EEEEEEEEEE    TTT      AAA    AAA RRR  RRR   PPP
GGGGGGGGGG EEEEEEEEEE    TTT      AAA    AAA RRR   RRR  PPP     (FPA)
A PROGRAM TO EXTRACT DATA FROM CECOR SUMMARY FILES FOR COMPARISON OF
AXIAL AND RADIAL POWER DISTRIBUTIONS.
GETRNP01 - GETARP FOR NT REVISION 1
MEASURED DATA EXTRACTED FROM: e2161kj.s02
PREDICTED DATA EXTRACTED FROM: s2predeq.100
```

RELATIVE RADIAL POWER DISTRIBUTION COMPARISON

```
+------------+
; PREDICTED  ;
; MEASURED   ;
; % DIFFER   ;
+------------+

                                   (MEAS.-PREDICTED)
            % DIFFERENCE = --------------------------- X 100.0
                                       PREDICTED

                        ;  .458 ;  .550 ;  .561 ;  .557 ;  .460 ;
                        ;  .443 ;  .528 ;  .542 ;  .537 ;  .439 ;
                        ; -3.17 ; -3.93 ; -3.34 ; -3.58 ; -4.66 ;

                ;  .467 ;  .689 ; 1.102 ; 1.152 ; 1.128 ; 1.155 ; 1.105 ;  .690 ;  .468 ;
                ;  .466 ;  .650 ; 1.079 ; 1.145 ; 1.117 ; 1.136 ; 1.072 ;  .652 ;  .462 ;
                ;  -.29 ; -5.71 ; -2.04 ;  -.60 ;  -.96 ; -1.62 ; -3.00 ; -5.46 ; -1.23 ;

        ;  .489 ; 1.107 ; 1.184 ; 1.158 ; 1.089 ; 1.152 ; 1.090 ; 1.158 ; 1.185 ; 1.108 ;  .489 ;
        ;  .491 ; 1.112 ; 1.181 ; 1.167 ; 1.080 ; 1.165 ; 1.066 ; 1.154 ; 1.167 ; 1.092 ;  .478 ;
        ;   .49 ;   .42 ;  -.23 ;   .81 ;  -.79 ;  1.17 ; -2.16 ;  -.35 ; -1.51 ; -1.48 ; -2.22 ;

;  .468 ; 1.106 ; 1.230 ; 1.180 ; 1.080 ; 1.138 ; 1.065 ; 1.137 ; 1.080 ; 1.180 ; 1.230 ; 1.107 ;  .467 ;
;  .482 ; 1.126 ; 1.235 ; 1.204 ; 1.088 ; 1.161 ; 1.072 ; 1.172 ; 1.074 ; 1.185 ; 1.204 ; 1.095 ;  .462 ;
;  2.90 ;  1.78 ;   .40 ;  2.01 ;   .75 ;  2.02 ;   .63 ;  3.05 ;  -.59 ;   .39 ; -2.08 ; -1.07 ; -1.03 ;

;  .690 ; 1.185 ; 1.180 ; 1.051 ; 1.074 ; 1.162 ; 1.121 ; 1.160 ; 1.074 ; 1.051 ; 1.180 ; 1.184 ;  .689 ;
;  .683 ; 1.204 ; 1.215 ; 1.062 ; 1.118 ; 1.182 ; 1.161 ; 1.183 ; 1.104 ; 1.039 ; 1.184 ; 1.170 ;  .660 ;
; -1.05 ;  1.57 ;  2.93 ;  1.03 ;  4.08 ;  1.71 ;  3.58 ;  2.01 ;  2.78 ; -1.15 ;   .30 ; -1.22 ; -4.15 ;

;  .460 ; 1.105 ; 1.158 ; 1.080 ; 1.074 ; 1.077 ; 1.198 ; 1.239 ; 1.195 ; 1.077 ; 1.074 ; 1.080 ; 1.158 ; 1.102 ;  .458 ;
;  .448 ; 1.104 ; 1.185 ; 1.093 ; 1.117 ; 1.102 ; 1.249 ; 1.255 ; 1.237 ; 1.082 ; 1.086 ; 1.062 ; 1.152 ; 1.065 ;  .431 ;
; -2.53 ;  -.09 ;  2.31 ;  1.22 ;  3.98 ;  2.30 ;  4.26 ;  1.28 ;  3.48 ;   .49 ;  1.09 ; -1.66 ;  -.50 ; -3.36 ; -5.93 ;

;  .557 ; 1.155 ; 1.090 ; 1.137 ; 1.160 ; 1.195 ; 1.168 ; 1.121 ; 1.168 ; 1.198 ; 1.162 ; 1.138 ; 1.089 ; 1.152 ;  .550 ;
;  .548 ; 1.166 ; 1.095 ; 1.181 ; 1.192 ; 1.255 ; 1.195 ; 1.127 ; 1.164 ; 1.222 ; 1.160 ; 1.148 ; 1.057 ; 1.117 ;  .515 ;
; -1.69 ;   .97 ;   .41 ;  3.86 ;  2.78 ;  4.99 ;  2.32 ;   .54 ;  -.34 ;  2.02 ;  -.20 ;   .84 ; -2.92 ; -3.07 ; -6.30 ;

;  .561 ; 1.128 ; 1.152 ; 1.065 ; 1.121 ; 1.239 ; 1.121 ; 1.043 ; 1.121 ; 1.239 ; 1.121 ; 1.065 ; 1.152 ; 1.128 ;  .561 ;
;  .552 ; 1.134 ; 1.174 ; 1.078 ; 1.176 ; 1.284 ; 1.143 ; 1.043 ; 1.082 ; 1.233 ; 1.136 ; 1.053 ; 1.145 ; 1.094 ;  .526 ;
; -1.62 ;   .50 ;  1.88 ;  1.19 ;  4.91 ;  3.59 ;  1.95 ;  -.01 ; -3.51 ;  -.48 ;  1.37 ; -1.08 ;  -.62 ; -3.06 ; -6.17 ;

;  .550 ; 1.152 ; 1.089 ; 1.138 ; 1.162 ; 1.198 ; 1.168 ; 1.121 ; 1.168 ; 1.195 ; 1.160 ; 1.137 ; 1.090 ; 1.155 ;  .557 ;
;  .536 ; 1.155 ; 1.089 ; 1.179 ; 1.198 ; 1.258 ; 1.196 ; 1.126 ; 1.158 ; 1.219 ; 1.161 ; 1.146 ; 1.056 ; 1.117 ;  .518 ;
; -2.58 ;   .30 ;  -.01 ;  3.61 ;  3.07 ;  4.99 ;  2.38 ;   .48 ;  -.84 ;  2.00 ;   .10 ;   .79 ; -3.13 ; -3.32 ; -6.92 ;

;  .458 ; 1.102 ; 1.158 ; 1.080 ; 1.074 ; 1.077 ; 1.195 ; 1.239 ; 1.198 ; 1.077 ; 1.074 ; 1.080 ; 1.159 ; 1.105 ;  .460 ;
;  .448 ; 1.100 ; 1.178 ; 1.086 ; 1.101 ; 1.095 ; 1.244 ; 1.251 ; 1.222 ; 1.085 ; 1.087 ; 1.056 ; 1.152 ; 1.062 ;  .419 ;
; -2.08 ;  -.18 ;  1.72 ;   .51 ;  2.50 ;  1.65 ;  4.10 ;   .94 ;  2.01 ;   .74 ;  1.18 ; -2.18 ;  -.49 ; -3.87 ; -8.99 ;

;  .689 ; 1.184 ; 1.180 ; 1.051 ; 1.074 ; 1.160 ; 1.121 ; 1.162 ; 1.074 ; 1.051 ; 1.180 ; 1.185 ;  .690 ;
;  .688 ; 1.202 ; 1.209 ; 1.052 ; 1.109 ; 1.176 ; 1.154 ; 1.172 ; 1.103 ; 1.048 ; 1.186 ; 1.172 ;  .662 ;
;  -.19 ;  1.51 ;  2.45 ;   .06 ;  3.30 ;  1.35 ;  2.90 ;   .89 ;  2.69 ;  -.24 ;   .47 ; -1.10 ; -4.03 ;

;  .467 ; 1.107 ; 1.230 ; 1.180 ; 1.080 ; 1.137 ; 1.065 ; 1.138 ; 1.080 ; 1.180 ; 1.230 ; 1.108 ;  .468 ;
;  .482 ; 1.129 ; 1.230 ; 1.205 ; 1.078 ; 1.167 ; 1.062 ; 1.156 ; 1.069 ; 1.190 ; 1.208 ; 1.099 ;  .466 ;
;  3.11 ;  2.00 ;   .00 ;  2.10 ;  -.20 ;  2.60 ;  -.24 ;  1.58 ; -1.03 ;   .84 ; -1.80 ;  -.81 ;  -.46 ;

        ;  .489 ; 1.109 ; 1.185 ; 1.158 ; 1.090 ; 1.152 ; 1.089 ; 1.158 ; 1.184 ; 1.107 ;  .489 ;
        ;  .486 ; 1.107 ; 1.176 ; 1.157 ; 1.065 ; 1.153 ; 1.060 ; 1.146 ; 1.162 ; 1.089 ;  .480 ;
        ;  -.59 ;  -.06 ;  -.61 ;  -.10 ; -2.33 ;   .06 ; -2.67 ; -1.01 ; -1.83 ; -1.63 ; -1.91 ;

                ;  .468 ;  .690 ; 1.105 ; 1.155 ; 1.128 ; 1.152 ; 1.102 ;  .689 ;  .467 ;
                ;  .465 ;  .651 ; 1.069 ; 1.128 ; 1.102 ; 1.120 ; 1.059 ;  .641 ;  .455 ;
                ;  -.69 ; -5.70 ; -3.22 ; -2.35 ; -2.34 ; -2.77 ; -3.94 ; -7.03 ; -2.59 ;

                        ;  .460 ;  .557 ;  .561 ;  .550 ;  .459 ;
                        ;  .438 ;  .530 ;  .533 ;  .519 ;  .432 ;
                        ; -4.89 ; -4.79 ; -5.06 ; -5.63 ; -5.65 ;
```

RELATIVE AXIAL POWER DISTRIBUTION COMPARISON

NODE	PREDICTED	MEAS.	% DIFFERENCE
1	.7240	.6805	-6.0021
2	.8770	.7778	-11.3077
3	1.0140	.8623	-14.9600
4	1.0480	.9334	-10.9346
5	1.0590	.9911	-6.4147
6	1.0650	1.0357	-2.7515
7	1.0690	1.0681	-.0824
8	1.0700	1.0895	1.8243
9	1.0670	1.1014	3.2203
10	1.0630	1.1053	3.9785
11	1.0580	1.1031	4.2581
12	1.0530	1.0964	4.1190
13	1.0480	1.0869	3.7123

FIGURE 8

GETARP Output for the 100% Power Plateau (continued)

14	1.0420	1.0761	3.2751
15	1.0380	1.0653	2.6290
16	1.0330	1.0554	2.1664
17	1.0290	1.0471	1.7583
18	1.0250	1.0408	1.5451
19	1.0220	1.0367	1.4428
20	1.0200	1.0347	1.4428
21	1.0180	1.0345	1.6167
22	1.0160	1.0355	1.9235
23	1.0150	2.0375	2.2141
24	1.0150	1.0397	2.4375
25	1.0160	1.0419	2.5470
26	1.0190	1.0435	2.4049
27	1.0220	1.0444	2.1886
28	1.0230	1.0443	2.0862
29	1.0220	1.0434	2.0988
30	1.0210	1.0418	2.0409
31	1.0190	1.0397	2.0360
32	1.0160	1.0375	2.1139
33	1.0140	1.0353	2.1039
34	1.0120	1.0336	2.1320
35	1.0100	1.0324	2.2143
36	1.0080	1.0317	2.3525
37	1.0050	1.0314	2.6315
38	1.0020	1.0312	2.9122
39	1.0000	1.0303	3.0304
40	.9970	1.0280	3.1083
41	.9940	1.0232	2.9393
42	.9900	1.0148	2.5062
43	.9850	1.0015	1.6753
44	.9770	.9820	.5106
45	.9660	.9550	-1.1371
46	.9510	.9195	-3.3174
47	.9330	.8744	-6.2849
48	.9100	.8191	-9.9912
49	.8700	.7533	-13.4179
50	.7640	.6769	-11.3952
51	.6470	.5905	-8.7288

PEAKING PARAMETER COMPARISON

PARAMETER	MEAS.	PREDICTED	% DIFFERENCE
FXY	1.5244	1.4700	3.7014 %
FR	1.4078	1.3900	1.2822 %
FZ	1.1053	1.0700	3.2983 %
FQ	1.7067	1.5500	10.1127 %

CALCULATED RMS VALUES
RADIAL - 2.3774
AXIAL - 4.7633
MEASURED ASI = .0263
PREDICTED ASI - .0266

ACCEPTANCE CRITERIA REPORT

MEASURED FXY WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
MEASURED FR WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
MEASURED FZ WAS WITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
*WARNING*MEASURED FQ WAS NOTWITHIN PLUS OR MINUS 10.000 % OF THE PREDICTED VALUE.
RMS ERROR ON AXIAL DISTRIBUTION WAS LESS THAN OR EQUAL TO 5.000 %.
RMS ERROR ON RADIAL DISTRIBUTION WAS LESS THAN OR EQUAL TO 5.000 %.
ALL PREDICTED RADIAL POWERS LESS THAN 0.9
WERE WITHIN PLUS OR MINUS 15.000 % OF MEASURED.
ALL PREDICTED RADIAL POWERS GREATER THAN OR EQUAL TO 0.9
WERE WITHIN PLUS OR MINUS 10.000 % OF MEASURED.

*WARNING*ALL ACCEPTANCE CRITERIA WERE NOT MET