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H. B. ROBINSON FLUENCE REDUCTION ANALYSIS FOR THE PARTIAL-LENGTH SHIELD ASSEMBLY CONCEPT

Work Performed Under File No. NF-1111.06

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Section 1

SUMMARY

1.1 OVERVIEW

Carolina Power and Light Company (CP&L) has developed a triad of programs aimed toward resolving concerns associated with the Pressurized Thermal Shock (PTS) issue for the H. B. Robinson Unit 2 (HBR2) pressure vessel. These are (1) a materials research program to establish a better estimate of the chemistry of the vessel welds, (2) a probabilistic analysis to assess the risk associated with PTS at HBR2, and (3) a program to reduce fast flux to areas of the vessel experiencing a potentially significant increase in RT_{NDT}. Each program has the independent potential to resolve PTS concerns for HBR2.

This report covers the third program and concludes that the proposed fast flux reduction scheme assures that no portion of the pressure vessel will reach the Nuclear Regulatory Commission's (NRC) screening criteria for RT_{NDT} before the expiration of the operating license (EOL) in 2007, which is presently projected to be about 27 EFPY (effective full power years). The conclusion is based on calculated reduction in fast flux to critical vessel areas due to inclusion of a new assembly design in future reloads. The new design, known as partial length shield assemblies (PLSAs), are presently being fabricated for the next reload (Cycle 10). The calculated results presented in this report are conservative estimates of the flux reduction that will be attained.

1.2 INTRODUCTION

This report documents the detailed analyses performed to evaluate the fast flux to critical vessel welds before and after installation of PLSA's. Qualifications of methods, codes, and personnel performing the analyses are given. Verification of calculated results for which benchmarking measurements exist is included, and CP&L plans for additional benchmarking are outlined. Finally, an estimate of uncertainty in calculated results is derived and applied to projections of vessel EOL RT_{NDT}.

1.3 BACKGROUND

One of CP&L's immediate responses to the PTS issue was a redesign of the HBR2 Cycle 9 (the present operating cycle) reload. The conventional out-in-in pattern was changed to a low-leakage loading pattern (L_3P) with gadolinia (Gd_2O_3) used in 208 fuel pins to control peaking. The pattern produced an estimated reduction factor of two in fast flux to critical areas of the vessel. That reduction extended by 3 EFPY the projected time to reach the screening criteria for RT_{NDT}.

The PLSA concept, shown in Figures 1-1 and 1-2, was designed and developed by CP&L engineers[1] to extend the time to reach the screening criteria beyond 13.5 EFPY. Preliminary calculations performed by Technology for Energy Corporation (TEC)[2] and the Exxon Nuclear Company (ENC)[3] were used in choosing shielding material and height. ENC was contracted to fabricate the assemblies and to perform the reload design for Cycle 10. TEC was contracted to perform detailed shielding analyses to quantify the

Figure 1-1. HBR2 PLSA Concept

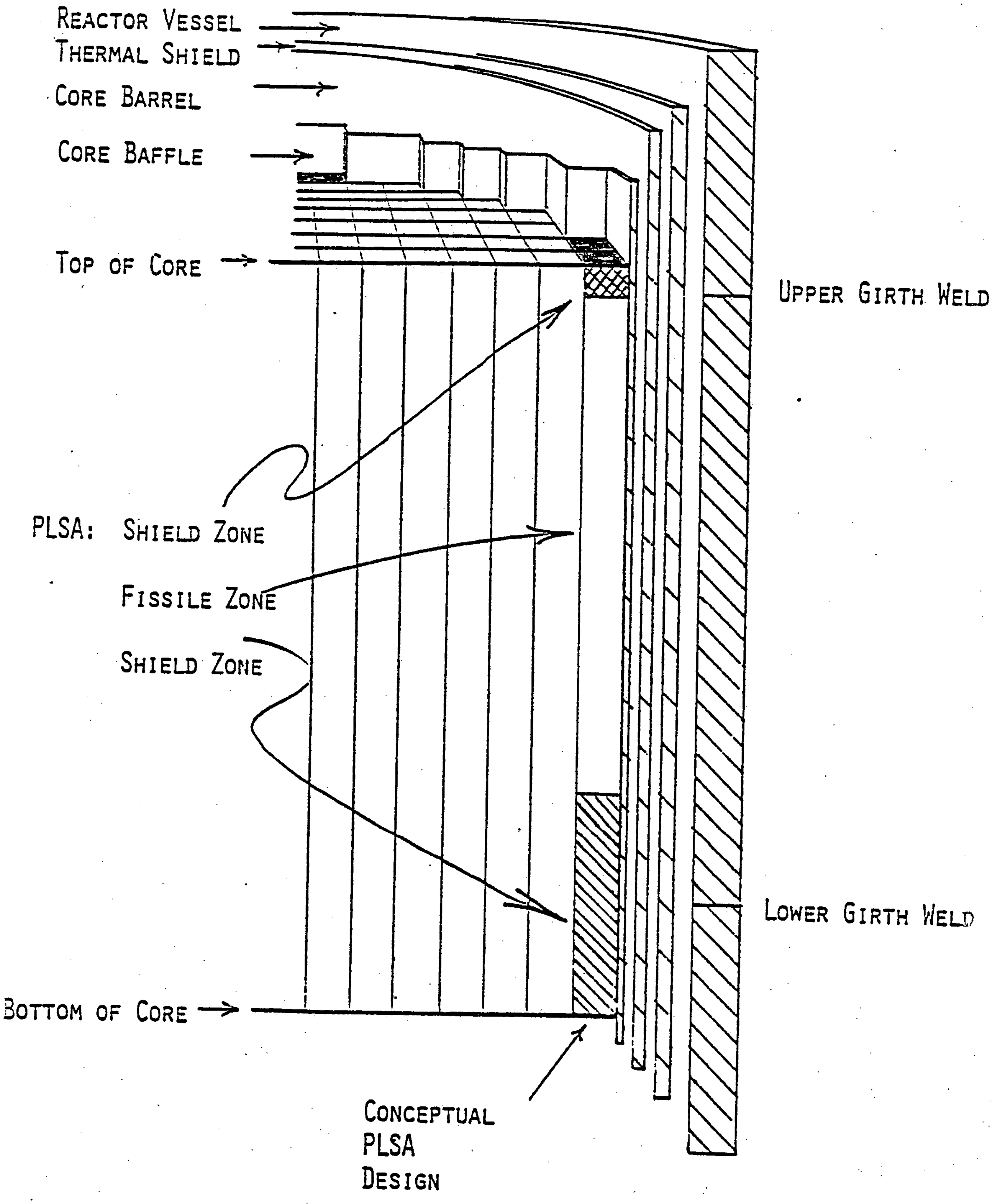
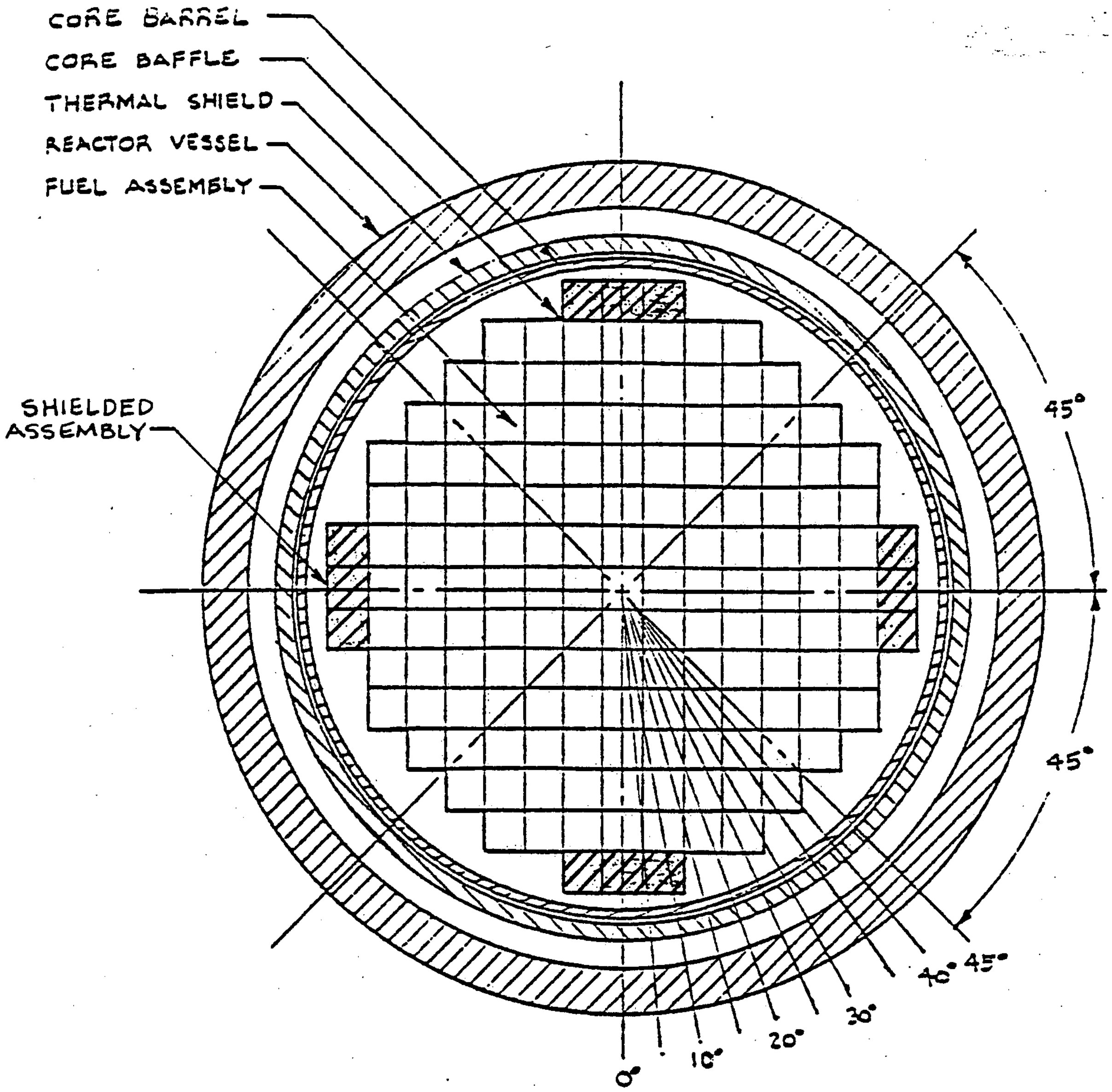


Figure 1-2. HBR2 PLSA Core Locations



expected fast fluence accumulation rates at the pressure vessel inner surface. This report documents the analyses and auxiliary calculations performed by TEC and CP&L.

1.4 PLSA DESCRIPTION

The PLSA design under fabrication is structurally identical to the standard Exxon fuel currently used at HBR2--upper and lower tie plates, grid straps, instrument and guide tubes, and fuel cladding all remain unchanged. Only within the fuel cladding does the PLSA assembly differ from the standard fuel.

The lower fuel pellet stack will be replaced by a stainless steel rod 0.35 in. in diameter and 42 in. in length. (The calculations in this report assume a 36 in. shield height and thus overestimate the actual flux to the vessel. A change of ±6 in. in shield zone length is documented in Reference 1 to have minor impact on core operations.) Above the inert rod is an insulator wafer, topped by a 96-in. stack of fuel pellets of the standard 0.3565-in. diameter with an enrichment in the range of 1.2-1.3 w/o. A 6-in. stack of pellets of the natural fissile enrichment topped by another insulator wafer and a plenum spring similar to that in a standard assembly covers the stack of low enrichment pellets.

PLSA assemblies will be loaded in the 12 outermost locations closest to the major axes. The inert shield material in the lower 42 inches of the assemblies will protect the limiting weld--the lower-to-intermediate shell circumferential weld--in its most critical areas near the major

axes. The fissile region has an enrichment chosen to insure the most vulnerable longitudinal weld in the intermediate shell does not reach its fluence limit at the end of the 32 EFPY plant design life. The upper (fertile) shield prevents the upper circumferential weld from becoming limiting. A diagram of the quarter-core symmetric loading of PLSAs with respect to girth weld locations is shown in Figure 1-1.

1.5 RESULTS AND CONCLUSIONS

Shielding analyses compared fast flux (fast fluence accumulation rates) at the pressure vessel inner surface for HBR2 Cycle 8 averaged neutron source distribution to the flux calculated using the projected Cycle 10 averaged distribution. The Cycle 8 source distribution was benchmarked to measured power distributions and was typical of previous cycles. The Cycle 10 source distribution was based on a shield height of 36 in. It was generated using the same methods and models as for Cycle 8 with additional benchmarking to available Cycle 9 measurements. The overall comparisons were thus consistent and, to the extent possible, based on benchmarked sources. The reduction factor for the critical circumferential weld locations, opposite the core flats, was calculated to be 9.2 and is conservative with respect to future cycles because the PLSAs in Cycle 10 are all fresh. The reduction factor for a shield height of 42 in., as the PLSAs are actually being fabricated, is estimated to be 10.7.

The calculated fluxes for Cycle 8 were benchmarked to dosimeter measurements for Capsules S, V, and T, which were removed, respectively, at the end of cycle (EOC)1, EOC3, and EOC8. The average difference between calculated and measured saturated activities for all dosimeters was 1.1% with a standard deviation of 13.6%.

Based on use of PLSAs with a shield height of 36 in. in all future cycles, a Cycle 9 fast flux reduction factor of 2, and assuming worst case weld chemistry the projected maximum fluence above 1 MeV at the lower circumferential weld after 27 EFPY meets the current screening criteria for allowable RT_{NDT}. The estimated maximum fluence for the actual shield height of 42 in. after 30 EFPY is 1.95×10^{19} n/cm^2. These results assure that use of PLSAs as-built, preclude any region of the HBR2 vessel reaching RT_{NDT} screening criteria before EOL (as seen in Figure 1-3). This conclusion allows ample time to complete ongoing dosimetry programs to measure actual vessel fluxes.

1.6 REFERENCES

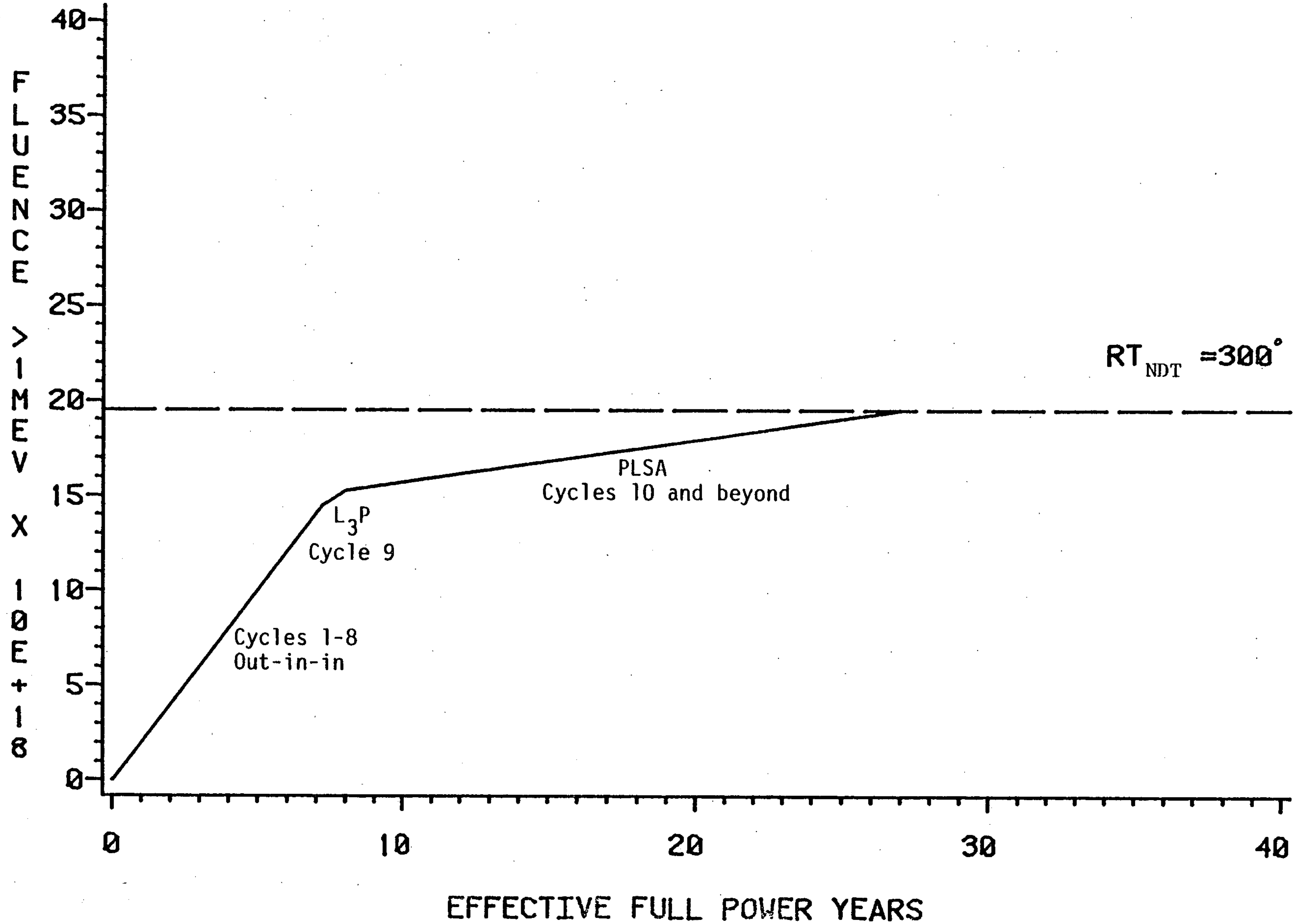
1. Dresser, T. M., "Feasibility of the Part-Length Shield Assembly as a Flux Reduction Technique," CP&L, File NF-1111.05, Serial NF-83-219, April 1983.

2. Howell, R. S., Simpkins, W. M., and Chen, H. H., "Preliminary Report Reactor Pressure Vessel Fluence Calculations in Support of the Partial-Length Shield Assembly Concept for the H. B. Robinson Power Plant," TEC, R-83-022, July 1983.

3. Copeland, R. A. et al., "Part Length Shielding Assembly Feasibility Report," ENC,XN-NF-699, March 1983.

Figure 1-3

HBR2 CALCULATED MAXIMUM CIRCUMFERENTIAL WELD FLUENCE
BASED ON 36 IN. SHIELD HEIGHT AFTER CYCLE 9



Section 2

DESCRIPTION OF WORK

2.1 INTRODUCTION

The TEC portion of the PLSA analysis project consisted of three phases: (1) selection of the PLSA shield material, (2) selection of the PLSA shield height, and (3) best estimation of the effectiveness of the PLSA design. The preliminary analysis of the first two phases indicated the "optimum" PLSA design to be a 36 to 42 in. stainless steel shield. This section describes the methodology and results of the best-estimate fluence reduction analysis based on this design.

2.2 BEST-ESTIMATE FLUX REDUCTION ANALYSIS

This section describes the analyses performed to provide a best estimate of the effectiveness of the 36-in. stainless steel PLSA design. It is subdivided into three sections: (1) an overview of the analysis -- Section 2.2.1, (2) a discussion of the source-term development -- Section 2.2.2, and (3) a discussion of the synthesis technique used -- Section 2.2.3.

2.2.1 Analysis Overview

The best-estimate flux reduction analysis was performed using Cycles 8 and 10. Cycle 8 was the last cycle for the H.B. Robinson Plant where flux reduction measures were not employed, and Cycle 10 will be the first cycle to employ the PLSA concept. The emphasis of this analysis was placed on the most critical location at the inner surface of the

reactor pressure vessel (i.e., axially at the core major axis and circumferentially at the level of the lower girth weld). To obtain a best estimate of the Cycle 8 and Cycle 10 flux distributions, a realistic three-dimensional source distribution was obtained for both cycles. The development of the source distributions is described in Section 2.2.2 and Section 4.3. These source distributions were used in a series of DOT-IV and ANISN-W transport calculations to develop R, R-Z, and R-θ group-wise flux distributions for both cycles.

The flux distributions were then used in the synthesis method (DOTSYN code) described in Section 2.2.3 to develop group-dependent three-dimensional flux distributions. The effectiveness of the PLSA design was evaluated by considering the ratio of the Cycle 8 to Cycle 10 flux distributions, each integrated over energies greater than 1 MeV (REDUCT code). Specifically, this analysis indicates that at the most critical location the 36-in. PLSA design results in a reduction factor of 9.2. A detailed presentation of the results of this analysis is given in Section 5.

2.2.2 <u>Source-term Development</u>

CP&L provided neutron source distributions for the TEC analyses that represented both a historical reference case and a projected case. This section summarizes the generation of the source distributions.

The following criteria were used to select the distributions:

1. The reference distribution should be typical or averaged to represent past operation at HBR2.

2. The projected distribution should be typical or averaged to represent expected operation after introduction of the PLSAs.

3. Consistent methods should be used to generate the reference and projected distributions.

4. Relative pin power distributions in x-y geometry should be supplied by CP&L since TEC proposed using DOTSOR to convert to neutron source distribution in R-θgeometry. Exposure - dependent K/ν factors should be applied to each assembly prior to DOTSOR processing.

Investigation showed that HBR2 Cycle 8 average power distribution was within a few percent of the measured 8-cycle average distribution[1] for the peripheral assemblies, satisfying Criterion 1. CP&L's analytic models of HBR2, a pin-by-pin, 2-group quarter-core PDQ7 and 3-D 1.5-group coarse-mesh quarter-core XTG, agreed very well with measurements for Cycle 8 and previous cycles. The models were benchmarked to the reference case (Cycle 8) and used consistently to generate the projected power distribution after insertion of the PLSA (Cycle 10), satisfying Criterion 3. Comparisons of preliminary calculations of power distributions for Cycles 10, 11, and 12 with the PLSAs inserted[2] showed Cycle 10 peripheral assembly powers were typical or greater than those in future cycles. Cycle 10 will have all fresh assemblies in peripheral locations of highest importance with regard to flux at the vessel, and thus represents the worst case loading. The projected Cycle 10 distributions were selected as satisfying Criterion 2. Criterion 4 is addressed in Section 4.3.

For both the reference case (Cycle 8) and the projected case (Cycle 10), the PDQ7 and XTG models were used to deplete the core in steps of 1000-2000 MWD/MTU to nominal cycle lengths. For Cycle 10, two PDQ7

depletions were performed, one typical of the core above the shielded region and another typical of the lower core with shield. The pin-wise relative power distributions from the PDQ7 cases were exposure-weighted to produce a Cycle 8 average, and an upper core and lower core average for Cycle 10. Relative axial distributions were obtained from the XTG cases by normalizing the cycle delta-exposure distributions to an integral of unity in each assembly and in each quarter assembly.

The Cycle 8 average relative power distribution from both PDQ7 and XTG were compared to measured distributions and showed standard deviations of 3% for both radial (PDQ7) and axial (XTG) calculations.

Comparisons with measurements available from Cycle 9 showed that both models continued to follow HBR2 power distributions with a standard deviation of less than 3%. These comparisons are important since the Cycle 9 core contains gadolinia pins not present in previous cycles; gadolinia pins will be used in all future cycles to control inner core power peaking induced by the low-leakage loading patterns.

The computer code AXFRAC was developed to convert relative power distributions from PDQ7 and XTG to DOTSOR input format (which computed neutron sources for DOT R-θ calculations) and to DOT and ANISN input format for R-Z and R calculations.

2.2.3 Synthesis Technique and Reduction Factor Definition

This section provides the details of the synthesis method and reduction factor used in the best-estimate analysis.

Synthesis Analysis

The synthesis method used in this analysis is essentially the same as that used (1) by ORNL in several benchmark analyses, including ANO-1 (as described in Section 3.2.2), and (2) in the EPRI LEPRICON package.[3] The method is defined by the following equation:

$$\phi_g(r,z,\theta) = \frac{\phi_g(r,z)}{\phi_g(r)} \phi_g(r,\theta).$$

The CP&L analysis, like the ANO-1 analysis, used DOT-IV to obtain the two-dimensional flux distributions and ANISN to obtain the one-dimensional flux distributions. The ELXSIR cross-section library was used in all transport calculations for both CP&L and ANO-1. Unlike the ANO-1 analysis, the HBR2 analysis relied upon superposition because of the significantly different (r,) distributions in and above the PLSA shield region. Therefore, in the HBR2 analysis the three-dimensional flux distribution was given by the following equation:

$$\phi_g(r,z,\theta) = \frac{\phi_g^u(r,z)}{\phi_g^u(r)} \phi_g^u(r,\theta) + \frac{\phi_g^L(r,z)}{\phi_g^L(r)} \phi_g^L(r,\theta).$$

The superscripts u and L designate the contribution to the three-dimensional flux distribution resulting from source neutrons originating in the core region (1) from the top of the shield to the top of the core, and (2) from the top of the shield to the bottom of the core, respectively. The three-dimensional source distributions used in these calculations were developed as described in Section 2.2.2 and Section 4.3.

The geometric models used in the DOT and ANISN calculations are described in Section 4.4. The sources and models were developed to give best estimates at the lower circumferential weld at the center of the core flats. Sample DOT and ANISN inputs for Cycle 10 are provided in Section 4.6.

Reduction Factor

The efficiency of the PLSA design was evaluated by defining a flux reduction factor consisting of the ratio of the Cycle 8 to Cycle 10 flux for energies greater than 1 MeV. For calculations using the ELXSIR cross-section library the reduction factor is given by the following equation:

$$RF = \sum_{g=1}^{27} \phi_g^u(r,z,\theta)/[\sum_{g=1}^{27} \phi_g^s(r,z,\theta).$$

In this equation the superscript u indicates the Cycle 8 flux, and the superscript s indicates the Cycle 10 flux.

2.3 REFERENCES

1. Attachment to Letter from E. E. Utley to H. R. Denton, CP&L, File NF-1111.04, February 9, 1983.

2. Dresser, T. M. "Feasibility of the Part-Length Shield Assembly as a Flux Reduction Technique," CP&L, File NF-1111.05, Serial NF-83-219, April 1983.

3. Maerker, R. E., M. L. Williams, and B. L. Broadhead. "Summary Documentation of EPRI Workshop on LWR Pressure Vessel Fluence Calculations with LEPRICON Code System," ORNL, meeting held at Palo Alto, California, April 18-19, 1983.

Section 3

QUALIFICATION AND VERIFICATION

3.1 QUALIFICATIONS OF THE ANALYSIS TEAM

For purposes of analysis and review, a joint team was formed consisting of members from CP&L and TEC. The primary team members were (1) W. K. Cantrell, (2) H. H. Chen, (3) C. W. Craven, (4) T. M. Dresser, (5) R. S. Howell, (6) J. C. Robinson, (7) W. M. Simpkins, and (8) M. L. Williams. The team has both a strong academic background and experience in all areas related to the flux reduction project. All individuals on the team hold degrees in nuclear engineering--five Ph.D.s, one M.S., and two B.S.s (one with two years graduate work). Complete résumés for the team members are included in Appendix A.

The team has more than 80 man-years of radiation transport, core physics, and related experience. This experience base includes methods development, code development, benchmarking, and applications. The experience of the team was developed in a variety of work areas including consulting, national laboratories, utilities, and universities.

Of particular significance to this project was direct involvement at the Oak Ridge National Laboratory (ORNL) with methods development for the LEPRICON system and ELXSIR cross-section library. Both were developed for the Electric Power Research Institute (EPRI), specifically for performing light water reactor (LWR) fluence analysis. Further, this

experience included benchmarking of LEPRICON modules and ELXSIR to measurements at Unit 1 of Arkansas Nuclear One (ANO-1), at the Pool Critical Assembly (PCA), and at the Pool Side Facility (PSF).[7,8]

3.2 CODE VERIFICATION AND BENCHMARKING

This section briefly covers the qualifications of the primary computer codes used in the fluence reduction project. The first subsection summarizes the benchmarking background of the codes, while the second subsection covers specific past benchmarking of methods/codes used in the best-estimate analysis of the PLSA effectiveness. The final subsection covers CP&L's plans for continued benchmarking.

3.2.1 History of Codes

The codes used in this project and their primary functions are listed in Table 3-1. A more detailed discussion of the code functions is provided in Section 4.1. The following paragraphs provide a brief background of these codes.

The AXFRAC, DOTSYN, REDUCT, DIFF, XPTX, XMIX, and DC2G codes were written specifically for the CP&L flux reduction project. All other codes in Table 3-1 are standard codes distributed by various groups.

ANISN-W evolved from the ANISN code developed at ORNL. ANISN has a long history of development that originates with the DSN code written at Los Alamos Scientific Laboratory. It has wide acceptance in the nuclear industry and has become an industry standard code.

Table 3-1

COMPUTER CODES AND FUNCTIONS

Code Name	Function
ANISN-W	One-dimensional radiation transport
DOS	Two-dimensional radiation transport and cross section mixing
AXFRAC	Source preparation
DOTSOR	R-θ source preparation
DOTSYN	Flux synthesis
REDUCT	Reduction factor analysis
XPOSE	Generate exposure-dependent diffusion parameters
PDQ-7	Relative x-y power distribution
XTG	Relative axial power distribution
AMPX-II	Cross section collapsing
DIFF	Preparation of two-group diffusion constants
XPTX	Preparation of two-group diffusion constants
XMIX	Preparation of two-group diffusion constants
DC2G	Preparation of two-group diffusion constants

The version of ANISN used in this project is traceable to the standard ANISN-W distributed by the Radiation Shielding Information Center (RSIC) at ORNL. Its installation on the University Computing Company (UCC) CYBER was verified by standard calculations distributed with the code by RSIC. During this project the code was compared to a VAX 11/780 version of ANISN-ORNL and was found to produce the same results using the slab geometry model and cross sections used in the flux reduction project (model described in Section 4.4.2).

The Discrete Ordinates System (DOS) principally consists of the two-dimensional radiation transport code DOT and the cross-section mixing code GIP. These codes have a long history of development and benchmarking at ORNL. They also have been used, benchmarked, and accepted by the nuclear industry and have become industry standards. The version used in this project is the latest distributed by RSIC (i.e., DOT 4.3 - 1982). Installation on the UCC-CYBER system was verified by use of the standard calculations distributed with the source code. Specific benchmark analyses using DOT 4.3 are described in Section 3.2.2.

DOTSOR was produced by ORNL for EPRI as part of the LEPRICON package for LWR fluence analysis. It is used to convert power distributions into DOT R-θ source distributions. DOTSOR was used in the ANO-1 benchmark analysis at ORNL (see Section 3.2.2). Installation on the UCC-IBM was verified by TEC using the ANO-1 data. In the CP&L fluence reduction project, the R-θ sources produced by DOTSOR were verified by comparing the sources listed in the DOT balance tables to assembly powers.

DOTSYN, like DOTSOR, was produced by ORNL (M. L. Williams) for EPRI as part of the LEPRICON package. This module produces a three-dimensional flux distribution from one- and two-dimensional flux distributions using the synthesis technique described in Section 2.2.3. The DOTSYN methodology was used in the ANO-1, PCA, and PSF benchmarks discussed in Section 3.2.2 as well as other analyses. The version of DOTSYN used in the CP&L fluence reduction analysis was produced specifically for this analysis, but was written by the same author that produced the code for EPRI. The version used in the CP&L analysis was verified by comparison to hand calculations.

PDQ7V2/010 (ARMP-compatible) is an industry standard multigroup fine-mesh diffusion code provided by EPRI through UCC.

XTGPWR (Version DMAY80) is the Exxon Nuclear Corporation's design nodal simulator, and differs from CP&L's version TNR05010 because it has been expanded to model 24 axial nodes. Version DMAY80 was made available to CP&L by ENC through UCC for the PLSA studies.

XPOSE (Version DMAR78) is ENC's revised LEOPARD code supplied to CP&L through UCC. It is used to provide two-group diffusion parameters (MND thermal treatment) for fueled regions in CP&L's PDQ and XTG models.

AMPX-II was developed at ORNL. It has been used to develop many benchmarked cross-section libraries, including the 218-group neutron library produced by an NRC-sponsored program[7] for criticality safety studies and the 56-group ELXSIR library produced for EPRI. The CP&L fluence reduction project used AMPX-II to reduce the 218-group library to a 102-group

neutron library (36 thermal groups) and then to a 2-group library for production of 2-group diffusion constants.

AXFRAC, REDUCT, DIFF, XPTX, XMIX, and DC2G were produced specifically for the CP&L fluence reduction project. The functions of each of these codes are described in Section 4.1. Each code was verified by comparing results with hand calculations and comparing intermediate results.

3.2.2 Past Benchmarking of Methods

The PCA located at ORNL is a low-power critical facility that has been used for several NRC-sponsored experiments to benchmark LWR pressure vessel (PV) fluence calculational methods. The methods used by TEC for this analysis of the H. B. Robinson vessel are essentially the same as used by ORNL in their calculations of the PCA experiments.[1,2] These methods are basically a DOT-IV[3] P3-S8 transport calculation using a VITAMIN-C[4]-based cross-section library, and are consistent with the ASTM-recommended procedures set forth in E706(II). Leakage in the third dimension of the PCA configuration was accounted for by using a synthesis approximation similar to that used by TEC in the H. B. Robinson Plant analysis. This approximation was verified for the PCA midplane analysis by comparison with 3-D Monte Carlo results.[5] With these methods ORNL was able to predict the experimental dosimeter reaction rates to an agreement of about 5% at the front of the simulated PV and about 10% at the T/4 position.[1] This accuracy is within the acceptable criteria for RPV fluence calculations.[6]

Further benchmarking of the methods used by TEC was performed by ORNL for the NRC at the Oak Ridge Research Reactor (ORR) Pool Side Facility

(PSF). One experiment completed at this facility is the "Westinghouse Perturbation Experiment."[7] In this experiment a Westinghouse dosimeter surveillance capsule (as used in the H. B. Robinson Plant) was placed in the neutron field of the PSF, along with a simulated thermal shield and PV. Calculations of the dosimeter reaction rates in the capsule agreed with the experimental results within about 10%. Off-midplane results were also obtained for the perturbation experiment, and it was found that the 3-D synthesis procedure, as used by TEC, was able to accurately account for the axial variation in the measured reaction rates, even with an asymmetrical core source distribution.[7]

A final validation of the fluence analysis methods used by TEC is given by benchmark results for the Arkansas Nuclear One, Unit 1, PWR owned by Arkansas Power and Light. This Babcock & Wilcox (B&W) plant has been calculated by ORNL for EPRI using virtually identical methods and data as TEC used for the H. B. Robinson Plant: DOTSOR[8] was used for the source generation, the ELXSIR[8] cross-section library was used, the transport calculations were performed with DOT-IV, and the DOTSYN synthesis was used.[8] Although the results of this study have not yet been published, they have been quoted at several meetings, and TEC and CP&L have been informed of the following results[9]:

For the cavity measurements outside the RPV at the midplane, the calculations agreed with the measured results within about 10% for essentially all dosimeters. There were no in-vessel measurements, and the off-midplane cavity comparisons are inconclusive because of cavity streaming effects.

Note that cavity streaming does not significantly affect in-vessel results, which are of interest in the present H. B. Robinson analysis.

In summary, the methods used by TEC for the H. B. Robinson RPV fluence calculation are state of the art and conform to ASTM recommended procedures. They have been benchmarked in other studies sponsored by the NRC and EPRI. The methods satisfy the target accuracies specified by the NRC for RPV fluence calculations,[6] and represent the best available technology for the H. B. Robinson analysis.

3.2.3 CP&L Plans for Additional Benchmarking

Capsules S, V, and T were removed from HBR2, respectively, at the ends of Cycles 1, 3, and 8. Relative to a major axis, their locations were 10°, 20°, and 0°, respectively. Measurements of dosimeter activities from these capsules are used here to provide benchmarks for the base case calculations.

For the present Cycle 9 (and planned for future cycles) dosimeters are placed outside the vessel, covering many angles and axial elevations. Additional in-vessel dosimetry is presently being evaluated in order to establish relationships between the outside-of-vessel dosimeter responses and within-vessel measurements.

The Cycle 10 measured power distribution will provide early benchmarks for the accuracy of sources used in the projected case calculations presented here. Measurements of the out-of-vessel dosimeters at EOC will provide benchmarks for extended calculations with the present models. We will thus have timely indications of any significant revisions to the final estimates of this analysis.

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3. Rhoades, W. A., and Childs, R. L. An Updated Version of the DOT 4 One- and Two-Dimensional Neutron/Photon Transport Code, ORNL-5851, Oak Ridge National Laboratory, 1982.

4. RSIC Data Library Collection, VITAMIN-C, 171 Neutron Group, 36 Gamma-Ray Group Cross Sections in AMPX and CCCC Interface Formats for Fusion and LMFBR Neutronics, DLC-41, Oak Ridge National Laboratory, 1978.

5. Moudlin, P. J., and R. E. Maerker. "Supplementary Neutron Flux Calculations for the ORNL Pool Critical Assembly Pressure Vessel Facility," Proceedings of Fourth ASTM-EURATOM Symposium on Reactor Dosimeter, NUREG/CP-0029, Vol. 2, Gaithersburg, Maryland, 1982.

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7. Maerker, R. E., and M. L. Williams. "Calculations of the Westinghouse Perturbation Experiment at the Poolside Facility," Proceedings of Fourth ASTM-EURATOM Symposium on Reactor Dosimeter, NUREG/CP-0029, Vol. 2, Gaithersburg, Maryland, 1982.

8. Maerker, R. E., M. L. Williams, and B. L. Broadhead. "Summary Documentation of EPRI Workshop on LWR Pressure Vessel Fluence Calculations with the LEPRICON Code System," Electric Power Research Institute, Palo Alto, 1983.

9. Williams, M. L. Personal communication.

Section 4

SUPPORTING MATERIAL

4.1 DESCRIPTION OF THE CODES USED IN THE ANALYSIS

This analysis used the computer codes that are listed in Table 4-1. For the codes distributed by either RSIC or EPRI or obtained from ENC, the description on the following pages consists of excerpts from the user manuals distributed with the computer codes. For a more detailed description of the codes, the user manuals listed in the references in Section 4 should be consulted. All other computer codes were written in the process of this analysis and are described in this report.

4.1.1 The GIP Computer Code

The GIP[1] code accepts nuclide-organized microscopic cross-section data in the ALC1 format. GIP prepares a group-organized file of microscopic and/or macroscopic cross sections for use by the DOT or ANISN computer codes. The macroscopic cross-section mixtures are prepared by GIP using the mixing table contained in the input data stream for the specific case. This mixing table consists of the microscopic nuclide identifiers, the associated number density, and the resultant mixture identifier.

4.1.2 The DOT-IV Computer Code

DOT IV[2] determines the flux or fluence of particles throughout a one- or two-dimensional geometric system due to sources either generated as a result of particle interaction with the medium or incident upon the

Table 4-1

COMPUTER CODES USED IN THE REACTOR PRESSURE VESSEL FLUENCE ANALYSIS

Code Name	Source of Code
DOS a. GIP b. DOT-IV	Radiation Shielding Information Center
ANISN-W	Radiation Shielding Information Center
AMPX-II a. NITAWL b. XSDRNPM	Radiation Shielding Information Center
DIFF	Technology for Energy Corporation
XPTX	Technology for Energy Corporation
XMIX	Technology for Energy Corporation
DC2G	Technology for Energy Corporation
PDQ-7	Electric Power Research Institute
XTG	Exxon Nuclear Corporation
XPOSE	Exxon Nuclear Corporation
AXFRAC	Carolina Power and Light
DOTSOR	Electric Power Research Institute
DOTSYN	Technology for Energy Corporation
REDUCT	Technology for Energy Corporation

system from external sources. The principal application is to the deep-penetration transport of neutrons and photons.

The Boltzman transport equation is solved using either the method of discrete ordinates or the diffusion theory approximation. In the discrete ordinates method, the primary mode of operation, balance equations are solved for the flow of particles moving in a set of discrete directions in each cell of a space mesh, and in each group of a multigroup energy structure. Iterations are performed until all implicitness in the coupling of cells, directions, groups, and source regeneration has been resolved.

4.1.3 The ANISN-W Computer Code

ANISN-W[3] solves the one-dimensional Boltzman transport equation for neutrons or gamma rays. The geometry may be slab, spherical, or cylindrical. The source may be fixed, or fission, or a subcritical combination of the two.

The solution technique is an advanced discrete ordinates method that represents a generalization of the method originated by G. C. Wick and developed and extended to curvilinear geometry by B. G. Carlson at Los Alamos Scientific Laboratory. ANISN-W was designed to solve deep penetration problems in which angle-dependent spectra are calculated in detail. ANISN-W includes techniques for handling general anisotropic scattering, pointwise convergence criteria, and alternate step-function difference equations that effectively remove the oscillating flux distributions sometimes found in discrete ordinates solutions.

4.1.4 The Nordheim's Integral Treatment and Working Library (NITAWL) Computer Code

NITAWL[4] is responsible for reading the general AMPX master library formatted cross sections, performing resonance self-shielding calculations, and collecting the data into a working library. The actual neutron resonance self-shielding calculation employs the Nordhiem integral treatment, though the narrow resonance and an infinite mass treatment are available as alternate methods.

4.1.5 The XSDRNPM Computer Code

The XSDRNPM[4] module is provided in the AMPX system for two purposes. First, it provides a one-dimensional transport capability for calculating reaction rates, eigenvalues, and critical dimensions. Second, it allows spatial cross-section weighting to be performed. XSDRNPM supports four weighting options: (1) cell weighting, (2) zone weighting, (3) region weighting, and (4) "inner" cell weighting. Additionally, XSDRNPM can use "inscatter" and "outscatter" approximations and calculate transport cross sections for use in diffusion theory applications.

4.1.6 The DIFF Computer Code

The DIFF code is used to compute the space-dependent diffusion coefficients by employing the equation of Fick's law. DIFF inputs the 102-group angular fluxes at the mesh interval boundaries from a flux tape produced by the XSDRNPM code. It calculates the total flux and current at each mesh boundary and collapses the fluxes and currents from 102 groups to 2 groups. Then the 2-group diffusion coefficients at each mesh boundary are calculated from the Fick's law generation. The flux

gradient at the mesh boundary is obtained by linearly differencing the fluxes at the nearby mesh boundaries. The 2-group diffusion coefficients in each region are calculated by space-averaging the diffusion coefficients over the interior mesh boundaries within each spatial region.

4.1.7 The XPTX Computer Code

The XPTX computer code is used to compute multigroup microscopic transport cross sections for nuclides in a working cross-section library. The transport cross-section calculation is based upon both the "inscatter" and "outscatter" approximations. The transport cross-section weighting function used in the inscatter approximation of the transport cross-section calculation is calculated by the XSDRNPM code.

4.1.8 The XMIX Computer Code

The XMIX code is used to compute the macroscopic transport cross sections in each material region. XMIX inputs the microscopic transport cross sections generated from the XPTX code and the number densities of nuclides in the region.

4.1.9 The DC2G Computer Code

The DC2G code is used to compute the 2-group diffusion coefficients in each region by collapsing the 102-group diffusion coefficients using the 102-group transport cross-section weighting function for that region. The 102-group diffusion coefficients in region k are calculated by

$$D_g^k = \frac{1}{3\,\Sigma_{trg}^k} \quad \text{for } g = 1 \text{ to } 102$$

where Σ_{trg}^{k} is the macroscopic transport cross section in group g and in region k.

4.1.10 The PDQ 7 Computer Code

The PDQ7/HARMONY[5] is a multigroup diffusion-depletion code. PDQ7 determines the spatial flux and power distribution from a specified geometry and material description. The HARMONY portion of the code performs the depletion phase of the problem by solving the differential equations describing the time behavior of the nuclide concentrations for that time interval. The new distribution of nuclide concentrations are used in the generation of few-group macroscopic cross sections for the next spatial calculation.

The CP&L PDQ7/HARMONY setup for the Robinson core is a 125 x 125 mesh with explicit description of the core, baffle, barrel, outside water, thermal shield, and vessel. Twenty-four isotopes are tracked for each mesh interval.

4.1.11 The XTG Computer Code

XTG[6] is a modified two-group coarse mesh reactor simulator. The model is designed to accept regular or MND group cross sections and simulate the reactor for any steady-state situation. The conditions under which the cross sections were generated are input, and XTG uses this information to store all cross sections on a common base (i.e., zero boron, zero Xenon). The cross sections are recalled and modified to fit the reactor conditions and account for Doppler effects, time and power dependent iodine and xenon, boron, power and moderator density changes, burnable poison, and control rods.

The PWR model was designed and tested at four nodes per assembly; however, it can be operated at one node per assembly if full core calculations are performed or if the centerline of the reactor does not bisect the central assemblies. The shuffling logic also assumes four nodes per assembly.

4.1.12 The XPOSE Computer Code

XPOSE[7] is identical in most ways to the LEOPARD code which combines the MUFT and SOFOCATE models with CINDER depletion. The original model has been expanded to include some trans-plutonium elements as well as Np-237 and Pu-238. In addition, the thermal energy range has been extended to 1.855 eV to allow the Pu-240 resonance at 1.056 eV to be treated in the thermal part of the code. The group structure is finer, and spatial self-shielding effects are accounted for in a detailed manner.

Edits are automated in XPOSE so that output is formatted for input to XTG or PDQ7.

4.1.13 The AXFRAC Computer Code

AXFRAC provides input to DOTSOR to normalize the pin-wise relative power distributions from PDQ7 and split the distributions into upper-core and lower-core regions according to the axial distributions from XTG. In addition, correction factors equal to the ratio of core-average κ/ν to assembly average κ/ν are applied to the normalization (DOTSOR then provides κ/ν corresponding to core average exposure).

A second function of AXFRAC is to provide neutron sources for the R-Z DOT and R ANISN calculations necessary for the synthesis of 3-D flux distributions.

The choice was made for the synthesis to model the R-Z and R distributions to represent the core along its major axis since the critical areas for vessel fluence accumulation are opposite the core flats. The R-Z source synthesized by AXFRAC from the PDQ7 and XTG relative power distributions does not assume the R and Z distributions are separable. The R distribution is somewhat arbitrary and is normalized by the ANISN calculation in the final synthesis. A listing of AXFRAC is given in Appendix B.

4.1.14 The DOTSOR Computer Code

The function of the DOTSOR[8] computer code is to produce a distributed neutron source in R-Θ geometry for input to the DOT-IV transport code, given a specified power distribution in X-Y coordinates. The code was specifically developed for application to LWR calculations in which the reactor core region can be specified easily on an X-Y coordinate grid, whereas the ex-core configuration is described by cylindrical geometry.

The DOTSOR calculation accepts the core power distribution as input, converts this distribution from the X-Y geometry to the R-Θ geometry, and converts the R-THETA power density to a neutron source density. The factor to convert from core power density to neutron source density is determined as a function of the core burnup. The final R-Θ neutron source is punched out in card format suitable for input into the DOT-IV computer code.

4.1.15 The DOTSYN Computer Code

The DOTSYN computer code was written at TEC to perform the flux synthesis calculations. This code receives as input the geometry description for the DOT-IV R-Θ model, the geometry input for the DOT-IV R-Z model, the geometry input for the ANISN-W radial model, and the associated multigroup neutron fluxes for these models. DOTSYN then uses these values to compute the three-dimensional neutron fluxes using the flux synthesis technique specified in Section 2.2.3. This synthesis technique utilized the same methods as those used in the analysis of the Arkansas Nuclear One, Unit 1 (ANO-1), in the development of the EPRI LEPRICON[8] package.

4.1.16 The REDUCT Computer Code

The REDUCT computer code is used to compute the reactor pressure vessel fluence reduction factor for the partial length shield assembly. The reduction factor is computed as the ratio of the flux greater than 1 MeV for the pre- and post-PLSA fluxes calculated in the DOTSYN computer code. The resulting three-dimensional reduction factor is traced on the printed output for specified regions of the problem geometry.

4.2 CROSS-SECTION LIBRARY DESCRIPTIONS

The five cross-section libraries listed in Table 4-2 were used in this analysis. Each of the following sections describes one of the listed libraries. For standard libraries obtained from sources outside of the analysis team, the descriptions provided are excerpts from the documentation provided by the source. A more complete description of the

cross-section libraries is provided in the references for these libraries.

Table 4-2

CROSS-SECTION LIBRARIES USED IN ANALYSES

Library Name	Supplier
CSRL master library	Radiation Shielding Information Center
102 group library	Technology for Energy Corporation
PLSA 2 group cross sections	Technology for Energy Corporation
Core 2 group cross sections	Carolina Power and Light
ELXSIR cross-section library	Electric Power Research Institute
XPOSE cross-section library	Exxon Nuclear Company

4.2.1 The CSRL Master Library

The CSRL[9] master library used in this analysis was specifically generated for criticality safety studies. The library contains data for the fuel, structural, and neutron-absorbing materials and is a data base for the generation of fine- or broad-group cross sections for shipping cask calculations and other criticality safety neutronics analyses. The group structure of the library was chosen to fit the important cross-section structure of materials likely to appear in criticality safety problems. Emphasis was placed on the resonance and thermal energy ranges. The 218-group structure contains 140 epithermal groups above and 78 thermal groups below 3.05 eV.

4.2.2 The 102-Group Cross-Section Library

The 102-group cross-section library was generated from a number of cell calculations using AMPX II modules NITAWL and XSDRNPM. The cell calculations consist of 1-D neutron transport calculations for the mockups of the fuel pin, "water hole" in a fuel assembly, shield pin in the PLSA, and slab zones of core baffle and water.

NITAWL was used both to perform neutron resonance self-shielding calculations for the resonance absorbers U-235 and U-238, and to convert the 218-group AMPX master cross-section library into the working format suitable for later neutron transport calculations. The Nordheim integral treatment was specified as the method of the neutron resonance self-shielding calculations for U-235 and U-238. The Dancoff correction factor for the cylindrical fuel element lattice under consideration was calculated using the method described in Reference 10.

Following the self-shielding calculations, XSDRNPM was used to perform eigenvalue calculations for the 2% and 3% UO_2 fuel pin cells. Fixed-source calculations were performed for the water hole cells and baffle-water, water-baffle-water 1-D slab zones. The U-235 fission spectrum was used as the isotopic surface source in the fixed-source calculations for the baffle-water zone, and the fission spectrum-1/E-Maxwellian cross-section weighting function was used as the source in the water-baffle-water zone calculation. The orders of angular quadrature and scattering were 8 and 3, respectively, for both eigenvalue and fixed-source calculations. Reflected and white boundary conditions were used at the left and right boundaries in the fuel cell calculations.

Reflected and vacuum boundary conditions were used in the fixed-source calculations.

The 102-group cell-averaged cross-section library for each cell calculation was generated by cell-weighting and group-collapsing the 218-group working libraries. Out of these 102 groups, 36 groups fall into the thermal group region of the final 2-group structure. The upper energy boundary of the thermal groups in the 102-group structure was set at 1.86 eV. The zone-weighting option was specified in the zone calculations to generate the zone-averaged 102-group cross-section libraries.

4.2.3 Two-Group PLSA Cross Sections

After the 102-group cell-averaged and zone-averaged cross sections had been generated, XSDRNPM was employed to perform an S_{16}, P_3 eigenvalue calculation for the 1-D slab core model with SS-304 as the PLSA shield material. Reflected and vacuum boundary conditions were used at the left and right boundaries, respectively. Zone-weighting was specified in the calculation to generate zone-averaged cross sections. The 102-group cross-section structure was collapsed to a 2-group structure. The cut-off energy for thermal neutrons was set to 1.86 eV.

Two-group diffusion constants for the SS-304 PLSA were calculated from the 2-group cross-section library generated by the 1-D slab XSDRNPM calculation as described above. These two-group constants were employed in the CP&L diffusion codes for the neutron flux and power distribution calculations for the actual core configuration. The two-group constants consist of the diffusion coefficients, macroscopic absorption, removal, and fission cross sections.

The thermal group diffusion coefficient using the mixed number density (MND) procedure was calculated for each of the regions. First, the thermal group transport cross section using the outscatter approximation was calculated by collapsing the outscatter transport cross sections in the thermal groups of the 102-group structure using the zone-averaged total flux as a weighting function in each zone. Then the MND diffusion coefficient for the thermal group was calculated from the equation:

$$D_2^{MND} = \frac{1}{3\Sigma_{tr2}^{MND}} ,$$

$$\Sigma_{tr2}^{MND} = \Sigma_{tr2} + (V_R - 1)\,\Sigma_{a2} ,$$

$$V_R = \frac{\sqrt{\pi}}{2}(293/T)^{1/2}(\bar{v}_{th}/220) ,$$

$\bar{v}_{th}$ = the neutron velocity in the zone,

T = the moderator temperature in the zone in °K,

Σ_{a2} = the thermal group absorption cross section in the zone, and

Σ_{tr2} = the flux-averaged outscatter transport cross section in the zone.

Note that V_R represents the Maxwellian-corrected average thermal neutron velocity normalized to 2200 m/s.

4.2.4 Two-Group Macroscopic Cross Sections

The cross-section data needed to solve the two-group diffusion equation are the absorption cross sections Σ_{a1} and Σ_{a2}, fission cross sections $\nu\Sigma_{f1}$ and $\nu\Sigma_{f2}$, and the removal cross section Σ_{R1} in each zone of the SS-304 PLSA core model. The microscopic cross sections for soluable boron in the thermal group for the MND procedure were also calculated.

The two-group constants were used in a PDQ calculation with the same geometric model as used in the 102-group XSDRNPM calculation for comparison purposes. The two-group constants and differences between the diffusion and transport calculations are summarized in Table 4-3. Only the PLSA constants from this study were used in the actual cycle 10 PDQ calculations; but the comparison shows they model the proper effect on fission rate near the fuel-PLSA interface.

4.2.5 The ELXSIR 56-Group Cross-Section Library

The ELXSIR[8] (EPRI LWR X sections for irradiation studies) P3, multigroup cross-section library was generated to serve as the standard DOT-IV library in the LEPRICON system for LWR dosimetry calculations. The cross sections are mainly applicable to problems concerning the transport of epithermal and high-energy neutrons from the core volume to the pressure vessel and cavity region of a LWR. These types of problems are frequently encountered in computing surveillance dosimetry activation

Table 4-3

TWO-GROUP DIFFUSION CONSTANTS AND SLAB MODEL COMPARISONS

Zone	1	2	3	4	5
Material	$U(2\%)O_2$	$U(3\%)O_2$	$U(3\%)O_2$	S.S.-304 PLSA	S.S.-304 PLSA
D_1	1.47E+00	1.38E+00	1.24E+00	1.22E+00	1.45E+00
D_2^{MND}	3.33E-01	3.30E-01	3.20E-01	2.89E-01	2.79E-01
Σ_a^1	8.31E-03	8.79E-03	9.36E-03	1.52E-03	1.68E-03
Σ_a^2	8.76E-02	1.16E-01	1.15E-01	7.01E-02	6.92E-02
Σ_R^1	1.87E-02	1.79E-02	2.01E-02	2.38E-02	2.88E-02
Σ_f^1	4.61E-03	5.72E-03	5.92E-03	0.0	0.0
Σ_f^2	1.22E-01	1.80E-01	1.78E-01	0.0	0.0

	% Error				
Fission rate	-0.974	1.45	0.318	-	-
Eigenvalue	1.15				

and/or the accumulated pressure vessel fluence or radiation damage. Although thermal and epithermal cross sections are included in the library, the group structure emphasizes the higher energy range. The cross sections were not generated for application to reactor criticality calculations. Of the 56 neutron groups in the ELXSIR library, the upper 27 energy groups represent energies greater than 1.0 MeV. Specifically, the upper 27 energy groups represent energies greater than 1.0026 MeV.

4.3 SOURCE-TERM DOCUMENTATION

This section provides additional supportive detail on the development of the three-dimensional source distribution as outlined in Section 2.2.2.

4.3.1 Generation of the Reference Distribution

In order to meet criterion 3 of Section 2.2.2, CP&L analytical models were used to generate both reference and projected distributions. The models are 2-D, 2-group, pin-by-pin, quarter-core using PDQ7/HARMONY[5,11], and 3-D, 1.5-group, coarse-mesh quarter-core using the nodal simulator, XTGPWR.[6] Cross sections for both models are supplied by XPOSE, ENC's LEOPARD-based code.[7] CP&L has used these models to perform design review and core follow functions for five cycles. The models are "best-estimate".

The Cycle 8 average radial-relative pin power distribution was obtained as the exposure-weighted average of distributions given by an eight-step depletion of the cycle with PDQ 7/HARMONY. TEC was supplied the eight-step distributions and the exposure-weighted average on tape at UCC.

Figure 4-1 compares normalized assembly delta exposures for Cycle 8 obtained with the PDQ7 model and measured (i.e., accumulated by the TOTE code).[12] The PDQ7 distribution for each assembly corresponds to the cycle-averaged pin distribution supplied to TEC. The standard deviation of PDQ7-measured differences is 3.1% and indicative of the uncertainty in the assembly-relative power distributions from the PDQ7 model.

The pin distributions supplied to TEC were normalized to a core-wide pin average of unity (split pin cells count as whole pins). Figures 4-2 and 4-3 show the averaged distributions for Locations H-15 and G-15 (closest to the vessel) normalized to an assembly average of unity.

Axial distributions were obtained from XTG simulation of Cycle 8. The cycle delta exposures obtained from XTG were normalized both assembly-wise and four-node-per-assembly-wise and supplied to TEC through UCC as shown in Table 4-4. The normalization is that each 24-axial node distribution (covering active fuel length) sums to unity.

Figure 4-4 compares the core-averaged distribution corresponding to the assembly distributions supplied to TEC with the measured distributions obtained from TOTE. The standard deviation of XTG-measured differences is about 3% on a nodal basis and indicates the uncertainty in the axial distributions from XTG.

4.3.2 Generation of Projected Distribution

PLSAs are scheduled to occupy the core flats in HBR2 beginning with Cycle 10. Since the PLSA-fueled region will contain new fuel (on the core flats), the selection of Cycle 10 as typical of future cycles will

CP&L Carolina Power & Light Company	INCORE ANALYSIS UNIT	ENGINEERING CALCULATION (COMPUTER INPUT)

PREPARED BY: K. Cantrell	DATE: 5/4/83	PAGE NO. ___ OF ___	
CHECKED BY: K. Karcher	DATE: 8/17/83		
SUBJECT: CYC 8 Normalized Assembly Delta Exposures			
COMPUTER PROGRAM: PDQ7-TOTE	VERSION:	PRODUCTION ☐ DEVELOPMENT ☐	TAPE NO. OR FILE NAME:
REACTOR: HBR#2	CYCLE: 8	EXPOSURE:	STATE:

	H	G	F	E	D	C	B	A
8	1 .680 .702	2 9 1.054 1.086	3 17 .944 .996	4 24 .933 .964	5 31 1.166 1.152	6 37 1.141 1.147	7 42 .939 .953	8 46 .846 .809
9	9 1.058 1.091	10 .934 .980	11 18 1.148 1.174	12 25 .992 1.029	13 32 1.183 1.183	14 38 .964 .988	15 43 1.210 1.166	16 47 .709 .672
10	17 .951 .990	18 1.155 1.172	19 .963 1.003	20 26 1.174 1.189	21 33 .981 1.010	22 39 1.099 1.096	23 44 1.028 .983	
11	24 .943 .965	25 1.000 1.026	26 1.179 1.183	27 1.088 1.117	28 34 .946 .976	29 40 1.173 1.140	30 45 .733 .698	
12	31 1.183 1.140	32 1.193 1.171	33 .988 1.010	34 .950 .975	35 .921 .934	36 41 .743 .724		
13	37 1.148 1.105	38 .968 .968	39 1.103 1.094	40 1.174 1.143	41 .742 .723			
14	42 .936 .933	43 1.208 1.144	44 1.028 .981	45 .733 .700				
15	46 .843 .798	47 .707 .664						

PDQ07
Measured (TOTE)

Figure 4-1
Cycle 8 Normalized Assembly Delta Exposures

Std. Dev. of PDQ07-TOTE Differences = 3.1%

Figure 4-2.

HBR2 CYC8 PDQ AVERAGED PIN RELATIVE POWER

ASSEMBLY 46 (H-15)

1.23	1.23	1.24	1.23	1.23	1.23	1.22	1.21
1.24	1.26	1.27	1.26	1.25	1.26	1.23	1.20
1.29	1.30	0.00	1.28	1.28	0.00	1.24	1.19
0.00	1.28	1.29	1.29	1.27	1.25	1.20	1.16
1.22	1.21	1.23	0.00	1.25	1.22	1.17	1.13
1.14	1.14	1.16	1.19	1.21	0.00	1.15	1.10
1.12	1.10	1.10	1.13	1.16	1.15	1.09	1.05
0.00	1.06	1.05	1.08	0.00	1.09	1.03	1.00
1.02	1.00	1.00	1.03	1.06	1.04	.99	.95
.94	.94	.96	.98	1.00	0.00	.94	.90
.91	.90	.92	0.00	.94	.91	.87	.83
0.00	.86	.87	.87	.85	.83	.80	.76
.77	.77	0.00	.76	.76	0.00	.72	.68
.63	.64	.65	.64	.63	.63	.61	.58
.49	.49	.49	.48	.48	.48	.47	.46

Figure 4-3.

HBR2 CYC8 PDQ AVERAGED PIN RELATIVE POWER

ASSEMBLY 47 (G-15)

1.45	1.47	1.48	1.48	1.48	1.47	1.45	1.42	1.40	1.38	1.33	1.28	1.22	1.12	.96
1.44	1.47	1.50	1.49	1.48	1.48	1.45	1.41	1.39	1.37	1.32	1.26	1.19	1.07	.87
1.42	1.47	0.00	1.50	1.49	0.00	1.47	1.42	1.40	0.00	1.31	1.24	0.00	1.02	.82
1.38	1.42	1.46	1.47	1.48	1.46	1.43	0.00	1.36	1.32	1.27	1.19	1.10	.96	.77
1.34	1.38	1.42	1.44	0.00	1.38	1.33	1.30	1.26	1.24	0.00	1.15	1.04	.91	.73
1.30	1.34	0.00	1.38	1.34	1.28	1.23	1.20	1.16	1.14	1.12	1.08	0.00	.86	.69
1.24	1.27	1.32	1.32	1.25	1.19	1.17	1.15	1.10	1.05	1.03	1.01	.93	.80	.64
1.18	1.20	1.24	0.00	1.20	1.13	1.12	0.00	1.05	.99	.97	0.00	.86	.73	.60
1.12	1.15	1.19	1.18	1.12	1.06	1.04	1.02	.97	.92	.90	.88	.80	.69	.55
1.06	1.09	0.00	1.11	1.07	1.01	.96	.93	.90	.87	.85	.82	0.00	.64	.51
.98	1.00	1.03	1.03	0.00	.96	.92	.89	.85	.83	0.00	.75	.68	.58	.46
.90	.92	.94	.93	.93	.90	.87	0.00	.81	.77	.73	.67	.61	.52	.41
.80	.83	0.00	.83	.81	0.00	.78	.74	.72	0.00	.64	.59	0.00	.46	.37
.69	.70	.70	.69	.67	.67	.64	.61	.59	.56	.53	.49	.45	.39	.32
.54	.53	.53	.52	.51	.50	.48	.46	.44	.42	.39	.37	.33	.30	.26

Table 4-4

XTG HBR2 Cycle 8 Averaged Axial Power Distributions

ASSEMBLY-WISE AXIAL SOURCE DISTRIBUTIONS
EAST-SOUTHEAST OCTANT
FORMAT(2I3,2X,8F9.5,2(/,8X,8F9.5))

COORDINATES		24 AXIAL NODE RELATIVE SOURCE DISTRIBUTION, TOP TO BOTTOM							
1	1	0.02661	0.03843	0.04226	0.04416	0.04412	0.04454	0.04530	0.0451
		0.04476	0.04450	0.04426	0.04401	0.04365	0.04343	0.04325	0.0430
		0.04284	0.04274	0.04274	0.04259	0.04237	0.04068	0.03788	0.0266
2	1	0.02452	0.03639	0.04179	0.04397	0.04469	0.04490	0.04493	0.0448
		0.04467	0.04452	0.04437	0.04423	0.04410	0.04398	0.04387	0.0438
		0.04375	0.04374	0.04373	0.04360	0.04305	0.04125	0.03644	0.0248
2	2	0.02615	0.03770	0.04263	0.04445	0.04496	0.04498	0.04486	0.0446
		0.04447	0.04428	0.04410	0.04392	0.04375	0.04359	0.04344	0.0433
		0.04323	0.04317	0.04313	0.04302	0.04255	0.04103	0.03671	0.0259
3	1	0.02593	0.03727	0.04219	0.04410	0.04473	0.04486	0.04481	0.0446
		0.04454	0.04438	0.04422	0.04407	0.04392	0.04378	0.04366	0.0435
		0.04347	0.04341	0.04334	0.04316	0.04260	0.04096	0.03657	0.0258
3	2	0.02410	0.03588	0.04139	0.04369	0.04454	0.04479	0.04481	0.0447
		0.04464	0.04453	0.04443	0.04433	0.04425	0.04417	0.04411	0.0440
		0.04405	0.04405	0.04403	0.04386	0.04323	0.04131	0.03632	0.0247
3	3	0.02602	0.03736	0.04229	0.04419	0.04482	0.04492	0.04484	0.0446
		0.04453	0.04436	0.04421	0.04405	0.04390	0.04376	0.04364	0.0435
		0.04344	0.04337	0.04329	0.04309	0.04250	0.04085	0.03649	0.0258
4	1	0.02580	0.03700	0.04187	0.04379	0.04448	0.04473	0.04486	0.0448
		0.04469	0.04454	0.04439	0.04422	0.04406	0.04392	0.04379	0.0436
		0.04357	0.04349	0.04338	0.04315	0.04253	0.04087	0.03651	0.0258
4	2	0.02536	0.03661	0.04164	0.04370	0.04447	0.04473	0.04480	0.0447
		0.04465	0.04453	0.04440	0.04427	0.04415	0.04403	0.04393	0.0438
		0.04377	0.04371	0.04361	0.04338	0.04272	0.04095	0.03643	0.0256
4	3	0.02382	0.03549	0.04103	0.04344	0.04440	0.04474	0.04482	0.0448
		0.04473	0.04465	0.04456	0.04448	0.04442	0.04436	0.04431	0.0442
		0.04425	0.04423	0.04417	0.04394	0.04320	0.04119	0.03614	0.0245
4	4	0.02413	0.03573	0.04123	0.04363	0.04459	0.04492	0.04497	0.0449
		0.04482	0.04471	0.04460	0.04449	0.04440	0.04431	0.04423	0.0441
		0.04413	0.04408	0.04397	0.04368	0.04289	0.04087	0.03591	0.0246
5	1	0.02291	0.03415	0.03954	0.04193	0.04294	0.04380	0.04499	0.0451
		0.04516	0.04511	0.04503	0.04495	0.04488	0.04482	0.04477	0.0447
		0.04471	0.04469	0.04462	0.04437	0.04363	0.04161	0.03655	0.0249
5	2	0.02330	0.03478	0.04034	0.04284	0.04392	0.04445	0.04477	0.0448
		0.04487	0.04483	0.04477	0.04471	0.04466	0.04462	0.04459	0.0445
		0.04456	0.04454	0.04446	0.04419	0.04339	0.04129	0.03614	0.0245
5	3	0.02488	0.03608	0.04125	0.04349	0.04443	0.04477	0.04488	0.0448
		0.04479	0.04469	0.04458	0.04447	0.04436	0.04427	0.04419	0.0441
		0.04405	0.04397	0.04382	0.04348	0.04266	0.04070	0.03601	0.0252
5	4	0.02437	0.03564	0.04101	0.04343	0.04448	0.04489	0.04500	0.0449
		0.04492	0.04483	0.04473	0.04462	0.04453	0.04444	0.04438	0.0443
		0.04425	0.04417	0.04399	0.04359	0.04265	0.04050	0.03559	0.0246
5	5	0.02278	0.03440	0.04036	0.04324	0.04456	0.04511	0.04530	0.0453
		0.04527	0.04520	0.04511	0.04502	0.04494	0.04488	0.04483	0.0447
		0.04475	0.04466	0.04446	0.04396	0.04282	0.04026	0.03471	0.0232
6	1	0.02332	0.03475	0.04032	0.04288	0.04402	0.04459	0.04492	0.04503

		0.04502	0.04496	0.04488	0.04481	0.04474	0.04467	0.04462	0.04458
		0.04454	0.04449	0.04436	0.04402	0.04314	0.04099	0.03589	0.02449
6	2	0.02469	0.03588	0.04110	0.04338	0.04435	0.04476	0.04493	0.04494
		0.04488	0.04479	0.04468	0.04456	0.04445	0.04435	0.04426	0.04418
		0.04410	0.04401	0.04384	0.04347	0.04262	0.04063	0.03594	0.02520
6	3	0.02262	0.03404	0.03987	0.04272	0.04407	0.04469	0.04497	0.04507
		0.04508	0.04507	0.04504	0.04501	0.04498	0.04497	0.04496	0.04496
		0.04496	0.04491	0.04475	0.04430	0.04321	0.04072	0.03525	0.02376
6	4	0.02012	0.03174	0.03834	0.04186	0.04366	0.04457	0.04502	0.04526
		0.04538	0.04547	0.04554	0.04561	0.04569	0.04579	0.04589	0.04599
		0.04608	0.04609	0.04594	0.04537	0.04393	0.04072	0.03416	0.02180
6	5	0.01985	0.03177	0.03869	0.04241	0.04430	0.04520	0.04561	0.04578
		0.04583	0.04584	0.04583	0.04583	0.04584	0.04586	0.04589	0.04593
		0.04595	0.04590	0.04565	0.04496	0.04334	0.03990	0.03309	0.02075
7	1	0.02337	0.03452	0.04011	0.04282	0.04412	0.04472	0.04500	0.04509
		0.04511	0.04507	0.04502	0.04497	0.04492	0.04489	0.04485	0.04483
		0.04479	0.04470	0.04449	0.04399	0.04285	0.04040	0.03517	0.02419
7	2	0.02005	0.03161	0.03817	0.04169	0.04352	0.04446	0.04496	0.04523
		0.04538	0.04548	0.04557	0.04565	0.04574	0.04585	0.04595	0.04606
		0.04615	0.04616	0.04600	0.04543	0.04398	0.04078	0.03424	0.02189
7	3	0.01953	0.03117	0.03798	0.04170	0.04365	0.04465	0.04517	0.04543
		0.04558	0.04568	0.04576	0.04584	0.04592	0.04602	0.04613	0.04623
		0.04632	0.04633	0.04613	0.04549	0.04391	0.04049	0.03367	0.02122
7	4	0.01906	0.03086	0.03795	0.04191	0.04399	0.04505	0.04556	0.04580
		0.04592	0.04598	0.04603	0.04607	0.04613	0.04619	0.04627	0.04635
		0.04640	0.04637	0.04611	0.04536	0.04360	0.03990	0.03280	0.02033
8	1	0.01923	0.03094	0.03791	0.04180	0.04387	0.04493	0.04547	0.04574
		0.04588	0.04595	0.04601	0.04606	0.04613	0.04620	0.04628	0.04636
		0.04641	0.04637	0.04610	0.04534	0.04358	0.03994	0.03294	0.02057
8	2	0.01895	0.03074	0.03786	0.04186	0.04399	0.04508	0.04562	0.04589
		0.04601	0.04608	0.04612	0.04617	0.04622	0.04628	0.04635	0.04643
		0.04647	0.04641	0.04612	0.04532	0.04350	0.03974	0.03260	0.02017

4-NODE-PER-ASSEMBLY AXIAL SOURCE DISTRIBUTIONS

EAST-SOUTHEAST OCTANT

FORMAT(2I3,2X,8F9.5,2(/,14X,8F9.5))

COORDINATES		24 AXIAL NODE RELATIVE SOURCE DISTRIBUTION, TOP TO BOTTOM							
1	1	0.02661	0.03843	0.04226	0.04416	0.04412	0.04454	0.04530	0.04515
		0.04476	0.04450	0.04426	0.04401	0.04365	0.04343	0.04325	0.04308
		0.04284	0.04274	0.04274	0.04259	0.04237	0.04068	0.03788	0.02663
2	1	0.02480	0.03667	0.04198	0.04409	0.04475	0.04494	0.04500	0.04488
		0.04470	0.04452	0.04435	0.04419	0.04403	0.04388	0.04376	0.04367
		0.04360	0.04357	0.04356	0.04344	0.04291	0.04117	0.03649	0.02503
2	2	0.02641	0.03792	0.04277	0.04453	0.04500	0.04501	0.04491	0.04471
		0.04450	0.04429	0.04409	0.04390	0.04371	0.04353	0.04337	0.04323
		0.04312	0.04306	0.04301	0.04289	0.04243	0.04094	0.03669	0.02599
2	3	0.02619	0.03772	0.04265	0.04447	0.04497	0.04498	0.04485	0.04466
		0.04446	0.04427	0.04409	0.04391	0.04374	0.04358	0.04343	0.04331
		0.04322	0.04316	0.04312	0.04301	0.04254	0.04103	0.03672	0.02593
3	1	0.02424	0.03611	0.04160	0.04386	0.04464	0.04485	0.04486	0.04477
		0.04465	0.04451	0.04439	0.04427	0.04417	0.04407	0.04398	0.04393
		0.04390	0.04390	0.04390	0.04377	0.04319	0.04133	0.03638	0.02473
3	2	0.02619	0.03772	0.04265	0.04447	0.04497	0.04498	0.04485	0.04466
		0.04446	0.04427	0.04409	0.04391	0.04374	0.04358	0.04343	0.04331
		0.04322	0.04316	0.04312	0.04301	0.04254	0.04103	0.03672	0.02593

3	3	0.02591	0.03749	0.04251	0.04438	0.04492	0.04495	0.04482	0.04464
		0.04445	0.04427	0.04411	0.04395	0.04379	0.04364	0.04351	0.04340
		0.04332	0.04327	0.04324	0.04313	0.04266	0.04111	0.03673	0.02581
4	1	0.02564	0.03704	0.04206	0.04403	0.04470	0.04484	0.04480	0.04468
		0.04454	0.04439	0.04424	0.04410	0.04396	0.04383	0.04372	0.04363
		0.04356	0.04352	0.04346	0.04330	0.04272	0.04104	0.03655	0.02565
4	2	0.02371	0.03557	0.04120	0.04359	0.04448	0.04476	0.04480	0.04474
		0.04466	0.04456	0.04448	0.04440	0.04433	0.04427	0.04422	0.04419
		0.04418	0.04420	0.04420	0.04404	0.04338	0.04140	0.03624	0.02443
4	3	0.02400	0.03581	0.04136	0.04369	0.04454	0.04478	0.04480	0.04472
		0.04462	0.04452	0.04442	0.04433	0.04425	0.04418	0.04412	0.04409
		0.04407	0.04408	0.04407	0.04392	0.04329	0.04137	0.03632	0.02463
4	4	0.02600	0.03740	0.04235	0.04425	0.04484	0.04492	0.04482	0.04466
		0.04449	0.04433	0.04417	0.04401	0.04386	0.04372	0.04360	0.04349
		0.04341	0.04335	0.04328	0.04311	0.04256	0.04095	0.03658	0.02585
4	5	0.02608	0.03740	0.04231	0.04420	0.04482	0.04492	0.04484	0.04469
		0.04453	0.04436	0.04420	0.04405	0.04390	0.04376	0.04363	0.04352
		0.04343	0.04335	0.04327	0.04307	0.04248	0.04083	0.03650	0.02588
5	1	0.02622	0.03750	0.04232	0.04417	0.04476	0.04487	0.04482	0.04469
		0.04453	0.04437	0.04420	0.04403	0.04388	0.04373	0.04359	0.04347
		0.04338	0.04330	0.04322	0.04303	0.04247	0.04088	0.03659	0.02597
5	2	0.02427	0.03600	0.04144	0.04371	0.04454	0.04478	0.04481	0.04474
		0.04464	0.04453	0.04443	0.04433	0.04423	0.04415	0.04408	0.04402
		0.04399	0.04399	0.04395	0.04378	0.04315	0.04127	0.03634	0.02481
5	3	0.02444	0.03614	0.04155	0.04378	0.04460	0.04482	0.04482	0.04474
		0.04463	0.04451	0.04439	0.04429	0.04419	0.04410	0.04402	0.04396
		0.04393	0.04392	0.04388	0.04371	0.04308	0.04123	0.03637	0.02493
5	4	0.02608	0.03740	0.04231	0.04420	0.04482	0.04492	0.04484	0.04469
		0.04453	0.04436	0.04420	0.04405	0.04390	0.04376	0.04363	0.04352
		0.04343	0.04335	0.04327	0.04307	0.04248	0.04083	0.03650	0.02588
5	5	0.02605	0.03731	0.04222	0.04414	0.04480	0.04492	0.04485	0.04472
		0.04456	0.04440	0.04425	0.04410	0.04395	0.04381	0.04368	0.04357
		0.04348	0.04340	0.04330	0.04307	0.04244	0.04075	0.03640	0.02584
6	1	0.02625	0.03746	0.04226	0.04408	0.04469	0.04485	0.04487	0.04477
		0.04462	0.04445	0.04428	0.04410	0.04393	0.04377	0.04363	0.04350
		0.04339	0.04329	0.04318	0.04296	0.04237	0.04077	0.03652	0.02601
6	2	0.02526	0.03660	0.04168	0.04376	0.04453	0.04478	0.04483	0.04477
		0.04467	0.04454	0.04441	0.04428	0.04415	0.04403	0.04393	0.04384
		0.04377	0.04371	0.04362	0.04339	0.04273	0.04094	0.03635	0.02544
6	3	0.02528	0.03660	0.04167	0.04375	0.04453	0.04476	0.04478	0.04472
		0.04461	0.04449	0.04437	0.04425	0.04413	0.04402	0.04392	0.04385
		0.04379	0.04373	0.04365	0.04343	0.04277	0.04099	0.03642	0.02551
6	4	0.02349	0.03523	0.04088	0.04335	0.04434	0.04469	0.04478	0.04478
		0.04472	0.04465	0.04459	0.04452	0.04447	0.04443	0.04439	0.04437
		0.04437	0.04437	0.04433	0.04411	0.04337	0.04130	0.03611	0.02435
6	5	0.02376	0.03546	0.04103	0.04345	0.04441	0.04474	0.04481	0.04478
		0.04471	0.04463	0.04455	0.04448	0.04441	0.04436	0.04431	0.04428
		0.04426	0.04425	0.04420	0.04398	0.04324	0.04122	0.03614	0.02452
6	6	0.02423	0.03581	0.04127	0.04363	0.04456	0.04486	0.04491	0.04485
		0.04476	0.04465	0.04454	0.04443	0.04434	0.04425	0.04418	0.04413
		0.04409	0.04405	0.04397	0.04371	0.04296	0.04098	0.03606	0.02477
6	7	0.02420	0.03580	0.04127	0.04366	0.04461	0.04493	0.04497	0.04492
		0.04482	0.04470	0.04459	0.04448	0.04438	0.04429	0.04421	0.04414
		0.04410	0.04404	0.04393	0.04364	0.04286	0.04086	0.03594	0.02467
7	1	0.02535	0.03653	0.04149	0.04350	0.04426	0.04460	0.04485	0.04485

		0.04476	0.04463	0.04449	0.04434	0.04420	0.04407	0.04395	0.04385
		0.04376	0.04368	0.04358	0.04334	0.04270	0.04097	0.03651	0.02574
7	2	0.02536	0.03655	0.04152	0.04357	0.04435	0.04465	0.04479	0.04478
		0.04469	0.04457	0.04444	0.04431	0.04418	0.04406	0.04396	0.04387
		0.04379	0.04372	0.04361	0.04338	0.04271	0.04096	0.03648	0.02570
7	3	0.02552	0.03671	0.04167	0.04370	0.04447	0.04472	0.04478	0.04473
		0.04463	0.04451	0.04438	0.04425	0.04413	0.04401	0.04390	0.04382
		0.04374	0.04367	0.04356	0.04332	0.04266	0.04092	0.03646	0.02574
7	4	0.02387	0.03550	0.04100	0.04340	0.04436	0.04471	0.04481	0.04479
		0.04473	0.04465	0.04457	0.04449	0.04442	0.04436	0.04431	0.04427
		0.04425	0.04423	0.04416	0.04392	0.04319	0.04119	0.03618	0.02465
7	5	0.02415	0.03576	0.04121	0.04357	0.04450	0.04482	0.04488	0.04484
		0.04475	0.04465	0.04455	0.04445	0.04436	0.04428	0.04421	0.04416
		0.04412	0.04408	0.04400	0.04374	0.04301	0.04104	0.03612	0.02476
7	6	0.02420	0.03580	0.04127	0.04366	0.04461	0.04493	0.04497	0.04492
		0.04482	0.04470	0.04459	0.04448	0.04438	0.04429	0.04421	0.04414
		0.04410	0.04404	0.04393	0.04364	0.04286	0.04086	0.03594	0.02467
7	7	0.02403	0.03565	0.04119	0.04363	0.04463	0.04497	0.04504	0.04499
		0.04489	0.04478	0.04466	0.04455	0.04445	0.04436	0.04428	0.04422
		0.04416	0.04410	0.04397	0.04365	0.04282	0.04075	0.03576	0.02447
8	1	0.02328	0.03451	0.03982	0.04211	0.04306	0.04387	0.04502	0.04517
		0.04514	0.04506	0.04497	0.04487	0.04478	0.04470	0.04463	0.04458
		0.04454	0.04451	0.04443	0.04420	0.04348	0.04154	0.03660	0.02513
8	2	0.02289	0.03443	0.04007	0.04262	0.04374	0.04433	0.04473	0.04487
		0.04489	0.04487	0.04482	0.04478	0.04475	0.04472	0.04470	0.04470
		0.04471	0.04471	0.04466	0.04441	0.04361	0.04146	0.03618	0.02436
8	3	0.02359	0.03512	0.04063	0.04307	0.04411	0.04456	0.04477	0.04483
		0.04480	0.04475	0.04468	0.04461	0.04456	0.04450	0.04446	0.04443
		0.04442	0.04440	0.04432	0.04406	0.04329	0.04124	0.03617	0.02462
8	4	0.02469	0.03597	0.04119	0.04345	0.04438	0.04472	0.04484	0.04482
		0.04475	0.04466	0.04456	0.04446	0.04436	0.04427	0.04419	0.04413
		0.04408	0.04401	0.04390	0.04360	0.04282	0.04087	0.03613	0.02515
8	5	0.02513	0.03635	0.04147	0.04366	0.04454	0.04483	0.04489	0.04484
		0.04475	0.04463	0.04452	0.04439	0.04427	0.04417	0.04408	0.04400
		0.04392	0.04384	0.04369	0.04337	0.04259	0.04068	0.03607	0.02531
8	6	0.02456	0.03590	0.04123	0.04358	0.04455	0.04490	0.04498	0.04494
		0.04486	0.04474	0.04464	0.04452	0.04441	0.04432	0.04424	0.04417
		0.04411	0.04403	0.04387	0.04352	0.04267	0.04062	0.03579	0.02483
8	7	0.02457	0.03588	0.04122	0.04359	0.04459	0.04495	0.04503	0.04499
		0.04490	0.04479	0.04468	0.04456	0.04445	0.04435	0.04427	0.04420
		0.04413	0.04403	0.04386	0.04348	0.04258	0.04049	0.03565	0.02477
8	8	0.02339	0.03493	0.04067	0.04336	0.04455	0.04503	0.04518	0.04518
		0.04512	0.04503	0.04494	0.04484	0.04475	0.04468	0.04462	0.04457
		0.04452	0.04444	0.04425	0.04381	0.04277	0.04041	0.03512	0.02384
8	9	0.02264	0.03423	0.04020	0.04311	0.04447	0.04505	0.04526	0.04530
		0.04526	0.04520	0.04513	0.04505	0.04499	0.04494	0.04490	0.04487
		0.04484	0.04476	0.04456	0.04406	0.04290	0.04031	0.03472	0.02326
9	1	0.02253	0.03379	0.03927	0.04174	0.04282	0.04373	0.04495	0.04516
		0.04519	0.04515	0.04509	0.04503	0.04499	0.04494	0.04491	0.04489
		0.04488	0.04487	0.04481	0.04455	0.04377	0.04168	0.03649	0.02475
9	2	0.02304	0.03448	0.04006	0.04260	0.04373	0.04433	0.04475	0.04490
		0.04492	0.04489	0.04484	0.04479	0.04475	0.04472	0.04469	0.04468
		0.04468	0.04467	0.04460	0.04432	0.04351	0.04137	0.03618	0.02451
9	3	0.02367	0.03511	0.04059	0.04305	0.04412	0.04460	0.04483	0.04489
		0.04487	0.04481	0.04474	0.04466	0.04460	0.04453	0.04448	0.04445

		0.04442	0.04438	0.04427	0.04398	0.04316	0.04108	0.03605	0.02465
9	4	0.02477	0.03594	0.04112	0.04339	0.04435	0.04473	0.04486	0.04486
		0.04480	0.04472	0.04462	0.04451	0.04441	0.04432	0.04424	0.04418
		0.04411	0.04403	0.04388	0.04353	0.04270	0.04072	0.03601	0.02520
9	5	0.02495	0.03606	0.04120	0.04347	0.04444	0.04481	0.04492	0.04491
		0.04484	0.04474	0.04463	0.04452	0.04441	0.04432	0.04424	0.04416
		0.04408	0.04398	0.04381	0.04342	0.04254	0.04052	0.03584	0.02519
9	6	0.02424	0.03545	0.04082	0.04328	0.04437	0.04481	0.04495	0.04497
		0.04492	0.04484	0.04476	0.04467	0.04459	0.04452	0.04446	0.04441
		0.04436	0.04428	0.04410	0.04369	0.04272	0.04053	0.03559	0.02468
9	7	0.02411	0.03532	0.04076	0.04329	0.04443	0.04489	0.04505	0.04505
		0.04500	0.04492	0.04483	0.04474	0.04466	0.04459	0.04453	0.04448
		0.04442	0.04432	0.04412	0.04367	0.04264	0.04036	0.03534	0.02447
9	8	0.02264	0.03423	0.04020	0.04311	0.04447	0.04505	0.04526	0.04530
		0.04526	0.04520	0.04513	0.04505	0.04499	0.04494	0.04490	0.04487
		0.04484	0.04476	0.04456	0.04406	0.04290	0.04031	0.03472	0.02326
9	9	0.02207	0.03379	0.04000	0.04309	0.04456	0.04520	0.04544	0.04549
		0.04546	0.04539	0.04531	0.04523	0.04516	0.04512	0.04508	0.04505
		0.04501	0.04492	0.04469	0.04414	0.04286	0.04007	0.03424	0.02261
10	1	0.02323	0.03467	0.04023	0.04275	0.04387	0.04447	0.04487	0.04500
		0.04499	0.04494	0.04487	0.04479	0.04473	0.04467	0.04462	0.04458
		0.04456	0.04452	0.04441	0.04411	0.04329	0.04118	0.03608	0.02457
10	2	0.02484	0.03604	0.04118	0.04339	0.04429	0.04468	0.04488	0.04491
		0.04484	0.04474	0.04462	0.04449	0.04437	0.04426	0.04416	0.04407
		0.04399	0.04390	0.04376	0.04345	0.04268	0.04081	0.03621	0.02543
10	3	0.02502	0.03623	0.04136	0.04355	0.04445	0.04480	0.04492	0.04491
		0.04483	0.04472	0.04460	0.04447	0.04434	0.04423	0.04412	0.04403
		0.04394	0.04384	0.04368	0.04334	0.04254	0.04063	0.03606	0.02539
10	4	0.02326	0.03473	0.04038	0.04303	0.04422	0.04474	0.04495	0.04501
		0.04499	0.04494	0.04488	0.04482	0.04476	0.04471	0.04467	0.04465
		0.04462	0.04456	0.04441	0.04403	0.04307	0.04080	0.03559	0.02420
10	5	0.02289	0.03432	0.04009	0.04287	0.04416	0.04473	0.04497	0.04505
		0.04505	0.04501	0.04497	0.04493	0.04489	0.04486	0.04485	0.04484
		0.04482	0.04478	0.04462	0.04419	0.04314	0.04072	0.03535	0.02392
10	6	0.02071	0.03230	0.03869	0.04201	0.04368	0.04450	0.04491	0.04512
		0.04523	0.04530	0.04536	0.04542	0.04549	0.04557	0.04565	0.04575
		0.04582	0.04584	0.04570	0.04520	0.04389	0.04090	0.03461	0.02236
10	7	0.02031	0.03196	0.03851	0.04198	0.04374	0.04461	0.04504	0.04525
		0.04537	0.04544	0.04549	0.04556	0.04563	0.04571	0.04580	0.04589
		0.04597	0.04598	0.04583	0.04527	0.04386	0.04071	0.03421	0.02188
10	8	0.02012	0.03191	0.03863	0.04221	0.04402	0.04490	0.04531	0.04549
		0.04557	0.04562	0.04565	0.04568	0.04571	0.04576	0.04582	0.04589
		0.04594	0.04593	0.04573	0.04511	0.04361	0.04033	0.03370	0.02136
10	9	0.02003	0.03202	0.03893	0.04262	0.04447	0.04534	0.04572	0.04585
		0.04588	0.04586	0.04583	0.04580	0.04578	0.04578	0.04579	0.04581
		0.04581	0.04574	0.04547	0.04478	0.04318	0.03976	0.03300	0.02073
11	1	0.02342	0.03484	0.04043	0.04301	0.04417	0.04471	0.04498	0.04506
		0.04504	0.04498	0.04490	0.04482	0.04474	0.04467	0.04462	0.04457
		0.04452	0.04445	0.04430	0.04392	0.04299	0.04079	0.03569	0.02439
11	2	0.02454	0.03573	0.04099	0.04333	0.04434	0.04477	0.04494	0.04497
		0.04492	0.04483	0.04473	0.04462	0.04451	0.04442	0.04433	0.04426
		0.04418	0.04408	0.04390	0.04352	0.04262	0.04057	0.03583	0.02508
11	3	0.02433	0.03552	0.04086	0.04327	0.04434	0.04479	0.04496	0.04498
		0.04494	0.04487	0.04477	0.04468	0.04459	0.04451	0.04444	0.04437
		0.04430	0.04420	0.04401	0.04360	0.04264	0.04050	0.03565	0.02488

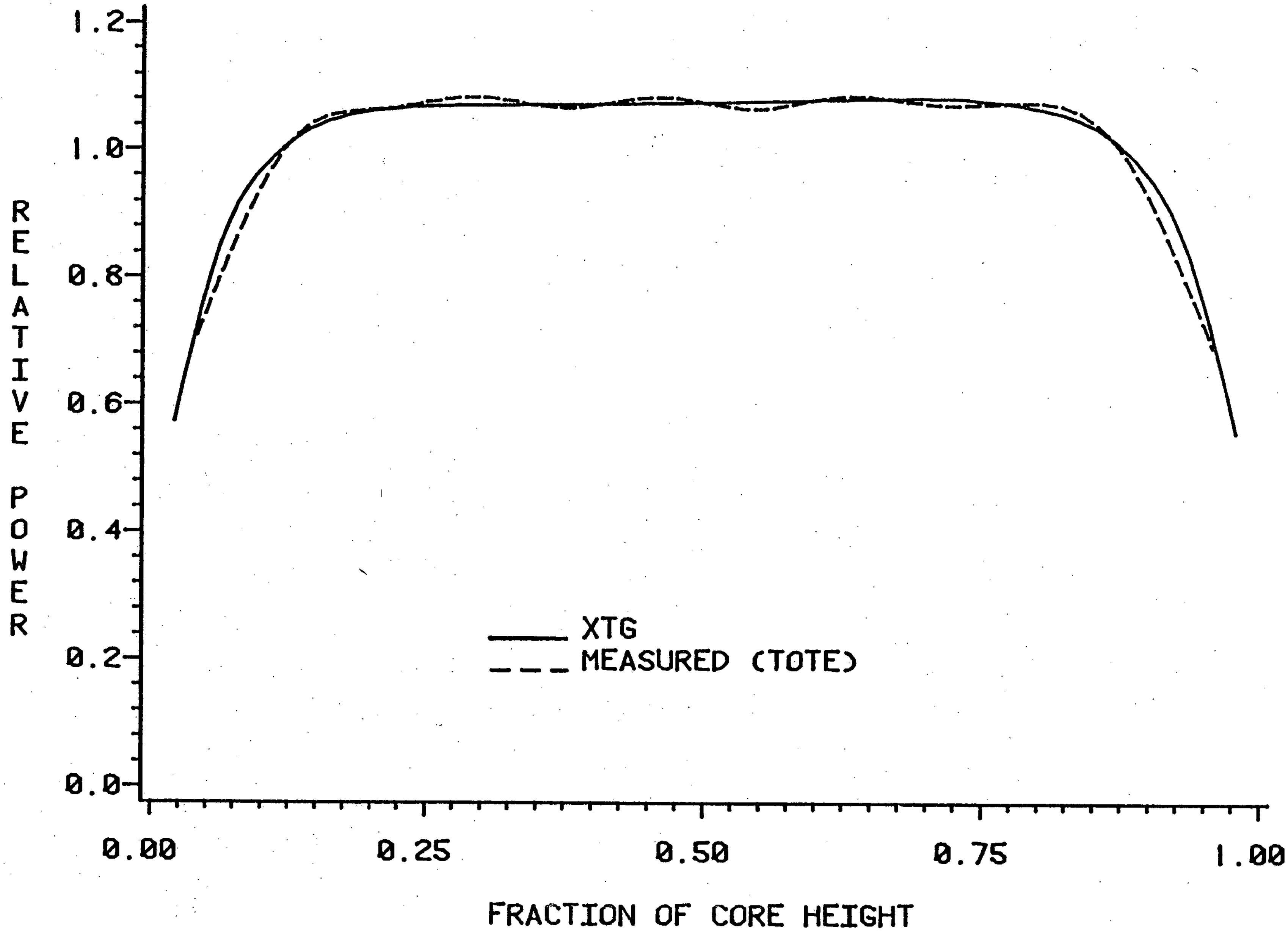
11	4	0.02241	0.03380	0.03969	0.04260	0.04400	0.04466	0.04496	0.04508
		0.04512	0.04511	0.04509	0.04507	0.04506	0.04505	0.04506	0.04507
		0.04507	0.04503	0.04486	0.04440	0.04327	0.04072	0.03517	0.02364
11	5	0.02192	0.03328	0.03932	0.04239	0.04391	0.04464	0.04499	0.04513
		0.04519	0.04521	0.04521	0.04522	0.04523	0.04524	0.04527	0.04531
		0.04533	0.04530	0.04512	0.04461	0.04338	0.04065	0.03489	0.02327
11	6	0.01985	0.03142	0.03807	0.04166	0.04353	0.04448	0.04497	0.04523
		0.04539	0.04549	0.04558	0.04568	0.04578	0.04589	0.04601	0.04613
		0.04624	0.04627	0.04611	0.04553	0.04406	0.04079	0.03413	0.02170
11	7	0.01952	0.03120	0.03804	0.04177	0.04372	0.04470	0.04519	0.04544
		0.04558	0.04566	0.04574	0.04582	0.04591	0.04600	0.04611	0.04622
		0.04631	0.04632	0.04613	0.04549	0.04391	0.04047	0.03362	0.02114
11	8	0.01952	0.03142	0.03843	0.04225	0.04421	0.04517	0.04561	0.04580
		0.04588	0.04590	0.04591	0.04592	0.04595	0.04599	0.04604	0.04609
		0.04613	0.04608	0.04582	0.04511	0.04344	0.03989	0.03293	0.02053
11	9	0.01952	0.03167	0.03886	0.04278	0.04476	0.04570	0.04608	0.04621
		0.04621	0.04617	0.04611	0.04605	0.04600	0.04598	0.04596	0.04595
		0.04591	0.04579	0.04546	0.04467	0.04289	0.03922	0.03218	0.01987
12	1	0.02370	0.03485	0.04032	0.04292	0.04414	0.04470	0.04495	0.04503
		0.04503	0.04498	0.04492	0.04486	0.04480	0.04475	0.04470	0.04467
		0.04462	0.04454	0.04434	0.04388	0.04284	0.04052	0.03545	0.02450
12	2	0.02066	0.03220	0.03857	0.04189	0.04358	0.04443	0.04489	0.04513
		0.04526	0.04534	0.04541	0.04547	0.04554	0.04562	0.04570	0.04579
		0.04586	0.04587	0.04573	0.04521	0.04389	0.04091	0.03464	0.02242
12	3	0.02022	0.03175	0.03825	0.04170	0.04347	0.04439	0.04487	0.04514
		0.04530	0.04540	0.04549	0.04557	0.04567	0.04577	0.04588	0.04599
		0.04609	0.04611	0.04597	0.04543	0.04404	0.04092	0.03446	0.02212
12	4	0.01990	0.03145	0.03806	0.04162	0.04348	0.04444	0.04494	0.04521
		0.04537	0.04548	0.04557	0.04567	0.04577	0.04589	0.04600	0.04612
		0.04622	0.04625	0.04610	0.04553	0.04407	0.04083	0.03422	0.02180
12	5	0.01959	0.03118	0.03793	0.04161	0.04355	0.04455	0.04506	0.04533
		0.04549	0.04560	0.04569	0.04579	0.04589	0.04600	0.04611	0.04624
		0.04633	0.04636	0.04618	0.04556	0.04402	0.04064	0.03387	0.02142
12	6	0.01924	0.03090	0.03781	0.04164	0.04366	0.04469	0.04522	0.04550
		0.04565	0.04575	0.04584	0.04593	0.04602	0.04612	0.04624	0.04636
		0.04645	0.04646	0.04626	0.04558	0.04394	0.04039	0.03343	0.02092
12	7	0.01909	0.03090	0.03800	0.04195	0.04402	0.04507	0.04557	0.04581
		0.04593	0.04598	0.04602	0.04606	0.04611	0.04618	0.04626	0.04633
		0.04639	0.04635	0.04609	0.04534	0.04358	0.03989	0.03278	0.02031
13	1	0.02302	0.03417	0.03988	0.04271	0.04410	0.04475	0.04505	0.04516
		0.04519	0.04518	0.04513	0.04509	0.04506	0.04504	0.04502	0.04500
		0.04497	0.04488	0.04465	0.04410	0.04286	0.04027	0.03487	0.02385
13	2	0.01982	0.03137	0.03801	0.04161	0.04351	0.04449	0.04501	0.04529
		0.04545	0.04556	0.04565	0.04574	0.04584	0.04595	0.04606	0.04617
		0.04626	0.04628	0.04610	0.04549	0.04398	0.04068	0.03402	0.02165
13	3	0.01944	0.03103	0.03782	0.04154	0.04351	0.04454	0.04507	0.04536
		0.04553	0.04565	0.04575	0.04585	0.04596	0.04607	0.04619	0.04631
		0.04641	0.04643	0.04625	0.04561	0.04403	0.04060	0.03376	0.02128
13	4	0.01933	0.03103	0.03794	0.04174	0.04374	0.04477	0.04528	0.04555
		0.04569	0.04579	0.04586	0.04593	0.04601	0.04609	0.04619	0.04629
		0.04637	0.04637	0.04615	0.04547	0.04383	0.04031	0.03337	0.02089
13	5	0.01915	0.03093	0.03797	0.04188	0.04394	0.04499	0.04550	0.04576
		0.04588	0.04595	0.04599	0.04604	0.04609	0.04616	0.04624	0.04633
		0.04638	0.04635	0.04609	0.04536	0.04363	0.03999	0.03293	0.02046
13	6	0.01893	0.03079	0.03798	0.04201	0.04414	0.04521	0.04572	0.04596

		0.04606	0.04610	0.04613	0.04615	0.04620	0.04625	0.04631	0.04637
		0.04641	0.04635	0.04606	0.04527	0.04345	0.03966	0.03247	0.02002
13	7	0.01881	0.03082	0.03817	0.04231	0.04449	0.04556	0.04606	0.04626
		0.04632	0.04632	0.04630	0.04629	0.04628	0.04629	0.04632	0.04634
		0.04633	0.04622	0.04588	0.04501	0.04308	0.03917	0.03188	0.01949
14	1	0.01946	0.03109	0.03793	0.04171	0.04371	0.04475	0.04528	0.04556
		0.04571	0.04580	0.04588	0.04595	0.04602	0.04611	0.04621	0.04630
		0.04637	0.04635	0.04611	0.04540	0.04373	0.04022	0.03335	0.02099
14	2	0.01915	0.03081	0.03776	0.04163	0.04369	0.04477	0.04532	0.04561
		0.04577	0.04587	0.04595	0.04603	0.04611	0.04621	0.04631	0.04642
		0.04650	0.04648	0.04624	0.04551	0.04380	0.04018	0.03317	0.02072
14	3	0.01901	0.03079	0.03788	0.04185	0.04395	0.04503	0.04557	0.04584
		0.04596	0.04603	0.04608	0.04612	0.04618	0.04625	0.04632	0.04640
		0.04645	0.04640	0.04613	0.04535	0.04356	0.03985	0.03273	0.02028
15	1	0.01889	0.03071	0.03789	0.04194	0.04410	0.04521	0.04575	0.04600
		0.04612	0.04617	0.04620	0.04623	0.04627	0.04632	0.04638	0.04645
		0.04647	0.04640	0.04608	0.04524	0.04336	0.03953	0.03234	0.01995
15	2	0.01875	0.03062	0.03787	0.04198	0.04417	0.04529	0.04583	0.04609
		0.04620	0.04625	0.04627	0.04629	0.04633	0.04637	0.04643	0.04647
		0.04649	0.04641	0.04608	0.04522	0.04330	0.03941	0.03215	0.01975
15	3	0.01869	0.03067	0.03805	0.04223	0.04445	0.04556	0.04609	0.04631
		0.04639	0.04640	0.04639	0.04638	0.04637	0.04638	0.04641	0.04642
		0.04641	0.04629	0.04592	0.04501	0.04303	0.03906	0.03174	0.01937

Figure 4-4

H.B. ROBINSON 2 CYCLE 8

NORMALIZED CORE DELTA EXPOSURE DISTRIBUTION



show conservatism with respect to estimating flux reduction at critical welds. In order to model Cycle 9, which is the present operating cycle, and Cycle 10, cross sections not available from XPOSE were obtained from ENC for CP&L's PDQ7 and XTG models. Specifically, ENC supplied cross sections for 208 fuel pins containing four weight percent Gd_2O_3 loaded in the Cycle 9 core and additional Gd_2O_3 pins for the Cycle 10 loading. Cross sections were provided to represent the Gd_2O_3 pins in PDQ7 and the Gd_2O_3 assemblies in XTG.[14] In addition, equivalent parameters were generated by TEC to represent the shield portion of the PLSA in CP&L's diffusion models as described in Sections 4.2.3 and 4.2.4.

Cycle 9 was depleted to nominal EOC in the PDQ7 and XTG models to provide a starting point for Cycle 10. Cycle 9 is at present past mid-cycle, but comparisons between PDQ7 and measured power distributions to this point are presented in Figures 4-5 through 4-7. XTG-measured comparisons are shown in Figure 4-8. Differences between analytic and measured distributions are consistent with the uncertainties quoted before and show that the models, including Gd_2O_3 cross sections, follow HBR2 well.

In order to model Cycle 10 in PDQ7, two cases were depleted; one representative of the axial region in which the PLSA contains active fuel, and the second representative of the axial region in which the PLSA contains shield material (SS304). In each case, the pin power distributions obtained in the PDQ 7 depletion were averaged (exposure-weighted) as was done for Cycle 8. The normalization in each plane was to a pin average of unity with no internormalization between planes. Figures 4-9 and 4-10 show the normalized cycle delta exposures for the two regions and correspond to the averaged pin distributions supplied to DOTSOR.

Figure 4-5

H. B. Robinson Unit 2
Quarter Core Averaged Assembly Power Distribution

Cycle 9 Map 414 09/01/82 D-206 Steps 00180MWD/MTU 92.8%HFP *CP&L PDQ*

	H	G	F	E	D	C	B	A
	1.229	1.414	1.114	1.187	1.061	0.893	0.876	0.316
1	1.228	1.405	1.092	1.149	1.035	0.886	0.873	0.315
	-0.048	-0.674	-2.013	-3.152	-2.442	-0.785	-0.266	-0.449
	1.411	1.213	1.280	1.056	1.281	1.010	0.823	0.238
2	1.408	1.206	1.265	1.042	1.266	1.011	0.821	0.237
	-0.273	-0.531	-1.151	-1.283	-1.170	0.092	-0.158	-0.434
	1.110	1.277	1.136	1.206	1.114	1.240	0.844	
3	1.089	1.267	1.140	1.207	1.118	1.253	0.858	
	-1.857	-0.742	0.316	0.076	0.346	1.061	1.718	
	1.189	1.056	1.202	1.031	1.149	1.124	0.680	
4	1.150	1.040	1.212	1.040	1.155	1.147	0.704	
	-3.343	-1.505	0.823	0.843	0.565	2.064	3.505	
	1.075	1.291	1.112	1.146	1.020	0.754	PREDICTED (CP&L PDQ)	
5	1.020	1.252	1.122	1.171	1.047	0.780	MEASURED (INCORE)	
	-5.071	-3.025	0.880	2.177	2.609	3.435	% DIFF (P-M)/P*100	
	0.933	1.026	1.247	1.127	0.754			
6	0.891	0.992	1.272	1.164	0.786			
	-4.458	-3.302	1.981	3.343	4.229			
	0.895	0.836	0.851	0.683				
7	0.869	0.816	0.856	0.712				
	-2.879	-2.430	0.502	4.224				
	0.313	0.241						
8	0.307	0.237						
	-1.932	-1.900						

STD. DEV. OF DIFFERENCES = 2.15 %

Figure 4-6

H. B. Robinson Unit 2
Quarter Core Averaged Assembly Power Distribution

Cycle 9 Map 431 01/11/83 D-216 Steps 03363MWD/MTU 93.4%HFP *CP&L PDQ*

	H	G	F	E	D	C	B	A
	1.036	1.199	1.020	1.235	1.068	0.953	1.029	0.393
1	1.042	1.203	1.016	1.218	1.044	0.930	1.021	0.398
	0.577	0.304	-0.399	-1.390	-2.289	-2.428	-0.770	1.229
	1.197	1.052	1.153	1.015	1.248	1.049	0.961	0.294
2	1.191	1.050	1.149	1.011	1.232	1.033	0.956	0.297
	-0.544	-0.274	-0.378	-0.421	-1.271	-1.533	-0.489	1.211
	1.016	1.151	1.042	1.135	1.084	1.240	0.923	
3	1.015	1.148	1.042	1.146	1.094	1.239	0.918	
	-0.125	-0.190	-0.029	0.991	0.877	-0.145	-0.461	
	1.236	1.014	1.131	1.006	1.149	1.134	0.721	
4	1.234	1.010	1.130	1.024	1.172	1.150	0.727	
	-0.166	-0.464	-0.031	1.772	1.955	1.461	0.862	
	1.077	1.252	1.081	1.146	1.127	0.807		
5	1.059	1.228	1.069	1.159	1.155	0.829		
	-1.665	-1.944	-1.072	1.133	2.541	2.721		
	0.986	1.059	1.243	1.134	0.807			
6	0.963	1.039	1.235	1.148	0.830			
	-2.363	-1.900	-0.687	1.265	2.792			
	1.042	0.970	0.927	0.722				
7	1.029	0.963	0.928	0.732				
	-1.196	-0.671	0.178	1.412				
	0.387	0.295						
8	0.379	0.296						
	-1.942	0.171						

PREDICTED (CP&L PDQ)
MEASURED (INCORE)
% DIFF (P-M)/P*100

STD. DEV. OF DIFFERENCES = 1.32 %

Figure 4-7

H. B. Robinson Unit 2
Quarter Core Averaged Assembly Power Distribution

Cycle 9 Map 444 08/25/83 D-213 Steps 08357MWD/MTU 93.0%HFP *CP&L PDQ*

	H	G	F	E	D	C	B	A
	0.905	1.045	0.956	1.314	1.060	1.010	1.241	0.508
1	0.937	1.078	0.967	1.303	1.034	0.985	1.231	0.507
	3.447	3.115	1.114	-0.840	-2.481	-2.475	-0.752	-0.082
	1.044	0.936	1.049	0.974	1.182	1.075	1.173	0.380
2	1.073	0.962	1.063	0.975	1.166	1.063	1.164	0.379
	2.773	2.772	1.370	0.197	-1.352	-1.203	-0.823	-0.053
	0.953	1.047	0.951	1.043	1.022	1.199	1.013	
3	0.963	1.064	0.966	1.053	1.027	1.201	1.015	
	1.031	1.607	1.626	0.935	0.496	0.158	0.176	
	1.313	0.972	1.039	0.957	1.113	1.095	0.739	
4	1.295	0.968	1.046	0.965	1.117	1.100	0.744	
	-1.376	-0.400	0.655	0.828	0.383	0.415	0.629	
	1.065	1.183	1.018	1.110	1.255	0.838	PREDICTED (CP&L PDQ)	
5	1.027	1.158	1.016	1.114	1.256	0.839	MEASURED (INCORE)	
	-3.504	-2.122	-0.179	0.355	0.129	0.156	% DIFF (P-M)/P*100	
	1.036	1.080	1.199	1.094	0.837			
6	0.999	1.056	1.193	1.094	0.837			
	-3.621	-2.237	-0.477	-0.063	-0.075			
	1.246	1.177	1.013	0.739				
7	1.234	1.173	1.017	0.740				
	-0.926	-0.322	0.392	0.233				
	0.497	0.379						
8	0.505	0.385						
	1.652	1.431						

STD. DEV. OF DIFFERENCES = 1.33 %

Figure 4-8

H. B. Robinson Unit 2
Core Averaged Axial Relative Power Distributions

	Axial Level (from top)	Measured (INCORE)	Predicted (XTG)	% Difference (P-M)/P*100
Cycle 9 Map 414 180MWD/MTU	1	.615	.574	-7.14
	2	.962	.918	-4.79
	3	1.091	1.046	-4.30
	4	1.122	1.104	-1.63
	5	1.155	1.135	-1.76
	6	1.141	1.152	0.95
	7	1.150	1.156	0.52
	8	1.114	1.147	2.88
	9	1.093	1.123	2.67
	10	1.026	1.071	4.20
	11	.912	.954	4.40
	12	.619	.620	0.16

Std. Dev. of Differences = 3.54 %

	Axial Level (from top)	Measured (INCORE)	Predicted (XTG)	% Difference (P-M)/P*100
Cycle 9 Map 432 3780MWD/MTU	1	.670	.635	-5.51
	2	.968	.955	-1.36
	3	1.051	1.041	-0.96
	4	1.061	1.065	0.38
	5	1.087	1.076	-1.02
	6	1.076	1.084	0.74
	7	1.101	1.093	-0.73
	8	1.087	1.101	1.27
	9	1.100	1.107	0.63
	10	1.072	1.099	2.46
	11	1.002	1.031	2.81
	12	.724	.714	-1.40

Std. Dev. of Differences = 2.10 %

	Axial Level (from top)	Measured (INCORE)	Predicted (XTG)	% Difference (P-M)/P*100
Cycle 9 Map 436 5445MWD/MTU	1	.693	.652	-6.29
	2	.981	.963	-1.87
	3	1.048	1.036	-1.16
	4	1.050	1.052	0.19
	5	1.073	1.059	-1.32
	6	1.059	1.066	0.66
	7	1.087	1.076	-1.02
	8	1.078	1.089	1.01
	9	1.102	1.102	0.00
	10	1.081	1.106	2.26
	11	1.023	1.054	2.94
	12	.727	.746	2.55

Std. Dev. of Differences = 2.39 %

CP&L Carolina Power & Light Company — INCORE ANALYSIS UNIT

ENGINEERING CALCULATION
(COMPUTER INPUT)

PREPARED BY: K Cantrell	DATE: 7/30/83	PAGE NO. ___ OF ___	
CHECKED BY: K. Karcher	DATE: 8/17/83		
SUBJECT: HBR2 Cycle 10 Assembly Exposures and Cycle Deltas			
COMPUTER PROGRAM: PDQ7	VERSION:	PRODUCTION ☐ DEVELOPMENT ☐	TAPE NO. OR FILE NAME:
REACTOR: HBR2	CYCLE: 10 Upper Core	EXPOSURE: Core Avg. Delta = 10429	STATE: HFP ARO

	H	G	F	E	D	C	B	A
8	1 13597 0 13597 1.304	2 9 24982 13146 11836 1.135	3 17 33607 23607 10000 .959	4 24 13746 0 13746 1.318	5 31 34232 23607 10625 1.019	6 37 23890 11153 12737 1.221	7 42 13334 0 13334 1.279	8 46 4566 0 4566 .438
9	9 24964 13151 11813 1.133	10 23884 12022 11862 1.137	11 18 22158 10481 11677 1.120	12 25 32798 22369 10429 1.000	13 32 20158 7517 12641 1.212	14 38 22307 9786 12521 1.201	15 43 12356 0 12356 1.185	16 47 3664 0 3664 .351
10	17 33482 23570 9912 .950	18 22169 10565 11604 1.113	19 34110 24103 10007 .960	20 26 13626 0 13626 1.307	21 33 30808 20301 10507 1.008	22 39 29466 19206 10260 .984	23 44 9917 0 9917 .951	
11	24 13550 0 13550 1.299	25 32773 22395 10378 .995	26 13659 0 13659 1.310	27 34313 24159 10154 .974	28 34 20227 8445 11782 1.130	29 40 11406 0 11406 1.094	30 45 7457 0 7457 .715	
12	31 34134 23570 10564 1.013	32 20146 7527 12619 1.210	33 30857 20344 10513 1.008	34 20223 8444 11779 1.129	35 11035 0 11035 1.058	36 41 24953 19963 4990 .478		
13	37 23952 11274 12688 1.217	38 22311 9821 12490 1.198	39 29451 19197 10254 .983	40 11402 0 11402 1.093	41 24963 19975 4988 .478			
14	42 13302 0 13302 1.276	43 12332 0 12332 1.182	44 9908 0 9908 .950	45 7453 0 7453 .715				
15	46 4558 0 4558 .437	47 3658 0 3658 .351						

EOC
BOC
Delta
Relative Delta

Figure 4-9
Assembly Exposures - Cycle 10, Upper Core

CP&L Carolina Power & Light Company

INCORE ANALYSIS UNIT

ENGINEERING CALCULATION
(COMPUTER INPUT)

PREPARED BY: K Cantrell DATE: 7/28/83

CHECKED BY: K. Karcher DATE: 8/17/83

PAGE NO. ___ OF ___

SUBJECT: HBR2 Cycle 10 Assembly Exposures and Cycle Deltas

COMPUTER PROGRAM: PDQ7

VERSION: 2

PRODUCTION / DEVELOPMENT

TAPE NO. OR FILE NAME: RPDQ101

REACTOR: HBR2

CYCLE: 10 Lower Core

EXPOSURE: Core Avg. Delta 10392

STATE: HFP ARO

	H	G	F	E	D	C	B	A
8	1 15171 0 15171 1.460	2, 9 26257 13146 13111 1.262	3, 17 34640 23607 11033 1.062	4, 24 14952 0 14952 1.439	5, 31 34645 23607 11038 1.062	6, 37 23136 11153 11983 1.153	7, 42 9795 0 9795 0.943	8, 46 0 0 0 0.0
9	9 26237 13151 13086 1.259	10 25139 12022 13119 1.262	11, 18 23347 10481 12866 1.238	12, 25 33722 22369 11353 1.092	13, 32 20748 7517 13231 1.273	14, 38 21848 .9786 12062 1.161	15, 43 9711 0 9711 0.934	16, 47 0 0 0 0.0
10	17 34508 25570 8938 0.860	18 23353 10565 12788 1.231	19 35154 24103 11051 1.063	20, 26 14963 0 14963 1.440	21, 33 31533 20301 11232 1.081	22, 39 29626 19206 10420 1.003	23, 44 9263 0 9263 0.891	
11	24 14740 0 14740 1.418	25 33693 22395 11298 1.087	26 14999 0 14999 1.443	27 35303 24159 11144 1.072	28, 34 21239 8445 12794 1.231	29, 40 12139 0 12139 1.168	30, 45 7641 0 7641 0.735	
12	31 34542 23570 10972 1.056	32 20735 7529 13208 1.271	33 31582 20344 11238 1.081	34 21235 18444 12791 1.231	35 12121 0 12121 1.166	36, 41 25399 19963 5436 0.523		
13	37 23198 11274 11924 1.147	38 21851 9821 12030 1.158	39 29611 19197 10414 1.002	40 12136 0 12136 1.163	41 25410 19975 5435 0.523			
14	42 9765 0 9765 0.940	43 9690 0 9690 0.932	44 9254 0 9254 0.890	45 7638 0 7638 0.735				
15	46 0 0 0 0.0	47 0 0 0 0.0						

EOC MWD/MTU
BOC MWD/MTU
Delta
Relative Delta

Figure 4-10
Assembly Exposures - Cycle 10, Lower Core

Axial distributions were obtained from XTG simulation of Cycle 10 by the same procedure as described for Cycle 8 and shown in Table 4-5 as provided to TEC through UCC.

4.3.3 Corrections to Source Distributions

Nominal full power at HBR2 is 2300 MWt; the loaded core contains 157 assemblies with 204 pins per assembly. These factors are appropriate for converting the relative power distributions to absolute pin powers. DOTSOR uses an exposure-dependent κ/ν to convert power distribution to neutron distribution; however, only one core-average exposure may be specified for each distribution. Figures 4-11 and 4-12 show the ratio of assembly-average κ/ν to core-average κ/ν at the average core exposures for Cycles 8 and 10, respectively. The exposure-dependent κ/ν is taken from XPOSE, as shown in Figure 4-13, and the average exposures are taken from the PDQ7 models. In generating the 3-D neutron source distributions, these factors make an additional correction, accounting for variances in κ/ν with exposures.

4.3.4 Study of HBR2 Power History and Westinghouse Capsule Analyses

During the burnup of a pressurized water reactor (PWR) reload core employing out-in-in strategy, there is a continuous power/flux flattening due to higher exposure of the inner core and "hot spots." A linear fit of relative power in Assembly A-8 (center assembly on a flat) for Cycle 8 gives the following multiplier as a function of core-average cycle exposure to the cycle average power of the assembly:

$$m = 0.9455 + .10896 \times 10^{-4} *(\text{CAVCEX in MWD/MTU}) \qquad (4.1)$$

Table 4-5

XTG HBR2 Cycle 10 Averaged Axial Power Distributions

ASSEMBLY-WISE AXIAL SOURCE DISTRIBUTIONS -- CYCLE 10
EAST-SOUTHEAST OCTANT
FORMAT(2I3,2X,8F9.5,2(/,8X,8F9.5))

COORDINATES		24 AXIAL NODE RELATIVE SOURCE DISTRIBUTION, TOP TO BOTTOM							
1	1	0.01734	0.02857	0.03553	0.03958	0.04193	0.04337	0.04432	0.04497
		0.04547	0.04586	0.04619	0.04648	0.04675	0.04700	0.04724	0.04742
		0.04755	0.04757	0.04737	0.04672	0.04516	0.04171	0.03460	0.02131
2	1	0.02051	0.03119	0.03703	0.04033	0.04226	0.04346	0.04423	0.04476
		0.04514	0.04542	0.04565	0.04584	0.04601	0.04615	0.04626	0.04634
		0.04636	0.04628	0.04603	0.04543	0.04412	0.04139	0.03573	0.02408
2	2	0.02046	0.03167	0.03751	0.04068	0.04248	0.04356	0.04426	0.04473
		0.04507	0.04533	0.04553	0.04570	0.04585	0.04597	0.04606	0.04612
		0.04613	0.04606	0.04583	0.04529	0.04411	0.04155	0.03601	0.02404
3	1	0.02139	0.03185	0.03757	0.04074	0.04257	0.04369	0.04441	0.04490
		0.04524	0.04549	0.04569	0.04584	0.04596	0.04605	0.04611	0.04612
		0.04607	0.04592	0.04559	0.04493	0.04361	0.04091	0.03535	0.02401
3	2	0.01993	0.03129	0.03737	0.04069	0.04257	0.04371	0.04444	0.04494
		0.04529	0.04556	0.04577	0.04595	0.04611	0.04622	0.04631	0.04635
		0.04634	0.04623	0.04595	0.04533	0.04403	0.04124	0.03534	0.02305
3	3	0.02026	0.03098	0.03713	0.04056	0.04255	0.04376	0.04454	0.04507
		0.04545	0.04574	0.04597	0.04615	0.04631	0.04642	0.04650	0.04654
		0.04650	0.04635	0.04600	0.04528	0.04381	0.04081	0.03465	0.02270
4	1	0.01092	0.02795	0.03537	0.03981	0.04245	0.04408	0.04518	0.04596
		0.04655	0.04703	0.04743	0.04778	0.04810	0.04839	0.04862	0.04877
		0.04882	0.04869	0.04830	0.04739	0.04544	0.04138	0.03335	0.01223
4	2	0.01985	0.03040	0.03661	0.04018	0.04233	0.04367	0.04456	0.04517
		0.04562	0.04596	0.04623	0.04646	0.04664	0.04678	0.04688	0.04691
		0.04684	0.04662	0.04618	0.04534	0.04371	0.04053	0.03422	0.02231
4	3	0.01044	0.02715	0.03476	0.03942	0.04222	0.04398	0.04515	0.04599
		0.04663	0.04715	0.04758	0.04797	0.04833	0.04865	0.04892	0.04912
		0.04920	0.04912	0.04873	0.04777	0.04567	0.04132	0.03290	0.01182
4	4	0.01868	0.02940	0.03598	0.03986	0.04221	0.04369	0.04466	0.04533
		0.04582	0.04620	0.04652	0.04678	0.04700	0.04717	0.04730	0.04737
		0.04733	0.04714	0.04669	0.04577	0.04395	0.04040	0.03354	0.02120
5	1	0.02028	0.03068	0.03674	0.04032	0.04250	0.04389	0.04481	0.04545
		0.04591	0.04626	0.04654	0.04678	0.04695	0.04707	0.04711	0.04703
		0.04678	0.04631	0.04558	0.04450	0.04275	0.03962	0.03369	0.02245
5	2	0.01894	0.02981	0.03623	0.04000	0.04227	0.04371	0.04467	0.04534
		0.04585	0.04624	0.04656	0.04684	0.04707	0.04726	0.04736	0.04735
		0.04719	0.04683	0.04621	0.04520	0.04345	0.04015	0.03376	0.02171
5	3	0.01932	0.02987	0.03619	0.03996	0.04228	0.04375	0.04472	0.04539
		0.04589	0.04627	0.04657	0.04683	0.04704	0.04719	0.04728	0.04728
		0.04715	0.04683	0.04624	0.04522	0.04339	0.03999	0.03357	0.02180
5	4	0.01685	0.02786	0.03494	0.03923	0.04187	0.04356	0.04469	0.04548

		0.04607	0.04654	0.04693	0.04728	0.04758	0.04784	0.04804	0.04815
		0.04815	0.04796	0.04746	0.04641	0.04433	0.04031	0.03274	0.01974
5	5	0.00899	0.02566	0.03372	0.03890	0.04214	0.04419	0.04556	0.04653
		0.04725	0.04783	0.04831	0.04874	0.04913	0.04948	0.04976	0.04995
		0.05001	0.04984	0.04927	0.04797	0.04532	0.04019	0.03101	0.01024
6	1	0.01787	0.02912	0.03608	0.04032	0.04294	0.04462	0.04574	0.04652
		0.04709	0.04754	0.04791	0.04822	0.04848	0.04864	0.04865	0.04842
		0.04782	0.04671	0.04511	0.04335	0.04108	0.03745	0.03096	0.01937
6	2	0.01783	0.02904	0.03596	0.04016	0.04275	0.04441	0.04552	0.04630
		0.04687	0.04732	0.04769	0.04801	0.04826	0.04844	0.04847	0.04830
		0.04780	0.04686	0.04547	0.04384	0.04164	0.03799	0.03142	0.01964
6	3	0.01834	0.02918	0.03590	0.03999	0.04252	0.04414	0.04521	0.04596
		0.04651	0.04693	0.04728	0.04757	0.04780	0.04795	0.04801	0.04792
		0.04761	0.04698	0.04600	0.04462	0.04248	0.03876	0.03206	0.02026
6	4	0.00861	0.02528	0.03355	0.03887	0.04220	0.04433	0.04576	0.04676
		0.04751	0.04812	0.04863	0.04909	0.04951	0.04986	0.05013	0.05027
		0.05024	0.04992	0.04918	0.04771	0.04491	0.03964	0.03026	0.00967
6	5	0.01610	0.02766	0.03530	0.03996	0.04282	0.04461	0.04575	0.04651
		0.04704	0.04742	0.04771	0.04794	0.04813	0.04826	0.04833	0.04831
		0.04814	0.04776	0.04701	0.04563	0.04314	0.03859	0.03046	0.01742
7	1	0.00809	0.02532	0.03460	0.04071	0.04460	0.04711	0.04878	0.04997
		0.05086	0.05158	0.05219	0.05273	0.05318	0.05348	0.05353	0.05309
		0.05168	0.04852	0.04314	0.03946	0.03601	0.03112	0.02322	0.00702
7	2	0.00839	0.02550	0.03450	0.04043	0.04421	0.04664	0.04826	0.04940
		0.05025	0.05093	0.05151	0.05202	0.05244	0.05274	0.05281	0.05245
		0.05129	0.04866	0.04417	0.04089	0.03755	0.03262	0.02460	0.00773
7	3	0.01430	0.02590	0.03412	0.03941	0.04274	0.04486	0.04625	0.04722
		0.04794	0.04850	0.04898	0.04939	0.04974	0.05001	0.05013	0.05002
		0.04950	0.04837	0.04654	0.04443	0.04146	0.03653	0.02818	0.01549
7	4	0.00698	0.02506	0.03392	0.03955	0.04304	0.04524	0.04667	0.04764
		0.04835	0.04891	0.04937	0.04977	0.05012	0.05040	0.05058	0.05060
		0.05038	0.04980	0.04872	0.04692	0.04380	0.03822	0.02849	0.00749
8	1	0.00832	0.03095	0.04313	0.05103	0.05596	0.05899	0.06087	0.06205
		0.06284	0.06339	0.06380	0.06411	0.06429	0.06428	0.06384	0.06246
		0.05880	0.04919	0.00338	0.00250	0.00217	0.00182	0.00130	0.00054
8	2	0.00842	0.03112	0.04318	0.05099	0.05586	0.05885	0.06069	0.06185
		0.06261	0.06315	0.06353	0.06382	0.06399	0.06397	0.06357	0.06230
		0.05893	0.05000	0.00365	0.00280	0.00246	0.00209	0.00151	0.00064

4-NODE-PER-ASSEMBLY AXIAL SOURCE DISTRIBUTIONS -- CYCLE 10

EAST-SOUTHEAST OCTANT

FORMAT(2I3,2X,8F9.5,2(/,14X,8F9.5))

COORDINATES		24 AXIAL NODE RELATIVE SOURCE DISTRIBUTION, TOP TO BOTTOM							
1	1	0.01734	0.02857	0.03553	0.03958	0.04193	0.04337	0.04432	0.04497
		0.04547	0.04586	0.04619	0.04648	0.04675	0.04700	0.04724	0.04742
		0.04755	0.04757	0.04737	0.04672	0.04516	0.04171	0.03460	0.02131
2	1	0.02027	0.03095	0.03686	0.04022	0.04219	0.04341	0.04420	0.04474
		0.04513	0.04543	0.04566	0.04587	0.04605	0.04621	0.04634	0.04643
		0.04647	0.04641	0.04617	0.04557	0.04425	0.04147	0.03572	0.02398
2	2	0.02023	0.03153	0.03740	0.04058	0.04240	0.04349	0.04421	0.04469
		0.04504	0.04531	0.04552	0.04571	0.04587	0.04600	0.04611	0.04618
		0.04620	0.04614	0.04593	0.04541	0.04425	0.04169	0.03613	0.02400
2	3	0.02067	0.03184	0.03762	0.04075	0.04252	0.04358	0.04427	0.04473
		0.04506	0.04531	0.04550	0.04566	0.04580	0.04592	0.04600	0.04605

		0.04605	0.04596	0.04573	0.04519	0.04403	0.04151	0.03605	0.02419
3	1	0.02076	0.03143	0.03720	0.04044	0.04234	0.04350	0.04426	0.04478
		0.04514	0.04542	0.04563	0.04581	0.04596	0.04609	0.04619	0.04625
		0.04625	0.04616	0.04589	0.04528	0.04399	0.04130	0.03574	0.02418
3	2	0.02067	0.03184	0.03762	0.04075	0.04252	0.04358	0.04427	0.04473
		0.04506	0.04531	0.04550	0.04566	0.04580	0.04592	0.04600	0.04605
		0.04605	0.04596	0.04573	0.04519	0.04403	0.04151	0.03605	0.02419
3	3	0.02070	0.03181	0.03762	0.04078	0.04256	0.04363	0.04431	0.04478
		0.04510	0.04535	0.04554	0.04570	0.04584	0.04594	0.04602	0.04606
		0.04605	0.04596	0.04572	0.04516	0.04397	0.04141	0.03589	0.02409
4	1	0.02182	0.03228	0.03781	0.04085	0.04260	0.04366	0.04434	0.04480
		0.04512	0.04536	0.04553	0.04567	0.04577	0.04585	0.04590	0.04591
		0.04586	0.04572	0.04541	0.04479	0.04356	0.04102	0.03576	0.02461
4	2	0.02011	0.03148	0.03750	0.04073	0.04255	0.04365	0.04435	0.04482
		0.04517	0.04543	0.04564	0.04582	0.04597	0.04609	0.04618	0.04623
		0.04623	0.04614	0.04589	0.04533	0.04411	0.04146	0.03571	0.02343
4	3	0.02005	0.03143	0.03747	0.04073	0.04257	0.04367	0.04438	0.04486
		0.04521	0.04547	0.04568	0.04585	0.04600	0.04613	0.04621	0.04626
		0.04626	0.04616	0.04591	0.04534	0.04409	0.04139	0.03559	0.02330
4	4	0.02125	0.03208	0.03784	0.04095	0.04272	0.04378	0.04445	0.04491
		0.04523	0.04546	0.04564	0.04578	0.04589	0.04596	0.04601	0.04601
		0.04596	0.04581	0.04550	0.04487	0.04361	0.04099	0.03545	0.02385
4	5	0.02030	0.03101	0.03715	0.04058	0.04257	0.04378	0.04456	0.04509
		0.04547	0.04576	0.04598	0.04617	0.04631	0.04642	0.04650	0.04653
		0.04648	0.04633	0.04597	0.04524	0.04377	0.04076	0.03460	0.02268
5	1	0.02095	0.03142	0.03734	0.04063	0.04255	0.04372	0.04448	0.04499
		0.04536	0.04563	0.04584	0.04601	0.04614	0.04624	0.04631	0.04633
		0.04628	0.04612	0.04577	0.04507	0.04366	0.04081	0.03494	0.02341
5	2	0.01988	0.03121	0.03731	0.04068	0.04260	0.04376	0.04451	0.04501
		0.04537	0.04565	0.04586	0.04604	0.04619	0.04631	0.04638	0.04642
		0.04639	0.04626	0.04595	0.04529	0.04394	0.04108	0.03510	0.02283
5	3	0.01970	0.03103	0.03720	0.04062	0.04258	0.04377	0.04453	0.04505
		0.04541	0.04569	0.04592	0.04610	0.04626	0.04638	0.04646	0.04650
		0.04648	0.04635	0.04603	0.04536	0.04397	0.04104	0.03496	0.02263
5	4	0.02030	0.03101	0.03715	0.04058	0.04257	0.04378	0.04456	0.04509
		0.04547	0.04576	0.04598	0.04617	0.04631	0.04642	0.04650	0.04653
		0.04648	0.04633	0.04597	0.04524	0.04377	0.04076	0.03460	0.02268
5	5	0.01929	0.02991	0.03643	0.04017	0.04238	0.04374	0.04462	0.04523
		0.04567	0.04601	0.04629	0.04652	0.04671	0.04687	0.04698	0.04705
		0.04703	0.04688	0.04649	0.04568	0.04401	0.04063	0.03385	0.02156
6	1	0.01098	0.02808	0.03548	0.03989	0.04248	0.04409	0.04516	0.04592
		0.04650	0.04696	0.04735	0.04769	0.04800	0.04828	0.04852	0.04868
		0.04874	0.04865	0.04829	0.04742	0.04552	0.04151	0.03351	0.01231
6	2	0.02003	0.03063	0.03679	0.04030	0.04239	0.04369	0.04454	0.04513
		0.04555	0.04587	0.04613	0.04634	0.04652	0.04665	0.04674	0.04677
		0.04671	0.04652	0.04611	0.04532	0.04375	0.04064	0.03440	0.02249
6	3	0.01990	0.03048	0.03668	0.04023	0.04236	0.04367	0.04454	0.04514
		0.04558	0.04590	0.04617	0.04639	0.04656	0.04670	0.04680	0.04683
		0.04678	0.04660	0.04619	0.04538	0.04378	0.04063	0.03432	0.02238
6	4	0.01062	0.02748	0.03502	0.03959	0.04232	0.04401	0.04515	0.04595
		0.04657	0.04706	0.04748	0.04785	0.04818	0.04849	0.04875	0.04894
		0.04903	0.04896	0.04860	0.04769	0.04567	0.04144	0.03314	0.01200
6	5	0.01024	0.02694	0.03465	0.03937	0.04220	0.04397	0.04515	0.04600
		0.04665	0.04717	0.04761	0.04800	0.04836	0.04870	0.04898	0.04919
		0.04929	0.04923	0.04886	0.04791	0.04578	0.04137	0.03278	0.01160

6	6	0.01864	0.02922	0.03591	0.03984	0.04221	0.04369	0.04466	0.04533
		0.04582	0.04621	0.04652	0.04679	0.04701	0.04720	0.04734	0.04741
		0.04739	0.04722	0.04679	0.04588	0.04406	0.04045	0.03340	0.02100
6	7	0.01887	0.02952	0.03604	0.03989	0.04222	0.04368	0.04465	0.04531
		0.04580	0.04618	0.04649	0.04675	0.04696	0.04713	0.04726	0.04732
		0.04727	0.04708	0.04662	0.04570	0.04389	0.04038	0.03361	0.02140
7	1	0.01085	0.02782	0.03526	0.03974	0.04241	0.04408	0.04520	0.04600
		0.04661	0.04710	0.04751	0.04788	0.04821	0.04850	0.04873	0.04887
		0.04890	0.04874	0.04830	0.04735	0.04535	0.04125	0.03320	0.01215
7	2	0.01983	0.03034	0.03655	0.04014	0.04231	0.04367	0.04458	0.04520
		0.04566	0.04601	0.04629	0.04653	0.04672	0.04687	0.04696	0.04697
		0.04688	0.04664	0.04615	0.04527	0.04362	0.04042	0.03412	0.02226
7	3	0.01965	0.03016	0.03641	0.04005	0.04226	0.04365	0.04457	0.04521
		0.04568	0.04604	0.04633	0.04657	0.04677	0.04692	0.04702	0.04705
		0.04697	0.04674	0.04627	0.04538	0.04369	0.04043	0.03404	0.02213
7	4	0.01057	0.02729	0.03483	0.03945	0.04223	0.04398	0.04516	0.04600
		0.04664	0.04715	0.04759	0.04797	0.04832	0.04864	0.04891	0.04908
		0.04915	0.04904	0.04862	0.04765	0.04555	0.04126	0.03296	0.01195
7	5	0.01032	0.02690	0.03454	0.03927	0.04214	0.04394	0.04515	0.04602
		0.04668	0.04722	0.04767	0.04807	0.04844	0.04877	0.04905	0.04925
		0.04934	0.04924	0.04883	0.04783	0.04566	0.04123	0.03272	0.01173
7	6	0.01887	0.02952	0.03604	0.03989	0.04222	0.04368	0.04465	0.04531
		0.04580	0.04618	0.04649	0.04675	0.04696	0.04713	0.04726	0.04732
		0.04727	0.04708	0.04662	0.04570	0.04389	0.04038	0.03361	0.02140
7	7	0.01872	0.02959	0.03605	0.03988	0.04221	0.04369	0.04466	0.04533
		0.04582	0.04620	0.04651	0.04677	0.04698	0.04715	0.04727	0.04733
		0.04727	0.04707	0.04660	0.04565	0.04383	0.04034	0.03368	0.02140
8	1	0.02018	0.03054	0.03667	0.04025	0.04242	0.04379	0.04470	0.04533
		0.04579	0.04614	0.04642	0.04665	0.04684	0.04696	0.04702	0.04698
		0.04681	0.04644	0.04583	0.04484	0.04314	0.03997	0.03387	0.02241
8	2	0.01852	0.02950	0.03602	0.03985	0.04214	0.04359	0.04456	0.04525
		0.04576	0.04617	0.04651	0.04680	0.04705	0.04726	0.04740	0.04744
		0.04734	0.04707	0.04653	0.04560	0.04386	0.04048	0.03386	0.02144
8	3	0.01874	0.02968	0.03614	0.03992	0.04218	0.04361	0.04457	0.04524
		0.04574	0.04613	0.04645	0.04673	0.04697	0.04717	0.04729	0.04733
		0.04723	0.04697	0.04646	0.04554	0.04382	0.04049	0.03396	0.02164
8	4	0.01973	0.03014	0.03638	0.04005	0.04229	0.04371	0.04464	0.04529
		0.04577	0.04613	0.04642	0.04666	0.04686	0.04701	0.04710	0.04710
		0.04698	0.04670	0.04616	0.04521	0.04346	0.04018	0.03385	0.02217
8	5	0.01895	0.02945	0.03591	0.03977	0.04213	0.04364	0.04463	0.04533
		0.04584	0.04623	0.04655	0.04683	0.04706	0.04723	0.04736	0.04740
		0.04733	0.04709	0.04657	0.04560	0.04375	0.04024	0.03356	0.02155
8	6	0.01704	0.02815	0.03507	0.03927	0.04183	0.04347	0.04456	0.04534
		0.04592	0.04638	0.04677	0.04711	0.04741	0.04768	0.04789	0.04801
		0.04803	0.04787	0.04741	0.04643	0.04446	0.04057	0.03320	0.02014
8	7	0.01689	0.02785	0.03491	0.03919	0.04183	0.04351	0.04463	0.04542
		0.04601	0.04648	0.04687	0.04722	0.04753	0.04780	0.04800	0.04813
		0.04814	0.04798	0.04751	0.04649	0.04444	0.04043	0.03286	0.01988
8	8	0.00929	0.02586	0.03374	0.03877	0.04191	0.04392	0.04527	0.04623
		0.04697	0.04756	0.04807	0.04852	0.04894	0.04932	0.04963	0.04985
		0.04995	0.04983	0.04934	0.04814	0.04565	0.04073	0.03176	0.01075
8	9	0.00885	0.02548	0.03361	0.03884	0.04211	0.04420	0.04559	0.04656
		0.04729	0.04787	0.04837	0.04881	0.04921	0.04956	0.04984	0.05004
		0.05009	0.04992	0.04934	0.04802	0.04534	0.04014	0.03084	0.01007
9	1	0.02039	0.03081	0.03681	0.04038	0.04258	0.04398	0.04492	0.04556

		0.04603	0.04638	0.04667	0.04690	0.04707	0.04718	0.04719	0.04707
		0.04675	0.04618	0.04533	0.04416	0.04236	0.03927	0.03352	0.02249
9	2	0.01912	0.02991	0.03630	0.04007	0.04235	0.04380	0.04477	0.04545
		0.04596	0.04636	0.04669	0.04696	0.04720	0.04737	0.04745	0.04740
		0.04717	0.04670	0.04595	0.04485	0.04306	0.03979	0.03355	0.02177
9	3	0.01938	0.03013	0.03644	0.04016	0.04241	0.04383	0.04478	0.04544
		0.04592	0.04630	0.04660	0.04686	0.04707	0.04723	0.04729	0.04724
		0.04703	0.04660	0.04589	0.04483	0.04307	0.03984	0.03368	0.02200
9	4	0.01984	0.03037	0.03652	0.04019	0.04243	0.04386	0.04480	0.04546
		0.04593	0.04629	0.04657	0.04681	0.04699	0.04712	0.04717	0.04712
		0.04692	0.04651	0.04583	0.04476	0.04295	0.03970	0.03363	0.02221
9	5	0.01876	0.02950	0.03595	0.03984	0.04225	0.04378	0.04480	0.04550
		0.04602	0.04641	0.04673	0.04700	0.04723	0.04739	0.04749	0.04749
		0.04735	0.04702	0.04640	0.04532	0.04339	0.03984	0.03326	0.02128
9	6	0.01704	0.02800	0.03502	0.03927	0.04190	0.04358	0.04470	0.04549
		0.04608	0.04655	0.04694	0.04728	0.04759	0.04784	0.04803	0.04812
		0.04809	0.04786	0.04733	0.04625	0.04418	0.04021	0.03275	0.01989
9	7	0.01643	0.02745	0.03474	0.03919	0.04194	0.04369	0.04486	0.04567
		0.04627	0.04674	0.04714	0.04749	0.04779	0.04805	0.04824	0.04835
		0.04833	0.04811	0.04757	0.04645	0.04425	0.04003	0.03216	0.01907
9	8	0.00885	0.02548	0.03361	0.03884	0.04211	0.04420	0.04559	0.04656
		0.04729	0.04787	0.04837	0.04881	0.04921	0.04956	0.04984	0.05004
		0.05009	0.04992	0.04934	0.04802	0.04534	0.04014	0.03084	0.01007
9	9	0.00858	0.02539	0.03371	0.03908	0.04245	0.04457	0.04596	0.04693
		0.04764	0.04819	0.04865	0.04905	0.04939	0.04969	0.04993	0.05008
		0.05008	0.04984	0.04918	0.04774	0.04488	0.03946	0.03000	0.00956
10	1	0.01857	0.02970	0.03633	0.04031	0.04275	0.04431	0.04534	0.04607
		0.04660	0.04702	0.04736	0.04764	0.04788	0.04803	0.04805	0.04787
		0.04741	0.04657	0.04535	0.04388	0.04183	0.03842	0.03217	0.02055
10	2	0.01817	0.02935	0.03608	0.04010	0.04257	0.04414	0.04520	0.04595
		0.04651	0.04694	0.04731	0.04761	0.04787	0.04805	0.04810	0.04797
		0.04757	0.04681	0.04569	0.04427	0.04224	0.03876	0.03233	0.02041
10	3	0.01841	0.02953	0.03616	0.04013	0.04255	0.04410	0.04514	0.04586
		0.04640	0.04682	0.04716	0.04745	0.04769	0.04785	0.04790	0.04779
		0.04744	0.04677	0.04575	0.04441	0.04242	0.03896	0.03259	0.02070
10	4	0.01971	0.03031	0.03657	0.04032	0.04263	0.04410	0.04508	0.04576
		0.04625	0.04662	0.04691	0.04715	0.04733	0.04744	0.04746	0.04734
		0.04701	0.04641	0.04550	0.04424	0.04229	0.03897	0.03291	0.02168
10	5	0.01848	0.02918	0.03583	0.03985	0.04234	0.04392	0.04498	0.04572
		0.04626	0.04667	0.04701	0.04730	0.04753	0.04770	0.04778	0.04775
		0.04754	0.04709	0.04632	0.04510	0.04305	0.03936	0.03257	0.02065
10	6	0.00926	0.02591	0.03384	0.03891	0.04208	0.04412	0.04549	0.04647
		0.04721	0.04780	0.04831	0.04877	0.04919	0.04954	0.04982	0.04998
		0.04996	0.04969	0.04902	0.04768	0.04508	0.04013	0.03122	0.01050
10	7	0.00869	0.02533	0.03354	0.03883	0.04214	0.04426	0.04568	0.04667
		0.04741	0.04800	0.04851	0.04897	0.04938	0.04973	0.05001	0.05018
		0.05019	0.04995	0.04929	0.04789	0.04514	0.03988	0.03051	0.00984
10	8	0.01629	0.02747	0.03502	0.03962	0.04247	0.04427	0.04544	0.04624
		0.04680	0.04721	0.04755	0.04782	0.04805	0.04824	0.04835	0.04838
		0.04827	0.04793	0.04724	0.04594	0.04351	0.03902	0.03090	0.01794
10	9	0.01625	0.02782	0.03541	0.04004	0.04288	0.04465	0.04578	0.04653
		0.04704	0.04740	0.04768	0.04790	0.04807	0.04819	0.04825	0.04823
		0.04806	0.04768	0.04694	0.04557	0.04308	0.03855	0.03048	0.01751
11	1	0.01717	0.02854	0.03583	0.04033	0.04314	0.04493	0.04613	0.04697
		0.04759	0.04807	0.04847	0.04881	0.04908	0.04926	0.04925	0.04897

		0.04824	0.04686	0.04486	0.04281	0.04033	0.03647	0.02973	0.01817
11	2	0.01718	0.02854	0.03578	0.04024	0.04302	0.04480	0.04599	0.04682
		0.04744	0.04792	0.04831	0.04865	0.04893	0.04911	0.04912	0.04887
		0.04820	0.04693	0.04507	0.04312	0.04068	0.03683	0.03007	0.01839
11	3	0.01754	0.02870	0.03580	0.04017	0.04289	0.04463	0.04579	0.04660
		0.04719	0.04765	0.04803	0.04835	0.04861	0.04877	0.04880	0.04859
		0.04802	0.04693	0.04533	0.04354	0.04117	0.03734	0.03060	0.01898
11	4	0.01824	0.02923	0.03600	0.04015	0.04274	0.04440	0.04549	0.04626
		0.04681	0.04725	0.04760	0.04789	0.04812	0.04827	0.04829	0.04813
		0.04768	0.04683	0.04557	0.04399	0.04174	0.03802	0.03145	0.01985
11	5	0.01697	0.02806	0.03523	0.03963	0.04238	0.04413	0.04530	0.04611
		0.04672	0.04719	0.04759	0.04792	0.04820	0.04840	0.04850	0.04846
		0.04818	0.04758	0.04660	0.04515	0.04281	0.03870	0.03132	0.01889
11	6	0.00843	0.02508	0.03344	0.03883	0.04221	0.04438	0.04584	0.04686
		0.04763	0.04825	0.04879	0.04927	0.04970	0.05006	0.05032	0.05045
		0.05037	0.04998	0.04914	0.04758	0.04471	0.03937	0.02991	0.00939
11	7	0.00789	0.02468	0.03332	0.03890	0.04240	0.04463	0.04610	0.04711
		0.04787	0.04847	0.04899	0.04944	0.04983	0.05016	0.05041	0.05054
		0.05048	0.05012	0.04930	0.04771	0.04468	0.03905	0.02919	0.00873
11	8	0.01565	0.02748	0.03527	0.04001	0.04292	0.04473	0.04589	0.04665
		0.04718	0.04756	0.04786	0.04810	0.04828	0.04842	0.04848	0.04844
		0.04824	0.04782	0.04702	0.04560	0.04304	0.03840	0.03012	0.01685
11	9	0.01619	0.02818	0.03586	0.04053	0.04336	0.04511	0.04620	0.04689
		0.04735	0.04765	0.04787	0.04803	0.04813	0.04818	0.04818	0.04807
		0.04782	0.04735	0.04651	0.04506	0.04251	0.03795	0.03000	0.01704
12	1	0.00850	0.02545	0.03430	0.04008	0.04375	0.04612	0.04773	0.04887
		0.04975	0.05046	0.05107	0.05161	0.05207	0.05240	0.05250	0.05218
		0.05110	0.04879	0.04513	0.04204	0.03872	0.03375	0.02555	0.00807
12	2	0.00862	0.02553	0.03427	0.03998	0.04361	0.04595	0.04753	0.04866
		0.04953	0.05022	0.05081	0.05134	0.05179	0.05212	0.05223	0.05195
		0.05096	0.04885	0.04547	0.04254	0.03928	0.03432	0.02609	0.00834
12	3	0.00896	0.02577	0.03424	0.03980	0.04332	0.04560	0.04713	0.04823
		0.04905	0.04971	0.05027	0.05077	0.05120	0.05152	0.05165	0.05144
		0.05064	0.04892	0.04615	0.04354	0.04040	0.03545	0.02721	0.00903
12	4	0.01487	0.02620	0.03417	0.03929	0.04252	0.04460	0.04599	0.04696
		0.04769	0.04828	0.04878	0.04921	0.04959	0.04988	0.05002	0.04991
		0.04939	0.04827	0.04648	0.04442	0.04155	0.03683	0.02876	0.01631
12	5	0.01428	0.02584	0.03389	0.03903	0.04227	0.04433	0.04570	0.04666
		0.04738	0.04795	0.04844	0.04887	0.04925	0.04954	0.04972	0.04972
		0.04940	0.04866	0.04741	0.04562	0.04278	0.03785	0.02932	0.01607
12	6	0.00747	0.02519	0.03375	0.03919	0.04260	0.04477	0.04621	0.04721
		0.04796	0.04857	0.04909	0.04955	0.04996	0.05029	0.05052	0.05060
		0.05044	0.04991	0.04891	0.04721	0.04423	0.03883	0.02934	0.00818
12	7	0.00671	0.02484	0.03381	0.03947	0.04297	0.04517	0.04661	0.04758
		0.04830	0.04886	0.04931	0.04971	0.05006	0.05034	0.05054	0.05060
		0.05045	0.04997	0.04901	0.04729	0.04418	0.03850	0.02851	0.00723
13	1	0.00758	0.02517	0.03497	0.04148	0.04564	0.04830	0.05006	0.05129
		0.05220	0.05293	0.05355	0.05409	0.05452	0.05479	0.05477	0.05418
		0.05238	0.04819	0.04074	0.03633	0.03274	0.02793	0.02041	0.00575
13	2	0.00771	0.02523	0.03489	0.04131	0.04540	0.04803	0.04976	0.05096
		0.05185	0.05256	0.05317	0.05368	0.05410	0.05437	0.05437	0.05382
		0.05217	0.04830	0.04138	0.03721	0.03366	0.02882	0.02117	0.00609
13	3	0.00811	0.02542	0.03470	0.04089	0.04483	0.04735	0.04900	0.05015
		0.05099	0.05166	0.05222	0.05270	0.05309	0.05334	0.05337	0.05293
		0.05159	0.04846	0.04296	0.03933	0.03588	0.03093	0.02306	0.00705

13	4	0.01407	0.02584	0.03436	0.03988	0.04337	0.04558	0.04702	0.04801
		0.04873	0.04930	0.04977	0.05017	0.05050	0.05072	0.05079	0.05055
		0.04976	0.04810	0.04538	0.04282	0.03966	0.03470	0.02652	0.01440
13	5	0.01377	0.02563	0.03410	0.03955	0.04296	0.04512	0.04651	0.04746
		0.04814	0.04867	0.04910	0.04946	0.04978	0.05000	0.05010	0.04997
		0.04948	0.04844	0.04676	0.04466	0.04155	0.03637	0.02768	0.01473
13	6	0.00705	0.02524	0.03413	0.03981	0.04334	0.04555	0.04698	0.04794
		0.04862	0.04915	0.04959	0.04996	0.05027	0.05052	0.05065	0.05061
		0.05029	0.04955	0.04828	0.04634	0.04314	0.03755	0.02800	0.00744
13	7	0.00623	0.02485	0.03419	0.04006	0.04367	0.04590	0.04730	0.04823
		0.04888	0.04937	0.04975	0.05007	0.05034	0.05054	0.05065	0.05059
		0.05029	0.04963	0.04846	0.04654	0.04323	0.03738	0.02732	0.00650
14	1	0.00843	0.03089	0.04290	0.05067	0.05553	0.05853	0.06040	0.06160
		0.06241	0.06300	0.06345	0.06379	0.06402	0.06405	0.06369	0.06247
		0.05920	0.05065	0.00396	0.00308	0.00270	0.00228	0.00163	0.00067
14	2	0.00849	0.03100	0.04295	0.05066	0.05548	0.05846	0.06031	0.06150
		0.06230	0.06287	0.06330	0.06363	0.06386	0.06389	0.06355	0.06239
		0.05927	0.05106	0.00409	0.00323	0.00285	0.00241	0.00173	0.00072
14	3	0.00866	0.03123	0.04304	0.05067	0.05542	0.05834	0.06015	0.06130
		0.06206	0.06260	0.06301	0.06331	0.06350	0.06352	0.06320	0.06213
		0.05928	0.05178	0.00443	0.00360	0.00321	0.00273	0.00199	0.00086
15	1	0.00812	0.03107	0.04354	0.05168	0.05675	0.05984	0.06173	0.06289
		0.06363	0.06412	0.06446	0.06469	0.06481	0.06469	0.06412	0.06245
		0.05806	0.04649	0.00230	0.00141	0.00118	0.00098	0.00069	0.00030
15	2	0.00812	0.03113	0.04356	0.05166	0.05672	0.05980	0.06167	0.06282
		0.06354	0.06403	0.06436	0.06459	0.06469	0.06458	0.06402	0.06241
		0.05816	0.04687	0.00237	0.00150	0.00125	0.00105	0.00076	0.00033
15	3	0.00810	0.03125	0.04362	0.05167	0.05668	0.05973	0.06157	0.06269
		0.06339	0.06386	0.06416	0.06437	0.06445	0.06434	0.06380	0.06228
		0.05829	0.04757	0.00255	0.00169	0.00145	0.00122	0.00088	0.00039

Figure 4-11
H.B. Robinson Unit 2 Cycle 8
Ratio Core Average K/Nu to Assembly Average K/Nu

	H	G	F	E	D	C	B	A	
8	43869 77.4 1.031	13399 80.1 .997	25435 78.7 1.015	26338 78.6 1.016	16063 79.7 1.001	16011 79.7 1.001	25940 78.6 1.015	4200 81.9 .974	
9		26138 78.6 1.015	12669 80.2 .995	24345 78.8 1.013	13478 80.1 .997	28188 78.4 1.018	6051 81.5 .979	3490 82.2 .971	
10			28309 78.4 1.018	13378 80.1 .996	24899 78.7 1.014	17318 79.6 1.003	5101 81.7 .976		
11				17161 79.6 1.003	24192 78.8 1.013	5918 81.5 .979	3626 82.1 .972	MWD/MTU K/NU (MEV) CORE/ASSY RATIO	
12					16348 79.7 1.002	3757 82.1 .972			

ASSEMBLY EXPOSURE = (BOC + EOC) / 2
K/NU VS. EXPOSURE FROM XPOSE (ENC 2.9% 500PPM 573F)

CORE AVERAGE EXPOSURE = (BOC + EOC) / 2 = 15243 MWD/MTU
CORE AVERAGE K/NU = 79.8 MEV

Figure 4-12
H.B. Robinson Unit 2 Cycle 10

Ratio Bottom Average K/Nu to Bottom Assembly Average K/Nu

	H	G	F	E	D	C	B	A	
	7586	19702	29124	7476	29126	17145	4898	0	
8	81.2	79.0	78.3	81.2	78.3	79.6	81.8	0	
	.984	1.011	1.020	.984	1.020	1.004	.977	0.0	
		18571	16914	28046	14133	15817	4856	0	
9		79.4	79.6	78.4	80.0	79.7	81.8	0	
		1.006	1.004	1.019	.999	1.002	.977	0.0	
			29629	7482	25917	24416	4632		
10			78.3	81.2	78.6	78.8	81.8		
			1.020	.984	1.016	1.014	.976		
				29731	14842	6070	3821		MWD/MTU
11				78.3	79.9	81.5	82.1		K/NU (MEV)
				1.020	1.000	.980	.973		CORE/ASSY RATIO
					6061	22681			
12					81.5	78.9			
					.980	1.012			

Ratio Top Average K/Nu to Top Assembly Average K/Nu

	H	G	F	E	D	C	B	A	
	6799	19064	28607	6873	28920	17522	6667	2283	
8	81.3	79.3	78.4	81.3	78.7	79.5	81.3	82.5	
	.982	1.007	1.017	.982	1.015	1.005	.982	.968	
		17953	16320	27584	13838	16047	6178	1832	
9		79.5	79.7	78.5	80.0	79.7	81.5	82.6	
		1.005	1.003	1.018	.998	1.002	.980	.966	
			29107	6813	25555	24336	4959		
10			78.3	81.3	78.6	78.8	81.8		
			1.020	.982	1.016	1.014	.977		
				29236	14336	5703	3729		MWD/MTU
11				78.3	79.9	81.6	82.1		K/NU (MEV)
				1.020	.999	.979	.973		CORE/ASSY RATIO
					5518	22458			
12					81.6	78.9			
					.979	1.012			

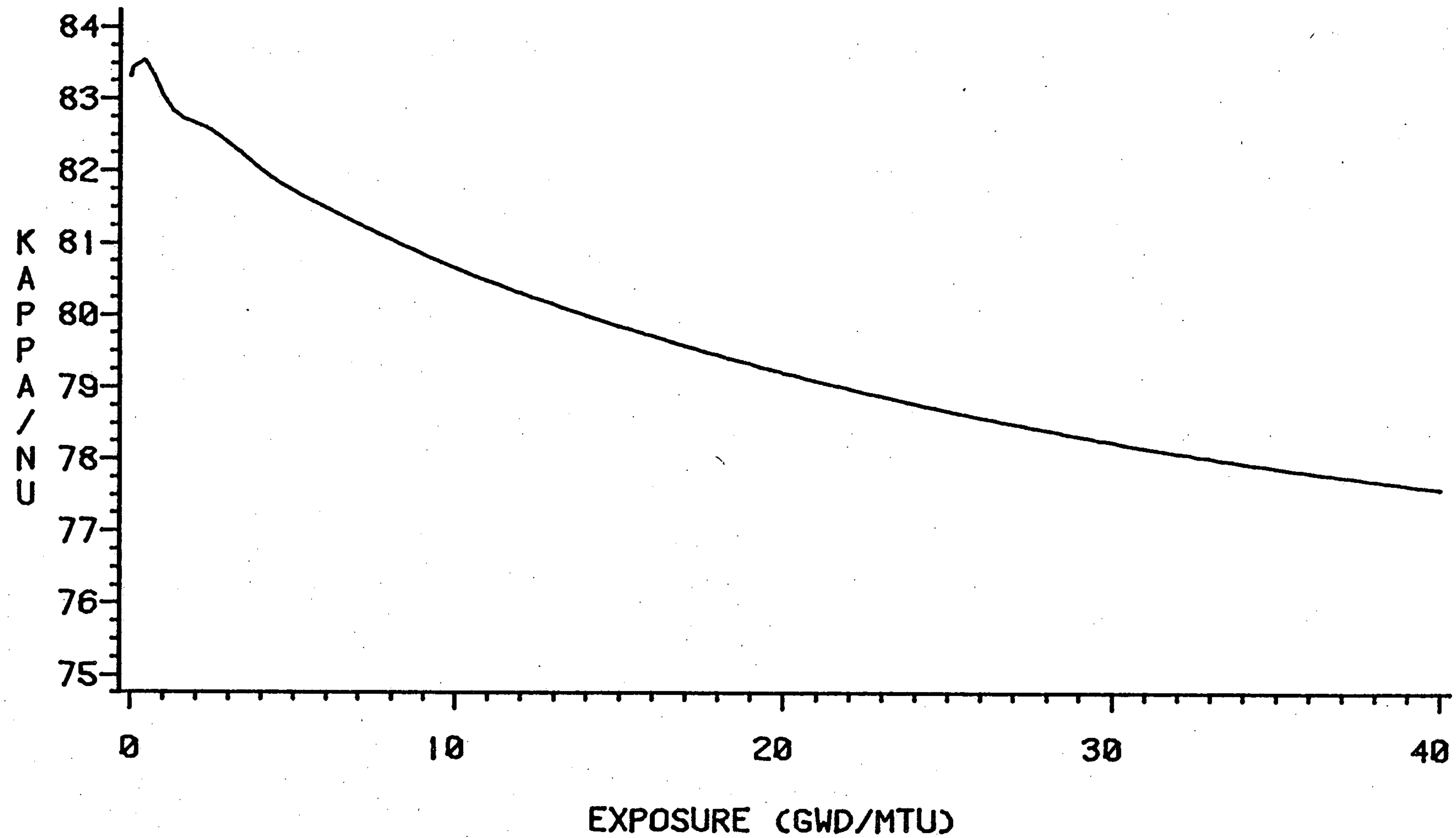
ASSEMBLY EXPOSURE = (BOC + EOC) / 2
K/NU VS. EXPOSURE FROM XPOSE (ENC 2.9% 500PPM 573F)

CORE AVERAGE EXPOSURE = (BOC + EOC) / 2 = 14750 MWD/MTU
CORE AVERAGE K/NU = 79.9 MEV

Figure 4-13

KAPPA/NU (MEV) VS. EXPOSURE

ENC 2.85 W/0 22GWT TM 573F 500 PPM
XPOSE (XPOSEUX 29/04/83)



A study was performed to assess the effect of this multiplier on the analyses of Capsules S, V, and T, removed from HBR2 at the end of Cycles 1, 3, and 8, respectively. The following quantities, used to determine saturation activity of the removed samples, were determined based on the daily operating history of the plant:

$$F = \sum_{j=1}^{N} mP_j/P_R \, (1 - \exp[-\lambda_i(t_j - t_{j-1})]) \exp[-\lambda_i(t_m - t_j)] \qquad (4.2)$$

$$EFPD = \sum_{j=1}^{N} mP_j/P_R \, [t_j - t_{j-1}] \qquad (4.3)$$

where P_R = reference full power

P_j = average power from t_{j-1} to t_j

t_m = time of capsule measurement

λ_i = decay constant of isotope i

These results are compared in Table 4-6 to analogous quantities calculated with the monthly power history as reported in the analyses of the Capsule T.[16] Note that the effect of power flattening and finer time history is small, but is a few percent for some isotopes. The Factor F(Monthly History) in Table 4-6 was used to back out measured dps/s from saturated activities reported for Capsule T.[16,17] The measured dps/s was reported for Capsules S and V.[18] In Table 4-7, saturated activities computed with F (Daily History) from Table 4-6 are compared to saturated activities reported in the above references. The corrected measured saturation activities shown in Table 4-7 were used for comparisons with calculated activities from the Cycle 8 Synthesis.

Table 4.6

Comparison of Saturation Factors for HBR#2 Surveillance Capsules

	Isotope	Decay Constant (1/day)	F(Daily Hist)	F(Month Hist)	Ratio
Capsule S	Mn-54	.22075E-2	.56211	.52855	1.0635
Capsule V	Co-58	.97079E-2	.86689	.83030	1.0441
	Mn-54	.22075E-2	.75357	.74311	1.0141
	Co-60	.36010E-3	.32483	.32179	1.0094
Capsule T	Co-58	.97079E-2	.06951	.06527	1.0650
	Mn-54	.22075E-2	.36235	.34257	1.0577
	Co-60	.36010E-3	.46115	.45062	1.0234
	Cs-137	.62840E-4	.14594	.14344	1.0174

Table 4.7

Comparison of Corrected and Reported Saturated Activities for HBR#2 Capsules

	Isotope	Corrected A_{Sat} (dps/g)	Reported A_{Sat} (dps/g)
Capsule S (EOC1 10')	Mn-54(Avg)	4.77E6	--
Capsule V (EOC3 20')	Co-58	4.833E7	4.76E7
	Mn-54(Avg)	3.278E6	3.19E6
	Co-60	3.54E5	3.43E5
Capsule T (EOC8 0')	Co-58	1.164E8	1.24E8
	Mn-54(Avg)	8.39E6	8.87E6
	Co-60	7.525E5	7.70E5
	Cs-137(Np)	8.565E7	8.71E7
	Cs-137(U238)	1.297E7	1.32E7

4.3.5 Normalization of Sources Input to DOT-4

A computer program AXFRAC, was written to provide normalization of input to DOTSOR for the HBR2 problem. The program is listed in Appendix B.

DOTSOR converts the PDQ7 relative pin power distribution in X-Y geometry to neutron source distribution in R-θ geometry. To normalize the distribution to absolute neutron source, the correspondence between X-Y zone (assembly) total power and R-θ zone total power must be provided. AXFRAC provided this input to DOTSOR based on the assembly distributions of Figures 4-1 and 4-10, respectively, for the Cycle 8 and Cycle 10 calculations. The K/ν corrections given in Figures 4-11 and 4-12 were also applied. The normalization was provided for an upper and a lower section based on integration of XTG assembly-wise axial distribution up to and then beyond the PLSA shield-fuel interface. The splitting is consistent with the synthesis-superposition technique for developing the final 3-D flux distributions.

AXFRAC also developed R-Z and R neutron source distributions for the R-Z DOT and R ANISN calculations that provided the synthesis functions for determining the 3-D flux. It is required that the normalization between these two calculations be consistent (not absolute), since together they provide only the Z shape to the final distribution. To provide greater accuracy in the region of greatest concern, the R-Z and R calculations model the geometry and source along the core major axis. The R-Z source was determined by combining the PDQ7 assembly distributions along the axis with quarter-assembly-wise axial distributions along the axis. The

power density distribution was multiplied by the R-Z mesh volumes and summed along Z to provide the R distribution input to ANISN.

AXFRAC was used to generate DOTSOR, DOT, and ANISN input for Cycle 8 upper core, lower core, and total core cases and for Cycle 10 upper core and lower core cases. The results were verified by hand calculations for sources within each PDQ7 and XTG zone. Equations governing generation of sources are given in Figure 4-14.

4.4 GEOMETRIC MODELS

The models listed in Table 4-8 were used in various stages of this analysis. Each of the following subsections describes one of the geometries used in the analysis.

4.4.1 One-Dimensional Model Used for Material Selection Reduction Factor Calculations

A one-dimensional slab model was developed to provide a preliminary estimate of the fluence reduction at the inner surface of the RPV for the various materials under consideration. The outer fuel assembly in the model was replaced with a PLSA containing either stainless steel, Inconel, Zircaloy, water, or natural uranium to investigate the fluence reduction. The model shown in Figure 4-15 specifically includes the outermost three fuel assemblies, the core baffle, the core barrel, the thermal shield, and the reactor pressure vessel. The material zones used in the model are defined in Table 4-9. The slab geometry

$$S^{u}(r,\Theta,E) = \frac{\overline{kw}\ \chi(E)}{[\kappa/\nu\ (r,E)]^{u}} \cdot \frac{A\ (r,\Theta)}{A\ (x,y)} \cdot P_{PDQ}^{Av}\ (x,y) \cdot \sum_{\substack{\text{above}\\ \text{shield}}} P_{XTG}^{r,\Theta}\ (z)$$

$$S^{L}(r,\Theta,E) = \frac{\overline{kw}\ \chi(E)}{[\kappa/\nu\ (r,E)]^{l}} \cdot \frac{A\ (r,\Theta)}{A\ (x,y)} \cdot P_{PDQ}^{Av}\ (x,y) \cdot \sum_{\text{shield}} P_{XTG}^{r,\Theta}\ (z)$$

$$S^{U}(r,z,E) = \frac{\overline{kw}\ \chi(E)}{[\kappa/\nu\ (r,E)]^{u}} \cdot \frac{V\ (r,Z)}{V\ (x,y)} \cdot \begin{cases} P_{PDQ}^{u}\ (o,\ y) \cdot P_{XTG}^{r,o^\circ}\ (z) & z > \text{shield hgt.} \\ o & z < \text{shield hgt.} \end{cases}$$

$$S^{L}(r,z,E) = \frac{\overline{kw}\ \chi(E)}{[\kappa/\nu\ (r,E)]^{L}} \cdot \frac{V\ (r,Z)}{V\ (x,y)} \cdot \begin{cases} o & z < \text{shield hgt.} \\ P_{PDQ}^{L}\ (o,\ y) \cdot P_{XTG}^{r,o^\circ}\ (z) & z > \text{shield hgt.} \end{cases}$$

$$S^{u}(r,E) = \sum_{\substack{\text{above}\\ \text{shield}}} S^{u}(r,z,E)$$

$$S^{L}(r,E) = \sum_{\text{shield}} S^{L}(r,z,E)$$

$\overline{kw}$ = average pin power

$\chi(E)$ = fission spectrum

κ/ν = (power/neutrons per fission)

$A(r,\Theta)$ = mesh area (in pin cell units) at r,Θ

$A(x,y)$ = PDQ pin cell fraction

$V(r,t)$ = mesh volume at r,z

$V(x,y)$ = arbitrary constant (at all x,y)

$P_{PDQ}\ (x,y)$ = cycle-average power (relative) PDQ

$$P_{PDQ}^{Av}\ (x,y) = 3/4 \cdot P_{PDQ}^{u}\ (x,y) + 1/4 \cdot P_{PDQ}^{L}\ (x,y)$$

$P_{XTG}^{r,\Theta}\ (z)$ = cycle-average axial distribution from XTG

$$\overline{kw} \sum_{1/8\ \text{core}} P_{PDQ}^{Av}(x,y)\ A(x,y) = 1/8\ .\ 2300\text{Mwt}$$

$$\sum_{Z} P_{XTG}^{r,\Theta}\ (z) = 1.0 \text{ at all } r,\Theta$$

Figure 4-14. Equations used in AXFRAC and DOTSOR.

Table 4-8

NEUTRONICS MODELS USED IN THE ANALYSES

Model	Purpose
1-D Reduction Model	Used to evaluate fluence reduction characteristics of various materials under consideration for use in the PLSA
1-D Eigenvalue Model	Used to evaluate the effect of the various materials under consideration on the core reactivity
Fuel Pin Cell Model	Used in geometric self-shielding calculation during cross-section generation
DOT-IV Homogeneous R-Z Model	Used in calculations to determine optimum partial length shield height
DOT-IV R-Θ Model	Used in preliminary circumferential flux reduction calculations as well as flux calculations for input to the flux synthesis
DOT-IV Heterogeneous R-Z Model	Used in the calculation of the flux for input to the flux synthesis

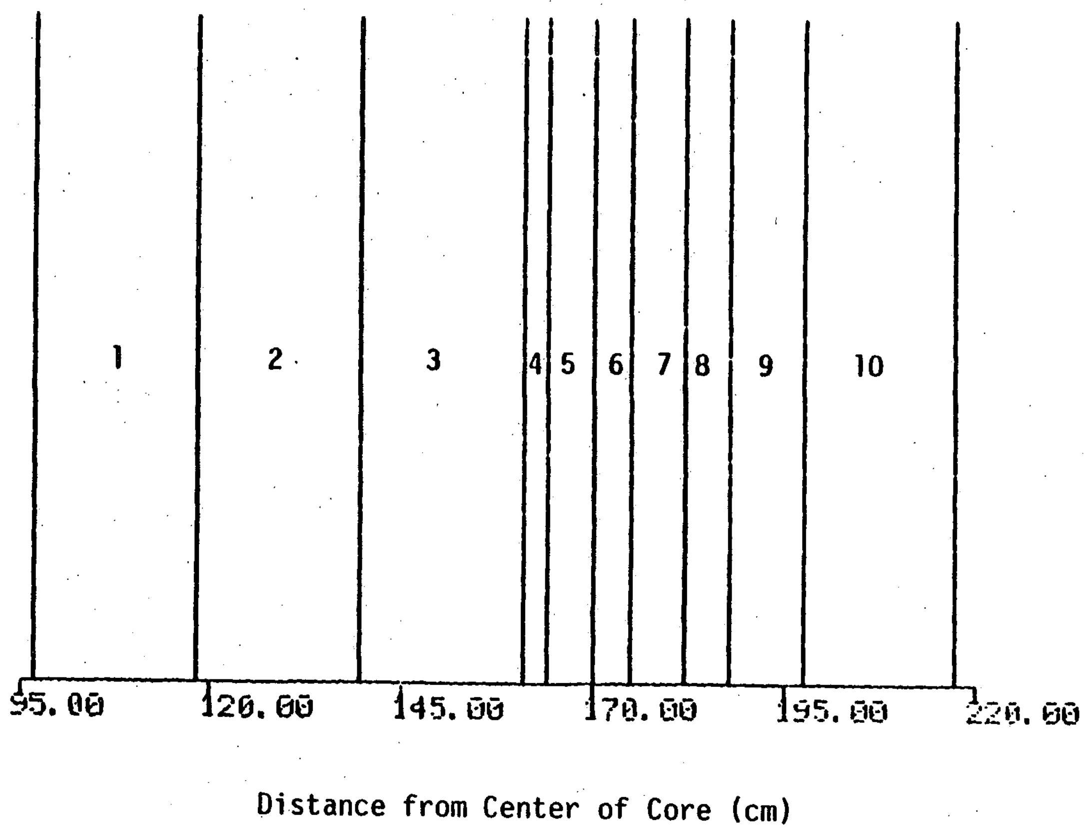


Figure 4-15. ANISN One-Dimensional Slab Model for Fixed Source Analysis (See Table 4-9 for zone definitions).

Table 4-9

ANISN ONE-DIMENSIONAL SLAB MODEL ZONE ASSIGNMENTS

Zone Number	Description
1	Fuel Assembly 1
2	Fuel Assembly 2
3	Fuel Assembly 3 or Shield Assembly
4	Core Baffle
5	H_2O
6	Core Barrel
7	H_2O
8	Thermal Shield
9	H_2O
10	Reactor Pressure Vessel

dimensions for the various material regions were taken as the radial dimensions at the position corresponding to the center of the core flats. The left boundary was treated as a reflected boundary, and the right boundary was treated as a vacuum boundary. The mesh spacing in this model is listed in Table 4-10.

4.4.2 One-Dimensional Eigenvalue Model

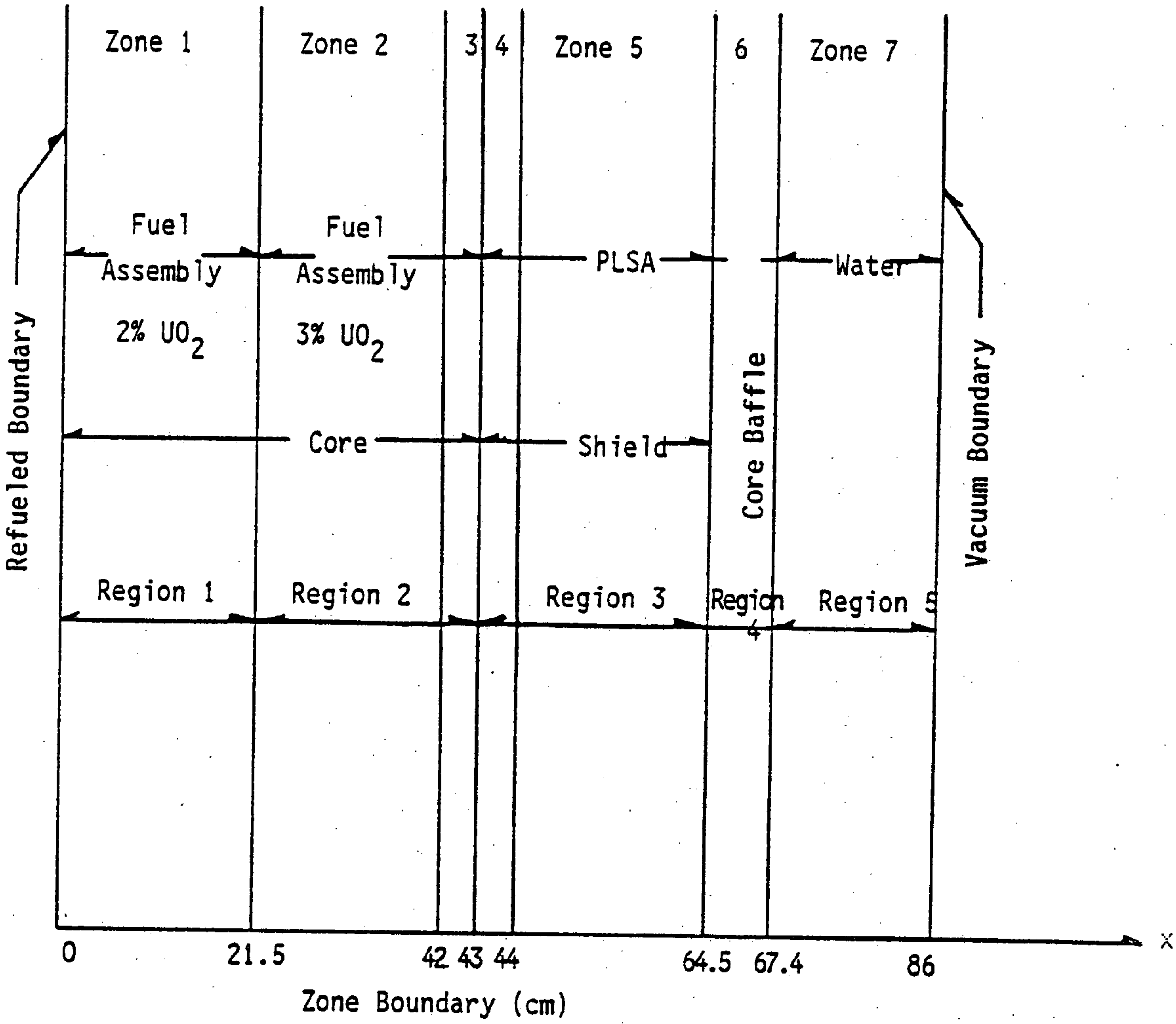
The geometrical configuration of the one-dimensional slab model is shown in Figure 4-16. The model consists of five material regions: three fuel assemblies of different fuel/PLSA materials, one core baffle region, and one region of 18 cm of water serving as the core reflector.

Each of the first three regions is one fuel assembly in thickness. For the base case, three fuel assemblies are composed of fuel having enrichments of 2, 2, and 3 weight percent U-235, respectively. For the PLSA cases, the first two fuel assemblies contain fuel having enrichments of 2 and 3 weight percent U-235, respectively. The third region is a PLSA consisting of one of the following shield materials: stainless steel-304, Inconel-718, Zircaloy-4, water, or depleted UO_2. For all cases except water, the PLSA is identical in geometry and material to a fuel assembly except that the fuel material is replaced by the specified shield material. The detailed design parameters of the fuel assemblies in the calculations were taken from Reference 19. For the case of water as the shield material, the third region is filled with water. No structural materials such as tubes are present. The fourth material region is composed of core baffle which is made of stainless steel (SS-304), and the last region consists of an 18-cm water reflector.

Table 4-10

MESH INTERVALS USED IN ONE-DIMENSIONAL SLAB MODEL

Region	Mesh Intervals (Number)	Interval Width (cm)
Fuel - 1	15	1.4336
Fuel - 2	12	1.4336
	5	0.8602
Fuel - 3	5	0.8602
	9	1.4336
	5	0.8602
Baffle	5	0.5716
H_2O-1	7	0.8404
Core Barrel	7	0.7373
H_2O-2	7	0.8503
Thermal Shield	3	0.6500
	3	0.9750
	3	0.6500
H_2O-3	11	0.8660
Vessel	6	0.8890
	11	1.3335



Fuel Temperature: 1300°F

Clad Temperature: 600°F

Water Temperature: 575°F

Water contains 500 ppm boron

Figure 4-16. One-Dimensional Slab PLSA Core Model for Eigenvalue Calculations.

This reflector is considered to provide an adequate model of the neutron transport effect of the shield and reflector materials beyond the core baffle such as the core-barrel, water, and thermal shield.

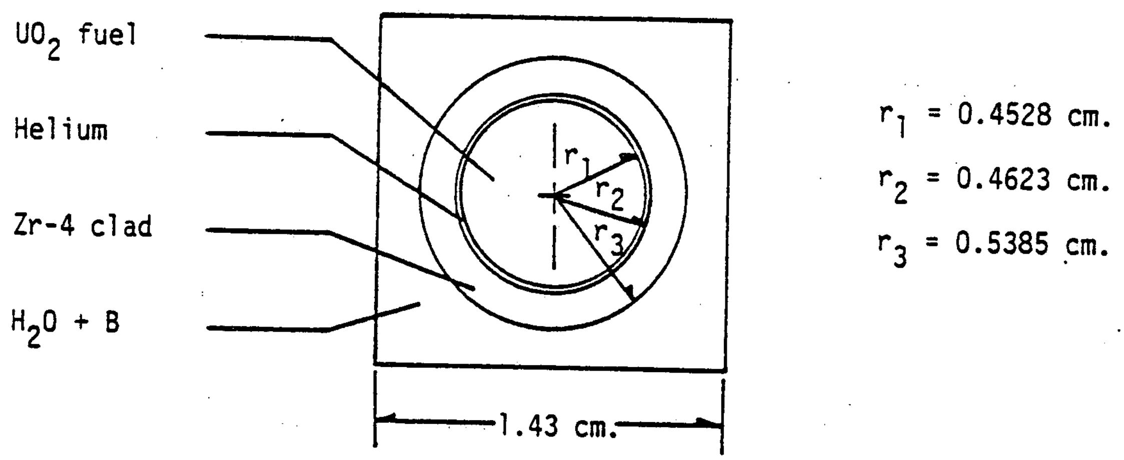
The one-dimensional slab eigenvalue analyses employed a reflected boundary condition (i.e., zero current) at the left boundary for all cases, while a vacuum boundary condition was applied at the right boundary.

4.4.3 Fuel Pin Cell Model

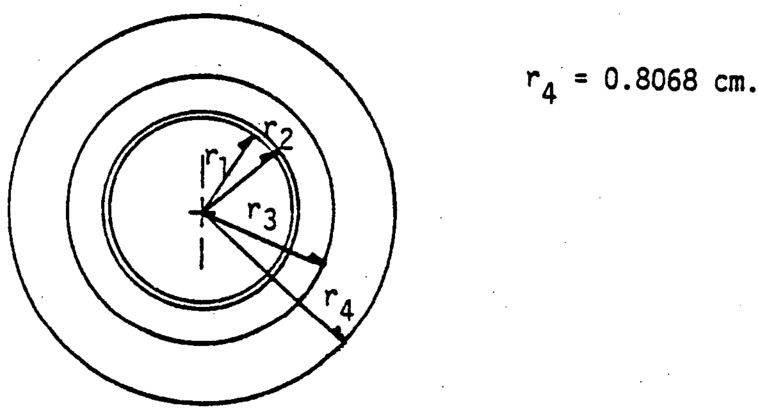
The fuel pin cell model shown in Figure 4-17 was developed in order to perform the cell calculations necessary for self-shielding calculations. A fuel pin cell consists of a fuel rod surrounded by boronated water mixture in a square area. This geometry with a square cross-sectional area was transformed to a cylindrical geometry with the same volume of water as in the original pin configuration.

4.4.4 DOT-IV Homogeneous R-Z Model

A two-dimensional R-Z analysis to determine the optimum shield height was performed with the model shown in Figure 4-18. The model utilizes 93 axial intervals and 70 radial intervals for a total of 6510 mesh points. The zones used in the model are listed in Table 4-11. Axially, the model contains regions that describe the shield, the lower fuel assembly structure, the upper fuel assembly structure, and the inactive fuel region. This model was obtained by computing the volume fractions of the various components as a function of the radius. This results in an inner region (zones 2 and 3) that represents the core as a homogeneous fuel assembly mixture; a region of transition (zones 5, 6, 7, 8, and 9) containing seven homogeneous annular regions each with different



(a) Fuel Pin Cell Model



(b) Equivalent Fuel Pin Cell Model

Figure 4-17. Fuel Pin Cell Model Geometry

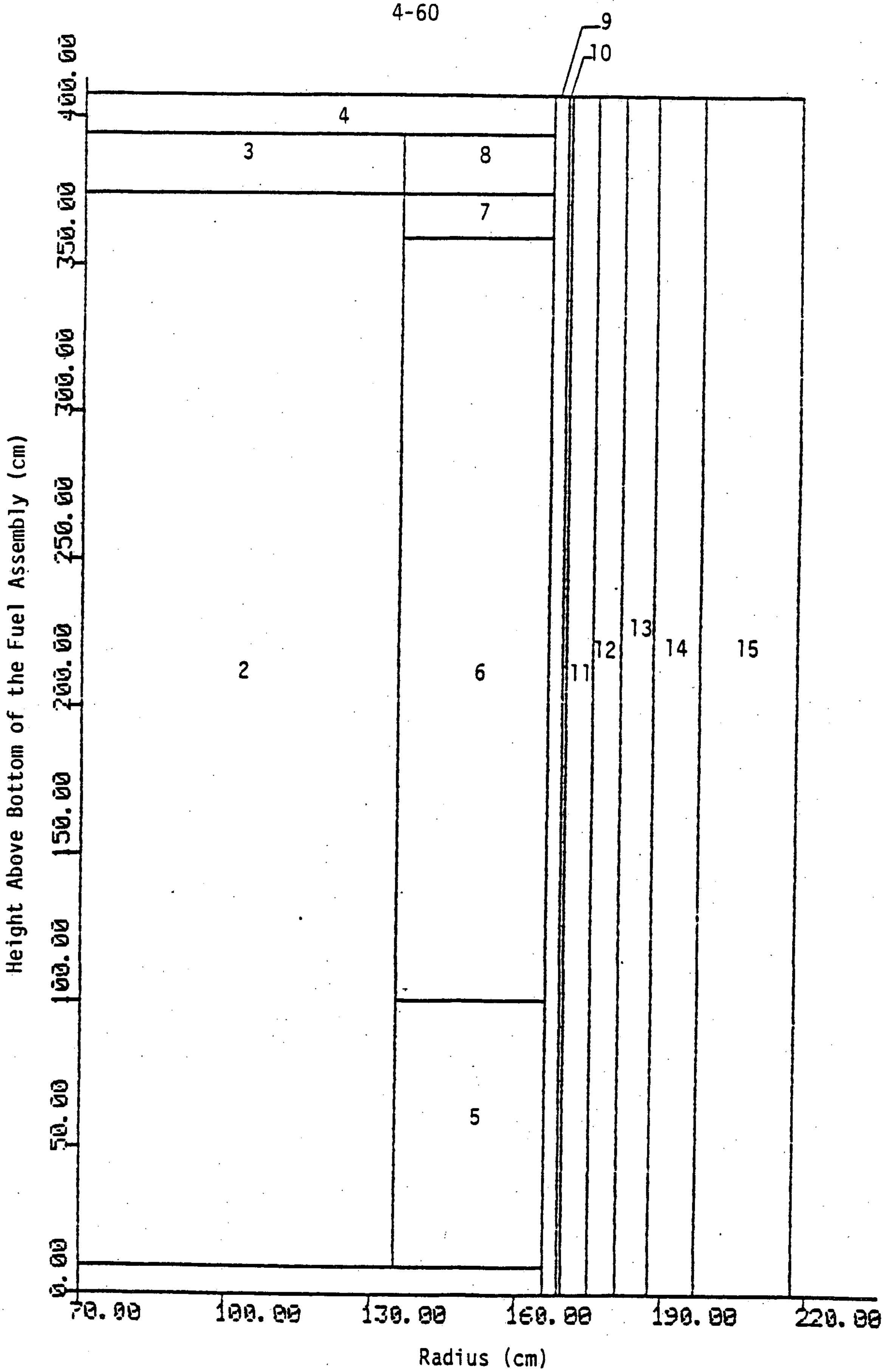


Figure 4-18. DOT-IV R-Z Reactor Model

Table 4-11

DOT-IV HOMOGENEOUS R-Z REACTOR MODEL ZONE ASSIGNMENTS

Zone	Description
1	Lower Fuel Assembly Structure
2	Active Core Fuel Assemblies
3	Inactive Core Fuel Assemblies
4	Upper Fuel Assembly Stucture
5	Lower Shield Transition Region
6	Active Core Fuel Assemblies Transition Region
7	Upper Shield Transition Region
8	Inactive Core Fuel Assemblies Transition Region
9	Core Baffel and H_2O Mixture
10	H_2O
11	Core Barrel
12	H_2O
13	Thermal Shield
14	H_2O
15	Reactor Pressure Vessel

volume fractions for fuel assemblies, core baffle, and water; and a heterogeneous representation of the core barrel, thermal shield, and reactor vessel.

The volume fractions in the transition region vary as shown in Table 4-12 for the shield, fuel, and inactive fuel. The assembly volume fractions listed imply for the case of the shield transition region that any fuel located further from the core center than the innermost edge of the shield assembly is also a shield. This change in the material was necessary since for a true homogeneous radial model the shield would have only a small influence on the average circumferential flux. This change allows a calculation of the reduction factor that is indicative of the reduction in the vessel fluence at the circumferential position corresponding to the center of the core flats. The total volume of the shield assembly in the transition region represents an effective shield thickness of 16 cm.

4.4.5 DOT-IV R-Θ Model

A two-dimensional R-θ model that explicitly describes the outer rows of fuel assemblies and the RPV components was developed. The model (shown in Figure 4-19, zones listed in Table 4-13) was defined using the variable mesh option of the DOT-IV computer code. Thus, a separate set of radial boundaries was defined for each of the 60 angular intervals in the one-eighth core model. The total number of radial intervals in any angular segment varied between 78 and 96. A total of 5183 mesh points were contained in the model. The angular boundary conditions and the inner boundary were all reflected. The outer boundary condition was vacuum.

Table 4-12

RADIAL VOLUME FRACTIONS IN THE DOT-IV R-Z MODEL

Transition Reason	Radius (cm)		Volume Fraction		
	Inner	Outer	Assembly	Baffle	H_2O
1	136.00	142.00	0.9781	0.0211	0.0008
2	142.00	147.00	0.8077	0.1453	0.0470
3	147.00	153.00	0.5235	0.1989	0.2776
4	153.00	157.50	0.3380	0.1353	0.5267
5	157.00	161.25	0.2638	0.0842	0.6520
6	161.25	166.25	0.0656	0.1769	0.7605
7	166.25	168.75	0.0000	0.0295	0.9705

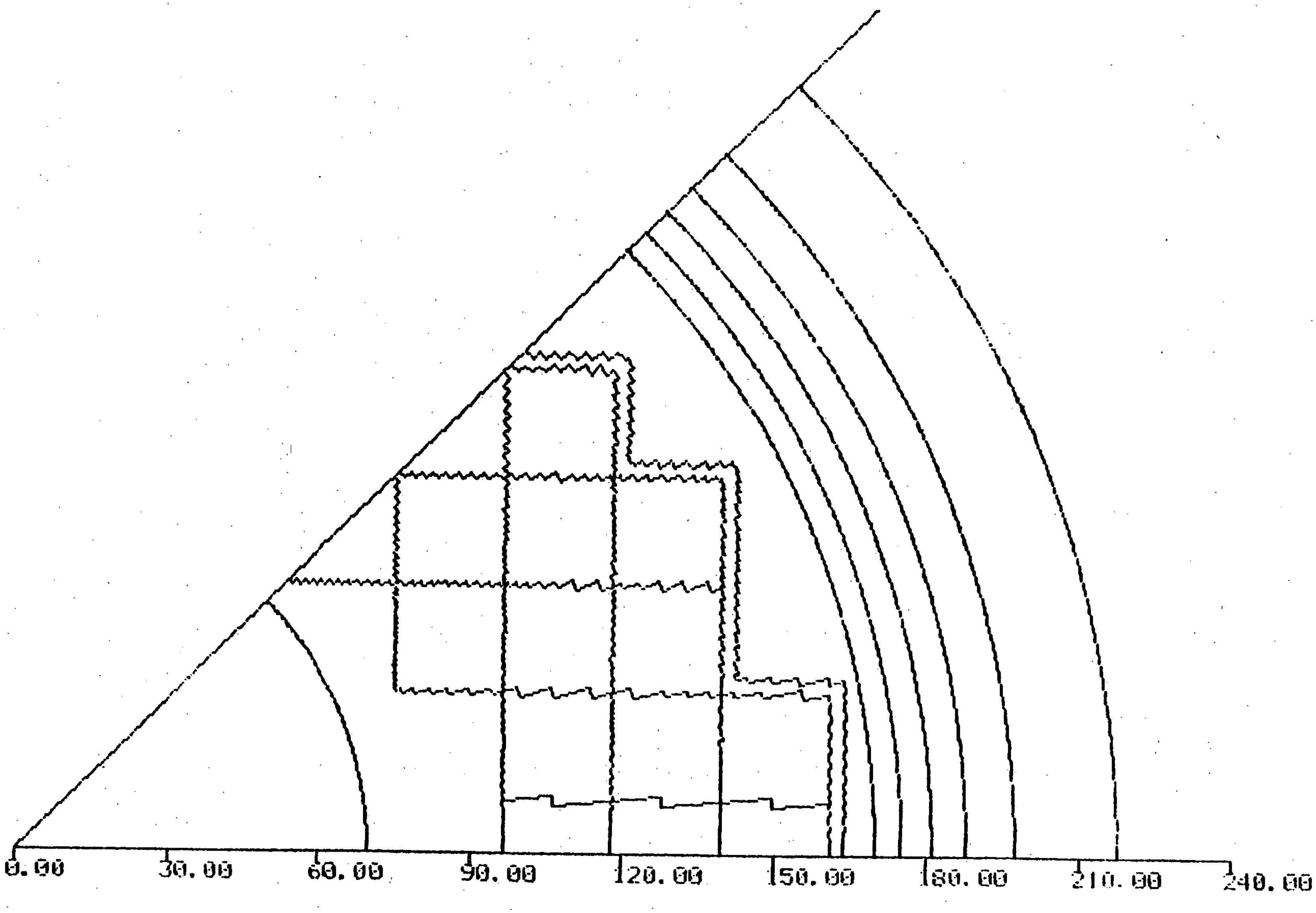


Figure 4-19. DOT-IV R-θ Reactor Model.

Table 4-13

DOT-IV R-Θ REACTOR MODEL ZONE ASSIGNMENTS

Zone Number	Description
1	Inner Fuel Assemblies
2-14	Fuel Assemblies
15-16	Fuel Assemblies or Shield Assemblies
17	Core Baffle
18	H_2O
19	Core Barrel
20	H_2O
21	Thermal Shield
22	H_2O
23	Reactor Pressure Vessel

4.4.6 DOT-IV Heterogeneous R-Z Model

The model shown in Figure 4-20 was developed to explicitly describe the fuel-to-pressure-vessel geometry along the core flat. Unlike the model described in Section 4.4.4, this model maintains the heterogeneous nature of the components of the model. This model contains the 13 distinct material regions shown in Figure 4-20 and listed in Table 4-14. This model was selected for use in the flux synthesis and reduction factor calculations because it most closely describes the geometry in the region of greatest interest. Flux synthesis using this model to determine the axial shape functions should provide a better estimate of the flux in the region of the core flat. However, this gain is at the loss of accuracy in the circumferential positions away from the core flat. These regions are of little interest because the partial length shield assemblies will have negligible effects in reducing the vessel fluence in regions away from the core flats.

4.5 NUMBER DENSITIES

All of the models used in this analysis describe only 10 different material regions of the reactor. Each of these 10 regions are listed with the associated volume fraction of the materials that comprise the region in Table 4-15.

Only a few materials are present in the various regions. Number densities for each of these materials are based upon the actual composition as provided in Reference 20. Table 4-16 lists the resulting number densities for each of the materials present in the model regions.

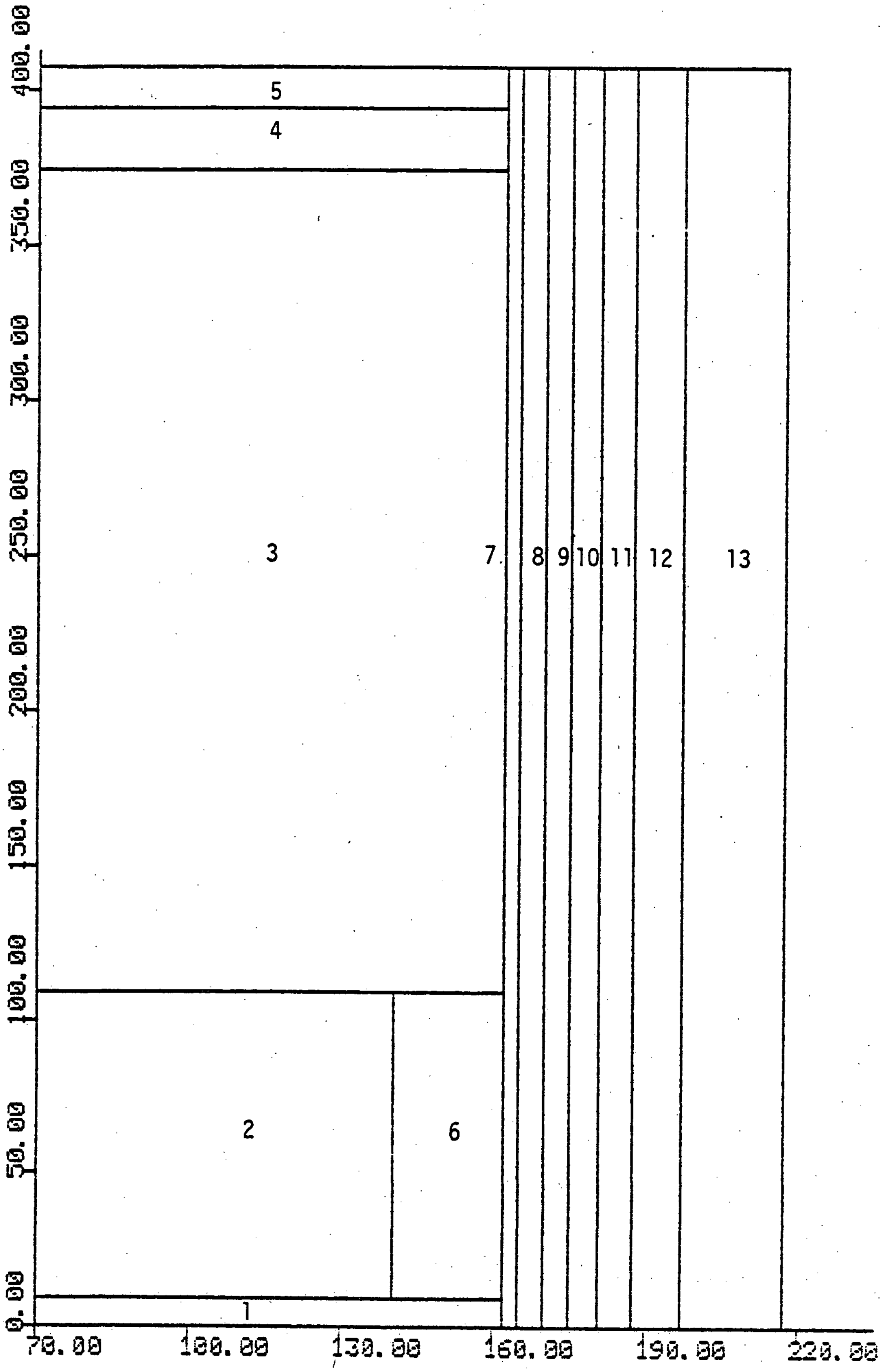


Figure 4-20. DOT-IV Heterogenerous R-Z Model.

Table 4-14

DOT-IV HOMOGENEOUS R-Z REACTOR MODEL ZONE ASSIGNMENTS

Zone	Description
1	Lower Fuel Assembly Structure
2, 3	Active Core Fuel Assemblies
4	Inactive Core Fuel Assemblies
5	Upper Fuel Assembly Stucture
6	Lower Shield Region
7	Core Baffel and H_2O Mixture
8	H_2O
9	Core Barrel
10	H_2O
11	Thermal Shield
12	H_2O
13	Reactor Pressure Vessel

Table 4-15

MATERIAL VOLUME FRACTIONS BY MATERIAL REGION

Region	Reactor Material	Volume Fraction
Fuel Assembly	H_2O	0.5895
	UO_2 or Alternate	0.2841
	Zircaloy 4	0.1143
	Helium or Void	0.0121
H_2O	H_2	1.0000
Boronated H_2 (500 ppm)	Boronated H_2O	1.0000
Core Baffle	Stainless Steel 304	1.0000
Core Baffle	Stainless Steel 304	1.0000
Thermal Shield	Stainless Steel 304	1.0000
Reactor Pressure Vessel	Carbon Steel	1.0000
Lower Assembly Structure	Inconel 718	0.0226
	Stainless Steel 304	0.2334
	H_2O	0.7440
Inactive Fuel Rods	H_2O	0.5895
	Zircaloy 4	0.1143
	Inconel 718	2.3280x10-4
Upper Assembly Structure	Stainless Steel 304	0.1447
	Inconel 718	0.0144
	H_2O	0.8409

Table 4-16

ELEMENT NUMBER DENSITIES (atoms/bn-cm) FOR REACTOR MATERIALS

Material	Element	Density
2.9 w% UO_2	O	4.599-2
	U-235	6.751-4
	U-238	2.232-2
2.0 w% UO_2	O	4.599-2
	U-235	4.659-4
	U-238	2.754-2
3.0 w% UO_2	O	4.599-2
	U-235	6.987-4
	U-238	2.231-2
Zircaloy 4	Fe	1.494-4
	Cr	7.641-5
	Zr	4.279-2
Stainless Steel 304	C	3.220-4
	Mn	1.760-3
	P	7.035-5
	S	4.523-5
	Si	1.721-3
	Cr	1.766-2
	Ni	7.616-3
	Fe	5.938-2
Inconel 718	Ni	4.411-2
	C	1.643-4
	Mn	1.796-4
	Fe	1.590-2
	Si	3.512-4
	Cr	1.802-2
	Al	1.097-3
	Mo	1.543-3
Carbon Steel	Fe	8.270-2
	Mn	1.200-3
	Si	1.000-4
	P	1.380-5
	S	2.220-5
	C	7.440-4

Table 4-16 (Continued)

Material	Element	Density (Number)
Natural UO_2	0	4.598-2
	U-235	1.641-4
	U-235	2.283-2
575°F H_2O	H	4.739-2
	0	2.370-2
Boronated H_2O	H	4.739-2
	0	2.370-2
	B-10	4.219-6
	B-11	1.556-5

*4.599-2 denotes 4.599×10^{-2}

4.6 SAMPLE INPUTS

This section contains sample input files for each major transport analysis required in the best-estimate flux reduction factor. These files consist of (1) DOT R-Z input for analysis of the top of core-Cycle 10, (2) DOT R-Z input for analysis of the bottom of core-Cycle 10, (3) DOT R-θ input for the top of core-Cycle 10, (4) DOT R-θ input for the bottom of core-Cycle 10, (5) ANISN-W input for the top of core-Cycle 10, (6) ANISN-W input for the bottom of core-Cycle 10.

Input for the PDQ7 and XTG diffusion calculations requires history files stored on magnetic tapes and cross-sections that are proprietary to Exxon Nuclear Company. These are not presented here but are available for NRC review upon request.

DOT R-Z INPUT CYCLE 10 TOP OF CORE

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$LASERUK     15.40.46. 09/09/83 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

DOT R-Z

CYC10 TOP

INPUT

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$LASERUK     15.40.46. 09/09/83 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

CPL HB ROBINSON R-Z CORE MODEL -36 IN SHLD- CYCLE 10 TOP-CORRECTED
61$$ 9 4 6 0 10 62 E
62$$ 0 3 13 78 83 56 5 6 61 0 3 124 124 0 48 1 1 0 0 0 1 -20 0 3 0 2
   3R0 2 4R0 0 14 0 1 1 3R0 0 3R0 4R1 4 100 2 0 0 19 63 3R0 1 4R0 6 0 E
63** 0. 2R0 1-3 A16 1-3 A19 .3 E T
  T
/  S8 FULL SYM 1  2  11
82**
-30861-5 -21822-5 21822-5 -61721-5 -57735-5 -21822-5 21822-5 57735-5
-8165-4 -7868-4 -57735-5 -21822-5 21822-5 57735-5 7868-4 -9759-4
-95119-5 -7868-4 -57735-5 -21822-5 21822-5 57735-5 7868-4 95119-5
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-8165-4 -7868-4 -57735-5 -21822-5 21822-5 57735-5 7868-4 -9759-4
-95119-5 -7868-4 -57735-5 -21822-5 21822-5 57735-5 7868-4 95119-5
83**
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2R-7868-4 -57735-5 -2182-4 -1-5 -21821-5 -57734-5 -7868-4 2R-95119-5
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81**
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2R22685-6 30247-6
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     3I382.649 396.115 398.415 2I402.715 412.115 F450.
86** 3I70. 130. 3I140.695 162.340 165.217 3I170.021 4I175.182 4I181.134
     7I187.959 15I197.485 217.488 F220.
  T
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3I170.021 4I175.182 4I181.134
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6.1873E+06 7.4082E+06 7.0469E+06 6.0653E+06 4.9659E+06 4.0657E+06
3.6788E+06 3.0119E+06  2.7253E+06 2.5924E+06 2.4660E+06
2.3653E+06 2.3457E+06 2.2313E+06 2.1225E+06 1.9205E+06 1.8268E+06
1.6530E+06 1.4957E+06 1.3534E+06 1.2246E+06 1.0026E+06 9.0718E+05
8.2085E+05 7.4274E+05 6.0810E+05 4.9787E+05 3.6883E+05 3.0197E+05
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4.0868E+04 3.4307E+04 2.6058E+04 2.4176E+04 2.1875E+04 1.5034E+04
1.1709E+04 7.1017E+03 5.5308E+03 3.3546E+03 2.6123E+03 1.5846E+03
1.0130E+02 1.0677E+01 4.1399E-01 1.0000E-05 0.0
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17R2 16R6 3R7 4R8 4R9 5R10 5R11 8R12 16R13 24078
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33R4 3R7 4R8 4R9 5R10 5R11 8R12 16R13 7078
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28$$ 28R30 28R0
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.13138E-03	.10384E-03	.10000E-03	.10038E-03	.12028E-03	.12245E-03
.12245E-03	.12551E-03	.12846E-03	.12846E-03	.13694E-03	.13694E-03
.13694E-03	.13694E-03	.13694E-03	.14286E-03	.14286E-03	.48374E-04
.48374E-04	.48374E-04	.48374E-04	.48374E-04	.57064E-04	.57064E-04

.57020E-04	.57020E-04	.57020E-04	0.	0.	0.
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.13138E-03	.10364E-03	.10000E-03	.10036E-03	.12026E-03	.12245E-03
.12245E-03	.12551E-03	.12846E-03	.12848E-03	.13694E-03	.13694E-03
.13694E-03	.13694E-03	.13694E-03	.14286E-03	.14286E-03	.48374E-04
.48374E-04	.48374E-04	.48374E-04	.48374E-04	.57064E-04	.57064E-04
.57064E-04	.57064E-04	.57064E-04	.57064E-04	.57064E-04	.57064E-04
.57020E-04	.57020E-04	.57020E-04	0.	0.	0.
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.13076E-03	.10315E-03	.99875E-04	.10034E-03	.12023E-03	.12240E-03
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.13668E-03	.13668E-03	.13668E-03	.14291E-03	.14291E-03	.48391E-04
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.57391E-04	.57391E-04	.57391E-04	.57391E-04	.57391E-04	.57391E-04
.57524E-04	.57524E-04	.57524E-04	0.	0.	0.
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.57391E-04	.57391E-04	.57391E-04	.57391E-04	.57391E-04	.57391E-04
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.12909E-03	.10183E-03	.99215E-04	.99747E-04	.11952E-03	.12141E-03
.12141E-03	.12439E-03	.12731E-03	.12731E-03	.13461E-03	.13461E-03
.13461E-03	.13461E-03	.13461E-03	.14108E-03	.14108E-03	.47773E-04
.47773E-04	.47773E-04	.47773E-04	.47773E-04	.57161E-04	.57161E-04
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.12566E-03	.99130E-04	.97386E-04	.97897E-04	.11730E-03	.11876E-03
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.12976E-03	.12976E-03	.12976E-03	.13615E-03	.13615E-03	.46104E-04
.46104E-04	.46104E-04	.46104E-04	.46104E-04	.55925E-04	.55925E-04
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.11884E-03	.93748E-04	.93133E-04	.93537E-04	.11208E-03	.11292E-03
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.53214E-04	.53214E-04	.53214E-04	0.	0.	0.
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.11292E-03	.11450E-03	.11719E-03	.11719E-03	.12030E-03	.12030E-03
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.11434E-03	.90198E-04	.90219E-04	.90559E-04	.10851E-03	.10894E-03
.10894E-03	.10994E-03	.11252E-03	.11252E-03	.11411E-03	.11411E-03
.11411E-03	.11411E-03	.11411E-03	.11904E-03	.11904E-03	.40310E-04
.40310E-04	.40310E-04	.40310E-04	.40310E-04	.49760E-04	.49760E-04
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.50467E-04	.50467E-04	.50467E-04	0.	0.	0.
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.10894E-03	.10994E-03	.11252E-03	.11252E-03	.11411E-03	.11411E-03
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.10454E-03	.10454E-03	.10454E-03	.10819E-03	.10819E-03	.38836E-04
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2.268-4 6.046-4
2.511-4 2.921-4
6.192-5 9.511-5
2.865-5 3.093-5
2.726-6 4.330-7
1.530-8 0.
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 MFA   U.C.C. NOS/BE L564  V1.6.06.2 23/08/83
16.00.13.LASERYI  FROM      9V
16.00.13.IP  00006666 WORDS - FILE INPUT  , DC 04
16.00.14.LASER,P2. LASER
16.00.14.ACCOUNT,GK7TEC,*----.
16.00.15.REWIND,OUTPUT.
16.00.16.ROUTE,OUTPUT,DEF,TID=8D.
16.00.16.UCC,BANNER,DOT R-2,CYC10 TOP,INPUT.
16.00.23.COPYBR,INPUT,AA.
16.00.24.COPYBR,INPUT,BB.
16.00.25.REWIND,AA,BB.
16.00.25.COPYSBF,BB,OUTPUT.
16.00.26.BEGIN,PPRINT,,I=OUTPUT,H=AA,FORM=2UP,COP
16.00.26.IES=1.
16.00.27.AT CY= 124 SN=GLOBAL
16.00.36.
16.00.36. COPYRIGHT, 1981, UNIVERSITY COMPUTING C
16.00.36.OMPANY.
16.00.36. REPRODUCTION PROHIBITED UNLESS SPECIFIC
16.00.36.ALLY
16.00.36. AUTHORIZED BY SEPERATE WRITING.
16.00.37.
16.00.37.RETURN,ZZZZZIN,ZZZZZPO,DAYFILE,DAYFIL.
16.00.37.IFE(FILE(AA,AS),H1)
16.00.37.COPYBR,AA,ZZZZZIN.
16.00.38.ENDIF,H1.
16.00.38.COPY,ZZZZZP1,ZZZZZIN.
16.00.39.RETURN,ZZZZZP1.
16.00.39.UCC,BANNER(D=ZZZZZIN, ,BIN,54)
16.00.42.REWIND,OUTPUT.
16.00.42.COPY,OUTPUT,ZZZZZIN.
16.00.44.IFE((T.AND.(DT.NE.TXD)),DLOOP)
16.00.44.SUMMARY.
16.00.44.MS    58496  WORDS  (    68736 MAX USED)
16.00.44.MM    30000B MAX SCM
16.00.44.CPR        1.263
16.00.44.IOR         .509
16.00.44.SRU        1.772
16.00.44.                        DATE 08/09/83
16.00.44.DAYFIL.
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DOT R-Z INPUT CYCLE 10 BOTTOM OF CORE

DOT R-Z
CYC10 BOT
INPUT

$$$LASEROH   16.11.31. 08/08/83 $$

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CPL HB ROBINSON R-Z CORE MODEL -36 IN SHLD- CYCLE 10 BOTTOM-CORRECTED
61$$ 9 4 8 0 10 62 E
82$$ 0 3 13 78 93 58 5 6 81 0 3 124 124 0 48 1 1 0 0 0 1 -20 0 3 0 2
   3R0 2 4R0 0 14 0 1 1 3R0 0 3R0 4R1 4 100 2 0 0 19 63 3R0 1 4R0 6 0 E
83** 0. 2R0 1-3 A16 1-3 A18 .3 6 T
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/  S8 FULL SYM 1  2  11
82**
-30881-5 -21822-5 21822-5 -61721-5 -57735-5 -21822-5 21822-5 57735-5
-8165-4 -7868-4 -57735-5 -21822-5 21822-5 57735-5 7868-4 -9759-4
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81**
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84$$ 11I1 13
85** 3I4.445 12.67 13.97 14I20.27 90.41 95.55 99.83 105.41 111.71
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      3I382.849 396.115 389.415 2I402.715 412.115 F450.
86** 3I70. 130. 3I140.685 162.340 165.217 3I170.021 4I175.182 4I181.134
      7I187.959 15I197.485 217.488 F220.
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2**   3I4.445 12.67 13.97 15.27 17.27 14I20.27 90.41 4I93.41 104.11
      105.41 106.71 108.71 111.71 34I116.71 352.809 357.809 360.809
      362.809 364.109 365.409 2I367.409 376.049 378.049 379.349
      380.649 3I382.849 398.115 398.115 389.415 400.715 2I402.715
      412.115
4** 3I70. 2I100. 4I115. 4I130. 15I140.695 2I162.340 3I165.217
3I170.021 4I175.182 4I181.134
     7I187.959 15I197.485 217.488
5**
1.7333E+07 1.4191E+07 1.2214E+07 1.1052E+07 1.0000E+07 8.6071E+06
8.1873E+06 7.4082E+06 7.0469E+06 6.0653E+06 4.9659E+06 4.0657E+06
3.6788E+06 3.0119E+06  2.7253E+06 2.5924E+06 2.4660E+06
2.3653E+06 2.3457E+06 2.2313E+06 2.1225E+06 1.9205E+06 1.8268E+06
1.6530E+06 1.4957E+06 1.3534E+06 1.2246E+06 1.0026E+06 9.0718E+05
8.2085E+05 7.4274E+05 6.0810E+05 4.9787E+05 3.6883E+05 3.0197E+05
2.1280E+05 1.8316E+05 1.1109E+05 9.8037E+04 8.6517E+04 6.7379E+04
4.0868E+04 3.4307E+04 2.6058E+04 2.4176E+04 2.1875E+04 1.5034E+04
1.1709E+04 7.1017E+03 5.5308E+03 3.3546E+03 2.6123E+03 1.5846E+03
1.0130E+02 1.0677E+01 4.1399E-01 1.0000E-05 0.0
89$
33R1 3R7 4R8 4R9 5R10 5R11 8R12 18R13 4078
17R2 16R6 3R7 4R8 4R9 5R10 5R11 8R12 18R13 24078
33R3 3R7 4R8 4R9 5R10 5R11 8R12 18R13 49078
33R4 3R7 4R8 4R9 5R10 5R11 8R12 18R13 7078
33R5 3R7 4R8 4R9 5R10 5R11 8R12 18R13 4078
9$$ 37 2R29 41 45 33 9 21 9 21 9 21 17
26$$ 28R30 28R0
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98**
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0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
.13349E-03	.10052E-03	.95822E-04	.93893E-04	.10194E-03	.10066E-03
.10066E-03	.97053E-04	.77558E-04	.77558E-04	.74462E-04	.74462E-04
.74462E-04	.74462E-04	.74462E-04	.62962E-04	.62962E-04	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
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0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
.13938E-03	.10495E-03	.99390E-04	.97883E-04	.10627E-03	.10580E-03
.10580E-03	.10302E-03	.82328E-04	.82328E-04	.80847E-04	.80847E-04
.80847E-04	.80847E-04	.80847E-04	.89866E-04	.89866E-04	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
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 .13938E-03  .10495E-03  .99390E-04  .97883E-04  .10627E-03  .10560E-03
 .10560E-03  .10302E-03  .82328E-04  .82328E-04  .80847E-04  .80847E-04
 .80847E-04  .80847E-04  .80847E-04  .59866E-04  .59866E-04 0.
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 .13938E-03  .10495E-03  .99390E-04  .97883E-04  .10627E-03  .10560E-03
 .10560E-03  .10302E-03  .82328E-04  .82328E-04  .80847E-04  .80847E-04
 .80847E-04  .80847E-04  .80847E-04  .59866E-04  .59866E-04 0.
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 .14217E-03  .10706E-03  .10158E-03  .10048E-03  .10909E-03  .10913E-03
 .10913E-03  .10795E-03  .86270E-04  .86270E-04  .86789E-04  .86789E-04
 .86789E-04  .86789E-04  .86789E-04  .78347E-04  .78347E-04 0.
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 .14217E-03  .10706E-03  .10158E-03  .10048E-03  .10909E-03  .10913E-03
 .10913E-03  .10795E-03  .86270E-04  .86270E-04  .86789E-04  .86789E-04
 .86789E-04  .86789E-04  .86789E-04  .78347E-04  .78347E-04 0.
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 .14217E-03  .10706E-03  .10158E-03  .10048E-03  .10909E-03  .10913E-03
 .10913E-03  .10795E-03  .86270E-04  .86270E-04  .86789E-04  .86789E-04
 .86789E-04  .86789E-04  .86789E-04  .78347E-04  .78347E-04 0.
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 .14217E-03  .10706E-03  .10158E-03  .10048E-03  .10909E-03  .10913E-03
 .10913E-03  .10795E-03  .86270E-04  .86270E-04  .86789E-04  .86789E-04
 .86789E-04  .86789E-04  .86789E-04  .78347E-04  .78347E-04 0.
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 .14217E-03  .10706E-03  .10158E-03  .10048E-03  .10909E-03  .10913E-03
 .10913E-03  .10795E-03  .86270E-04  .86270E-04  .86789E-04  .86789E-04
 .86789E-04  .86789E-04  .86789E-04  .78347E-04  .78347E-04 0.
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 .14217E-03  .10706E-03  .10158E-03  .10048E-03  .10909E-03  .10913E-03
 .10913E-03  .10795E-03  .86270E-04  .86270E-04  .86789E-04  .86789E-04
 .86789E-04  .86789E-04  .86789E-04  .78347E-04  .78347E-04 0.
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 .14217E-03  .10706E-03  .10158E-03  .10048E-03  .10909E-03  .10913E-03
 .10913E-03  .10795E-03  .86270E-04  .86270E-04  .86789E-04  .86789E-04
 .86789E-04  .86789E-04  .86789E-04  .78347E-04  .78347E-04 0.
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782 62076
  T
88**
4.075-5 1.780-4
3.389-4 7.300-4
2.528-3 1.455-3
4.270-3 2.885-3
1.343-2 3.145-2
5.018-2 3.227-2
```

```
2.237-2 2.313-2
1.956-2 3.927-3
2.372-2 2.385-2
4.772-2 2.368-2
4.655-2 4.505-2
4.306-2 4.074-2
7.384-2 3.269-2
2.993-2 2.723-2
4.884-2 3.766-2
4.221-2 2.054-2
2.522-2 7.853-3
1.653-2 2.602-3
2.174-3 3.329-3
3.917-3 8.184-4
9.260-4 1.935-4
2.268-4 5.046-4
2.511-4 2.921-4
8.192-5 9.511-5
2.865-5 3.083-5
2.728-5 4.330-7
1.530-8 0.
  T
```

```
  MPA   U.C.C. NOS/BE L584  V1.8.06.2 23/08/83
16.12.42.LASEROU  FROM      SV
16.12.42.IP  00003520 WORDS - FILE INPUT  , DC 04
16.12.42.LASER,P2. LASER
16.12.43.ACCOUNT,GK7TEC,*---*.
16.12.43.REWIND,OUTPUT.
16.12.43.ROUTE,OUTPUT,DEF,TID=80.
16.12.44.UCC,BANNER,DOT R-Z,CYC10 BOT,INPUT.
16.12.45.COPYBR,INPUT,AA.
16.12.45.COPYBR,INPUT,BB.
16.12.45.REWIND,AA,BB.
16.12.45.COPYSBF,BB,OUTPUT.
16.12.45.BEGIN,PPRINT,,I=OUTPUT,H=AA,FORM=2UP,COP
16.12.45.IES=1.
16.12.46.AT CY= 124 SN=GLOBAL
16.12.48.
16.12.48. COPYRIGHT, 1981, UNIVERSITY COMPUTING C
16.12.48.OMPANY.
16.12.48. REPRODUCTION PROHIBITED UNLESS SPECIFIC
16.12.48.ALLY
16.12.48. AUTHORIZED BY SEPERATE WRITING.
16.12.48.
16.12.48.RETURN,ZZZZZIN,ZZZZZPO,DAYFILE,DAYFIL.
16.12.49.IFE(FILE(AA,AS),H1)
16.12.49.COPYBR,AA,ZZZZZIN.
16.12.49.ENDIF,H1.
16.12.49.COPY,ZZZZZP1,ZZZZZIN.
16.12.49.RETURN,ZZZZZP1.
16.12.49.UCC,BANNER(O=ZZZZZIN, ,BIN,54)
16.12.51.REWIND,OUTPUT.
16.12.51.COPY,OUTPUT,ZZZZZIN.
16.12.51.IFE((T.AND.(OT.NE.TXO)),DLOOP)
16.12.51.SUMMARY.
16.12.51.MS    58496  WORDS  (    68736 MAX USED)
16.12.51.MM   300008 MAX SCM
16.12.51.CPR        1.166
16.12.51.IOR         .469
16.12.51.SRU        1.635
16.12.51.                        DATE 09/09/83
16.12.51.DAYFIL.
```

DOT R-θ INPUT CYCLE 10 TOP OF CORE

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$LASERZP    18.07.52. 09/09/83 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

DOT R-T

CYC10 TOP

INPUT


```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$LASERZP    18.07.52. 09/09/83 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```



```
 CPL HB ROBINSON R-THETA -- CYCLE 10 TOP -- CORRECTED
61$$ 9 4 8 0 10 8Z E
62$$  0  3  23 -98 80 28 5 8 33 0 0 2R32 0 48 2 1 0 3R1 -20 0 3 0 2 3R0
 2 4R0 0 23 0 1 1 3R0 0 3R0 4R1 4 100 2 0 0 2 75 3R0 1 4R0 6 0  E
63** 0  2R0 1-3 A16 1-3  A19 0.3 E T
71$$ 58I1 80
72$$ 3R83 2R82 83 85 89 82 3R83 78 81 87 86 85 85 88 86 88 90 91
     89 84 89 86 86 84 84 81 81 80 80 80 82 80 85 87 86 87 90 88
      94 94 93 89 94 92 91 88 90 88 88 88 89 88 89 95 98
    T
82**
-30881-5 -21822-5 21822-6 -61721-5 -57735-5 -21822-5 21822-6 57735-5
-8165-4 -7888-4 -57735-5 -21822-5 21822-5 57735-6 7888-4 -9759-4
-95119-5 -7888-4 -57735-5 -21822-5 21822-5 57735-5 7888-4 95119-5
-30881-5 -21822-5 21822-5 -61721-5 -57735-5 -21822-5 21822-5 57735-5
-8165-4 -7888-4 -57735-5 -21822-5 21822-5 57735-5 7888-4 -9759-4
-95119-5 -7888-4 -57735-5 -21822-5 21822-5 57735-5 7888-4 95119-5
83**
-1-5 2R-21821-5 -1-5 -2182-4 2R-57734-5 -2182-4 -1-5 -2182-4 -57735-5
2R-7888-4 -57735-5 -2182-4 -1-5 -21821-5 -57734-5 -7888-4 2R-95119-5
-7888-4 -57734-5 -21821-5 1-5 2R21821-5 1-5 2182-4 2R57734-5 2182-4 1-5
2182-4 57735-5 2R7888-4 57735-5 2182-4 1-5 21821-5 57734-5 7888-4
2R95119-5 7888-4 57734-5 21821-5
81**
0 2R30247-6 0 4R22885-6 0 22885-8 23148-6 2R22885-6 23148-8 22885-8 0
30247-6 2R22885-6 2R30247-6 2R22885-6 30247-6 0 2R30247-6 0 4R22885-6 0
22885-6 23148-8 2R22885-8 23148-8 22885-8 0 30247-6 2R22885-8 2R30247-8
2R22885-6 30247-6
84$$
    2I1 23
88** 70.0 100.0 120.0 135.0 150.0 158.0 168.0 3I170.021 4I175.182
   4I181.134 7I187.959 15I197.485 217.488      F220
85** 1I0.0 0.01059 1I0.01443 0.02835 0.03142 0.03810 0.03974 0.04532
   0.05121 0.05603 0.06044 0.06617 0.07058 0.07504 0.08071 0.08545
    0.0902 0.09620 0.10088 0.10521 2I0.11176 0.125  F.13
   T
2** 3I0.0  0.01059 0.01222  0.01443  0.01781 2I0.02039 0.02833 0.03142
    0.03354 0.03482 1I0.03610  0.03842  0.03974  0.04238 0.04532 0.04827
    0.05121 0.05382  0.05603 0.05844 0.06044 0.06244 0.06444 0.06617
    0.06790 0.07058  0.07328 0.07504 0.07683 0.07861 0.07975 0.08071
    0.08189 0.08367  0.08545 0.08703 0.08861 0.09020 0.09117 0.09285
    0.09452 0.09620  0.09872 0.10088 0.10305 0.10521 0.10738 0.10955
  5I0.11176 0.125
4** 3I7.0000+1 9.6771+1 3I1.0000+2 116.0 118.276 5I1.2000+2
3I1.3500+2 7I1.3978+2 5I1.5000+2 2I1.5800+2 1I1.6129+2
1I1.6414+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 9.6798+1 3I1.0000+2 116.0 118.31 5I1.2+2 3I1.3500+2
7I1.3982+2 5I1.5000+2 2I1.5800+2 1I1.6133+2 1I1.6419+2
2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
3I7.0000+1 9.6852+1 3I1.0000+2 116.0 118.37 5I1.2000+2
3I1.3500+2 7I1.3990+2 5I1.5000+2 2I1.5800+2 1I1.6142+2
1I1.6428+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 9.6932+1 3I1.0000+2 116.0 118.47 5I1.2000+2
3I1.3500+2 7I1.4001+2 5I1.5000+2 2I1.5800+2 1I1.6155+2
1.6442+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 9.7017+1 3I1.0000+2 116.0 118.58 5I1.2000+2
3I1.3500+2 7I1.4014+2 5I1.5000+2 2I1.5800+2 1I1.6169+2
1.6456+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 9.7108+01 3I1.0000+2 116.0 118.69 3I1.2000+2
```

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2I1.2867+2 3I1.3500+2 7I1.4027+2 5I1.5000+2 2I1.5800+2
1I1.6185+2 1.6471+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 9.728+1 1I1.0000+2 1I1.0700+2 2I112.8372
118.87 2I1.2000+2 3I125.00 3I135.00 7I1.4049+2 5I1.5000+2
2I1.5800+2 1I1.6210+2 1.6497+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 2I83.7308 97.462 4I1.0000+2 1I115.833 119.12
2I1.2000+2 1I125.00 2I130.00 4I135.00 6I1.4078+2 5I1.5000+2
3I1.5800+02 2I1.6244+2 1.6531+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I90.7672 97.890 3I1.0000+2 5I1.2000+2 4I1.3500+2
6I1.4111+2 5I1.5000+2 3I1.5800+2 2I1.6282+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I90.9706 97.961 1I1.0000+2 3I107.0 5I120.00
4I1.3500+2 6I1.4150+2 5I1.5000+2 3I1.5800+2 1I1.6327+2
2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I91.2007 98.268 1I1.0000+2 1I106.667 2I120.00
2I130.00 5I135.00 5I1.4194+2 5I1.5000+2 4I1.5800+2
1I1.6378+2 1.6600+2 2I1.6668+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I91.4182 98.566 1I1.0000+2 2I105.00 5I120.00
5I1.3500+2 5I1.4236+2 5I1.5000+2 4I1.5800+2 1I1.6426+2
1.6600+2 1I1.6717+02
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I1.2000+2 1I127.00 1I132.00 5I135.00
5I1.4274+2 5I1.5000+2 1.5800+2 4I1.5916+2 1.6600+2
1I1.6752+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I115.00 120.00 5I1.2105+2 5I1.3500+2
5I1.4306+2 1.5000+2 4I1.5136+2 4I1.5800+2 1.6477+2
2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I115.00 120.00 10I1.2127+2 6I1.3500+2
1I1.4332+2 2I1.4898+2 5I1.5000+2 1.5800+2 5I1.5891+2
2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I1.1500+2 1.2000+2 10I1.2148+2
4I1.3500+2 1I1.4121+2 4I1.4357+2 2I1.5000+2 2I1.5372+2
5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I115.00 120.00 8I1.2170+2 1I1.3500+2
4I1.3896+2 3I1.4382+2 1.4909+2 5I1.5000+2 5I1.5800+2
2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I115.00 1I120.00 7I1.2193+2
1I1.3269+2 6I1.3500+2 1I1.4410+2 1I1.4704+2 5I1.5000+2
5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I187.485 217.488
 3I7.0000+1 2I1.0000+2 1I115.00 1I1.2000+2 2I1.2232+2
6I1.2643+2 7I1.3500+2 1I1.4456+2 1I1.4762+2 5I1.5000+2
5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 115.00 1.1857+2 1I1.2000+2
9I1.2291+2 7I1.3500+2 1I1.4525+2 1I1.4822+2 5I1.5000+2
5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 3I1.1130+2 2I1.2000+2 8I1.2358+2
8I1.3500+2 1I1.4604+2 1.4903+2 5I1.5000+2 5I1.5800+2
2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I82.25 1+2 1.0189+2 5I1.0491+2 3I1.2000+2
7I1.2429+2 8I1.3500+2 2I1.4689+2 5I150 5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I82.25 100.00 6I1.0226+2 3I1.2000+2 7I1.2499+2
9I1.3500+2 1I1.4771+2 1.5000+2 5I1.5073+2 5I1.5800+2 2I1.6600+02
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488

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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 1I8.3105+1 1.0000+2 5I1.0500+2 3I1.2000+2
4I1.2833+2 2I1.3500+2 8I1.3851+2 1.5000+2 2I1.5157+2
2I1.5477+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I187.485 217.488

 1I7.0000+1 1I8.2077+1 1.0000+2 5I1.0553+2 3I1.2000+2
2I1.2898+2 11I1.3500+2 1I1.5000+2 2I1.5243+2 1I1.5568+2
5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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128.00 1I129.6 2I1.3149+2 11I1.3500+2 2I1.5000+2 2I1.5318+2
1I1.5629+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I187.485 217.488
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1.2756+2 3I1.3042+2 11I1.3500+2 2I1.5000+2 2I1.5413+2
5I1.5800+2 2I1.6800+2
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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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4I120.00 1I1.3238+2 11I1.3500+2 4I1.5000+2 1.5645+2
1.5800+2 4I1.5965+2 2I1.6600+2
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4I1.2000+2 1.3314+2 11I1.3500+2 5I1.5000+2 1.5735+2
1I1.5800+2 3I1.6057+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 1I8.5225+1 1.0000+2 1.0958+2 1.1459+2
5I1.2000+2 1.3383+2 11I1.3500+2 5I1.5000+2 2I1.5800+2
3I1.6151+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.958 15I197.485 217.488
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5I1.2000+2 11I1.3500+2 6I1.5000+2 3I1.5800+2 2I1.6231+2
2I1.6600+2
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 1I7.0000+1 1I8.5956+1 1I1.0000+2 1I1.1130+2 5I1.2000+2
11I1.3500+2 4I1.5000+2 1I1.5582+2 2I1.5800+2 2I1.6174+2
2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.958 15I197.485 217.488
 1I7.0000+1 1I8.6278+1 1I1.0000+2 1I1.1093+2 11I1.2000+2
11I1.3500+2 2I1.5000+2 2I1.5395+2 1.5800+2 4I1.5979+2
2I1.6800+2
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11I1.2000+2 1.3500+2 10I1.3630+2 1.5000+2 4I1.5144+2
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1I116.74 1I120.00 1I1.3500+2 8I1.3718+2 1.4855+2
2I1.5000+2 2I1.5419+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 1I8.7848+1 1.0000+2 1I1.0424+2
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2I1.4594+2 1.5000+2 4I1.5148+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 1I8.8381+1 1.0000+2 4I1.0255+2 2I1.1383+2
11I1.2000+2 2I1.3500+2 3I1.3888+2 3I1.4358+2 1.4903+2
5I1.5000+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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11I1.2000+2 3I1.3500+2 1.3975+2 3I1.4130+2
2I1.4686+2 5I1.5000+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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5I1.5000+2 5I1.5800+2  2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 8.8868+1 1I93.868 98.381 5I1.0000+2 3I1.1554+2
11I1.2000+2 1I1.3500+2 2I1.3773+2 2I1.4122+2 3I1.4463+2
5I1.5000+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 9.0495+1 9.6825+01 6I1.0000+2 2I1.1635+2
11I1.2000+2 5I1.3500+2 2I1.4221+2 3I1.4584+2
8I1.5000+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 9.1140+1 9.5327+1 8I1.0000+2 1.1718+2
8I1.2000+2 1.3348+2 6I1.3500+2 2I1.4322+2 2I1.4688+2
5I1.5000+2 5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 88.977 91.977 1I9.3528+1 7I1.0000+2 1.1828+2
8I1.2000+2 2I1.3094+2 7I1.3500+2 2I1.4453+2 1.4803+2
5I1.5000+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 89.121 91.821 2I9.2947+1 7I1.0000+2 4I1.2000+2
4I1.2827+2 8I1.3500+2 2I1.4808+2 5I1.5000+2 5I1.5800+2
2I1.6600+2
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 2I7.0000+1 8.9940+1 1I9.3881+1 7I1.0000+2 3I1.2000+2
6I1.2592+2 9I1.3500+2 1I1.4783+2 1.5000+2 5I1.5109+2
5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 8.8337+1 9.4851+1 7I1.0000+2 1.2000+2
1.2195+2 8I1.2367+2 10I1.3500+2 1.4805+2 1I1.5000+2
3I1.5265+2 5I1.5800+2 2I1.6600+2
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 1I7.0000+1 1I8.6805+1 9.5860+1 7I1.0000+2 1.2000+2
1.2153+2 8I1.2325+2 11I1.3500+2 1.5000+2 2I1.5084+2
2I1.5428+2 5I1.5800+2 2I1.66+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 1I8.5338+1 9.6812+1 4I1.0000+2 1I1.2000+2
7I1.2460+2 11I1.3500+2 1I1.5000+2 2I1.5229+2
1I1.5597+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 8.3923+1 2I88.923 98.015 4I1.0000+2
1.1749+2 2I1.2000+2 6I1.2802+2 11I1.3500+2
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 1I7.0000+1 2I8.2560+1 2I1.0000+2 1I1.1558+2 5I1.2000+2
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4I1.2905+2 8I1.3500+2 2I1.4626+2 1.5000+2 5I1.5058+2
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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 2I8.0004+1 97.00 100.00 2I1.0163+2
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2I1.4401+2 1.4828+2 5I1.5000+2 5I1.5800+2
2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 7.0000+1 3I7.8808+1 1.0000+2 2I1.0293+2 3I1.1033+2
9I1.2000+2 1I1.3234+2 4I1.3500+2 2I1.4185+2
2I1.4604+2 5I1.5000+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 7.0000+1 4I7.7660+1 1.0000+2 1I1.0429+2 8I1.0872+2
10I1.2000+2 1.3408+2 3I1.3500+2 2I1.3879+2
4I1.4392+2 5I1.5000+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488

 7.0000+1 4I7.6559+1 1.0000+2 103.00 105.71
9I1.0718+2 11I1.2000+2 1.3500+2 1I1.3591+2
2I1.3781+2 5I1.4188+2 5I1.5000+2 5I1.5800+2
2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488

5**
1.7333E+07 1.4191E+07 1.2214E+07 1.1052E+07 1.0000E+07 8.8071E+06
8.1873E+06 7.4082E+06 7.0488E+06 6.0653E+06 4.9853E+06 4.0657E+06
3.6788E+06 3.0119E+06  2.7253E+06 2.5924E+06 2.4660E+06
2.3853E+06 2.3457E+06 2.2313E+06 2.1225E+06 1.9205E+06 1.8268E+06
1.6530E+06 1.4957E+06 1.3534E+06 1.2246E+06 1.0026E+06 9.0718E+05
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&95
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   5R1 5R7 11R12 17R16 3R17 3R18 4R19 5R20 5R21 8R22 16R23
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1 7R2 4 23R5 2R10 3R17 21R18 4R19 5R20 5R21 8R22 16R23
955 16R25 9 17 6 17 9 17 13
28$$ 28R30
 T
96**
1973+12 167499+10 149569+10 187515+10 256751+10 201257+10 233514+10      1  1
271491+10 256358+10 272681+10 275994+10 289716+10 218391+10 283345+10    1  2
235978+10 274721+10 217773+10 226165+10 259842+10 249306+10 244827+10    1  3
126614+10 1278+12 128098+10 855548+9 994587+9 112648+10 108096+10        1  4
917897+9 582427+9 868536+9 79692+10 739375+8 471174+9 455062+9 488219+9  1  5
417298+9 283894+9 452                                                    1  6
2289+12 175569+10 186584+10 167447+10 22511+11 225782+10 288369+10       2  1
272332+10 233979+10 272979+10 277089+10 148693+10 275866+10 278531+10    2  2
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209983+10	193842+10	182533+10	17385+11	172074+10	163329+10	144024+10		41	4
136665+10	116077+10	821281+9	56Z					41	5
250988+10	198693+10	230297+10	214229+10	233253+10	248513+10	251461+10		42	1
190438+10	1382+12	240813+10	248834+10	183894+10	183215+10	281963+10		42	2
236264+10	250772+10	24551+11	232171+10	238383+10	232817+10	231671+10		42	3
102013+10	885687+9	178097+10	185181+10	137434+10	178342+10	180818+10		42	4
156048+10	140882+10	122988+10	885371+9	58Z				42	5
211186+10	22882+11	228584+10	183044+10	23275+11	246652+10	243667+10		43	1
243188+10	242055+10	251077+10	24182+11	844258+9	204275+10	247792+10		43	2
244882+10	24058+11	232904+10	220884+10	234807+10	221804+10	227815+10		43	3
192797+10	14681+11	731144+9	173775+10	180015+10	141897+10	110837+10	60Z	43	4
190478+10	246052+10	187515+10	229445+10	150013+10	234847+10	2527+12		44	1
254053+10	113222+10	255759+10	249574+10	240358+10	247844+10	251791+10		44	2

```
255748+10 250851+10 743073+9 250574+10 255059+10 246087+10 241302+10    44  3
208306+10 178716+10 235753+10 222139+10 140885+10 213015+10 198504+10   44  4
184839+10 173838+10 154848+10 138323+10 993505+9 612                    44  5
219748+10 23248+11 207502+10 220618+10 232951+10 234989+10 252275+10    45  1
254455+10 257237+10 166441+10 236353+10 189738+10 233838+10 24828+11    45  2
248814+10 250599+10 260089+10 253301+10 253189+10 258189+10 21894+11    45  3
247194+10 238876+10 503461+9 157657+10 181141+10 495322+9 201139+10     45  4
190534+10 176768+10 156752+10 123422+10 107125+10 612                   45  5
250142+10 203084+10 249015+10 231185+10 255256+10 258223+10 238785+10   46  1
260021+10 102369+10 204284+10 187841+10 237903+10 244895+10 248942+10   46  2
253148+10 621407+9 20995+11 17762+11 607023+9 249+13 245016+10 218699+10 46  3
226385+10 214805+10 205224+10 194785+10 1808+12 155806+10 130746+10     46  4
12211+11 11127+11 983392+9 76435+10 602                                 46  5
252372+10 179187+10 226841+10 231701+10 25657+11 138312+10 104148+10    47  1
246867+10 244273+10 253913+10 246638+10 23655+11 247147+10 18166+11     47  2
25605+11 215024+10 251351+10 487399+9 218009+10 212278+10 20033+11      47  3
183816+10 148127+10 135083+10 128183+10 118283+10 38698+10 900666+9     47  4

913898+9 710225+9 592                                                   47  5
203806+10 249787+10 234759+10 191335+10 230838+10 237711+10 254782+13   48  1
261595+10 21213+11 239926+10 254308+10 250678+10 251115+10 140563+10    48  2
244295+10 236493+10 241409+10 245254+10 250015+10 18014+11 204263+10    48  3
237958+10 210487+10 219754+10 209863+10 187121+10 162069+10 144805+10   48  4
13443+11 863053+9 123319+10 121733+10 917309+9 10647+11 954069+9        48  5
829355+9 616843+9 572                                                   48  6
172403+10 260768+10 239535+10 260329+10 228028+10 224804+10 254645+10   49  1
165126+10 212351+10 201393+10 257136+10 251494+10 248884+10 248377+10   49  2
180007+10 19187+11 232184+10 238288+10 190455+10 188128+10 223853+10    49  3
205044+10 171385+10 153775+10 148345+10 14438+11 139337+10 849961+9     49  4
11664+11 587771+9 840615+9 924544+9 299424+9 814371+9 745794+9 570369+9 49  5
562                                                                     49  6
232958+10 208056+10 184464+10 21848+11 25717+11 253859+10 168843+10     50  1
255986+10 191022+10 189549+10 247967+10 220011+10 242537+10 228979+10   50  2
224685+10 230076+10 225834+10 209097+10 178243+10 180838+10 157744+10   50  3
989757+9 112549+10 127239+10 380481+9 130079+10 12313+11 974723+9       50  4
104114+10 101453+10 78623+10 822437+9 754389+9 658305+9 60276+10 562    50  5
232558+10 229897+10 216297+10 249871+10 233893+10 256497+10 241858+10   51  1
239538+10 248302+10 139788+10 194739+10 164713+10 218248+10 213494+10   51  2
182478+10 166377+10 164482+10 14814+11 157287+10 12265+11 135706+10     51  3
140722+10 134102+10 128568+10 118795+10 112037+10 1043+12 842704+9      51  4
511103+9 7717+11 531835+9 497082+9 580874+9 43461+10 542                51  5
202789+10 250396+10 212231+10 182492+10 226129+10 201805+10 217561+10   52  1
25182+11 249537+10 250382+10 229879+10 241129+10 228394+10 219580+10    52  2
217199+10 174835+10 168469+10 144973+10 447248+9 155974+10 14068+11     52  3
408839+9 133457+10 130973+10 124127+10 987998+9 788848+9 103093+10      52  4
95822+10 893031+9 838021+9 852332+9 580542+9 813147+9 529001+9 441795+9 52  5
276176+9 532                                                            52  6
221872+10 208897+10 222147+10 1832+12 256825+10 188123+10 256013+10     53  1
181243+10 177529+10 231029+10 232587+10 220028+10 171127+10 182108+10   53  2
159221+10 155276+10 13253+11 138798+10 137578+10 129134+10 121812+10    53  3
101868+10 728569+9 101034+10 943276+9 877668+9 470685+9 472935+9        53  4
682792+9 473995+9 220005+9 453313+9 375184+9 276978+9 522               53  5
241095+10 238073+10 194718+10 220823+10 210155+10 217542+10 253485+10   54  1
259551+10 208785+10 226274+10 229399+10 235772+10 240998+10 212027+10   54  2
195198+10 215504+10 185603+10 158098+10 134678+10 644975+9 131533+10    54  3
826519+9 118085+10 120588+10 113768+10 106264+10 993745+9 933884+9      54  4
831127+9 775251+9 387245+9 626598+9 576231+9 494919+9 417979+9 264751+9 54  5
532                                                                     54  6
217722+10 238485+10 201877+10 187994+10 179612+10 208108+10 175798+10   55  1
242756+10 248609+10 249611+10 253154+10 126915+10 224612+10 229823+10   55  2
219653+10 204383+10 15928+11 149162+10 145038+10 140028+10 862276+9     55  3
12305+11 120957+10 100271+10 101938+10 993547+9 678748+9 48022+10       55  4
775851+9 522798+9 583446+9 526868+9 361117+9 552                        55  5
227321+10 196338+10 220471+10 175575+10 208611+10 25392+11 257747+10    56  1
235247+10 248638+10 253357+10 123898+10 255959+10 198287+10 245084+10   56  2
133385+10 18699+11 211716+10 19518+11 153055+10 141187+10 136831+10     56  3
961472+9 498327+9 120081+10 80071+10 875313+9 717809+9 568502+9 805284+9 56  4
71451+10 816485+9 417174+9 572                                          56  5
215631+10 241712+10 21203+11 178081+10 18259+11 217351+10 220858+10     57  1
253955+10 182788+10 245487+10 252851+10 258492+10 254389+10 228819+10   57  2
603352+9 248908+10 184272+10 220838+10 213195+10 201448+10 185129+10    57  3
146749+10 13327+11 126358+10 118277+10 117255+10 105301+10 101549+10    57  4
807895+9 749219+9 714559+9 505897+9 572                                 57  5
220484+10 184099+10 185511+10 215818+10 14846+11 21872+11 251879+10     58  1
241116+10 245071+10 253901+10 208677+10 203727+10 171595+10 25407+11    58  2
248803+10 244305+10 231227+10 64295+10 189441+10 207257+10 184855+10    58  3
190208+10 17131+11 133972+10 120887+10 104948+10 385336+9 834978+9      58  4
811663+9 570388+9 582                                                   58  5
210872+10 221829+10 222374+10 218883+10 215094+10 209867+10 219838+10   59  1

249218+10 245139+10 251207+10 255841+10 260704+10 267777+10 142149+10   59  2
241495+10 270444+10 229317+10 238465+10 247751+10 242026+10 23762+11    59  3
186145+10 194281+10 229015+10 106649+10 145842+10 190206+10 175785+10   59  4
156228+10 124889+10 108974+10 100111+10 874889+9 630357+9 612           59  5
17054+11 18123+11 159958+10 216943+10 180737+10 183737+10 168734+10     60  1
22088+11 244328+10 248811+10 252216+10 249354+10 14994+11 257393+10     60  2
253205+10 153948+10 256744+10 257668+10 252021+10 228865+10 145386+10   60  3
23793+11 230823+10 228533+10 199731+10 150679+10 193843+10 183764+10    60  4
109247+10 168662+10 151203+10 129848+10 102529+10 681867+9 622          60  5
  T
98==
4.075-5 1.760-4
3.389-4 7.300-4
2.528-3 1.455-3
4.270-3 2.985-3
1.343-2 3.145-2
5.016-2 3.227-2
7.716-2 4.356-2
2.267-2 2.313-2
1.955-2 3.927-3
2.372-2 2.385-2
4.772-2 2.368-2
4.855-2 4.505-2
4.306-2 4.074-2
7.364-2 3.269-2
  T
```

```
 MFA   U.C.C. NOS/BE L564  V1.6.06.2 23/08/83
16.09.51.LASERZ2  FROM      9Y
16.09.51.IP  00005184 WORDS - FILE INPUT  , DC 04
16.09.51.LASER,P2. LASER
16.09.51.ACCOUNT,GK7TEC,*----*.
16.09.52.REWIND,OUTPUT.
16.09.52.ROUTE,OUTPUT,DEF,TID=8D.
16.09.53.UCC,BANNER,DOT R-T,CYC10 TOP,INPUT.
16.09.54.COPYBR,INPUT,AA.
16.09.55.COPYBR,INPUT,BB.
16.09.55.REWIND,AA,BB.
16.09.55.COPYSBF,BB,OUTPUT.
16.09.55.BEGIN,PPRINT,,I=OUTPUT,H=AA,FORM=2UP,COP
16.09.55.IES=1.
16.09.58.AT CY= 124 SN=GLOBAL
16.09.59.
16.09.59. COPYRIGHT, 1981, UNIVERSITY COMPUTING C
16.09.59.OMPANY.
16.09.59. REPRODUCTION PROHIBITED UNLESS SPECIFIC
16.09.59.ALLY
16.09.59. AUTHORIZED BY SEPERATE WRITING.
16.09.59.
16.09.59.RETURN,ZZZZZIN,ZZZZZPO,DAYFILE,DAYFIL.
16.09.59.IFE(FILE(AA,AS),H1)
16.09.59.COPYBR,AA,ZZZZZIN.
16.09.59.ENDIF,H1.
16.10.00.COPY,ZZZZZP1,ZZZZZIN.
16.10.00.RETURN,ZZZZZP1.
16.10.00.UCC,BANNER(O=ZZZZZIN, ,BIN,54)
16.10.04.REWIND,OUTPUT.
16.10.04.COPY,OUTPUT,ZZZZZIN.
16.10.04.IFE((T.AND.(OT.NE.TXO)),OLOOP)
16.10.05.SUMMARY.
16.10.05.MS    58496  WORDS  (    68736 MAX USED)
16.10.05.MM   300008 MAX SCM
16.10.05.CPR       1.184
16.10.05.IOR        .490
16.10.05.SAU       1.674
16.10.05.                          DATE 09/09/83
16.10.05.DAYFIL.
```

DOT R-θ INPUT CYCLE 10 BOTTOM OF CORE

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$LASER07    16.14.45. 09/09/83 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```

DOT R=T

CYC10 BOT

INPUT

```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$LASER07    16.14.45. 09/09/83 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

 CPL HB ROBINSON R-THETA -- CYCLE 10 BTM
61$$ 9 4 8 0 10 6Z E
62$$  0  3  23 -98 60 28 5 8 33 0 0 2R32 0 48 2 1 0 3R1 -20 0 3 0 2 3R0
 2 4R0 0 23 0 1 1 3R0 0 3R0 4R1 4 100 2 0 0 2 75 3R0 1 4R0 8 0  E
63** 0  2R0 1-3 A16 1-3  A19 0.3 E T
71$$ 58I1 60
72$$ 3R83 2R82 83 85 89 82 3R83 78 81 87 86 85 85 86 86 88 90 91
     89 88 89 88 86 84 84 81 81 80 80 80 82 80 85 87 88 87 90 88
     94 94 93 89 94 92 91 88 90 88 89 88 89 89 89 95 98
   T
82**
-30881-5 -21822-5 21822-5 -81721-5 -57735-5 -21822-5 21822-5 57735-5
-8165-4 -7868-4 -57735-5 -21822-5 21822-5 57735-5 7868-4 -9759-4
-95119-5 -7868-4 -57735-5 -21822-5 21822-5 57735-5 7868-4 95119-5
-30881-5 -21822-5 21822-5 -81721-5 -57735-5 -21822-5 21822-5 57735-5
-8165-4 -7868-4 -57735-5 -21822-5 21822-5 57735-5 7888-4 -9759-4
-95119-5 -7868-4 -57735-5 -21822-5 21822-5 57735-5 7868-4 95119-5
83**
-1-5 2R-21821-5 -1-5 -2182-4 2R-57734-5 -2182-4 -1-5 -2182-4 -57735-5
2R-7888-4 -57735-5 -2182-4 -1-5 -21821-5 -57734-5 -7868-4 2R-95119-5
-7868-4 -57734-5 -21821-5 1-5 2R21821-5 1-5 2182-4 2R57734-5 2182-4 1-5
2182-4 57735-5 2R7888-4 57735-5 2182-4 1-5 21821-5 57734-5 7888-4
2R95119-5 7868-4 57734-5 21821-5
81**
0 2R30247-6 0 4R22885-6 0 22885-6 23148-6 2R22885-6 23148-6 22885-6 0
30247-6 2R22885-6 2R30247-6 2R22885-6 30247-6 0 2R30247-6 0 4R22885-6 0
22885-6 23148-6 2R22885-6 23148-6 22885-6 0 30247-6 2R22885-6 2R30247-6
2R22885-6 30247-6
84$$
   2I1 23
86** 70.0 100.0 120.0 135.0 150.0 158.0 186.0 3I170.021 4I175.182
   4I181.134 7I187.959 15I197.485 217.488     F220
85** 1I0.0 0.01059 1I0.01443 0.02835 0.03142 0.03810 0.03974 0.04532
   0.05121 0.05803 0.06044 0.06617 0.07058 0.07504 0.08071 0.08545
    0.0902 0.09620 0.10088 0.10521 2I0.11176 0.125  F.13
   T
2** 3I0.0  0.01059 0.01222  0.01443  0.01761 2I0.02039 0.02933 0.03142
    0.03354 0.03482 1I0.03610  0.03842  0.03974  0.04238 0.04532 0.04827
    0.05121 0.05362  0.05603 0.05844 0.06044 0.06244 0.06444 0.06617
    0.06790 0.07058  0.07328 0.07504 0.07683 0.07861 0.07975 0.08071
    0.08189 0.08367  0.08545 0.08703 0.08861 0.09020 0.09117 0.09285
    0.09452 0.09620  0.09872 0.10088 0.10305 0.10521 0.10738 0.10955
  5I0.11178 0.125
4** 3I7.0000+1 9.6771+1 3I1.0000+2 116.0 118.276 5I1.2000+2
3I1.3500+2 7I1.3978+2 5I1.5000+2 2I1.5800+2 1I1.6129+2
1I1.6414+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 9.6798+1 3I1.0000+2 116.0 118.31 5I1.2+2 3I1.3500+2
7I1.3982+2 5I1.5000+2 2I1.5800+2 1I1.6133+2 1I1.6419+2
2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
3I7.0000+1 9.6852+1 3I1.0000+2 116.0 118.37 5I1.2000+2
3I1.3500+2 7I1.3990+2 5I1.5000+2 2I1.5800+2 1I1.6142+2
1I1.6428+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 9.6932+1 3I1.0000+2 116.0 118.47 5I1.2000+2
3I1.3500+2 7I1.4001+2 5I1.5000+2 2I1.5800+2 1I1.6155+2
1.6442+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 9.7017+1 3I1.0000+2 116.0 118.58 5I1 2000+2
3I1.3500+2 7I1.4014+2 5I1.5000+2 2I1.5800+2 1I1.6169+2
1.6456+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.958 15I197.485 217.488
 3I7.0000+1 9.7108+01 3I1.0000+2 116.0 118.69 3I1.2000+2
```

```
2I1.2857+2 3I1.3500+2 7I1.4027+2 5I1.5000+2 2I1.5800+2
1I1.5185+2 1.5471+2 2I1.5800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 9.726+1 1I1.0000+2 1I1.0700+2 2I112.8372
1I8.87 2I1.2000+2 3I125.00 3I135.00 7I1.4049+2 5I1.5000+2
2I1.5800+2 1I1.5210+2 1.5497+2 2I1.5800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 2I83.7308 97.452 4I1.0000+2 1I115.833 119.12
2I1.2000+2 1I125.00 2I130.00 4I135.00 8I1.4078+2 5I1.5000+2
3I1.5800+02 2I1.5244+2 1.5531+2 2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I90.7672 97.890 3I1.0000+2 5I1.2000+2 4I1.3500+2
6I1.4111+2 5I1.5000+2 3I1.5800+2 2I1.5282+2 2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I90.9706 97.961 1I1.0000+2 3I107.0 5I120.00
4I1.3500+2 6I1.4150+2 5I1.5000+2 3I1.5800+2 1I1.5327+2
2I1.5800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I91.2007 98.268 1I1.0000+2 1I106.667 2I120.00
2I130.00 5I135.00 5I1.4184+2 5I1.5000+2 4I1.5800+2
1I1.5378+2 1.5600+2 2I1.5568+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I91.4182 98.558 1I1.0000+2 2I105.00 5I120.00
5I1.3500+2 5I1.4236+2 5I1.5000+2 4I1.5800+2 1I1.5426+2
1.5500+2 1I1.5717+02
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I1.2000+2 1I127.00 1I132.00 5I135.00
5I1.4274+2 5I1.5000+2 1.5800+2 4I1.5915+2 1.5500+2
1I1.5752+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I115.00 120.00 5I1.2105+2 5I1.3500+2
5I1.4306+2 1.5000+2 4I1.5136+2 4I1.5800+2 1.5477+2
2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I115.00 120.00 10I1.2127+2 8I1.3500+2
1I1.4332+2 2I1.4598+2 5I1.5000+2 1.5800+2 5I1.5891+2
2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I1.1500+2 1.2000+2 10I1.2148+2
4I1.3500+2 1I1.4121+2 4I1.4357+2 2I1.5000+2 2I1.5372+2
5I1.5800+2 2I1.5800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I115.00 120.00 8I1.2170+2 1I1.3500+2
4I1.3595+2 3I1.4382+2 1.4909+2 5I1.5000+2 5I1.5800+2
2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I115.00 1I120.00 7I1.2193+2
1I1.3269+2 6I1.3500+2 1I1.4410+2 1I1.4704+2 5I1.5000+2
5I1.5800+2 2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 1I115.00 1I1..2000+2 2I1.2232+2
6I1.2543+2 7I1.3500+2 1I1.4456+2 1I1.4752+2 5I1.5000+2
5I1.5800+2 2I1.5800+2
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 3I7.0000+1 2I1.0000+2 1I5.00 1.1857+2 1I1.2000+2
9I1.2291+2 7I1.3500+2 1I1.4525+2 1I1.4822+2 5I1.5000+2
5I1.5800+2 2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 2I1.0000+2 3I1.1130+2 2I1.2000+2 8I1.2358+2
8I1.3500+2 1I1.4804+2 1.4903+2 5I1.5000+2 5I1.5800+2
2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I92.25 1+2 1.0169+2 5I1.0491+2 3I1.2000+2
7I1.2429+2 8I1.3500+2 2I1.4589+2 5I150 5I1.5800+2 2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 1I92.25 100.00 6I1.0228+2 3I1.2000+2 7I1.2499+2
8I1.3500+2 1I1.4771+2 1.5000+2 5I1.5073+2 5I1.5800+2 2I1.5600+02
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 2I7.0000+1 9.5515+1 1.0000+2 6I1.0281+2 4I1.2000+2
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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488

 2I7.0000+1 1I8.8409+1 1.0000+2 6I1.0393+2 2I1.2000+2
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 1I7.0000+1 1I8.5658+1 1.0000+2 5I1.0445+2 2I1.2000+2
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4I1.2833+2 2I1.3500+2 8I1.3851+2 1.5000+2 2I1.5167+2
2I1.5477+2 5I1.5800+2 2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488

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2I1.2898+2 11I1.3500+2 1I1.5000+2 2I1.5243+2 1I1.5555+2
5I1.5800+2 2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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128.00 1I129.5 2I1.3149+2 11I1.3500+2 2I1.5000+2 2I1.5316+2
1I1.5629+2 5I1.5800+2 2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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1.2755+2 3I1.3042+2 11I1.3500+2 2I1.5000+2 2I1.5413+2
5I1.5800+2 2I1.5800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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4I120.00 1I1.3238+2 11I1.3500+2 4I1.5000+2 1.5845+2
1.5800+2 4I1.5865+2 2I1.5500+2
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4I1.2000+2 1.3314+2 11I1.3500+2 5I1.5000+2 1.5735+2
1I1.5800+2 3I1.5057+2 2I1.5500+2
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 1I7.0000+1 1I8.5225+1 1.0000+2 1.0958+2 1.1459+2
5I1.2000+2 1.3393+2 11I1.3500+2 5I1.5000+2 2I1.5800+2
3I1.5151+2 2I1.5500+2
I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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2I1.5500+2
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 1I7.0000+1 1I8.5955+1 1I1.0000+2 1I1.1130+2 5I1.2000+2
11I1.3500+2 4I1.5000+2 1I1.5582+2 2I1.5800+2 2I1.5174+2
2I1.5500+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 1I8.5278+1 1I1.0000+2 1I1.1093+2 11I1.2000+2
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2I1.5800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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11I1.2000+2 1.3500+2 10I1.3630+2 1.5000+2 4I1.5144+2
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2I1.5000+2 2I1.5419+2 5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 1I8.7848+1 1.0000+2 1I1.0424+2
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2I1.4594+2 1.5000+2 4I1.5148+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 1I8.8381+1 1.0000+2 4I1.0255+2 2I1.1383+2
11I1.2000+2 2I1.3500+2 3I1.3888+2 3I1.4358+2 1.4903+2
5I1.5000+2 5I1.5800+2 2I1.6600+2
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11I1.2000+2 3I1.3500+2 1.3975+2 3I1.4130+2
2I1.4686+2 5I1.5000+2 5I1.5800+2 2I1.6800+2
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5I1.5000+2 5I1.5800+2  2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 8.9868+1 1I93.868 98.381 5I1.0000+2 3I1.1554+2
11I1.2000+2 1I1.3500+2 2I1.3773+2 2I1.4122+2 3I1.4483+2
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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
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11I1.2000+2 5I1.3500+2 2I1.4221+2 3I1.4564+2
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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 9.1140+1 9.5327+1 6I1.0000+2 1.1718+2
8I1.2000+2 1.3348+2 6I1.3500+2 2I1.4322+2 2I1.4868+2
5I1.5000+2 5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 88.977 91.977 1I9.3528+1 7I1.0000+2 1.1828+2
8I1.2000+2 2I1.3094+2 7I1.3500+2 2I1.4453+2 1.4803+2
5I1.5000+2 5I1.5800+2 2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 3I7.0000+1 89.121 91.621 2I9.2947+1 7I1.0000+2 4I1.2000+2
4I1.2827+2 6I1.3500+2 2I1.4608+2 5I1.5000+2 5I1.5800+2
2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 2I7.0000+1 8.9940+1 1I9.3881+1 7I1.0000+2 3I1.2000+2
6I1.2592+2 9I1.3500+2 1I1.4753+2 1.5000+2 5I1.5109+2
5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 8.8337+1 9.4851+1 7I1.0000+2 1.2000+2
1.2195+2 8I1.2387+2 10I1.3500+2 1.4905+2 1I1.5000+2
3I1.5285+2 5I1.5800+2 2I1.6800+2
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1.2153+2 8I1.2325+2 11I1.3500+2 1.5000+2 2I1.5064+2
2I1.5428+2 5I1.5800+2 2I1.88+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 1I8.5338+1 9.6912+1 4I1.0000+2 1I1.2000+2
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1I1.5597+2 5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 8.3923+1 2I88.923 98.015 4I1.0000+2
1.1748+2 2I1.2000+2 6I1.2802+2 11I1.3500+2
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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 1I7.0000+1 2I8.0004+1 97.00 100.00 2I1.0183+2
2I1.1201+2 7I1.2000+2 3I1.3068+2 6I1.3500+2
2I1.4401+2 1.4828+2 5I1.5000+2 5I1.5800+2
2I1.6600+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 7.0000+1 3I7.8808+1 1.0000+2 2I1.0293+2 3I1.1033+2
9I1.2000+2 1I1.3234+2 4I1.3500+2 2I1.4185+2
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3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488
 7.0000+1 4I7.7860+1 1.0000+2 1I1.0429+2 8I1.0872+2
10I1.2000+2 1.3409+2 3I1.3500+2 2I1.3979+2
4I1.4392+2 5I1.5000+2 5I1.5800+2 2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488

 7.0000+1 4I7.6559+1 1.0000+2 103.00 106.71
9I1.0718+2 11I1.2000+2 1.3500+2 1I1.3591+2
2I1.3781+2 5I1.4188+2 5I1.5000+2 5I1.5800+2
2I1.6800+2
3I170.021 4I175.182 4I181.134 7I187.959 15I197.485 217.488

5**
1.7333E+07 1.4191E+07 1.2214E+07 1.1052E+07 1.0000E+07 8.8071E+06
8.1873E+06 7.4082E+06 7.0498E+06 6.0653E+06 4.9659E+06 4.0657E+06
3.6788E+06 3.0119E+06  2.7253E+06 2.5924E+06 2.4660E+06
2.3653E+06 2.3457E+06 2.2313E+06 2.1225E+06 1.9205E+06 1.8288E+06
1.6530E+06 1.4957E+06 1.3534E+06 1.2246E+06 1.0026E+06 9.0718E+05
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1 7R2 4 23R5 2R10 3R17 21R18 4R19 5R20 5R21 8R22 16R23
955 16R25 9 17 9 17 9 17 13
28SS 28R20
 T
96**
694738+9 508208+9 451587+9 500373+9 740133+9 573859+9 658982+9 745947+9    1  1
686864+9 714214+9 697637+9 719837+9 519432+9 654586+9 522622+9 668204+9    1  2
399661+9 420761+9 477482+9 457011+9 460376+9 622                           1  3
689362+9 532863+9 563484+9 50038+10 848563+9 843866+9 74871+10 748744+9    2  1
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407197+9 326611+9 30135+10 460452+9 460793+9 622                           2  3
571709+9 441114+9 567182+9 457895+9 738268+9 424103+9 725984+9 635921+9    3  1
657345+9 71256+10 697576+9 720637+9 554905+9 640052+9 375087+9 60563+10    3  2
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635798+9	603108+9	771556+9	756885+9	748525+9	750245+9	541489+9	578388+9	49	2
692944+9	679151+9	542803+9	530951+9	639431+9	586044+9	488482+9	43735+10	49	3
424958+9	411005+9	398743+9	242178+9	332418+9	167508+9	239784+9	263673+9	49	4
855127+8	232759+9	213312+9	163258+9	58Z				49	5
698267+9	626874+9	580428+9	652038+9	77075+10	760189+9	475745+9	768433+9	50	1
573982+9	570234+9	748475+9	682136+9	730972+9	691529+9	657826+9	658701+9	50	2
645041+9	597032+9	507743+9	456694+9	448656+9	281561+9	320389+9	382348+9	50	3
10844+10	370975+9	351365+9	278352+9	297438+9	289833+9	227613+9	235287+9	50	4
215988+9	188593+9	14412+10	58Z					50	5
69727+10	692372+9	651745+9	748844+9	700615+9	769913+9	726891+9	720844+9	51	1
747579+9	420904+9	586936+9	497654+9	657442+9	61219+10	519595+9	4728+11	51	2
467579+9	421329+9	447553+9	34928+10	388585+9	401163+9	382819+9	36148+10	51	3
339494+9	320339+9	298401+9	269781+9	146362+9	221015+9	152286+9	142521+9	51	4
168587+9	124757+9	54Z						51	5
607915+9	753323+9	638336+9	550395+9	678275+9	603612+9	652889+9	757119+9	52	1
750962+9	753643+9	692098+9	727244+9	690222+9	659341+9	628797+9	497858+9	52	2
473244+9	412254+9	127295+9	446663+9	400605+9	118521+9	380757+9	374098+9	52	3
354605+9	282542+9	225718+9	296194+9	27454+10	255935+9	240225+9	18705+10	52	4
168578+9	178012+9	15194+10	128957+9	793916+8	53Z			52	5
66538+10	628708+9	668049+9	552688+9	77076+10	584082+9	769208+9	545208+9	53	1
534636+9	6928+11	671045+9	633956+9	487948+9	461353+9	453338+9	442308+9	53	2
377681+9	395877+9	39276+10	389107+9	348735+9	291533+9	208128+9	289524+9	53	3
270459+9	251735+9	135027+9	135743+9	198046+9	136154+9	632434+8	130352+9	53	4

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107533+9 796845+8 522                                                      53  5
72607+10 716508+9 585192+9 564891+9 533574+9 85677+10 781484+9 778909+8   54  1
628526+9 880065+9 590781+9 71204+10 897095+9 610028+9 852473+9 621785+9   54  2
472813+9 444823+9 383923+9 184017+9 375372+8 238009+9 337628+8 345407+9   54  3
325817+9 304551+9 284954+9 267822+9 238501+9 222524+8 111181+9 179778+9   54  4
185685+9 1424+11 12033+10 762322+8 537                                     54  5
660001+9 720423+9 606385+8 506029+8 541898+8 618896+9 528007+9 730542+9   55  1
712236+9 717322+9 727711+9 369382+9 848884+9 853001+9 634852+9 590541+9   55  2
485355+9 425619+9 41407+10 399857+9 246444+9 351904+9 346209+8 28721+10   55  3
282187+9 284837+9 194718+9 132151+9 222849+9 150292+9 16783+10 151606+9   55  4
101131+9 552                                                               55  5
688848+9 59127+10 662649+9 528793+9 830103+9 763251+9 774493+9 707527+9   56  1
717941+9 727323+9 355742+9 735678+9 581244+9 707183+9 384602+9 540264+9   56  2
612765+8 564947+9 438554+9 403427+9 391168+9 274902+9 142597+9 343768+9   56  3
143434+9 250946+9 205885+9 162613+9 231337+9 205449+9 177433+9 120148+9   56  4
572                                                                        56  5
857797+9 727281+9 536846+9 530137+9 550836+9 656853+9 688968+9 783832+9   57  1

489531+9 736779+6 728025+9 741314+9 728385+9 65736+10 173862+9 717576+9   57  2
532167+9 638274+6 617444+9 584199+9 536757+8 42136+10 38123+10 367352+9   57  3
336657+9 335876+9 301828+9 291277+6 231947+9 215314+6 205579+9 145618+9   57  4
572                                                                        57  5
570568+9 852711+9 658453+9 851096+9 448391+9 681614+8 757841+9 725455+9   58  1
735411+9 73058+10 597798+6 583243+9 494569+8 730835+9 711038+9 706183+9   58  2
673399+9 187019+9 548668+9 600535+9 536311+9 552659+9 49729+10 3849+11    58  3
345708+9 30078+10 104828+9 268481+9 23341+10 164219+9 592                 58  4
644772+8 665637+9 668052+6 652863+9 649264+9 633902+9 664117+9 750297+9   59  1
735516+9 725434+9 732913+9 746452+9 766174+9 406465+9 690796+9 774316+9   59  2
66455+10 690283+9 713532+9 698748+9 688753+9 583842+9 567894+9 664175+9   59  3
30834+10 424109+9 653244+9 611617+9 454226+9 359744+9 312478+8 287362+9   59  4
251548+9 181453+9 612                                                      59  5
525574+9 573809+9 480393+9 653451+9 545605+9 555022+9 504249+9 668488+9   60  1
732006+9 717356+9 72261+10 713599+9 426768+9 741311+9 728294+9 440274+9   60  2
735846+9 739925+9 724768+9 658917+9 419619+9 687986+9 868792+9 883478+9   60  3
579416+9 438031+9 570091+9 538392+9 318227+9 491235+9 440891+9 377809+9   60  4
29613+10 186045+9 622                                                      60  5
  T
BB**
4.075-5 1.760-4
3.389-4 7.300-4
2.528-3 1.466-3
4.270-3 2.985-3
1.343-2 3.145-2
5.016-2 3.227-2
7.716-2 4.356-2
2.267-2 2.313-2
1.856-2 3.927-3
2.372-2 2.385-2
4.772-2 2.388-2
4.655-2 4.505-2
4.306-2 4.074-2
7.384-2 3.269-2
  T
```

```
 MFA   U.C.C. NOS/BE L584  V1.6.06.2 23/08/83
16.15.31.LASER1E  FROM     8V
16.15.31.IP  00004800 WORDS - FILE INPUT  , DC 04
16.15.31.LASER,P2. LASER
16.15.32.ACCOUNT,GK7TEC,*---*.
16.15.33.REWIND,OUTPUT.
16.15.33.ROUTE,OUTPUT,DEF,TID=BD.
16.15.33.UCC,BANNER,DOT R-T,CYC10 BOT,INPUT.
16.15.34.COPYBR,INPUT,AA.
16.15.34.COPYBR,INPUT,BB.
16.15.35.REWIND,AA,BB.
16.15.35.COPYSBF,BB,OUTPUT.
16.15.35.BEGIN,PPRINT,,I=OUTPUT,H=AA,FORM=2UP,COP
16.15.35.IES=1.
16.15.37.AT CY= 124 SN=GLOBAL
16.15.40.
16.15.40. COPYRIGHT, 1981, UNIVERSITY COMPUTING C
16.15.40.OMPANY.
16.15.40. REPRODUCTION PROHIBITED UNLESS SPECIFIC
16.15.40.ALLY
16.15.40. AUTHORIZED BY SEPERATE WRITING.
16.15.40.
16.15.40.RETURN,ZZZZZIN,ZZZZZPO,DAYFILE,DAYFIL.
16.15.40.IFE(FILE(AA,AS),H1)
16.15.40.COPYBR,AA,ZZZZZIN.
16.15.41.ENDIF,H1.
16.15.41.COPY,ZZZZZP1,ZZZZZIN.
16.15.41.RETURN,ZZZZZP1.
16.15.41.UCC,BANNER(D=ZZZZZIN, ,BIN,64)
16.15.43.REWIND,OUTPUT.
16.15.43.COPY,OUTPUT,ZZZZZIN.
16.15.44.IFE((T.AND.(OT.NE.TXO)),DLOOP)
16.15.44.SUMMARY.
16.15.44.MS   58496 WORDS (   68736 MAX USED)
16.15.44.MM   30000B MAX SCM
16.15.44.CPR       1.190
16.15.44.IOR        .486
16.15.44.SRU       1.676
16.15.44.                         DATE 09/09/83
16.15.44.DAYFIL.
```

```
***** CYBER PAGE PRINT - END OF JOB LASER1E
***** CYBER PAGE PRINT - END OF JOB LASER1E
***** CYBER PAGE PRINT - END OF JOB LASER1E
***** CYBER PAGE PRINT - END OF JOB LASER1E
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***** CYBER PAGE PRINT - END OF JOB LASER1E
***** CYBER PAGE PRINT - END OF JOB LASER1E
***** CYBER PAGE PRINT - END OF JOB LASER1E
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ANISN-W INPUT CYCLE 10 TOP OF CORE

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$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$LASER15    16.19.12. 09/08/83 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
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$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$LASER15    16.19.12. 09/08/83 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
```


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      69500
1-D RADIAL HB ROBINSON MODEL - CYCLE 10 TOP
15SS 1 0 3 8 2 1 0 9 78 0 27 5 6 32 2R0 2R124 2Z
     1 0 0 20 2 1 2Z 1 1 3Z 1 1 0
16** 2Z 1-4 1.42089 5Z .5 2-4 1 2Z
 T
17**
 .13023E-05  .10273E-05  .10218E-05  .10255E-05  .12286E-05  .12373E-05
 .12373E-05  .12538E-05  .12830E-05  .12830E-05  .13186E-05  .13186E-05
 .13186E-05  .13186E-05  .13186E-05  .13844E-05  .13844E-05  .48200E-06
 .46200E-06  .46200E-06  .46200E-06  .46200E-06  .55188E-06  .55188E-06
 .55188E-06  .55188E-06  .55188E-06  .55188E-06  .55188E-06  .55188E-06
 .55145E-06  .55145E-06  .55145E-06 0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
 .58248E-05  .44371E-05  .44131E-05  .44291E-05  .53071E-05  .53440E-05
 .53440E-05  .54139E-05  .55411E-05  .55411E-05  .56866E-05  .56866E-05
 .56866E-05  .56866E-05  .56866E-05  .56928E-05  .56928E-05  .19954E-05
 .19954E-05  .19954E-05  .19954E-05  .19954E-05  .23836E-05  .23838E-05
 .23836E-05  .23836E-05  .23836E-05  .23836E-05  .23836E-05  .23838E-05
 .23817E-05  .23817E-05  .23817E-05 0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
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 .10831E-04  .85440E-05  .84977E-05  .85285E-05  .10219E-04  .10290E-04
 .10290E-04  .10425E-04  .10670E-04  .10670E-04  .10950E-04  .10950E-04
 .10950E-04  .10950E-04  .10950E-04  .11347E-04  .11347E-04  .38423E-05
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 .45862E-05  .45862E-05  .45862E-05 0.          0.          0.
0.          0.          0.          0.          0.          0.
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0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
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0.          0.          0.          0.          0.          0.
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 .23330E-04  .18404E-04  .18304E-04  .18371E-04  .22012E-04  .22165E-04
 .22165E-04  .22455E-04  .22983E-04  .22983E-04  .23586E-04  .23586E-04
 .23586E-04  .23586E-04  .23586E-04  .24442E-04  .24442E-04  .82763E-05
 .82763E-05  .82763E-05  .82763E-05  .82763E-05  .98864E-05  .98864E-05
 .98864E-05  .98864E-05  .98864E-05  .98864E-05  .98864E-05  .98864E-05
 .98787E-05  .98787E-05  .98787E-05 0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
0.          0.          0.          0.          0.          0.
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 .80782E-04  .83733E-04  .83388E-04  .83818E-04  .78229E-04  .78759E-04
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 .81680E-04  .81680E-04  .81680E-04  .84642E-04  .84642E-04  .28861E-04
 .28861E-04  .28861E-04  .28861E-04  .28861E-04  .34237E-04  .34237E-04
 .34237E-04  .34237E-04  .34237E-04  .34237E-04  .34237E-04  .34237E-04
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0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
.48500E-04	.38882E-04	.36483E-04	.36615E-04	.43874E-04	.44179E-04
.44179E-04	.44757E-04	.45809E-04	.45809E-04	.47011E-04	.47011E-04
.47011E-04	.47011E-04	.47011E-04	.48718E-04	.48718E-04	.16496E-04
.16496E-04	.16496E-04	.16496E-04	.16496E-04	.19705E-04	.19705E-04
.19705E-04	.19705E-04	.19705E-04	.19705E-04	.19705E-04	.19705E-04
.19690E-04	.19690E-04	.19690E-04	0.	0.	0.
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.13646E-03	.10765E-03	.10707E-03	.10746E-03	.12876E-03	.12965E-03
.12965E-03	.13135E-03	.13444E-03	.13444E-03	.13798E-03	.13798E-03
.13798E-03	.13798E-03	.13798E-03	.14297E-03	.14297E-03	.48411E-04
.48411E-04	.48411E-04	.48411E-04	.48411E-04	.57829E-04	.57829E-04
.57829E-04	.57829E-04	.57829E-04	.57829E-04	.57829E-04	.57829E-04
.57784E-04	.57784E-04	.57784E-04	0.	0.	0.
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0.	0.	0.	0.	0.	0.
.85397E-04	.75255E-04	.74847E-04	.75118E-04	.90009E-04	.90635E-04
.90635E-04	.91820E-04	.93979E-04	.93979E-04	.95446E-04	.95446E-04
.95446E-04	.95446E-04	.95446E-04	.99943E-04	.99943E-04	.33842E-04
.33842E-04	.33842E-04	.33842E-04	.33842E-04	.40428E-04	.40428E-04
.40428E-04	.40428E-04	.40428E-04	.40428E-04	.40428E-04	.40428E-04
.40395E-04	.40395E-04	.40395E-04	0.	0.	0.
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.42921E-03	.33858E-03	.33678E-03	.33797E-03	.40497E-03	.40778E-03
.40778E-03	.41311E-03	.42282E-03	.42282E-03	.43393E-03	.43393E-03
.43393E-03	.43393E-03	.43393E-03	.44986E-03	.44986E-03	.15226E-03
.15226E-03	.15226E-03	.15226E-03	.15226E-03	.18188E-03	.18188E-03
.18188E-03	.18188E-03	.18188E-03	.18188E-03	.18188E-03	.18188E-03
.18174E-03	.18174E-03	.18174E-03	0.	0.	0.
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.10051E-02	.79289E-03	.78858E-03	.79145E-03	.94834E-03	.95493E-03
.95493E-03	.96742E-03	.99016E-03	.99016E-03	.10182E-02	.10182E-02
.10182E-02	.10182E-02	.10182E-02	.10530E-02	.10530E-02	.35656E-03
.35656E-03	.35656E-03	.35656E-03	.35656E-03	.42593E-03	.42593E-03
.42593E-03	.42593E-03	.42593E-03	.42593E-03	.42593E-03	.42593E-03
.42560E-03	.42560E-03	.42560E-03	0.	0.	0.
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.16207E-02	.16207E-02	.16207E-02	.15794E-02	.15794E-02	.56869E-03
.56869E-03	.56869E-03	.56869E-03	.56869E-03	.57932E-03	.57932E-03
.57932E-03	.57932E-03	.57932E-03	.57932E-03	.57932E-03	.57932E-03
.57879E-03	.57879E-03	.57879E-03	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
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.10313E-02	.81358E-03	.80915E-03	.81208E-03	.87306E-03	.97983E-03
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.10426E-02	.10426E-02	.10426E-02	.10805E-02	.10805E-02	.36586E-03
.36586E-03	.36586E-03	.36586E-03	.36586E-03	.43703E-03	.43703E-03
.43703E-03	.43703E-03	.43703E-03	.43703E-03	.43703E-03	.43703E-03
.43669E-03	.43669E-03	.43669E-03	0.	0.	0.
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.13921E-02	.10982E-02	.10922E-02	.10962E-02	.13135E-02	.13226E-02
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.14074E-02	.14074E-02	.14074E-02	.14585E-02	.14585E-02	.49386E-03
.49386E-03	.49386E-03	.49386E-03	.49386E-03	.58994E-03	.58994E-03
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.26490E-03	.26490E-03	.26490E-03	.26490E-03	.26490E-03	.26490E-03
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UNIVERSITY COMPUTING COMPANY

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 .99653E-03  .99653E-03  .99653E-03 0.          0.          0.
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0.          0.          0.          0.          0.          0.
  T
3== F0.
  T
1== F0.
4== 3I70. 2I100. 4I115. 4I130. 15I140.895 2I182.360 3I185.217
3I170.021 4I175.182 4I181.134
    7I187.959 15I197.485 217.488
5== F1.
6== 0.2R0.0604938
    0          4R0.0453704
    0 0.0453704            0.0482982 0.0453704 1N3
    0            0.0604938 0.0453704 1N2 1N4
7== -.3086067          -.2182179 1M1
    -.6172134 -.5773503 -.2182179 1M2
    -.8184965          -.7867958 -.5773503 -.2182179 1M3
    -.8759 -.8511887 -.7867958 -.5773503 -.2182179 1M4
8SS 17R1 18R2 3R3 4R4 4R5 5R6 5R7 8R8 18R9
9SS 29 33 9 21 9 21 9 21 17
19SS F3
  T



  MFA   U.C.C. NOS/BE L564  V1.6.06.2 23/08/83
16.20.06.LASER18  FROM      9V
16.20.06.IP  00003008 WORDS - FILE INPUT  , DC 04
16.20.06.LASER,P2. LASER
16.20.07.ACCOUNT,GK7TEC,*---*.
16.20.08.REWIND,OUTPUT.
16.20.08.ROUTE,OUTPUT,DEF,TID=8D.
16.20.08.UCC,BANNER,ANISNW,CYC10 TOP,INPUT.
16.20.10.COPYBR,INPUT,AA.
16.20.10.COPYBR,INPUT,BB.
16.20.10.REWIND,AA,BB.
16.20.10.COPYSBF,BB,OUTPUT.
16.20.11.BEGIN,PPRINT,,I=OUTPUT,H=AA,FORM=2UP,COP
16.20.11.IES=1.
16.20.12.AT CY= 124 SN=GLOBAL
16.20.14.
16.20.14. COPYRIGHT, 1981, UNIVERSITY COMPUTING C
16.20.14.OMPANY.
16.20.14. REPRODUCTION PROHIBITED UNLESS SPECIFIC
16.20.14.ALLY
16.20.14. AUTHORIZED BY SEPERATE WRITING.
16.20.14.
16.20.14.RETURN,ZZZZZIN,ZZZZZPO,DAYFILE,DAYFIL.
16.20.15.IFE(FILE(AA,AS),H1)
16.20.15.COPYBR,AA,ZZZZZIN.
16.20.15.ENDIF,H1.
16.20.15.COPY,ZZZZZP1,ZZZZZIN.
16.20.15.RETURN,ZZZZZP1.
16.20.15.UCC,BANNER(D=ZZZZZIN, ,BIN,54)
16.20.25.REWIND,OUTPUT.
16.20.25.COPY,OUTPUT,ZZZZZIN.
16.20.25.IFE((T.AND.(DT.NE.TXD)),DLOOP)
16.20.25.SUMMARY.
16.20.25.MS    54848  WORDS  (    65088 MAX USED)
16.20.25.MM    30500B MAX SCM
16.20.25.CPR        1.153
16.20.25.IOR         .464
16.20.25.SRU        1.618
16.20.25.                          DATE 08/09/83
16.20.29.DAYFIL.
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***** CYBER PAGE PRINT - END OF JOB LASER18
***** CYBER PAGE PRINT - END OF JOB LASER18
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ANISN-W INPUT CYCLE 10 BOTTOM OF CORE

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$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$LASERIR   16.16.56. 08/08/83 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$LASERIR   16.16.56. 08/08/83 $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

       68500.
1-D RADIAL HB ROBINSON MODEL - CYCLE 10 BOTTOM
1555 1 0 3 8 2 1 0 9 78 0 27 5 6 32 2R0 2R124 22
      1 0 0 20 2 1 22 1 1 32 1 1 0
16** 22 1-4 1.42089 52 .5 2-4 1 22
 T
17**
 .40980E-06  .30843E-06  .31312E-06  .30823E-06  .33572E-06  .32801E-06
 .32801E-06  .31295E-06  .25009E-06  .25009E-06  .22828E-06  .22828E-06
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 .14167E-05  .13516E-05  .10801E-05  .10801E-05  .97731E-06  .97731E-06
 .97731E-06  .97731E-06  .97731E-06  .82708E-06  .82708E-06 0.
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 .20349E-04  .19414E-04  .15515E-04  .15515E-04  .14038E-04  .14038E-04
 .14038E-04  .14038E-04  .14038E-04  .11880E-04  .11880E-04 0.
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  T
3** FO.
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1** FO.
4** 3I70. 2I100. 4I115. 4I130. 15I140.695 2I162.340 3I185.217
3I170.021 4I175.182 4I181.134
    7I187.959 15I197.485 217.486
5** F1.
6** 0 2R0.0604938
    0       4R0.0453704
    0 0.0453704         0.0482952 0.0453704 1N3
    0          0.0604938 0.0453704 1N2 1N4
7** -.3085057          -.2182179 1M1
    -.8172134 -.5773503 -.2182179 1M2
    -.8164965          -.7857958 -.5773503 -.2182179 1M3
    -.9759 -.9511897 -.7857958 -.5773503 -.2182179 1M4
8$$ 17R1 16R2 3R3 4R4 4R5 5R8 5R7 8R8 15R9
9$$ 29 33.9 21 9 21 9 21 17
18$$ F3
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16.17.50.LASER1Y  FROM     9V
16.17.50.IP  00002944 WORDS - FILE INPUT  , DC 04
16.17.50.LASER,P2. LASER
16.17.50.ACCOUNT,CK7YEC,*---*.
16.17.51.REWIND,OUTPUT.
16.17.51.ROUTE,OUTPUT,DEF,TID=8D.
16.17.51.UCC,BANNER,ANISNW,CYC10 BOT,INPUT.
16.17.53.COPYBR,INPUT,AA.
16.17.53.COPYBR,INPUT,BB.
16.17.53.REWIND,AA,BB.
16.17.53.COPYSBF,BB,OUTPUT.
16.17.53.BEGIN,PPRINT,,I=OUTPUT,H=AA,FORM=2UP,COP
16.17.53.IES=1.
16.17.54.AT CY= 124 SN=GLOBAL
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16.17.56. COPYRIGHT, 1981, UNIVERSITY COMPUTING C
16.17.56.OMPANY.
16.17.56. REPRODUCTION PROHIBITED UNLESS SPECIFIC
16.17.56.ALLY
16.17.56. AUTHORIZED BY SEPERATE WRITING.
16.17.56.
16.17.56.RETURN,ZZZZZIN,ZZZZZPO,DAYFILE,DAYFIL.
16.17.57.IFE(FILE(AA,AS),H1)
16.17.57.COPYBR,AA,ZZZZZIN.
16.17.57.ENDIF,H1.
16.17.57.COPY,ZZZZZP1,ZZZZZIN.
16.17.58.RETURN,ZZZZZP1.
16.17.58.UCC,BANNER(D=ZZZZZIN, ,BIN,64)
16.17.59.REWIND,OUTPUT.
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16.18.00.IDR         .454
16.18.00.SRU        1.562
16.18.00.                        DATE 08/09/83
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Section 5

RESULTS AND CONCLUSIONS

The synthesis procedure was used to construct group flux distributions from DOT and ANISN results for critical areas of interest for both the Cycle 8 and Cycle 10 cores. These areas included the locations of S, V, and T surveillance capsules for Cycle 8, and the pressure vessel inner surface axially at 0 degrees, radially at the lower circumferential weld, and radially at the core midplane for both cycles. Summing the top 27 ELXSIR group fluxes gave distributions of the flux above 1 Mev.

The detailed results are presented in this section along with dosimeter activations and fluences above 1 MeV computed with the flux results. The calculated activations are compared with measurements for the HBR2 capsules and projections of max. fluences (based on current RT-NDT screening criteria) are given.

5.1 FLUXES AT THE PRESSURE VESSEL INNER SURFACE

Fluxes above 1 MeV for the Cycle 8 and Cycle 10 cases are given in Tables 5-1 through 5-3 for the pressure vessel inner surface along the lower girth weld, along the core midplane, and axially at the core major axis, respectively. Figures 5-1 and 5-2 depict graphically the flux and flux reduction factor, FRF (defined as the ratio Cycle 8 flux/Cycle 10 flux), distributions for the lower circumferential weld, while Figures 5-3 and 5-4 depict the same quantities axially for the vessel surface at the core major axis (0 degrees). The beltline longitudinal weld is at 4 degrees where flux is slightly less than at 0 degrees. The maximum

Table 5-1

FLUX, FLUENCE (ABOVE 1MEV), AND RT-NDT AT 27 EFPY
RADIALLY ALONG HBR2 VESSEL LOWER GIRTH WELD INNER SURFACE

ANGLE DEG	CYC 8 FLUX	CYC 10 FLUX	EOC 8 FLUENCE	27 EFPY FLUENCE	(**) RT-NDT DEG. F
.48	.6396E+11	.6958E+10	.1450E+20	.1949E+20	300.1
1.43	.6366E+11	.6974E+10	.1443E+20	.1942E+20	299.9
2.38	.6306E+11	.7010E+10	.1430E+20	.1930E+20	299.5
3.34	.6216E+11	.7067E+10	.1409E+20	.1912E+20	298.9
4.11	.6108E+11	.7136E+10	.1385E+20	.1890E+20	298.2
4.80	.6005E+11	.7206E+10	.1361E+20	.1870E+20	297.5
5.77	.5833E+11	.7324E+10	.1322E+20	.1836E+20	296.4
6.84	.5586E+11	.7507E+10	.1266E+20	.1788E+20	294.8
7.88	.5304E+11	.7739E+10	.1202E+20	.1734E+20	292.9
8.95	.4972E+11	.8060E+10	.1127E+20	.1674E+20	290.7
10.02	.4624E+11	.8496E+10	.1048E+20	.1617E+20	288.6
10.94	.4326E+11	.8990E+10	.9806E+19	.1575E+20	287.1
11.69	.4084E+11	.9443E+10	.9259E+19	.1544E+20	285.9
12.30	.3894E+11	.9838E+10	.8827E+19	.1522E+20	285.0
12.77	.3743E+11	.1013E+11	.8486E+19	.1504E+20	284.3
13.20	.3604E+11	.1043E+11	.8170E+19	.1488E+20	283.7
13.62	.3469E+11	.1072E+11	.7863E+19	.1473E+20	283.1
14.07	.3328E+11	.1102E+11	.7543E+19	.1457E+20	282.4
14.78	.3115E+11	.1149E+11	.7061E+19	.1435E+20	281.5
15.79	.2883E+11	.1219E+11	.6536E+19	.1421E+20	281.0
16.85	.2693E+11	.1294E+11	.6104E+19	.1420E+20	280.9
17.91	.2543E+11	.1365E+11	.5765E+19	.1427E+20	281.2
18.87	.2439E+11	.1427E+11	.5528E+19	.1439E+20	281.7
19.74	.2358E+11	.1479E+11	.5346E+19	.1451E+20	282.2
20.60	.2293E+11	.1525E+11	.5198E+19	.1463E+20	282.7
21.40	.2242E+11	.1560E+11	.5083E+19	.1471E+20	283.0
22.12	.2200E+11	.1587E+11	.4987E+19	.1477E+20	283.3
22.84	.2160E+11	.1606E+11	.4896E+19	.1480E+20	283.3
23.51	.2122E+11	.1616E+11	.4810E+19	.1476E+20	283.2
24.13	.2085E+11	.1619E+11	.4726E+19	.1469E+20	282.9
24.93	.2039E+11	.1617E+11	.4622E+19	.1457E+20	282.4
25.89	.1976E+11	.1595E+11	.4481E+19	.1429E+20	281.3
26.69	.1919E+11	.1564E+11	.4351E+19	.1397E+20	279.9
27.34	.1877E+11	.1539E+11	.4255E+19	.1372E+20	278.9
27.98	.1837E+11	.1514E+11	.4165E+19	.1347E+20	277.8
28.50	.1807E+11	.1492E+11	.4096E+19	.1327E+20	277.0
28.88	.1784E+11	.1476E+11	.4045E+19	.1312E+20	276.3
29.27	.1761E+11	.1458E+11	.3992E+19	.1295E+20	275.6
29.80	.1727E+11	.1432E+11	.3915E+19	.1271E+20	274.5
30.44	.1688E+11	.1398E+11	.3826E+19	.1242E+20	273.1
31.05	.1650E+11	.1365E+11	.3741E+19	.1213E+20	271.8
31.62	.1615E+11	.1332E+11	.3661E+19	.1185E+20	270.5
32.19	.1579E+11	.1298E+11	.3579E+19	.1156E+20	269.1
32.65	.1550E+11	.1271E+11	.3514E+19	.1133E+20	267.9
33.12	.1517E+11	.1240E+11	.3440E+19	.1106E+20	266.6

33.73	.1478E+11	.1202E+11	.3350E+19	.1074E+20	264.9
34.33	.1438E+11	.1164E+11	.3261E+19	.1042E+20	263.2
35.09	.1390E+11	.1117E+11	.3151E+19	.1002E+20	261.1
35.93	.1340E+11	.1069E+11	.3039E+19	.9617E+19	258.9
36.71	.1296E+11	.1027E+11	.2939E+19	.9257E+19	256.8
37.49	.1256E+11	.9886E+10	.2848E+19	.8932E+19	254.9
38.27	.1221E+11	.9543E+10	.2769E+19	.8642E+19	253.1
39.05	.1192E+11	.9250E+10	.2702E+19	.8396E+19	251.6
39.84	.1168E+11	.8998E+10	.2647E+19	.8187E+19	250.2
40.63	.1148E+11	.8794E+10	.2603E+19	.8019E+19	249.1
41.43	.1134E+11	.8632E+10	.2570E+19	.7887E+19	248.3
42.22	.1123E+11	.8510E+10	.2547E+19	.7789E+19	247.6
43.01	.1117E+11	.8423E+10	.2532E+19	.7721E+19	247.2
43.81	.1113E+11	.8368E+10	.2522E+19	.7678E+19	246.9
44.60	.1111E+11	.8341E+10	.2518E+19	.7657E+19	246.7

(**)

RT-NDT = -56 + 283.*(F/E19)**0.194 + 2*SIG

2*SIG = 34

Table 5-2

FLUX AND FLUENCE (ABOVE 1MEV) RADIALLY
ALONG HBR2 VESSEL INNER SURFACE AT CORE MIDPLANE

ANGLE DEG	CYC 8 FLUX	CYC 10 FLUX	EOC 8 FLUENCE	27 EFPY FLUENCE
.48	.6977E+11	.4155E+11	.1582E+20	.4160E+20
1.43	.6945E+11	.4138E+11	.1574E+20	.4142E+20
2.38	.6880E+11	.4104E+11	.1560E+20	.4106E+20
3.34	.6783E+11	.4053E+11	.1538E+20	.4053E+20
4.11	.6665E+11	.3993E+11	.1511E+20	.3989E+20
4.80	.6552E+11	.3936E+11	.1485E+20	.3928E+20
5.77	.6365E+11	.3843E+11	.1443E+20	.3827E+20
6.84	.6097E+11	.3712E+11	.1382E+20	.3684E+20
7.88	.5788E+11	.3566E+11	.1312E+20	.3523E+20
8.95	.5426E+11	.3401E+11	.1230E+20	.3337E+20
10.02	.5045E+11	.3236E+11	.1144E+20	.3147E+20
10.94	.4717E+11	.3105E+11	.1069E+20	.2990E+20
11.69	.4452E+11	.3002E+11	.1009E+20	.2865E+20
12.30	.4244E+11	.2925E+11	.9620E+19	.2769E+20
12.77	.4079E+11	.2863E+11	.9247E+19	.2692E+20
13.20	.3926E+11	.2807E+11	.8900E+19	.2622E+20
13.62	.3778E+11	.2753E+11	.8564E+19	.2554E+20
14.07	.3623E+11	.2697E+11	.8213E+19	.2483E+20
14.78	.3389E+11	.2616E+11	.7684E+19	.2379E+20
15.79	.3135E+11	.2539E+11	.7108E+19	.2272E+20
16.85	.2926E+11	.2489E+11	.6634E+19	.2192E+20
17.91	.2763E+11	.2459E+11	.6263E+19	.2135E+20
18.87	.2648E+11	.2445E+11	.6004E+19	.2099E+20
19.74	.2561E+11	.2437E+11	.5806E+19	.2074E+20
20.60	.2490E+11	.2433E+11	.5645E+19	.2054E+20
21.40	.2435E+11	.2429E+11	.5520E+19	.2038E+20
22.12	.2389E+11	.2422E+11	.5415E+19	.2023E+20
22.84	.2346E+11	.2412E+11	.5318E+19	.2007E+20
23.51	.2305E+11	.2395E+11	.5225E+19	.1987E+20
24.13	.2265E+11	.2373E+11	.5134E+19	.1964E+20
24.93	.2215E+11	.2341E+11	.5022E+19	.1933E+20
25.89	.2148E+11	.2284E+11	.4870E+19	.1883E+20
26.69	.2087E+11	.2222E+11	.4730E+19	.1831E+20
27.34	.2041E+11	.2175E+11	.4627E+19	.1792E+20
27.98	.1998E+11	.2128E+11	.4529E+19	.1753E+20
28.50	.1965E+11	.2089E+11	.4455E+19	.1722E+20
28.88	.1941E+11	.2061E+11	.4400E+19	.1700E+20
29.27	.1916E+11	.2031E+11	.4343E+19	.1675E+20
29.80	.1879E+11	.1987E+11	.4261E+19	.1641E+20
30.44	.1837E+11	.1934E+11	.4164E+19	.1598E+20
31.05	.1796E+11	.1882E+11	.4072E+19	.1557E+20
31.62	.1758E+11	.1832E+11	.3985E+19	.1518E+20
32.19	.1719E+11	.1780E+11	.3896E+19	.1478E+20
32.65	.1688E+11	.1739E+11	.3826E+19	.1446E+20
33.12	.1652E+11	.1693E+11	.3746E+19	.1410E+20

33.73	.1609E+11	.1637E+11	.3648E+19	.1366E+20
34.33	.1566E+11	.1581E+11	.3551E+19	.1323E+20
35.09	.1514E+11	.1514E+11	.3433E+19	.1270E+20
35.93	.1460E+11	.1445E+11	.3310E+19	.1215E+20
36.71	.1412E+11	.1384E+11	.3201E+19	.1168E+20
37.49	.1369E+11	.1330E+11	.3103E+19	.1124E+20
38.27	.1331E+11	.1281E+11	.3017E+19	.1086E+20
39.05	.1299E+11	.1239E+11	.2945E+19	.1053E+20
39.84	.1273E+11	.1203E+11	.2885E+19	.1026E+20
40.63	.1252E+11	.1174E+11	.2838E+19	.1003E+20
41.43	.1236E+11	.1151E+11	.2803E+19	.9857E+19
42.22	.1225E+11	.1134E+11	.2778E+19	.9726E+19
43.01	.1218E+11	.1121E+11	.2761E+19	.9634E+19
43.81	.1214E+11	.1113E+11	.2751E+19	.9575E+19
44.60	.1212E+11	.1109E+11	.2747E+19	.9547E+19

Table 5.3

FLUX AND FLUENCE (ABOVE 1MEV) AXIALLY
ALONG HBR2 VESSEL INNER SURFACE (ANGLE 0 DEG)
AND
RT-NDT AT 27 EFPY FOR BELTLINE LONGITUDINAL WELD

IN ABOVE FUEL BOT	CYC 8 FLUX	CYC 10 FLUX	EOC 8 FLUENCE	27 EFPY FLUENCE	(*) RT-NDT DEG. F
-3.35	.8838E+10	.6928E+09	.2003E+19	.2532E+19	
-2.54	.1201E+11	.9364E+09	.2723E+19	.3438E+19	
-1.73	.1458E+11	.1135E+10	.3305E+19	.4172E+19	
-.92	.1704E+11	.1327E+10	.3864E+19	.4877E+19	
-.26	.1909E+11	.1488E+10	.4329E+19	.5465E+19	
.26	.2067E+11	.1613E+10	.4687E+19	.5918E+19	
.91	.2255E+11	.1760E+10	.5113E+19	.6456E+19	
1.89	.2545E+11	.1984E+10	.5769E+19	.7284E+19	
3.40	.2976E+11	.2317E+10	.6746E+19	.8516E+19	
5.24	.3478E+11	.2736E+10	.7884E+19	.9968E+19	
7.08	.3953E+11	.3170E+10	.8961E+19	.1137E+20	
8.92	.4392E+11	.3611E+10	.9957E+19	.1268E+20	
10.76	.4795E+11	.4057E+10	.1087E+20	.1391E+20	
12.61	.5156E+11	.4501E+10	.1169E+20	.1505E+20	
14.45	.5477E+11	.4944E+10	.1242E+20	.1608E+20	
16.29	.5758E+11	.5391E+10	.1305E+20	.1702E+20	
18.13	.6006E+11	.5860E+10	.1362E+20	.1790E+20	
19.97	.6217E+11	.6370E+10	.1409E+20	.1871E+20	
21.81	.6396E+11	.6958E+10	.1450E+20	.1949E+20	
23.65	.6543E+11	.7665E+10	.1483E+20	.2026E+20	202.3
25.49	.6662E+11	.8552E+10	.1510E+20	.2108E+20	204.1
27.33	.6753E+11	.9687E+10	.1531E+20	.2198E+20	206.0
29.17	.6822E+11	.1117E+11	.1546E+20	.2303E+20	208.1
30.69	.6868E+11	.1287E+11	.1557E+20	.2416E+20	210.3
31.70	.6894E+11	.1430E+11	.1563E+20	.2508E+20	212.1
32.54	.6913E+11	.1557E+11	.1567E+20	.2589E+20	213.6
33.38	.6926E+11	.1692E+11	.1570E+20	.2672E+20	215.1
34.22	.6940E+11	.1831E+11	.1573E+20	.2759E+20	216.6
35.07	.6953E+11	.1975E+11	.1576E+20	.2848E+20	218.2
35.74	.6970E+11	.2097E+11	.1580E+20	.2926E+20	219.5
36.26	.6976E+11	.2188E+11	.1581E+20	.2982E+20	220.4
36.91	.6973E+11	.2302E+11	.1581E+20	.3049E+20	221.5
37.89	.6969E+11	.2476E+11	.1580E+20	.3152E+20	223.2
39.46	.6962E+11	.2741E+11	.1578E+20	.3310E+20	225.6
41.78	.6977E+11	.3076E+11	.1582E+20	.3514E+20	228.7
44.43	.7001E+11	.3383E+11	.1587E+20	.3703E+20	231.4
47.09	.7013E+11	.3619E+11	.1590E+20	.3848E+20	233.4
49.74	.7015E+11	.3795E+11	.1590E+20	.3954E+20	234.8
52.40	.7012E+11	.3920E+11	.1590E+20	.4028E+20	235.8
55.06	.7007E+11	.4007E+11	.1588E+20	.4079E+20	236.5
57.71	.7000E+11	.4067E+11	.1587E+20	.4113E+20	236.9
60.37	.6994E+11	.4107E+11	.1586E+20	.4136E+20	237.2

63.02	.6988E+11	.4132E+11	.1584E+20	.4149E+20	237.4
65.68	.6983E+11	.4148E+11	.1583E+20	.4157E+20	237.5
68.33	.6977E+11	.4155E+11	.1582E+20	.4160E+20	237.6
70.99	.6974E+11	.4157E+11	.1581E+20	.4161E+20	237.6
73.65	.6970E+11	.4155E+11	.1580E+20	.4158E+20	237.5
76.30	.6967E+11	.4150E+11	.1579E+20	.4155E+20	237.5
78.96	.6963E+11	.4142E+11	.1579E+20	.4149E+20	237.4
81.61	.6961E+11	.4132E+11	.1578E+20	.4142E+20	237.3
84.27	.6956E+11	.4118E+11	.1577E+20	.4133E+20	237.2
86.92	.6953E+11	.4104E+11	.1576E+20	.4124E+20	237.1
89.58	.6947E+11	.4086E+11	.1575E+20	.4111E+20	236.9
92.24	.6941E+11	.4066E+11	.1573E+20	.4098E+20	236.7
94.89	.6931E+11	.4042E+11	.1571E+20	.4082E+20	236.5
97.55	.6920E+11	.4015E+11	.1569E+20	.4063E+20	236.3
100.20	.6903E+11	.3983E+11	.1565E+20	.4040E+20	236.0
102.86	.6882E+11	.3944E+11	.1560E+20	.4011E+20	235.6
105.52	.6851E+11	.3896E+11	.1553E+20	.3975E+20	235.1
108.17	.6809E+11	.3836E+11	.1544E+20	.3929E+20	234.5
110.83	.6752E+11	.3763E+11	.1531E+20	.3871E+20	233.7
113.48	.6676E+11	.3674E+11	.1514E+20	.3800E+20	232.7
116.14	.6578E+11	.3566E+11	.1491E+20	.3712E+20	231.5
118.79	.6451E+11	.3438E+11	.1463E+20	.3605E+20	230.0
121.45	.6289E+11	.3287E+11	.1426E+20	.3475E+20	228.1
124.11	.6082E+11	.3107E+11	.1379E+20	.3318E+20	225.7
126.76	.5815E+11	.2891E+11	.1318E+20	.3125E+20	222.7
129.42	.5473E+11	.2632E+11	.1241E+20	.2888E+20	218.8
132.07	.5049E+11	.2333E+11	.1145E+20	.2607E+20	213.9
134.39	.4589E+11	.2032E+11	.1040E+20	.2316E+20	208.4
135.96	.4214E+11	.1804E+11	.9554E+19	.2090E+20	203.7
136.94	.3950E+11	.1653E+11	.8955E+19	.1936E+20	200.3
137.59	.3770E+11	.1552E+11	.8546E+19	.1833E+20	197.9
138.11	.3622E+11	.1472E+11	.8210E+19	.1749E+20	
138.76	.3432E+11	.1370E+11	.7781E+19	.1643E+20	
139.72	.3158E+11	.1227E+11	.7160E+19	.1492E+20	
140.85	.2840E+11	.1072E+11	.6439E+19	.1323E+20	
141.98	.2529E+11	.9283E+10	.5733E+19	.1162E+20	
142.94	.2277E+11	.8184E+10	.5163E+19	.1036E+20	
143.59	.2110E+11	.7472E+10	.4784E+19	.9530E+19	
144.11	.1976E+11	.6903E+10	.4480E+19	.8869E+19	
144.76	.1808E+11	.6201E+10	.4099E+19	.8045E+19	
145.81	.1555E+11	.5200E+10	.3524E+19	.6839E+19	
147.14	.1283E+11	.4206E+10	.2909E+19	.5593E+19	
148.46	.1045E+11	.3378E+10	.2370E+19	.4527E+19	
149.79	.8414E+10	.2693E+10	.1908E+19	.3629E+19	
150.84	.7094E+10	.2259E+10	.1608E+19	.3052E+19	
151.49	.6313E+10	.2004E+10	.1431E+19	.2713E+19	
152.01	.5693E+10	.1804E+10	.1291E+19	.2444E+19	
152.66	.4942E+10	.1562E+10	.1120E+19	.2120E+19	
153.67	.3933E+10	.1241E+10	.8917E+18	.1685E+19	
154.90	.2955E+10	.9307E+09	.6699E+18	.1265E+19	
156.13	.1947E+10	.6137E+09	.4413E+18	.8339E+18	

(*) RT-NDT = -56 + (-10 + 470*CU + 350*CU*NI)*(F/E19)**.27 + 2*SIG
2*SIG = 2 * 17 + 60, CU = 0.27, NI = 0.2

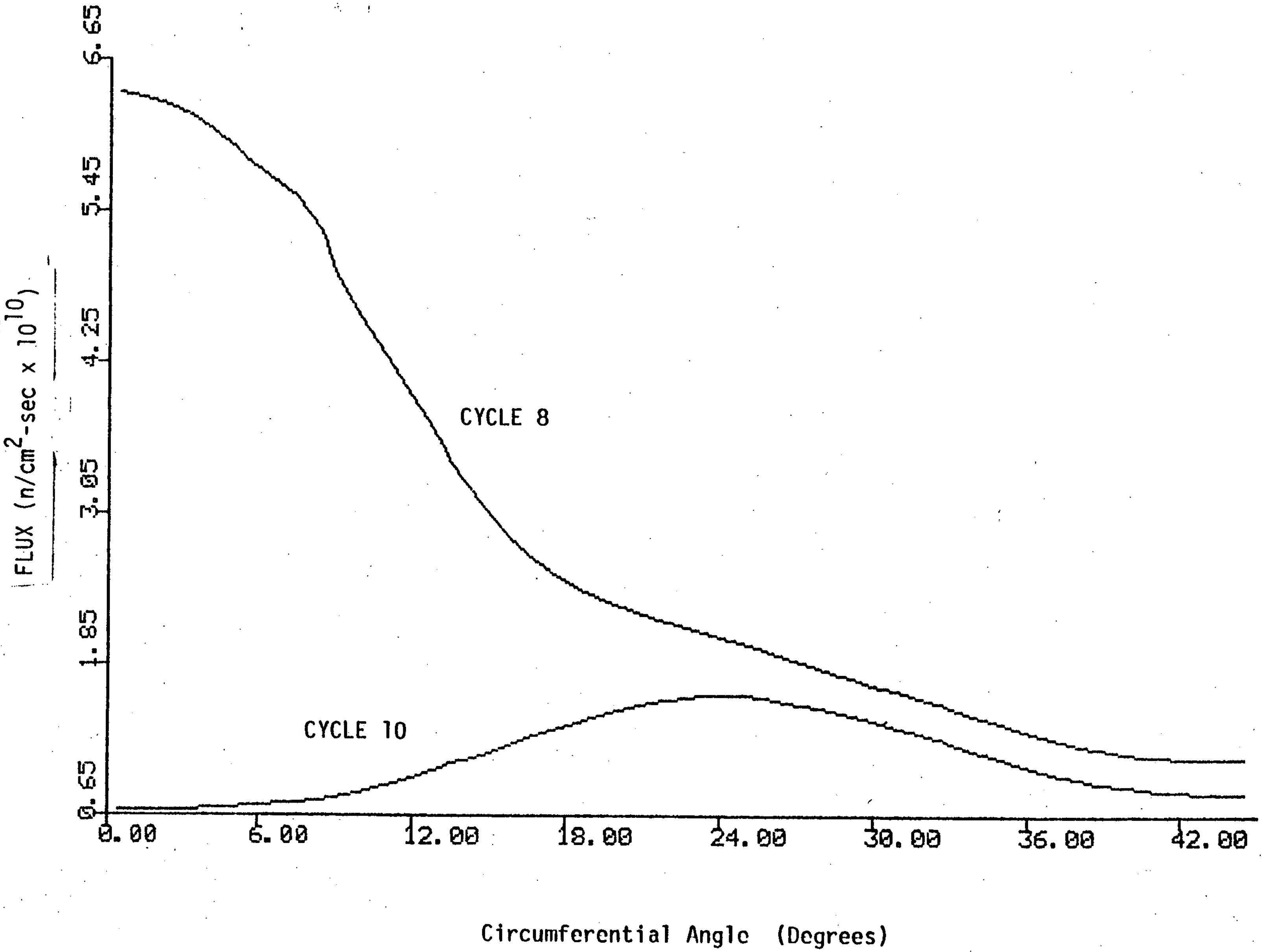


Figure 5-1. Lower Circumferential Weld Best Estimate Flux Distribution for Cycles 8 and 10.

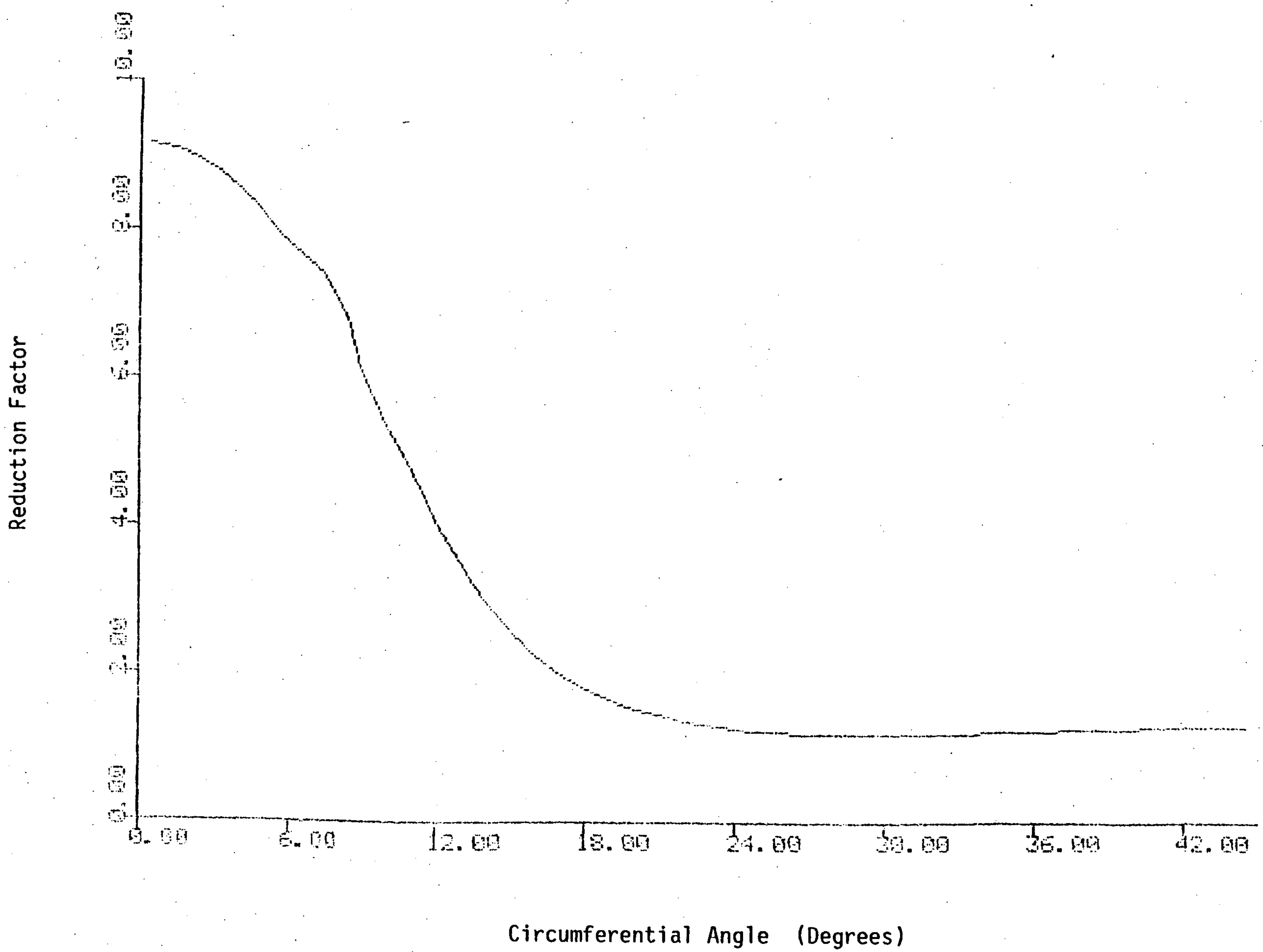


Figure 5-2. Lower Circumferential Weld Best Estimate Reduction Factor for the 36 inch Stainless Steel PLSA Design.

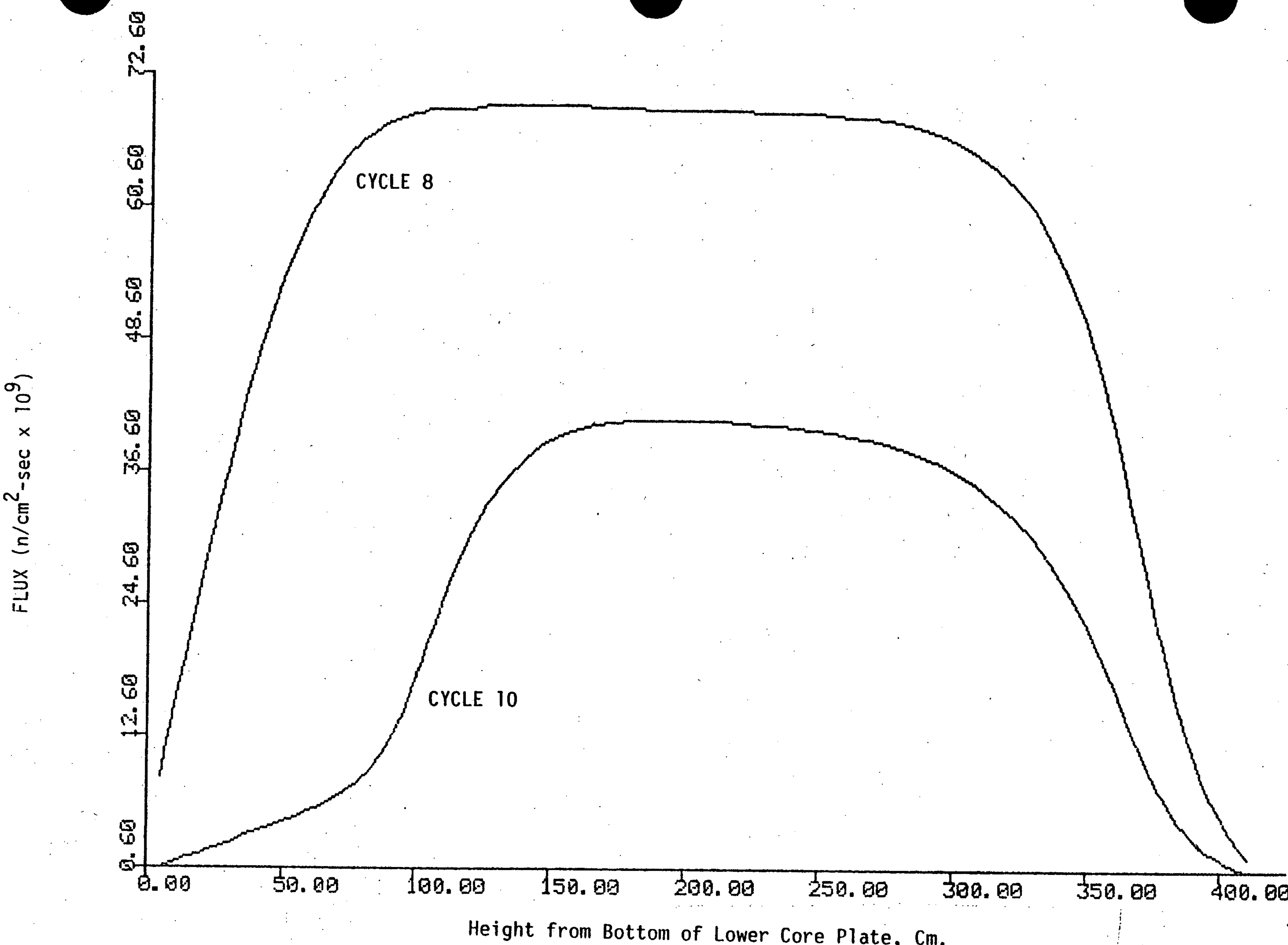


Figure 5-3. Axial Flux Distributions for Cycle 8 and Cycle 10 at the Center of the Core Flat.

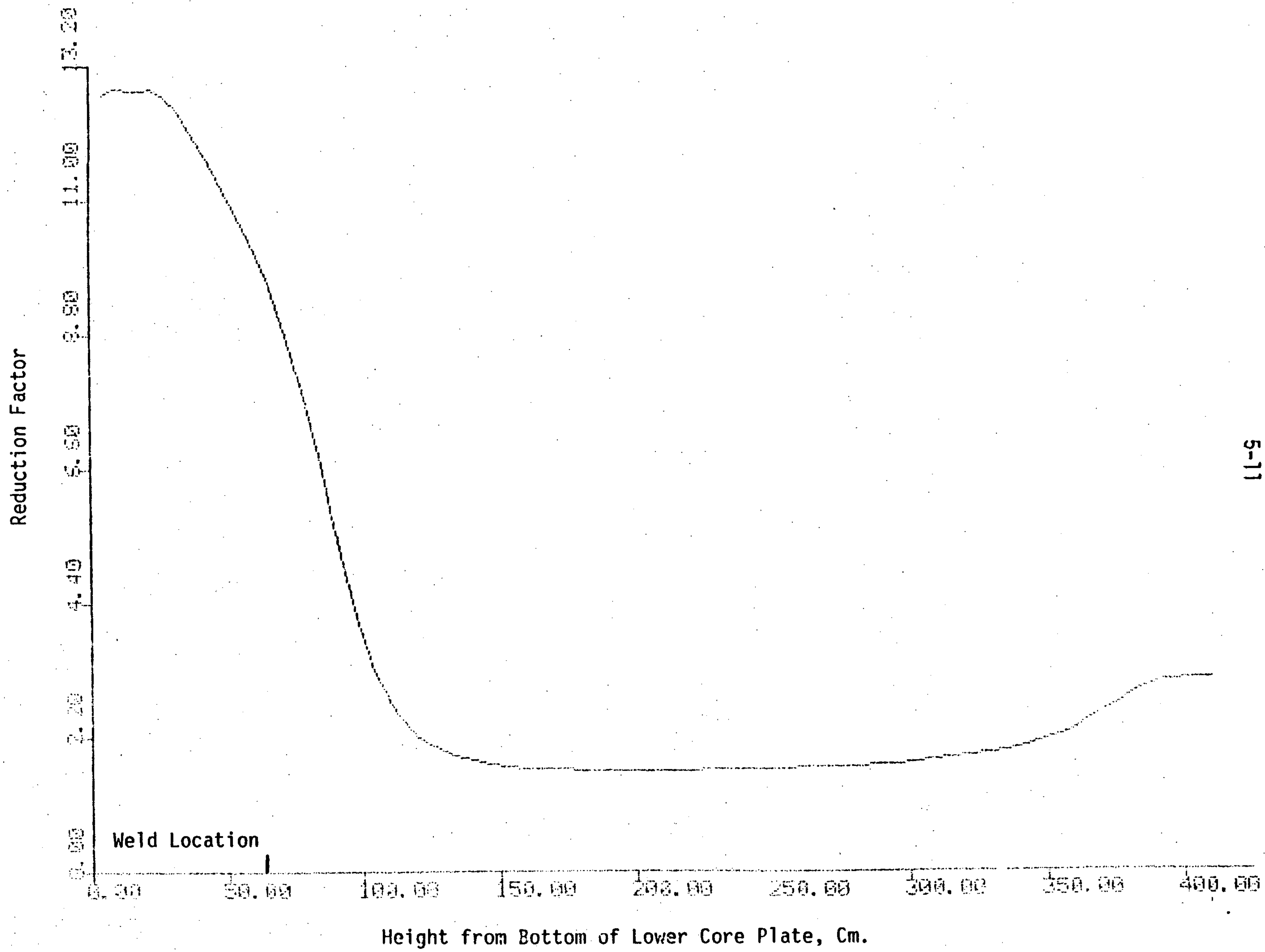


Figure 5-4. Axial Best Estimate Reduction Factor Distribution at the Center of the Core Flats.

flux (energy above 1 MeV) at the vessel inner surface for the Cycle 8 case is 7.015E+10 n/cm2 which is in excellent agreement with 6.882E+10 reported in Reference 1 for Capsule T measurements. The maximum along the lower circumferential weld for Cycle 8 is 6.396E+10 n/cm2 at the core major axis; at the corresponding lower weld position for Cycle 10 the flux is 6.958E+9, giving a reduction factor of 9.2. Vessel surface fluxes at the core midplane (major axis) are 6.977E+10 for Cycle 8 and 4.155E+10 for Cycle 10, both within 1 percent of maximum for the respective cases.

5.2 COMPARISON OF CYCLE 8 RESULTS WITH DOSIMETER MEASUREMENTS

Dosimeter cross-sections for detectors measured in HBR2 Capsules S, V, and T were computed with a spectrum from a 56-group ANISN-W calculation simulating the core major axis for the Cycle 8 case. The capsules were not modeled explicitly, and the spectrum was taken from the interface between the thermal shield outer surface and the downcomer water. Group cross-sections from the ELXSIR library were averaged as

$$\sigma\ (E>1\text{MeV}) = \sum_{g=1}^{56} \sigma_g\ \phi_g \Big/ \sum_{g=1}^{27} \phi_g$$

These cross-sections were used with the synthesis fluxes (energy above 1 MeV) at the capsule locations to give calculated saturation activities for each dosimeter. The results are shown in Table 5-4 and comparisons with corrected measurements made. The average percent difference between calculated and measured for all dosimeters is 1.1% with a standard deviation of 13.6%. The half-life of Mn-54 (313 days) is midrange compared to other dosimeters, and the reaction Fe54 (n,p) Mn54 generally

Table 5-4

Comparison of Calculated and Measured Saturation Activities for H. B. Robinson Surveillance Capsules

Reaction	X-section(2)	0 Deg(EOC8)	10 Deg(EOC1)	20 Deg(EOC3)
		Measured Saturated Activity(1)		
Cu(n,a)Co		7.525E+5	-	3.54E+5
Ni(n,p)Co		1.164E+8	-	4.833E+7
Fe(n,p)Mn		8.39E+6	4.77E+6	3.278E+6
U(n,f)Cs		1.297E+7	-	-
Np(n,f)Cs		8.565E+7	-	-
		Calculated Saturation Activities		
Cu(n,a)Co	.5545E-3	7.123E+5	-	2.904E+5
Ni(n,p)Co	.09287	1.2775E+8	-	5.209E+7
Fe(n,p)Mn	.06857	8.572E+6	6.147E+6	3.495E+6
U(n,f)Cs	.3484	1.087E+7	-	-
Np(n,f)Cs	2.879	9.313E+7	-	-
		Per Cent Difference (Calc-Meas)/Calc*100		
Cu(n,a)Co		-5.6	-	-22.1
Ni(n,p)Co		8.9	-	7.2
Fe(n,p)Mn		2.1	22.4	8.7
U(n,f)Cs		-19.3	-	-
Np(n,f)Cs		8.0	-	-
Calculated Flux(E>1Mev)		1.958E+11	1.404E+11	7.984E+10

(1) Section 4.3.4, Table 4-8

(2) Averaged over spectrum from 1-D 56-group ANISN (ELXSIR library) just outside thermal shield (no explicit model of capsules).

considered most reliable. The comparisons are 2.1% for capsule T, 8.7% for capsule V, and 22% for capsule S (EOC1). It is noted the Cycle 8 source distribution was least representative of Cycle 1.

5.3 PROJECTED FLUENCES AND RT-NDT

Based on the synthesis fluxes, fluences above 1 Mev at EOC 8 and at 27 EFPY and RT-NDT (27 EFPY) were computed for the vessel inner surface along the lower circumferential weld, along the core midplane, and axially at the major axis.

At EOC 8 the vessel had been exposed 7.2 EFPY; Cycle 9 was projected to add 0.8 EFPY at a flux reduction factor of 2. RT-NDT was computed with the limit formulas from SECY-82-465, Appendix E. The projection to 27EFPY is shown because it is the point at which the screening criteria is first reached by any part of the vessel. $RT\text{-}NDT_0$ was taken as -56F and the axial weld compositions of 0.27% Cu and 0.2% Ni were used. Maximum 0.35% Cu and 1.2% Ni were assumed for the girth welds. Results are tabulated in Table 5-1 for the lower girth weld and Table 5-3 for the beltline longitudinal weld. The fluences are plotted in Figures 5-5 through 5-7.

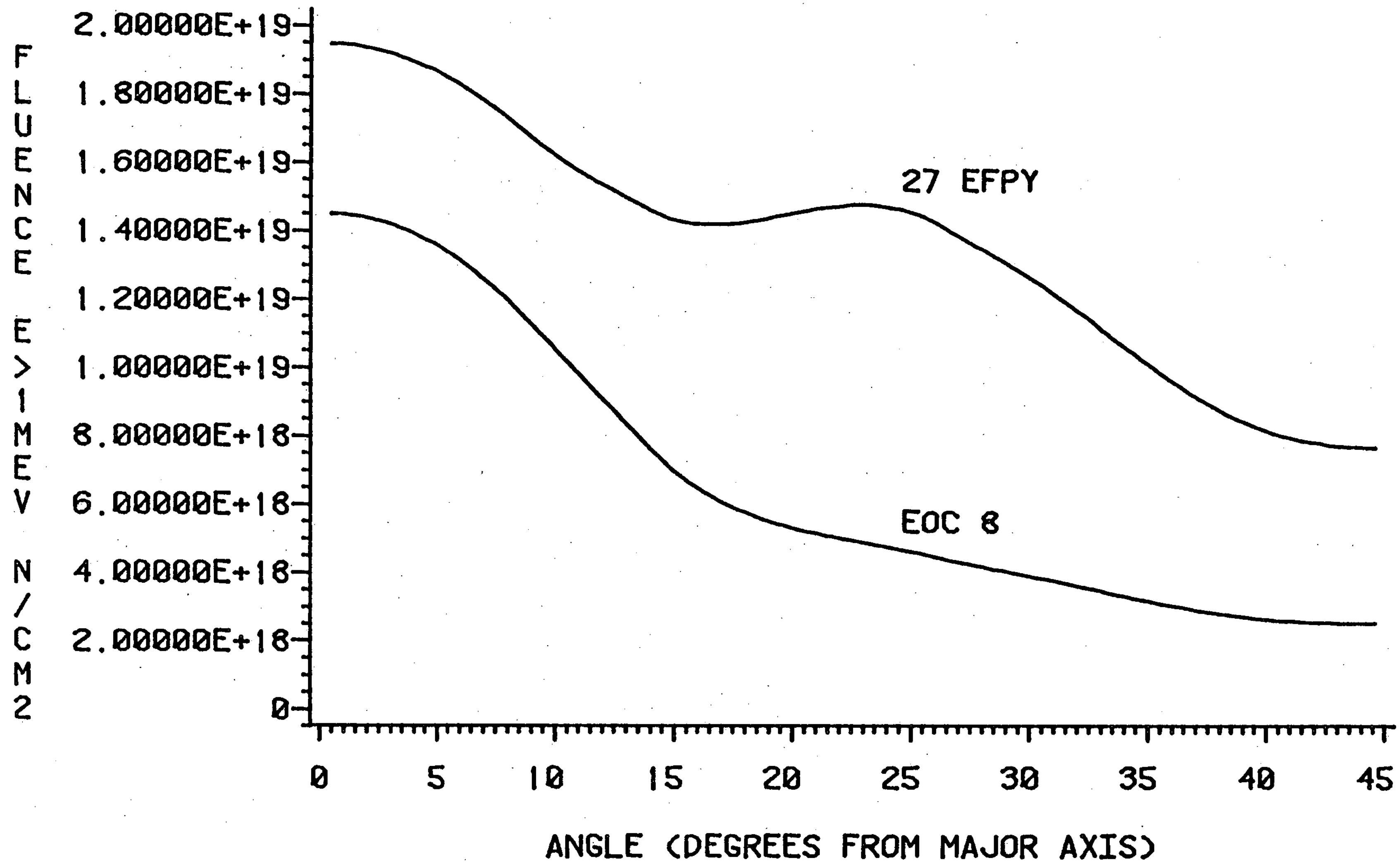
5.4 DISCUSSION AND CONCLUSIONS

5.4.1 Uncertainties and Sensitivities

Table 5-5 lists estimated uncertainties in the source calculations along with sensitivities determined for the synthesis-superposition technique for constructing 3-D fluxes. The bases for estimating uncertainties in

Figure 5-5

HBR2 CALCULATED FLUENCE (E>1MEV) BASED ON 36 IN. SHIELD HEIGHT
LOWER WELD INNER SURFACE



Fig[illegible]-6

HBR2 CALCULATED FLUENCE (E>1MEV) BASED ON 36 IN. SHIELD HEIGHT
CORE MIDPLANE INNER SURFACE

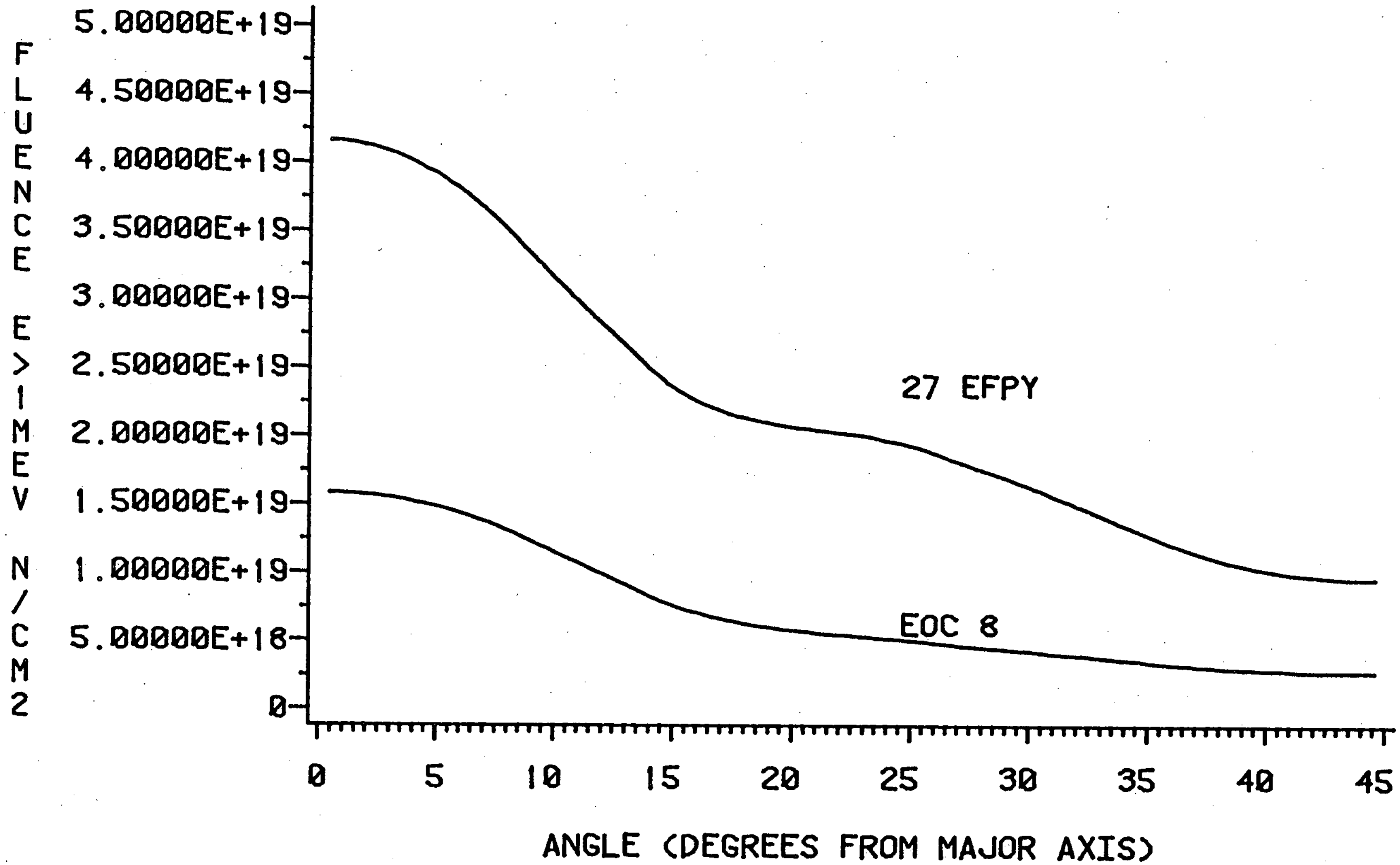
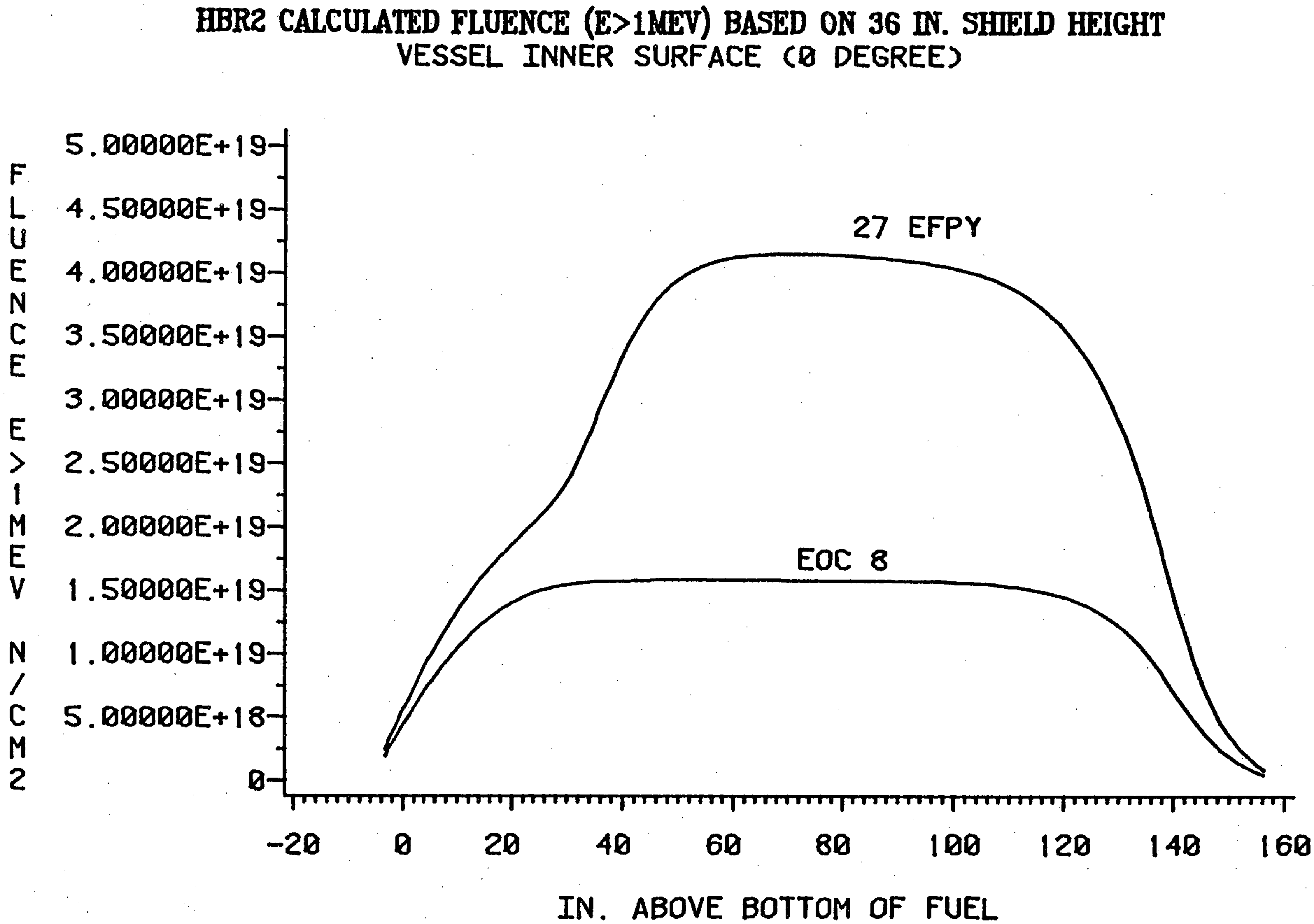


Figure 5-7


HBR2 CALCULATED FLUENCE (E>1MEV) BASED ON 36 IN. SHIELD HEIGHT
VESSEL INNER SURFACE (0 DEGREE)
FLUENCE E>1MEV N/CM2
5.00000E+19
4.50000E+19
4.00000E+19
3.50000E+19
3.00000E+19
2.50000E+19
2.00000E+19
1.50000E+19
1.00000E+19
5.00000E+18
0
27 EFPY
EOC 8
-20
0
20
40
60
80
100
120
140
160
IN. ABOVE BOTTOM OF FUEL

the sources are the comparisons with the averaged Cycle 8 power measurements, corroborated by the Cycle 9 state-point comparisons. The radial component contains additional uncertainty for pin distribution within an assembly. The superposition estimate is based on comparisons of fast flux at the vessel inner surface calculated first assuming the Cycle 8 case to be a one-axial region core and second assuming a two-axial region core. (The latter case was used for all comparisons with the Cycle 10 case and calculations of FRF.) The estimate for uncertainty in the synthesis is based on comparisons of fast flux at the vessel inner surface calculated for the Cycle 10 case first assuming separable axial and radial source distributions in the DOT R-Z and ANISN problems and second representing the axial distributions as a function of radius. (The latter more closely represents the actual case and was used for all comparisons with Cycle 8). This comparison gave differences ranging from less than 1% at the core midplane to 12% at the top and bottom of the problem. The 5% shown in Table 5-4 represents the region of the lower circumferential weld. The RMS combination of these estimates is 7.75%, which gives a 2-sigma uncertainty of 15.5% for calculated fluxes at the vessel inner surface, lower circumferential weld region.

Table 5-4 lists the calculated-measured differences of dosimeter saturation activities for the HBR2 measured capsules. All comparisons fall within $\sqrt{2}$ times the estimated calculational 2-sigma. This would be expected if measurement and calculational uncertainties are equal.

Table 5-5

ESTIMATED UNCERTAINTIES IN CALCULATED PRESSURE VESSEL SURFACE FLUXES

Radial Source Distribution	5.0%
Axial Source Distribution	3.0%
Synthesis Sensitivity	5.0%
Superposition Sensitivity	1.0%
RMS Combination	7.75%
2-Sigma	15.5%

5.4.2 Conservatisms

The synthesis calculations contain two major conservatisms with respect to calculated fluxes at the limiting vessel inner surfaces. First, water outside the core in the downcomer region was modeled at 575F instead of the nominal full power 547F. The density difference is approximately 4% and results in higher calculated fluxes to the vessel (in both the Cycle 8 and Cycle 10 cases). Second, the analysis was performed assuming a shield height of 36 in. in the PLSAs, whereas they are being fabricated to a height of 42 in. The flux reduction at the lower weld to be expected from the additional height is estimated by the FRF from the present calculation at 6 in. below the weld. This value is 10.7 and results in the calculated time to reach allowable RT-NDT increasing to 30 EFPY, more than 10% margin in the present calculations.

5.4.3 Conclusions

The use of the 42 in. stainless steel PLSA design on the core flats of HBR2 cores commencing with Cycle 10 will sufficiently shield critical welds to preclude reaching present screening criteria for pressure vessel RT-NDT before projected expiration of operating license.

APPENDIX A

Résumés of Key Personnel

WELDON KERMIT CANTRELL

Senior Engineer - Incore Analysis

EDUCATION:

North Carolina State University: B.S., Nuclear Engineering (1975)
Graduate Work 8/75 - 6/77

SUMMARY OF EXPERIENCE:

Mr. Cantrell's primary responsibilities with CP&L have centered around development of computer programs and methods for use in reactor design, operations, and fuel management support.

His early duties included neutronics design review, start-up support, and operations follow for H. B. Robinson Unit 2, a PWR. Considerable experience with the design codes, PDQ07, XPOSE(LEOPARD), and processors, on both IBM and CDC mainframes was attained. He maintained and verified the operations support codes, INCORE, TOTE, and FOLLOW; he wrote and implemented FDELTAI, a code automating calibration of ex-core detectors.

He participated in start-up physics tests at HBR2 for Cycles 6, 7, and 9. He helped develop and implement specific plant procedures for verifying reactivity measurements during these tests.

More recently he has worked on the benchmarking and validation of Scandpower's FMS codes, particularly the cross-section code, RECORD, and participated in preparation of CP&L's Topical Report on BWR Steady-State Analysis Methods.

Prior to joining CP&L, Mr. Cantrell worked as a graduate teaching assistant in the Nuclear Engineering Department, North Carolina State University.

PROFESSIONAL ACHIEVEMENTS AND ACTIVITIES:

Registered Professional Engineer, North Carolina, February 1982

Member American Nuclear Society

Member National Society of Professional Engineers

PROFESSIONAL ACHIEVEMENTS AND ACTIVITIES: (continued)

Member Professional Engineers of North Carolina

Member American Association for the Advancement of Science

PAPERS AND PUBLICATIONS:

W. K. Cantrell, et al, "The INCORE Code: Production Version PNR16010 and Auxiliary Codes Documentation," NF-1106.01, CP&L, March 1983.

K. E. Karcher, W. K. Cantrell, and D. W. Schroeder, "A Description and Validation of Steady-State Analysis Methods for Boiling Water Reactors: Topical Report," NF-1583.01, CP&L, February 1983.

R. R. Wojnarowski, W. K. Cantrell, and T. M. Dresser, "H. B. Robinson Unit 2 - Cycle 9 Startup Test Report," NF-908.01, CP&L, September 1982.

W. K. Cantrell, T. M. Dresser, and K. E. Kutcher, "H. B. Robinson Unit 2 Cycle 8 Startup and Operations Analysis," NF-1101.03, CP&L, October 1980.

W. K. Cantrell and T. M. Dresser, "Neutronics Analysis Techniques for H. B. Robinson Cycle 7 Design," NF-1101.03, CP&L, July 1980.

W. K. Cantrell, P. S. Shieh, and D. W. Schroeder, "B2C4 Reload Design Verification Using the SCANDPOWER BWR Model," NF-1101.03, NF-80-394, CP&L, June 1980.

W. K. Cantrell, P. S. Shieh, and D. W. Schroeder, "B1C3 Reload Design Verification Using the SCANDPOWER BWR Model," NF-1101.03, NF-80-283, CP&L, May 1980.

W. K. Cantrell, et al, "H. B. Robinson Unit 2 Nuclear Peaking Factor Uncertainties Cycles 4, 5, and 6," NF-1049, CP&L, December 1979.

T. M. Dresser and W. K. Cantrell, "H. B. Robinson Unit 2 Cycle 7 Startup Test Report," NF-908.01, CP&L, September 1979.

W. K. Cantrell and T. M. Dresser, "H. B. Robinson Unit 2 Cycle 7 Startup and Operations Neutronics Design Analysis," NF-1101.03, CP&L, September 1979.

PAPERS AND PUBLICATIONS: (continued)

W. K. Cantrell, "H. B. Robinson Unit 2 -- Cycle 6 Core Performance Report," NF-901.01, CP&L, May 1979.

T. M. Dresser and W. K. Cantrell, "H. B. Robinson Unit 2 Cycle 7 Safety Analysis and Fuel Management Design Review," NF-401.1003, CP&L, April 1979.

T. M. Dresser and W. K. Cantrell, "H. B. Robinson Unit 2 Cycle 6 Startup Test Report," NF-908.01, CP&L, June 1978.

T. M. Dresser and W. K. Cantrell, "H. B. Robinson Unit 2 Cycle 6 Neutronics Design Evaluation," NF-401.0903, CP&L, February 1978.

THOMAS MAXWELL DRESSER

Senior Engineer - Fuel Projects

EDUCATION:

University of Maryland: B.S., cum laude, Nuclear Engineering/
Computer Science (1979)

SUMMARY OF EXPERIENCE:

Mr. Dresser's background experience at CP&L centered around development of computer programs and methods for core design, operations, and fuel management of PWRs. His present responsibilities are in contract administration and procurement of nuclear fuel and related services in support of fuel cycle front end requirements.

His previous duties included neutronics design review, start-up support, and operations follow for the PWR, H. B. Robinson Unit 2. He gained extensive experience in the maintenance and verification of the nodal simulator, XTGPWR, and the cross-section generator, XPOSE(LEOPARD), in both IBM and CDC environments. He developed, benchmarked, and implemented the code system, EXSPACK, for plant computations of estimated critical position (ECP), xenon transient worth, and shutdown margin required boron concentration.

He participated in start-up physics tests at HBR2 for Cycles 6-9, serving as Start-up Engineer for Cycle 9.

Mr. Dresser is co-inventor of the Part Length Shield Assembly (PLSA) concept which maximizes local fast neutron shielding with minimal adverse impact to core performance.

Mr. Dresser worked extensively with EXXON Nuclear personnel in the development of the low leakage reload strategy for HBR2 Cycles 9 through 13. The strategy leads to extended equilibrium cycle length commencing with Cycle 11.

PROFESSIONAL ACHIEVEMENTS AND ACTIVITIES:

Member American Nuclear Society

Member Tau Beta Pi

THOMAS MAXWELL DRESSER (continued)

PAPERS AND PUBLICATIONS:

T. M. Dresser, "Feasibility of the Part Length Shield Assembly as a Flux Reduction Technique," NF-1111.05, CP&L, April 1983.

I. Z. Stone and T. M. Dresser, "Final Reload Design for H. B. Robinson Unit 2 Cycle 10, Batch XN-7, Region 13," PWR:043:82, ENC, December 1982.

R. R. Wojnarowski and T. M. Dresser, "FOLLOW (PNR07010) Documentation," NF-1101.01A, NF-2183.008, October 1982.

R. R. Wojnarowski, W. K. Cantrell, and T. M. Dresser, "H. B. Robinson Unit 2 Cycle 9 Startup Test Report," NF-908.01, CP&L, September 1982.

T. M. Dresser, "H. B. Robinson Unit 2 Cycle 8 Core Performance Report," NF-901.01, CP&L, April 1982.

T. M. Dresser, "CP&L's CDC Version of XTGPWR," NF-1101.01, CP&L, December 1981.

T. M. Dresser, "EXSPACK (PNR02010): The Estimated critical position/ Xenon transient/ Shutdown margin, PACKage Program and Users' Manual," NF-1106.01, CP&L, December 1980.

W. K. Cantrell, T. M. Dresser, and K. E. Kutcher, "H. B. Robinson Unit 2 Cycle 8 Startup and Operations Analysis," NF-1101.03, CP&L, October 1980.

W. K. Cantrell and T. M. Dresser, "Neutronics Analysis Techniques for H. B. Robinson Cycle 7 Design," NF-1101.03, CP&L, July 1980.

T. M. Dresser and W. K. Cantrell, "H. B. Robinson Unit 2 Cycle 7 Startup Test Report," NF-908.01, CP&L, September 1979.

W. K. Cantrell and T. M. Dresser, "H. B. Robinson Unit 2 Cycle 7 Startup and Operations Neutronics Design Analysis," NF-1101.03, CP&L, September 1979.

T. M. Dresser and W. K. Cantrell, "H. B. Robinson Unit 2 Cycle 7 Safety Analysis and Fuel Management Design Review," NF-401.1003, CP&L, April 1979.

T. M. Dresser and W. K. Cantrell, "H. B. Robinson Unit 2 Cycle 6 Startup Test Report," NF-908.01, CP&L, June 1978.

T. M. Dresser and W. K. Cantrell, "H. B. Robinson Unit 2 Cycle 6 Neutronics Design Evaluation," NF-401.0903, CP&L, February 1978.

JAMES C. ROBINSON

Vice President, Products Group

EDUCATION:

The University of Tennessee: B.S., Nuclear Engineering (1960)

The University of Tennessee: M.S., Nuclear Engineering (1961)

The University of Tennessee: Ph.D., Engineering Science (1966)

SUMMARY OF EXPERIENCE:

Dr. Robinson is a founder of TEC and is Vice President of Products. He also serves as a senior advisor in company instrumentation development activities, field services, and surveillance and diagnostics activities.

Prior to the founding of TEC, Dr. Robinson was a full Professor of Nuclear Engineering at The University of Tennessee. He served as a consultant to the Development Section of the Instrumentation and Controls Division of the Oak Ridge National Laboratory from 1964 to 1976. He played a significant role in establishing the reputation of that group as the center of excellence for noise analysis as applied to surveillance and diagnostic activities to the nuclear power industry.

In addition to surveillance and diagnostic activities, Dr. Robinson has been active in analytical methods development activities. This includes the application of finite element methods to nuclear analysis, variational approximate methods applied to integral parameters, sensitivity analysis, generalized perturbation theory, and the development of space-time kinetics codes.

Dr. Robinson also has contributed significantly to the determination of reactivity from (a) rod drops (inverse kinetics methods), (b) noise analysis, and (c) modified source multiplication techniques. The thrust of the development was toward large fast reactors, but the methodology is applicable to large thermal systems as well.

An internationally recognized expert in the fields of (a) methods development and (b) surveillance and diagnostics, Dr. Robinson is the author of many papers in these areas.

PROFESSIONAL ACHIEVEMENTS AND ACTIVITIES:

Member, American Society for Engineering Educators

Member and Fellow of American Nuclear Society

Reviewer for Nuclear Science and Engineering and other technical publications

Registered Professional Engineer, State of Tennessee

CLYDE W. CRAVEN, JR.

Vice President, Director of Engineering Programs

EDUCATION:

University of Tennessee: B.S., Nuclear Engineering (1961)

University of Tennessee: M.S., Nuclear Engineering (1963)

University of Tennessee: Ph.D., Engineering Sciences (1965)

SUMMARY OF EXPERIENCE:

At Technology for Energy Corporation (TEC), Dr. Craven is responsible for the overall marketing of engineered systems and services to electric utilities and the government sector.

Before employment at TEC, Dr. Craven was the Director of Engineering Technology at System Development Corporation. He directed a nationwide staff of the Systems Management and Engineering Division.

Previous to his employment at System Development Corporation, Dr. Craven was Vice President of Science Applications, Inc. (SAI). At SAI he was the program manager for their initial involvement in the Department of Energy's Strategic Petroleum Reserve (SRP) program which entailed direction of environmental impact statements for various alternative oil storage sites.

Before employment at SAI, Dr. Craven worked for the Oak Ridge National Laboratory (ORNL). At ORNL he was Director of the Regional and Urban Studies Department and was responsible for developing and directing engineering, political science, and legal research programs.

PROFESSIONAL ORGANIZATIONS, HONORS, AND AWARDS:

American Society Engineering Management
American Association for the Advancement of Science
American Nuclear Society
Listed in Who's Who in the Southwest

PUBLICATIONS:

Approximately 20 publications in the fields of systems analysis, nuclear cross sections, reactor physics, and regional environmental systems analysis.

ROBERT S. HOWELL

Supervisor, Nuclear Engineering Section

EDUCATION:

The University of Tennessee (Chattanooga): B.A., Physics (1971)

Texas A&M University: M.S., Health Physics/Nuclear Engineering (1972)

The University of Tennessee: Ph.D., Nuclear Engineering (1981)

SUMMARY OF EXPERIENCE:

At TEC Dr. Howell is the supervisor of the Nuclear Engineering Section and specializes in particle transport, criticality analysis, and radiation protection. He is responsible for development of Class A atmospheric dispersion and dose assessment model capabilities for nuclear power plant emergency response facilities, and has been actively involved in engineering analysis (including detector response correlations), for incorporation in emergency plans. He has served as the project engineer on several projects, including a recent CRBR hypothetical core disruptive accident analysis.

Prior to joining TEC, he was employed as a Staff Scientist with Science Applications, Inc. Responsibilities in the area of radiation shielding included such analyses as (1) the Clinch River Breeder Reactor Coolant Pipe Chaseway neutron streaming benchmark using the MORSE/BREESE Monte Carlo code, (2) discrete ordinates analysis of radiation dose rates within a proposed spent fuel storage facility, and (3) radiation dose assessments within the reactor containment building of WPPSS Units 1 and 4 using a mixed albedo-full transport Monte Carlo model. Typical criticality safety analyses included both unit and interaction analyses under accident and normal conditions for a variety of equipment and areas within the GE fuel fabrication plant.

As an applied Health Physicist at Oak Ridge National Laboratory, Dr. Howell's major responsibilities included providing general health physics services and consultation to research and craft personnel within the thermonuclear, reactor, and environmental science research areas; at the 86 in. cyclotron; and at various high-level hot cell facilities (fission products and curium) during cell decontamination.

Prior to employment at ORNL, he served as the Senior Health Physicist for a joint NASA/USAF contractor at the Kennedy Space Center/Cape Canaveral Air Force Station. Major responsibilities included implementation of the radiation protection program; providing health physics services and technical consultation; preparation and review of technical documents and operating procedures pertaining to radiation protection; and preparation of contingency plans for use and launch of multi-hundred thousand curie plutonium sources.

PROFESSIONAL ACHIEVEMENTS AND ACTIVITIES:

American Nuclear Society

Health Physics Society

Society for Risk Analysis

HANCHANG H. CHEN (JOHN)

Nuclear Engineer

EDUCATION:

National Tsing Hua University: B.S., Nuclear Engineering (1970)

National Tsing Hua University: M.S., Nuclear Engineering (1973)

The University of Tennessee: Ph.D., Nuclear Engineering (1980)

SUMMARY OF EXPERIENCE:

Dr. Chen, as a nuclear engineer in the Nuclear Engineering Department, is responsible for engineering work involving the analyses of pressure vessel neutron fluence using AMPX, ANISN, and DOT-IV, the calculation of source term release rate calculations for atmospheric effluents, the assessment of radiological doses associated with emergency (NUREG-0654) and routine (10CFR50, Appendix I) conditions, and the development of an atmospheric dispersion and dose assessment capability for nuclear power plant emergencies.

Prior to his current position, Dr. Chen was a systems engineer in the Digital Systems Department. He was responsible for system software development, testing and integration for the computer-based gaseous effluent monitoring system.

Prior to assuming his current position, Dr. Chen was involved in research and development work which included designing and implementing a computer-based signal conditioning system; heat transfer and thermal analyses; implementing computer software for digital filtering; and developing and implementing a transient, 2-D discrete-element model for the simulation of radionuclide transport by groundwater flow.

Dr. Chen also had primary responsibility for a project involving groundwater migration of buried low-level radioactive waste. He has developed and implemented a computer code for plume element atmospheric transport and dispersion for the radiological dose assessment due to the release of radioactive gaseous effluents and later implemented an atmospheric dispersion computer code on a minicomputer.

Prior to joining TEC, Dr. Chen was an instructor of nuclear engineering at Tsing Hua University, Taiwan. His teaching and research fields included digital system and logic circuit design, minicomputer hardware and software systems, design and implementation of computer interfaces, and software consultation projects.

HANCHANG H. CHEN (continued)

PROFESSIONAL ACHIEVEMENTS AND ACTIVITIES:

Member of the Honor Society of Phi Kappa Phi

Member of the American Nuclear Society

PUBLICATIONS:

"Neutron Activation Analysis of Underground Water in the Wells of Blackfeet Disease Affected Area in Taiwan," J. Nucl. Sci. Taiwan, 1974.

"Sensitivity Analysis for Transport of Radionuclide in a Groundwater Flow System," Trans. Am. Nucl. Soc., Vol. 39, p. 498 (1981).

WILLIAM M. SIMPKINS

Staff Engineer

EDUCATION:

The University of Tennessee: B.S., Nuclear Engineering (1979)

The Univeristy of Tennessee: M.S., Nuclear Engineering (1981)

SUMMARY OF EXPERIENCE:

While at TEC, Mr. Simpkins' primary responsibilities have included performing both neutronics and thermal hydraulic calculations using large computer systems as well as software development for micro/mini computer based systems.

Mr. Simpkins has aided in the investigation of alternate reloading schemes for the Clinch River Breeder Reactor (CRBR) using a two dimensional neutron transport code. He has been responsible for determining the propagation of a neutron pulse through the CRBR shield using a one dimensional, time dependent neutron transport code. He has aided in the implementation of a two dimensional pebble bed reactor thermal hydraulic code on the IBM 360.

Mr. Simpkins has assisted in the software development for a PDP-11 based rotating machinery analysis system. He has been responsible for the software development for a microcomputer "INTEL 8080" based gaseous effluent radiation monitor. He performed both a thermal and a stress analysis for an irradiation capsule to be inserted into the Oak Ridge Reactor. He has aided in the analysis of experimental gamma thermometer data to determine the thermometer sensitivity.

Prior to joining TEC, Mr. Simpkins was employed as a research assistant at The University of Tennessee. He was responsible for software development for microcomputer-based surveillance systems. Programming languages included PDP-11 assembler and Fortran.

PROFESSIONAL ACHIEVEMENTS AND ACTIVITIES:

Member, Tau Beta Pi Honor Society

MARK L. WILLIAMS

Oak Ridge National Laboratory, Consultant

EDUCATION:

Louisiana State University: B.S., Engineering Science (1973)

Georgia Institute of Technology: M.S., Nuclear Engineering (1974)

The University of Tennessee: Ph.D., Nuclear Engineering (1979)

SUMMARY OF EXPERIENCE:

Performed shielding analysis for Fast Flux Test Facility, Clinch River Breeder Reactor, Gas Cooled Fast Reactor, and totamak fusion reactor.

Performed LMFBR core physics studies.

Developed time-dependent perturbation theory for reactor burn-up calculations.

In charge of multi-year project funded by the Electric Power Research Institute (EPRI) to improve reactor physics codes used by utilities for LWR analysis.

Participated in study to determine radiation damage to PWR pressure vessels (Benchmarked LEPRICON to the Arkansas Nuclear One Reactor).

PROFESSIONAL ACHIEVEMENTS AND ACTIVITIES:

Tau Beta Pi, Phi Kappa Phi, American Nuclear Society, biographical listing in International Biography, Who's Who in the South and Southwest.

Thermal Reactor Data Testing Committee of Cross-Section Evaluation Working Group (CSEWG); reviewer for Nuclear Science and Engineering and Nuclear Technology journals; lecturer University of Tennessee short-course on "Computational Methods in Nuclear Engineering"; Contributing author to CRC Handbook of Nuclear Reactor Calculations; ORNL student coordinator for Engineering Physics Division.

APPENDIX B

AXFRAC Source Listing

AXFRAC SOURCE LISTING

AXFRAC

SOURCE

LISTING

$$LASER4T   16.32.13. 08/09/83 $$$

```
      PROGRAM AXFRAC (INPUT,OUTPUT,PUNCH,TAPE5=INPUT,
     1                TAPE6=OUTPUT,TAPE7=PUNCH)
C     CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      PURPOSE:  1.   TO SPLIT SOURCE POWERS FOR INPUT TO DOTSOR ACCORDIN
C                     TO AXIAL DISTRIBUTIONS FROM XTG.  (FOR HBR#2)
C                2.   TO GENERATE R-Z AND R NEUTRON SOURCE DENSITIES ALON
C                     FLATS FOR INPUT TO DOT AND ANISN
C
C      INPUT:   (TAPE5)
C                  1.  BOTTOM RELATIVE POWERS FROM PDQ7 FOR 37 XY SOURCES
C                  2.  TOP RELATIVE POWERS FROM PDQ7 FOR 37 XY SOURCES
C                  3.  KAPPA/NU CORRECTIONS FOR LOWER SE OCTANT
C                  4.  # OF R,# OF Z,Z# FUEL STARTS,Z# PLSA ENDS,Z# FUEL STO
C                              R-MESH (CM), Z-MESH (CM)
C                  5.  XTG AXIAL DISTRIBUTIONS  FROM CP&L
C
C      OUTPUT:  (TAPE6)
C                   1.  TOTAL, BOTTOM 3FT, AND TOP 9FT SOURCES FOR INPUT TO
C                       DOTSOR X-Y 9** ARRAY AND R-T 11** ARRAY.
C                   2.  TOTAL, BOTTOM, AND TOP SOURCES FOR R-Z DOT (98** ARRA
C                   3.  ENERGY DEPENDENT R SOURCES FOR R ANISN
C
C      REFERENCE:  W.K.CANTRELL   7/30/83
C
C     CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      DIMENSION CARD(12),FB(26),FT(26),AX(24),XY(37),RT(23),VXY(37)
      DIMENSION BXY(37),BRT(23),TXY(37),TRT(23),IXY(37),IRT(23),JRT(23)
      DIMENSION AKNU(26)
      DIMENSION AXO(87,24),DRMESH(100),DZMESH(100),PRMESH(125),
     1          XZMESH(24),IRM(15),RZSOR(78,93),BRSOR(79),TRSOR(79),
     2          DUM(24),CHI(56),ROUT(78),RZBXY(37),RZTXY(37),
     3          PINB(8),PINT(8),CARD1(12)
C
      DATA XY/37*0.0/
      DATA RT/23*0.0/
      DATA BRT/23*0.0/
      DATA TRT/23*0.0/
      DATA VXY/0.25,8*0.5,7*1.0,0.5,8*1.0,0.5,6*1.0,0.5,6*1.0/
      DATA IXY/1,2,4,7,11,16,21,26,2,3,5,8,12,17,22,28,3,11,6,9,13,
     1          18,23,4,12,20,10,14,19,24,5,13,21,14,15,20,99/
      DATA IRT/99,10,13,14,15,16,17,18,19,20,21,22,23,24,25,26,7*1/
      DATA JRT/99,27,21,28,35,6,14,22,29,36,7,15,23,30,8,16,7*1/
      DATA IRM/1,2,5,8,13,18,25,32,41,50,59,68,75,82,85/
      DATA PRMESH/0.71501,124*1.43002/
      DATA XZMESH/24*15.24/
      DATA CHI /4.075E-5,1.760E-4,3.389E-4,7.300E-4,2.528E-3,1.465E-3,
     1          4.270E-3,2.985E-3,1.343E-2,3.145E-2,5.016E-2,3.227E-2,
     2          7.716E-2,4.356E-2,2.267E-2,2.313E-2,1.956E-2,3.927E-3,
     3          2.372E-2,2.385E-2,4.772E-2,2.368E-2,4.655E-2,4.505E-2,
     4          4.306E-2,4.074E-2,7.384E-2,3.269E-2,2.993E-2,2.723E-2,
     5          4.684E-2,3.766E-2,4.221E-2,2.054E-2,2.522E-2,7.653E-3,
     6          1.653E-2,2.602E-3,2.174E-3,3.329E-3,3.917E-3,8.184E-4,
     7          9.280E-4,1.935E-4,2.288E-4,6.048E-4,2.511E-4,2.921E-4,
     8          8.192E-5,9.511E-5,2.685E-5,3.093E-5,2.728E-5,4.330E-7,
     9          1.530E-8,0.      /
C
      READ (5,*) BXY
      READ (5,*) TXY
      READ (5,*) AKNU
      READ (5,*) NR,NZ,NFS,NPLSA,NFE
      READ (5,*) (DRMESH(I),I=1,NR),(DZMESH(I),I=1,NZ)
      WRITE (6,470) BXY
```

```
      WRITE (6,480) TXY
      WRITE (6,490) AKNU
C
C
C       COMPUTE CORE AVG RELATIVE DIST. (75-25 TOP-BOTTOM SPLIT)
C
      DO 110 I=1,36
      XY(I)=BXY(I)*0.25+TXY(I)*0.75
  110 CONTINUE
C       CONVERT PD07 RELATIVE DIST. TO MWT
C       CORRECT FOR DIFFERENCES IN KAPPA/NU
C
      AMW=2300.0/157.0
      DO 120 I=1,37
      RZBXY(I)=BXY(I)
      RZTXY(I)=TXY(I)
      J=IXY(I)
      BXY(I)=VXY(I)*XY(I)*AKNU(J)*AMW
      TXY(I)=VXY(I)*XY(I)*AKNU(J)*AMW
  120 CONTINUE
C
C       PUT AVERAGE POWER IN R-T ZONE 1
C
      BRT(1)=3.1415927/8.0*70.0*70.0+12.5*(8.486*2.54)**2
      BRT(1)=157.0/8.0*(8.486*2.54)**2-BRT(1)
      BRT(1)=BRT(1)/((8.486*2.54)**2)*AKNU(6)*AMW
      TRT(1)=BRT(1)
C
C       CORRESPOND X-Y AND R-T SOURCES
C
      DO 130 I=2,16
      J=JRT(I)
      BRT(I)=BXY(J)
      TRT(I)=TXY(J)
      IF (I.EQ.2.OR.I.EQ.5) BRT(I)=BRT(I)/2.0
      IF (I.EQ.2.OR.I.EQ.5) TRT(I)=TRT(I)/2.0
  130 CONTINUE
C
C       READ AXIAL DISTRIBUTIONS AND SUM INTO BOTTOM AND TOP FRACTIONS
C
      READ (5,500) CARD
      WRITE (6,510) CARD
      READ (5,500) ARD
      READ (5,500) ARD
      READ (5,500) ARD
      READ (5,500) ARD
      DO 160 I=1,26
      READ (5,*) M,J,AX
      WRITE (6,520) M,J,AX
      SUM=0.0
      DO 140 K=19,24
      SUM=SUM+AX(K)
  140 CONTINUE
      FB(I)=SUM
      SUM=0.0
      DO 150 K=1,18
      SUM=SUM+AX(K)
  150 CONTINUE
      FT(I)=SUM
  160 CONTINUE
C
C       DISTRIBUTE RADIAL DISTRIBUTIONS BY AXIAL FRACTIONS AND SUM
C
      DO 170 L=1,36
      J=IXY(L)
      BXY(L)=BXY(L)*FB(J)
      TXY(L)=TXY(L)*FT(J)
      XY(L)=BXY(L)+TXY(L)
  170 CONTINUE
      F1=0.0
      DO 180 L=1,9
      F1=F1+FB(L)
      F2=F2+FT(L)
  180 CONTINUE
      F1=F1+FB(11)+FB(12)
      F1=F1/11.0
      F2=F2+FT(11)+FT(12)
      F2=F2/11.0
      BRT(1)=BRT(1)*F1
      TRT(1)=TRT(1)*F2
      RT(1)=TRT(1)+BRT(1)
      DO 190 L=2,16
      J=IRT(L)
      BRT(L)=BRT(L)*FB(J)
      TRT(L)=TRT(L)*FT(J)
      RT(L)=BRT(L)+TRT(L)
  190 CONTINUE
C
C       COMPUTE R-Z PIN AND NODAL MESH
C
      DO 200 I=1,126
      PRMESH(I)=PRMESH(I-1)+PRMESH(I)
  200 CONTINUE
      XZMESH(1)=XZMESH(1)+DZMESH(NFS)
      DO 210 I=2,24
      XZMESH(I)=XZMESH(I-1)+XZMESH(I)
  210 CONTINUE
C
C       ECHO R-Z INPUT
C
      WRITE (6,530) PRMESH,XZMESH,(DRMESH(I),I=1,NR)
      WRITE (6,540) (DZMESH(I),I=1,NZ)
      WRITE (6,550) NR,NZ,NFS,NPLSA,NFE,CHI
C
C       READ QUARTER-ASSEMBLY AXIAL DISTRIBUTIONS AND INVERT
C
      READ (5,500) CARD1
      WRITE (6,510) CARD1
      READ (5,500) ARD
      READ (5,500) ARD
      READ (5,500) ARD
      READ (5,500) ARD
      DO 220 I=1,87
      READ (5,520) M,MM,(AXO(I,J),J=1,24)
      WRITE (6,520) M,MM,(AXO(I,J),J=1,24)
  220 CONTINUE
      DO 250 I=1,87
      DO 230 J=1,24
      K=25-J
      DUM(K)=AXO(I,J)
  230 CONTINUE
      DO 240 J=1,24
      AXO(I,J)=DUM(J)
  240 CONTINUE
  250 CONTINUE
C
C       COMPUTE PDO SOURCE DENSITY ALONG FLATS
C
      DO 280 I=1,8
      J=IXY(I)
      PINB(I)=RZBXY(I)*AKNU(J)*AMW
      PINT(I)=RZTXY(I)*AKNU(J)*AMW
```

```
C
C       COMPUTE R-Z SOURCE
C
      NEND=NFE-1
      NREND=NR-1
      DO 320 J=NFS,NEND
      DO 270 L=1,24
      IF (DZMESH(J).LT.XZMESH(L)) GO TO 280
  270 CONTINUE
  280 CONTINUE
      DO 310 I=1,NREND
      DO 290 M=1,125
      IF (DRMESH(I).LT.PRMESH(M)) GO TO 300
  290 CONTINUE
  300 CONTINUE
C
C       PICK AXIAL DISTRIBUTION BEHIND PLSA
C
      IO=IRM(M/8+1)
      IF (M.GT.114) GO TO 310
      IF (M.LE.114) MP=8
      IF (M.LE.98) MP=7
      IF (M.LE.83) MP=6
      IF (M.LE.68) MP=5
      IF (M.LE.53) MP=4
      IF (M.LE.38) MP=3
      IF (M.LE.23) MP=2
      IF (M.LE.8) MP=1
C
      IF (L.LE.6) SPIN=PINB(MP)
      IF (L.GT.6) SPIN=PINT(MP)
      VF=1.0/((8.466*2.54)**2*15.24)
      RZSOR(I,J)=SPIN*AXO(IO,L)*VF
  310 CONTINUE
  320 CONTINUE
C
C       INTEGRATE FOR R SOURCE
C
      IR=NR-1
      IZ=NZ-1
      NPLSAM=NPLSA-1
      DO 350 I=1,IR
      DO 330 J=1,NPLSAM
      BRSOR(I)=BRSOR(I)+RZSOR(I,J)*(DZMESH(J+1)-DZMESH(J))
  330 CONTINUE
      DO 340 J=NPLSA,NEND
      TRSOR(I)=TRSOR(I)+RZSOR(I,J)*(DZMESH(J+1)-DZMESH(J))
  340 CONTINUE
  350 CONTINUE
C
C       WRITE RESULTS
C
      WRITE (6,560) CARD
      DO 360 I=1,36
      J=IXY(I)
      WRITE (6,570) I,BXY(I),TXY(I),XY(I),FB(J),FT(J)
  360 CONTINUE
      WRITE (6,570) I,BXY(37),TXY(37),XY(37)
      TOTB=0.0
      TOTT=0.0
      TOT=0.0
      DO 370 I=1,37
      TOTB=TOTB+BXY(I)
      TOTT=TOTT+TXY(I)
      TOT=TOT+XY(I)
  370 CONTINUE
      WRITE (6,580) TOTB,TOTT,TOT
      WRITE (6,590) CARD
      I=1
      WRITE (6,570) I,BRT(1),TRT(1),RT(1),F1,F2
      DO 380 I=2,16
      J=IRY(I)
      WRITE (6,570) I,BRT(I),TRT(I),RT(I),FB(J),FT(J)
  380 CONTINUE
      DO 390 I=17,23
      WRITE (6,570) I,BRT(I),TRT(I),RT(I)
  390 CONTINUE
      TOTB=0.0
      TOTT=0.0
      TOT=0.0
      DO 400 I=1,23
      TOTB=TOTB+BRT(I)
      TOTT=TOTT+TRT(I)
      TOT=TOT+RT(I)
  400 CONTINUE
      WRITE (6,580) TOTB,TOTT,TOT
      WRITE (6,600) CARD
      WRITE (6,610) BXY
      WRITE (6,620) CARD
      WRITE (6,610) TXY
      WRITE (6,630) CARD
      WRITE (6,610) XY
      WRITE (6,640) CARD
      WRITE (6,650) BRT
      WRITE (6,660) CARD
      WRITE (6,650) TRT
      WRITE (6,670) CARD
      WRITE (6,650) RT
      WRITE (6,680) CARD1
      WRITE (6,690) ((RZSOR(I,J),I=1,IR),J=1,IZ)
      WRITE (6,700) CARD1
      WRITE (6,690) ((RZSOR(I,J),I=1,IR),J=1,NPLSAM)
      NZUP=IZ-NPLSA
      WRITE (6,710) IR,NZUP,IR
      WRITE (6,720) CARD1
      NPLSA2=NPLSA-2
      WRITE (6,730) IR,NPLSA2,IR
      WRITE (6,690) ((RZSOR(I,J),I=1,IR),J=NPLSA,IZ)
      WRITE (6,740) CARD1
      DO 420 I=1,27
      DO 410 J=1,IR
      ROUT(J)=CHI(I)*BRSOR(J)
  410 CONTINUE
      WRITE (6,750) I,(ROUT(J),J=1,IR)
  420 CONTINUE
      WRITE (6,760) CARD1
      DO 440 I=1,27
      DO 430 J=1,IR
      ROUT(J)=CHI(I)*TRSOR(J)
  430 CONTINUE
      WRITE (6,750) I,(ROUT(J),J=1,IR)
  440 CONTINUE
      WRITE (6,770) CARD1
      DO 460 I=1,27
      DO 450 J=1,IR
      ROUT(J)=CHI(I)*(TRSOR(J)+BRSOR(J))
  450 CONTINUE
      WRITE (6,750) I,(ROUT(J),J=1,IR)
  460 CONTINUE
      STOP
C
```

```
C                                                                       AXF 658
  470 FORMAT (1H1/" ECHO OF INPUT:"//" BOTTOM X-Y DISTRIBUTION",8F8.3/24AXF 660
     1X,8F8.3/24X,7F8.3/24X,7F8.3/24X,6F8.3,18X,F8.3)                   AXF 662
  480 FORMAT (//"      TOP X-Y DISTRIBUTION",8F8.3/24X,8F8.3/24X,7F8.3/24XAXF 664
     1,7F8.3/24X,6F8.3,18X,F8.3)                                        AXF 666
  490 FORMAT (//"      KAPPA/NU CORRECTIONS",F8.3/24X,2F8.3/24X,3F8.3/24X,AXF 668
     14F8.3/24X,5F8.3/24X,5F8.3/24X,4F8.3/24X,2F8.3)                    AXF 670
  500 FORMAT (12A6)                                                     AXF 672
  510 FORMAT (//12A6///)                                                AXF 674
  520 FORMAT (2I3,2X,8F9.5,2(/,8X,8F9.5))                               AXF 676
  530 FORMAT (1H1//" ECHO OF INPUT FOR R-Z SOURCES:"//" PDQ PIN MESH:"/1AXF 678
     12(10F9.3/),5F9.3,//" XTG Z MESH:"/4(8F9.3/)//" DOT R MESH:"/10(10FAXF 680
     29.3/))                                                            AXF 682
  540 FORMAT (/" DOT Z MESH (BOTTOM TO TOP):"/10(10F9.3/))              AXF 684
  550 FORMAT (//" DOT R MESHES ",I5/" DOT Z MESHES ",I5/" FUEL STARTS ",AXF 686
     1I5/" PLSA ENDS",I5/" FUEL ENDS ",I5//" CHI (U235):"/6(10X,10E12.5/AXF 688
     2))                                                                AXF 690
  560 FORMAT (1H1," OUTPUT BEGINS:",//1H ,12A6/" FRACTIONS OF ASSEMBLY PAXF 692
     1OWER IN BOTTOM 3FT AND TOP 9FT OF CORE"////" XY SOR",T10,"BOTTOM",AXF 694
     2T25,"TOP",T40,"TOTAL",T55,"FRAC-B",T70,"FRAC-T"//)                AXF 696
  570 FORMAT (I5,T10,F8.4,T25,F8.4,T40,F8.4,T55,F8.4,T70,F8.4)          AXF 698
  580 FORMAT (/" TOTAL",T10,F8.4,T25,F8.4,T40,F8.4,T55,F8.4,T70,F8.4)   AXF 700
  590 FORMAT (1H1////1H ,12A6/" FRACTIONS OF R-THETA POWER IN BOTTOM 3FTAXF 702
     1 AND TOP 9FT OF CORE"////" R-T SOR",T10,"BOTTOM",T25,"TOP",T40,"TOAXF 704
     2TAL",T55,"FRAC-B",T70,"FRAC-T"//)                                 AXF 706
  600 FORMAT (1H1" CARDS FOR R-T DOTSOR:"///" 9**"/" '",12A6,"BOTTOM")  AXF 708
  610 FORMAT (6E12.5)                                                   AXF 710
  620 FORMAT (/////" 9**"/" '",12A6," TOP")                             AXF 712
  630 FORMAT (/////" 9**"/" '",12A6," TOTAL")                           AXF 714
  640 FORMAT (1H1///" 11**"/" '",12A6,"BOTTOM")                         AXF 716
  650 FORMAT (6E12.5)                                                   AXF 718
  660 FORMAT (/////" 11**"/" '",12A6," TOP")                            AXF 720
  670 FORMAT (/////" 11**"/" '",12A6," TOTAL")                          AXF 722
  680 FORMAT (1H1" SOURCE CARDS FOR R-Z DOT:"///" 86**"/" '",12A6,"TOTALAXF 724
     1")                                                                AXF 726
  690 FORMAT (6E12.5)                                                   AXF 728
  700 FORMAT (1H1//" 86**"/" '",12A6,"BOTTOM")                          AXF 730
  710 FORMAT (I3,"Z",I3"Q",I2)                                          AXF 732
  720 FORMAT (1H1//" 86**"/" '",12A6,"TOP")                             AXF 734
  730 FORMAT (I3,"Z",I3"Q",I2)                                          AXF 736
  740 FORMAT (1H1" SOURCE CARDS FOR ANISN :"///" 17**"/" '",12A6,"BOTTOMAXF 738
     1")                                                                AXF 740
  750 FORMAT (" 'GROUP",I3/(6E12.5))                                    AXF 742
  760 FORMAT (1H1//" 17**"/" '",12A6,"TOP")                             AXF 744
  770 FORMAT (1H1//" 17**"/" '",12A6,"TOTAL")                           AXF 746
      END                                                               AXF 748
```

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  MFA    U.C.C. NOS/BE L584  V1.6.08.2 23/08/83
16.30.55.LASER4T   FROM      9V
16.30.55.IP   00003848 WORDS - FILE INPUT   , DC 04
16.30.55.LASER,P2. LASER
16.30.55.ACCOUNT,GK7TEC,*---*.
16.30.55.REWIND,OUTPUT.
16.30.55.ROUTE,OUTPUT,DEF,TID=2D.
16.30.55.UCC,BANNER,AXFRAC,SOURCE,LISTING.
16.32.14.COPYBR,INPUT,AA.
16.32.14.COPYBR,INPUT,BB.
16.32.15.REWIND,AA,BB.
16.32.15.COPYSBF,BB,OUTPUT.
16.32.15.BEGIN,PPRINT,,I=OUTPUT,H=AA,FORM=2UP,COP
16.32.15.IES=1.
16.32.17.AT CY= 124 SN=GLOBAL
16.32.20.
16.32.20. COPYRIGHT, 1981, UNIVERSITY COMPUTING C
16.32.20.OMPANY.
16.32.20. REPRODUCTION PROHIBITED UNLESS SPECIFIC
16.32.20.ALLY
16.32.20. AUTHORIZED BY SEPERATE WRITING.
16.32.20.
16.32.20.RETURN,ZZZZZIN,ZZZZZPO,DAYFILE,DAYFIL.
16.32.20.IFE(FILE(AA,AS),H1)
16.32.20.COPYBR,AA,ZZZZZIN.
16.32.21.ENDIF,H1.
16.32.21.COPY,ZZZZZP1,ZZZZZIN.
16.32.21.RETURN,ZZZZZP1.
16.32.21.UCC,BANNER(D=ZZZZZIN, ,BIN,54)
16.32.23.REWIND,OUTPUT.
16.32.23.COPY,OUTPUT,ZZZZZIN.
16.32.24.IFE((T.AND.(OT.NE.TXO)),OLOOP)
16.32.24.SUMMARY.
16.32.24.MS    58496  WORDS  (    68736 MAX USED)
16.32.24.MM    300008 MAX SCM
16.32.24.CPR        1.135
16.32.24.IOR         .471
16.32.24.SRU        1.607
16.32.24.                       DATE 09/09/83
16.32.24.DAYFIL.
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