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SINGLE-CHANNEL CONTINUOUS-TRIAL-FUNCTION CALCULATIONS IN A FAST REACTOR CONFIGURATION

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ABSTRACT

A series of two-dimensional synthesis calculations using the SYN2D module of the ARC system with continuous trial functions have been performed for a typical LMFBR configuration. The procedure has produced remarkably accurate values of a variety of physically significant reactor parameters.

INTRODUCTION

A series of two-dimensional synthesis calculations using the SYN2D module of the ARC system with continuous trial functions has been performed for a reactor model similar to a LMFBR configuration. The object of the calculations was to investigate the quality of the synthesis results that can be obtained in this situation for a variety of one-dimensional trial function choices.

REACTOR CONFIGURATION

The reactor model chosen for this study is the reactor described in Ref. 1. This model is similar in many aspects to a typical 1000-MWe LMFBR design. The dimensions of the reactor and its subdivision in major regions are shown in Fig. 1, where one-quarter of the configuration is depicted in r-z coordinates.

For the neutronic calculations, both synthesis and finite-difference, the reactor isotopic compositions were specified in more detail as shown in Fig. 2 and in Tables I and II, where the geometrical layout of the finer region structure and its isotopic compositions are specified. Table I gives a beginning-of-cycle (BOC) isotopic composition and Table II gives the middle-of-cycle (MOC) composition.

The calculations in this study were performed using six energy groups whose boundaries are listed in Table III. The cross sections used are from the 29601 cross section set, which is a 6-group set obtained from an original 29-group set prepared for FFTF studies, called the 29001 set.[2]

The first step in the calculations was to obtain two-dimensional fluxes and the corresponding values of k_{eff}, power fractions, and regional and total breeding ratios using a regular finite difference approximation to the problem. The values obtained were then used as standard or "exact" values against which the various synthesis results were compared. The ARC modules DIF2D[3] and INVENT,[4] which perform two-dimensional diffusion calculations and inventories respectively, were used to obtain these parameters.

SYNTHESIS CALCULATIONS

The synthesis calculations in this study are of the single-channel continuous-trial function type; there is only one expansion of the flux in terms of trial functions, which applies over the entire axial domain. Galerkin weighting was employed throughout.

Five trial functions were used. All of them were one-dimensional radial flux shapes, obtained with the DIF1D[5] module of the ARC system, using the five different radial MOC compositions in the reactor (see Fig. 2.).

Trial Function 1 is the one-dimensional flux in an infinitely long cylinder with radial compositions and dimensions identical to those in the core region of the reactor, starting with CZA1, CZA2, . . ., and ending with the reflector region DEFRD. Trial Functions 2, 3, and 4 are the one-dimensional fluxes in infinitely long cylinders with radial compositions and dimensions identical to those in the first, second, and third axial blanket regions starting with compositions ABA11, ABA21, and ABA31, respectively. Trial function 5 is a reflector trial function using only the reflector composition across the REFAX region, in which a volume source proportional to the fission source generated in calculating Trial Function 4 was introduced.

Using these five trial functions, a series of synthesis calculations was performed for the MOC configuration (Table II). Trial Function 1, the one based upon core compositions, was present in all the calculations performed. Table IV simmarizes some typical k_{eff} results obtained.

The values obtained are quite good for the calculations with five, three, and even two trial functions. The last, and surprisingly good, calculation using only one trial function shows the importance of the core contribution to k_{eff}.

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Using these five trial functions, a series of synthesis calculations was performed for the MOC configuration (Table II). Trial Function 1, the one based upon core compositions, was present in all the calculations performed. Table IV summarizes some typical k_{eff} results obtained.

The values obtained are quite good for the calculations with five, three, and even two trial functions. The last, and surprisingly good, calculation using only one trial function shows the importance of the core contribution to k_{eff}.

The values of regional breeding ratios for the regions are shown in Fig. 1. The total breeding ratios were calculated with the INVENT[4] module using the fluxes from the two-dimensional calculation and synthesis calculations 1, 2, and 7. These values, together with the regional power fractions, peak power, peak power location, and k_{eff}, are listed in Table V. The synthesis results, especially those using five trial functions, are remarkably accurate. The errors never exceed a few percent and generally are well under 1%.

One more synthesis calculation was performed, using five trial functions, to test the ability of the trial functions obtained for the middle-of-cycle conditions to synthesize fluxes corresponding to an appreciably different burnup stage of the same reactor. This calculation used the same five trial functions previously described to expand the flux corresponding to the beginning-of-cycle composition given in Table I. The results are listed in Table VI. As expected, the accuracy obtained is clearly less in this case. Nevertheless, most of the values obtained are still within a few percent of the corresponding two-dimensional results. Quantities such as k_{eff}, peak power, and peak power location are predicted quite well.

CONCLUSIONS

The continuous synthesis procedure using a few one-dimensional trial functions has produced remarkably accurate values of a variety of physically significant reactor parameters. When the trial functions are used in a model with appreciably different compositions than the model for which they were calculated, the results, even though still acceptable are, as expected, of lower quality. This implies that synthesis methods could be used for fuel cycle calculations, employing trial functions computed for a single stage in the cycle.

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The values of radiant brightness ratios for the regions are shown in Fig. 1. The total brightness ratios were calculated with the DATAN(4) module using the fluxes from the two-dimensional calculation and synthesis calculations 1, 2, and 7. These values, together with the peaking power fractions, peak power location, and k_{eff}, are tabulated in Table V. The synthesis results, especially those using five trial functions, are remarkably accurate. The error never exceed a few percent and generally are well under 1%.

One more synthesis calculation was performed, using five trial functions, to test the ability of the trial functions obtained for the multi-cycle conditions to synthesize fluxes corresponding to a very markedly different burnup stage of the same reactor. This calculation used the same five trial functions previously determined to expand the flux corresponding to the beginning-of-cycle conditions given in Table I. The results are listed in Table VI. As expected, the accuracy obtained is slightly less in this case. Nevertheless, most of the values obtained are still within a few percent of the corresponding two-dimensional results. Quantities such as k_{eff}, peak power, and peak power location are predicted quite well.

CONCLUSIONS

The continuous synthesis procedure using a few one-dimensional trial functions has produced remarkably accurate values of a variety of physically significant reactor parameters. When the trial functions are used in a model with appreciably different composition than the model for which they were calculated, the results, even though still acceptable as expected, of lower quality. This implies that synthesis methods could be used for real cycle calculations, employing trial functions computed for a single stage in the cycle.

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TABLE I. Beginning-of-Cycle Isotopic Composition

				M1	U238	M7	O 16		
				M2	PU239	M8	LUFP		
				M3	PU240	M9	TA181		
				M4	PU241	M10	SS		
				M5	PU242	M11	NA 23		
				M6	U235				
CZA1	M1	0.75784E-02M2	0.83804E-03M3	0.36211E-03		ABA11	M1	0.10105E-01M2	0.17053E-03M3	0.60418E-05
CZA1	M4	0.13721E-03M5	0.48331E-04M6	0.18432E-04		ABA11	M4	0.10980E-06M5	0.16767E-08M6	0.26626E-04
CZA1	M7	0.11817E-05M8	0.27026E-03M9	0.0		ABA11	M7	0.10580E-05M8	0.40138E-04M9	0.0
CZA1	M10	0.12709E-01M11	0.83235E-02			ABA11	M10	0.12709E-01M11	0.83235E-02	
CZA2	M1	0.75797E-02M2	0.83795E-03M3	0.36204E-03		ABA12	M1	0.10106E-01M2	0.16984E-03M3	0.59887E-05
CZA2	M4	0.13731E-03M5	0.48314E-04M6	0.18450E-04		ABA12	M4	0.10835E-06M5	0.16465E-08M6	0.26643E-04
CZA2	M7	0.11775E-05M8	0.26897E-03M9	0.0		ABA12	M7	0.10538E-05M8	0.39865E-04M9	0.0
CZA2	M10	0.12709E-01M11	0.83235E-02			ABA12	M10	0.12709E-01M11	0.83235E-02	
CZA3	M1	0.75833E-02M2	0.83769E-03M3	0.36188E-03		ABA13	M1	0.10109E-01M2	0.16803E-03M3	0.58493E-05
CZA3	M4	0.13755E-03M5	0.48270E-04M6	0.18499E-04		ABA13	M4	0.10458E-06M5	0.15685E-08M6	0.26690E-04
CZA3	M7	0.11666E-05M8	0.26556E-03M9	0.0		ABA13	M7	0.10426E-05M8	0.39147E-04M9	0.0
CZA3	M10	0.12709E-01M11	0.83235E-02			ABA13	M10	0.12709E-01M11	0.83235E-02	
CZA4	M1	0.75893E-02M2	0.83724E-03M3	0.36159E-03		ABA14	M1	0.10113E-01M2	0.16497E-03M3	0.56177E-05
CZA4	M4	0.13797E-03M5	0.48194E-04M6	0.18582E-04		ABA14	M4	0.98424E-07M5	0.14435E-08M6	0.26769E-04
CZA4	M7	0.11480E-05M8	0.25989E-03M9	0.0		ABA14	M7	0.10237E-05M8	0.37959E-04M9	0.0
CZA4	M10	0.12709E-01M11	0.83235E-02			ABA14	M10	0.12709E-01M11	0.83235E-02	
CZA5	M1	0.75975E-02M2	0.83654E-03M3	0.36116E-03		ABA15	M1	0.10119E-01M2	0.16056E-03M3	0.52910E-05
CZA5	M4	0.13856E-03M5	0.48082E-04M6	0.18702E-04		ABA15	M4	0.89946E-07M5	0.12763E-08M6	0.26883E-04
CZA5	M7	0.11209E-05M8	0.25191E-03M9	0.0		ABA15	M7	0.99627E-06M8	0.36307E-04M9	0.0
CZA5	M10	0.12709E-01M11	0.83235E-02			ABA15	M10	0.12709E-01M11	0.83235E-02	
CZA6	M1	0.76093E-02M2	0.83543E-03M3	0.36046E-03		ABA16	M1	0.10126E-01M2	0.15441E-03M3	0.48462E-05
CZA6	M4	0.13937E-03M5	0.47915E-04M6	0.18867E-04		ABA16	M4	0.78835E-07M5	0.10660E-08M6	0.27042E-04
CZA6	M7	0.10824E-05M8	0.24148E-03M9	0.0		ABA16	M7	0.95719E-06M8	0.34188E-04M9	0.0
CZA6	M10	0.12709E-01M11	0.83235E-02			ABA16	M10	0.12709E-01M11	0.83235E-02	
CZA7	M1	0.76262E-02M2	0.83305E-03M3	0.35894E-03		ABA17	M1	0.10143E-01M2	0.14334E-03M3	0.41071E-05
CZA7	M4	0.14059E-03M5	0.47598E-04M6	0.19127E-04		ABA17	M4	0.61485E-07M5	0.75964E-09M6	0.27329E-04
CZA7	M7	0.10175E-05M8	0.22743E-03M9	0.0		ABA17	M7	0.88726E-06M8	0.30460E-04M9	0.0
CZA7	M10	0.12709E-01M11	0.83235E-02			ABA17	M10	0.12709E-01M11	0.83235E-02	
CZB1	M1	0.70911E-02M2	0.10794E-02M3	0.49265E-03		ABB11	M1	0.10165E-01M2	0.12698E-03M3	0.31276E-05
CZB1	M4	0.19772E-03M5	0.65478E-04M6	0.18074E-04		ABB11	M4	0.40825E-07M5	0.43520E-09M6	0.27758E-04
CZB1	M7	0.85488E-06M8	0.26360E-03M9	0.0		ABB11	M7	0.78202E-06M8	0.25360E-04M9	0.0
CZB1	M10	0.12709E-01M11	0.83235E-02			ABB11	M10	0.12709E-01M11	0.83235E-02	
CZB2	M1	0.71164E-02M2	0.10828E-02M3	0.49127E-03		ABB12	M1	0.10187E-01M2	0.11032E-03M3	0.22605E-05
CZB2	M4	0.20090E-03M5	0.64885E-04M6	0.18483E-04		ABB12	M4	0.25070E-07M5	0.22461E-09M6	0.28198E-04
CZB2	M7	0.76086E-06M8	0.23335E-03M9	0.0		ABB12	M7	0.67170E-06M8	0.20969E-04M9	0.92000E-03
CZB2	M10	0.12709E-01M11	0.83235E-02			ABB12	M10	0.12709E-01M11	0.83235E-02	
CZC1	M1	0.70302E-02M2	0.10704E-02M3	0.49606E-03		ABC11	M1	0.10122E-01M2	0.16136E-03M3	0.41347E-05
CZC1	M4	0.18858E-03M5	0.67083E-04M6	0.16956E-04		ABC11	M4	0.60782E-07M5	0.77699E-09M6	0.26866E-04
CZC1	M7	0.11113E-05M8	0.23849E-03M9	0.0		ABC11	M7	0.98613E-06M8	0.34491E-04M9	0.0
CZC1	M10	0.12709E-01M11	0.83235E-02			ABC11	M10	0.12709E-01M11	0.83235E-02	
RB11	M1	0.11736E-01M2	0.20283E-03M3	0.57890E-05		RB12	M1	0.11854E-01M2	0.11454E-03M3	0.18243E-05
RB11	M4	0.93499E-07M5	0.13265E-08M6	0.30778E-04		RB12	M4	0.16507E-07M5	0.12622E-09M6	0.33088E-04
RB11	M7	0.12518E-05M8	0.43070E-04M9	0.0		RB12	M7	0.72607E-06M8	0.15169E-04M9	0.0
RB11	M10	0.23618E-01M11	0.38901E-02			RB12	M10	0.23618E-01M11	0.38901E-02	
RB21	M1	0.11813E-01M2	0.15134E-03M3	0.31784E-05		RB22	M1	0.11893E-01M2	0.84732E-04M3	0.10140E-05
RB21	M4	0.37344E-07M5	0.38096E-09M6	0.32127E-04		RB22	M4	0.67472E-08M5	0.37952E-10M6	0.33842E-04
RB21	M7	0.98386E-06M8	0.18651E-04M9	0.0		RB22	M7	0.56874E-06M8	0.68236E-05M9	0.0
RB21	M10	0.23618E-01M11	0.38901E-02			RB22	M10	0.23618E-01M11	0.38901E-02	

Table I (Contd.)

ABA21	M1	0.10189E-01M2	0.11249E-03M3	0.26851E-05
ABA21	M4	0.32359E-07M5	0.31796E-09M6	0.28130E-04
ABA21	M7	0.72976E-06M8	0.16140E-04M9	0.0
ABA21	M10	0.12709E-01M11	0.83235E-02	
ABA22	M1	0.10190E-01M2	0.11201E-03M3	0.26609E-05
ABA22	M4	0.31923E-07M5	0.31217E-09M6	0.28142E-04
ABA22	M7	0.72668E-06M8	0.16031E-04M9	0.0
ABA22	M10	0.12709E-01M11	0.83235E-02	
ABA23	M1	0.10191E-01M2	0.11073E-03M3	0.25974E-05
ABA23	M4	0.30786E-07M5	0.29720E-09M6	0.28175E-04
ABA23	M7	0.71849E-06M8	0.15744E-04M9	0.0
ABA23	M10	0.12709E-01M11	0.83235E-02	
ABA24	M1	0.10194E-01M2	0.10857E-03M3	0.24920E-05
ABA24	M4	0.28928E-07M5	0.27318E-09M6	0.28231E-04
ABA24	M7	0.70464E-06M8	0.15268E-04M9	0.0
ABA24	M10	0.12709E-01M11	0.83235E-02	
ABA25	M1	0.10198E-01M2	0.10547E-03M3	0.23428E-05
ABA25	M4	0.26369E-07M5	0.24099E-09M6	0.28311E-04
ABA25	M7	0.68447E-06M8	0.14606E-04M9	0.0
ABA25	M10	0.12709E-01M11	0.83235E-02	
ABA26	M1	0.10203E-01M2	0.10113E-03M3	0.21387E-05
ABA26	M4	0.22597E-07M5	0.20025E-09M6	0.28424E-04
ABA26	M7	0.65565E-06M8	0.13746E-04M9	0.0
ABA26	M10	0.12709E-01M11	0.83235E-02	
ABA27	M1	0.10214E-01M2	0.92346E-04M3	0.17602E-05
ABA27	M4	0.17163E-07M5	0.13484E-09M6	0.28653E-04
ABA27	M7	0.59784E-06M8	0.11923E-04M9	0.0
ABA27	M10	0.12709E-01M11	0.83235E-02	
ABB21	M1	0.10230E-01M2	0.79176E-04M3	0.12621E-05
ABB21	M4	0.10407E-07M5	0.68628E-10M6	0.29004E-04
ABB21	M7	0.50995E-06M8	0.92395E-05M9	0.0
ABB21	M10	0.12709E-01M11	0.83235E-02	
ABB22	M1	0.10244E-01M2	0.67425E-04M3	0.87389E-06
ABB22	M4	0.59867E-08M5	0.32564E-10M6	0.29319E-04
ABB22	M7	0.42707E-06M8	0.74864E-05M9	0.92000E-03
ABB22	M10	0.12709E-01M11	0.83235E-02	
ABC21	M1	0.10207E-01M2	0.99220E-04M3	0.15892E-05
ABC21	M4	0.14431E-07M5	0.11073E-09M6	0.28495E-04
ABC21	M7	0.62739E-06M8	0.12827E-04M9	0.0
ABC21	M10	0.12709E-01M11	0.83235E-02	
RB13	M1	0.11905E-01M2	0.69018E-04M3	0.67828E-06
RB13	M4	0.37410E-08M5	0.17143E-10M6	0.34268E-04
RB13	M7	0.45006E-06M8	0.62227E-05M9	0.0
RB13	M10	0.23618E-01M11	0.38901E-02	
RB23	M1	0.11936E-01M2	0.51255E-04M3	0.38602E-06
RB23	M4	0.15859E-08M5	0.54692E-11M6	0.34705E-04
RB23	M7	0.35532E-06M8	0.29638E-05M9	0.0
RB23	M10	0.23618E-01M11	0.38901E-02	
ABA31	M1	0.10242E-01M2	0.70238E-04M3	0.11130E-05
ABA31	M4	0.86508E-08M5	0.53776E-10M6	0.29195E-04
ABA31	M7	0.48191E-06M8	0.65764E-05M9	0.0
ABA31	M10	0.12709E-01M11	0.83235E-02	
ABA32	M1	0.10242E-01M2	0.69925E-04M3	0.11028E-05
ABA32	M4	0.85328E-08M5	0.52791E-10M6	0.29204E-04
ABA32	M7	0.47980E-06M8	0.65333E-05M9	0.0
ABA32	M10	0.12709E-01M11	0.83235E-02	
ABA33	M1	0.10243E-01M2	0.69095E-04M3	0.10762E-05
ABA33	M4	0.82254E-08M5	0.50248E-10M6	0.29225E-04
ABA33	M7	0.47419E-06M8	0.64201E-05M9	0.0
ABA33	M10	0.12709E-01M11	0.83235E-02	
ABA34	M1	0.10245E-01M2	0.67698E-04M3	0.10319E-05
ABA34	M4	0.77226E-08M5	0.46158E-10M6	0.29262E-04
ABA34	M7	0.46470E-06M8	0.62319E-05M9	0.0
ABA34	M10	0.12709E-01M11	0.83235E-02	
ABA35	M1	0.10247E-01M2	0.65682E-04M3	0.96900E-06
ABA35	M4	0.70271E-08M5	0.40654E-10M6	0.29315E-04
ABA35	M7	0.45084E-06M8	0.59684E-05M9	0.0
ABA35	M10	0.12709E-01M11	0.83235E-02	
ABA36	M1	0.10250E-01M2	0.62847E-04M3	0.88215E-06
ABA36	M4	0.61030E-08M5	0.33626E-10M6	0.29390E-04
ABA36	M7	0.43084E-06M8	0.56226E-05M9	0.0
ABA36	M10	0.12709E-01M11	0.83235E-02	
ABA37	M1	0.10255E-01M2	0.56491E-04M3	0.70429E-06
ABA37	M4	0.43512E-08M5	0.21331E-10M6	0.29561E-04
ABA37	M7	0.38627E-06M8	0.48007E-05M9	0.0
ABA37	M10	0.12709E-01M11	0.83235E-02	
ABB31	M1	0.10268E-01M2	0.46905E-04M3	0.47374E-06
ABB31	M4	0.23957E-08M5	0.95639E-11M6	0.29822E-04
ABB31	M7	0.31826E-06M8	0.35469E-05M9	0.0
ABB31	M10	0.12709E-01M11	0.83235E-02	
ABB32	M1	0.10277E-01M2	0.39221E-04M3	0.31466E-06
ABB32	M4	0.12926E-08M5	0.41722E-11M6	0.30034E-04
ABB32	M7	0.26009E-06M8	0.28320E-05M9	0.92000E-03
ABB32	M10	0.12709E-01M11	0.83235E-02	
ABC31	M1	0.10256E-01M2	0.57715E-04M3	0.56456E-06
ABC31	M4	0.30573E-08M5	0.13750E-10M6	0.29554E-04
ABC31	M7	0.38036E-06M8	0.49293E-05M9	0.0
ABC31	M10	0.12709E-01M11	0.83235E-02	
RB14	M1	0.11942E-01M2	0.39723E-04M3	0.23920E-06
RB14	M4	0.78545E-09M5	0.21225E-11M6	0.35016E-04
RB14	M7	0.27023E-06M8	0.25315E-05M9	0.0
RB14	M10	0.23618E-01M11	0.38901E-02	
RB24	M1	0.11953E-01M2	0.29878E-04M3	0.14211E-06
RB24	M4	0.35766E-09M5	0.74721E-12M6	0.35251E-04
RB24	M7	0.21796E-06M8	0.13042E-05M9	0.0
RB24	M10	0.23618E-01M11	0.38901E-02	
REFAX	M10	4.26485E-02M11	1.0952 E-02	
REFRD	M10	7.8857 E-02M11	1.65375E-03	

(Slot 1)

TABLE II. Middle-of-Cycle Isotopic Composition

				M1	U238	M7	O 16		
				M2	PU239	M8	LUFP		
				M3	PU240	M9	TA181		
				M4	PU241	M10	SS		
				M5	PU242	M11	NA 23		
				M6	U235				
CZA1	M1	0.72268D-02M2	0.87732D-03M3	0.38228D-03	ABA11	M1	0.98658D-02M2	0.35007D-03M3	0.17292D-04
CZA1	M4	0.11058D-03M5	0.54023D-04M6	0.13058D-04	ABA11	M4	0.45742D-06M5	0.11319D-07M6	0.21840D-04
CZA1	M7	0.23803D-05M8	0.58751D-03M9	0.0 D+00	ABA11	M7	0.22527D-05M8	0.92241D-04M9	0.0 D+00
CZA1	M10	0.12709D-01M11	0.83235D-02		ABA11	M10	0.12709D-01M11	0.83235D-02	
CZA2	M1	0.72307D-02M2	0.87714D-03M3	0.38210D-03	ABA12	M1	0.98688D-02M2	0.34816D-03M3	0.17096D-04
CZA2	M4	0.11082D-03M5	0.53978D-04M6	0.13105D-04	ABA12	M4	0.44588D-06M5	0.11065D-07M6	0.21891D-04
CZA2	M7	0.23696D-05M8	0.58383D-03M9	0.0 D+00	ABA12	M7	0.22406D-05M8	0.91336D-04M9	0.0 D+00
CZA2	M10	0.12709D-01M11	0.83235D-02		ABA12	M10	0.12709D-01M11	0.83235D-02	
CZA3	M1	0.72407D-02M2	0.87664D-03M3	0.38164D-03	ABA13	M1	0.98767D-02M2	0.34310D-03M3	0.16581D-04
CZA3	M4	0.11145D-03M5	0.53860D-04M6	0.13232D-04	ABA13	M4	0.43028D-06M5	0.10410D-07M6	0.22023D-04
CZA3	M7	0.23412D-05M8	0.57417D-03M9	0.0 D+00	ABA13	M7	0.22087D-05M8	0.88964D-04M9	0.0 D+00
CZA3	M10	0.12709D-01M11	0.83235D-02		ABA13	M10	0.12709D-01M11	0.83235D-02	
CZA4	M1	0.72573D-02M2	0.87577D-03M3	0.38084D-03	ABA14	M1	0.98898D-02M2	0.33458D-03M3	0.15729D-04
CZA4	M4	0.11250D-03M5	0.53660D-04M6	0.13444D-04	ABA14	M4	0.39845D-06M5	0.93716D-08M6	0.22247D-04
CZA4	M7	0.22934D-05M8	0.55815D-03M9	0.0 D+00	ABA14	M7	0.21545D-05M8	0.85058D-04M9	0.0 D+00
CZA4	M10	0.12709D-01M11	0.83235D-02		ABA14	M10	0.12709D-01M11	0.83235D-02	
CZA5	M1	0.72807D-02M2	0.87443D-03M3	0.37964D-03	ABA15	M1	0.99085D-02M2	0.32231D-03M3	0.14537D-04
CZA5	M4	0.11401D-03M5	0.53365D-04M6	0.13749D-04	ABA15	M4	0.35516D-06M5	0.80082D-08M6	0.22577D-04
CZA5	M7	0.22241D-05M8	0.53585D-03M9	0.0 D+00	ABA15	M7	0.20758D-05M8	0.79656D-04M9	0.0 D+00
CZA5	M10	0.12709D-01M11	0.83235D-02		ABA15	M10	0.12709D-01M11	0.83235D-02	
CZA6	M1	0.73117D-02M2	0.87228D-03M3	0.37774D-03	ABA16	M1	0.99336D-02M2	0.30543D-03M3	0.12948D-04
CZA6	M4	0.11603D-03M5	0.52932D-04M6	0.14164D-04	ABA16	M4	0.29987D-06M5	0.63557D-08M6	0.23017D-04
CZA6	M7	0.21270D-05M8	0.50700D-03M9	0.0 D+00	ABA16	M7	0.19652D-05M8	0.72717D-04M9	0.0 D+00
CZA6	M10	0.12709D-01M11	0.83235D-02		ABA16	M10	0.12709D-01M11	0.83235D-02	
CZA7	M1	0.73574D-02M2	0.86766D-03M3	0.37362D-03	ABA17	M1	0.99713D-02M2	0.27914D-03M3	0.10585D-04
CZA7	M4	0.11910D-03M5	0.52110D-04M6	0.14823D-04	ABA17	M4	0.22309D-06M5	0.42454D-08M6	0.23719D-04
CZA7	M7	0.19627D-05M8	0.46734D-03M9	0.0 D+00	ABA17	M7	0.17857D-05M8	0.63278D-04M9	0.0 D+00
CZA7	M10	0.12709D-01M11	0.83235D-02		ABA17	M10	0.12709D-01M11	0.83235D-02	
CZB1	M1	0.69689D-02M2	0.10580D-02M3	0.50307D-03	ABB11	M1	0.10019D-01M2	0.24452D-03M3	0.77451D-05
CZB1	M4	0.17133D-03M5	0.70584D-04M6	0.14604D-04	ABB11	M4	0.14077D-06M5	0.22684D-08M6	0.24667D-04
CZB1	M7	0.15873D-05M8	0.52098D-03M9	0.0 D+00	ABB11	M7	0.15381D-05M8	0.52410D-04M9	0.0 D+00
CZB1	M10	0.12709D-01M11	0.83235D-02		ABB11	M10	0.12709D-01M11	0.83235D-02	
CZB2	M1	0.69238D-02M2	0.10634D-02M3	0.49822D-03	ABB12	M1	0.10071D-01M2	0.20615D-03M3	0.51542D-05
CZB2	M4	0.17915D-03M5	0.68975D-04M6	0.15629D-04	ABB12	M4	0.76969D-07M5	0.99924D-09M6	0.25729D-04
CZB2	M7	0.13432D-05M8	0.44344D-03M9	1.4964 D-03	ABB12	M7	0.12658D-05M8	0.40646D-04M9	0.92000D-03
CZB2	M10	0.12709D-01M11	0.83235D-02		ABB12	M10	0.12709D-01M11	0.83235D-02	
CZC1	M1	0.68873D-02M2	0.10627D-02M3	0.50472D-03	ABC11	M1	0.10034D-01M2	0.23319D-03M3	0.73912D-05
CZC1	M4	0.17414D-03M5	0.70455D-04M6	0.14898D-04	ABC11	M4	0.13454D-06M5	0.21927D-08M6	0.24976D-04
CZC1	M7	0.15396D-05M8	0.49332D-03M9	0.0 D+00	ABC11	M7	0.14701D-05M8	0.48876D-04M9	0.0 D+00
CZC1	M10	0.12709D-01M11	0.83235D-02		ABC11	M10	0.12709D-01M11	0.83235D-02	
BB11	M1	0.11620D-01M2	0.29455D-03M3	0.97752D-05	BB12	M1	0.11795D-01M2	0.16765D-03M3	0.33187D-05
BB11	M4	0.18926D-06M5	0.33145D-08M6	0.28462D-04	BB12	M4	0.37660D-07M5	0.36859D-09M6	0.31705D-04
BB11	M7	0.18154D-05M8	0.65575D-04M9	0.0 D+00	BB12	M7	0.10950D-05M8	0.21135D-04M9	0.0 D+00
BB11	M10	0.23619D-01M11	0.38902D-02		BB12	M10	0.23619D-01M11	0.38902D-02	
BB21	M1	0.11756D-01M2	0.20124D-03M3	0.50488D-05	BB22	M1	0.11863D-01M2	0.11264D-03M3	0.16303D-05
BB21	M4	0.70958D-07M5	0.87727D-09M6	0.30837D-04	BB22	M4	0.13184D-07M5	0.90540D-10M6	0.33092D-04
BB21	M7	0.13315D-05M8	0.25584D-04M9	0.0 D+00	BB22	M7	0.77763D-06M8	0.93033D-05M9	0.0 D+00
BB21	M10	0.23619D-01M11	0.38902D-02		BB22	M10	0.23619D-01M11	0.38902D-02	

TABLE II (Contd.)

ABA21	M1	0.10048D-01M2	0.23141D-03M3	0.80046D-05
ABA21	M4	0.14616D-04M5	0.23648D-08M6	0.24866D-04
ABA21	M7	0.15945D-05M8	0.36197D-04M9	0.0 D+00
ABA21	M10	0.12709D-01M11	0.83235D-02	
ABA22	M1	0.10050D-01M2	0.22997D-03M3	0.79054D-05
ABA22	M4	0.14352D-06M5	0.23073D-08M6	0.24904D-04
ABA22	M7	0.15849D-05M8	0.35810D-04M9	0.0 D+00
ABA22	M10	0.12709D-01M11	0.83235D-02	
ABA23	M1	0.10055D-01M2	0.22616D-03M3	0.76446D-05
ABA23	M4	0.13666D-06M5	0.21596D-08M6	0.25000D-04
ABA23	M7	0.15555D-07M8	0.34794D-04M9	0.0 D+00
ABA23	M10	0.12709D-01M11	0.83235D-02	
ABA24	M1	0.10063D-01M2	0.21972D-03M3	0.72126D-05
ABA24	M4	0.12552D-06M5	0.19253D-08M6	0.25175D-04
ABA24	M7	0.15162D-05M8	0.33114D-04M9	0.0 D+00
ABA24	M10	0.12709D-01M11	0.83235D-02	
ABA25	M1	0.10075D-01M2	0.21042D-03M3	0.66065D-05
ABA25	M4	0.11038D-06M5	0.16184D-08M6	0.25423D-04
ABA25	M7	0.14530D-05M8	0.30722D-04M9	0.0 D+00
ABA25	M10	0.12709D-01M11	0.83235D-02	
ABA26	M1	0.10092D-01M2	0.19761D-03M3	0.58022D-05
ABA26	M4	0.91199D-07M5	0.12505D-08M6	0.25767D-04
ABA26	M7	0.13642D-05M8	0.27718D-04M9	0.0 D+00
ABA26	M10	0.12709D-01M11	0.83235D-02	
ABA27	M1	0.10110D-01M2	0.17799D-03M3	0.46377D-05
ABA27	M4	0.65447D-07M5	0.79833D-09M6	0.26305D-04
ABA27	M7	0.12227D-05M8	0.23437D-04M9	0.0 D+00
ABA27	M10	0.12709D-01M11	0.83235D-02	
ABB21	M1	0.10147D-01M2	0.15308D-03M3	0.32857D-07
ABB21	M4	0.39066D-07M5	0.39687D-09M6	0.27016D-04
ABB21	M7	0.10318D-05M8	0.18522D-04M9	0.0 D+00
ABB21	M10	0.12709D-01M11	0.83235D-02	
ABB22	M1	0.10179D-01M2	0.12611D-03M3	0.20809D-05
ABB22	M4	0.19634D-07M5	0.15645D-09M6	0.27788D-04
ABB22	M7	0.82348D-06M8	0.13866D-04M9	0.92000D-03
ABB22	M10	0.12709D-01M11	0.83235D-02	
ABC21	M1	0.10157D-01M2	0.14457D-03M3	0.30532D-05
ABC21	M4	0.35902D-07M5	0.36427D-09M6	0.27247D-04
ABC21	M7	0.97448D-06M8	0.17088D-04M9	0.0 D+00
ABC21	M10	0.12709D-01M11	0.83235D-02	
RB13	M1	0.11876D-01M2	0.10039D-03M3	0.12789D-05
RB13	M4	0.91239D-08M5	0.54764D-10M6	0.33406D-04
RB13	M7	0.69470D-06M8	0.80771D-05M9	0.0 D+00
RB13	M10	0.23619D-01M11	0.38902D-02	
RB23	M1	0.11913D-01M2	0.67538D-04M3	0.61953D-06
RB23	M4	0.31349D-08M5	0.13221D-10M6	0.34244D-04
RB23	M7	0.49793D-06M8	0.40146D-05M9	0.0 D+00
RB23	M10	0.23619D-01M11	0.38902D-02	
ABA31	M1	0.10162D-01M2	0.14195D-03M3	0.33283D-05
ABA31	M4	0.40587D-07M5	0.42055D-09M6	0.27091D-04
ABA31	M7	0.10675D-05M8	0.14357D-04M9	0.0 D+00
ABA31	M10	0.12709D-01M11	0.83235D-02	
ABA32	M1	0.10163D-01M2	0.14097D-03M3	0.32831D-05
ABA32	M4	0.39780D-07M5	0.40939D-09M6	0.27118D-04
ABA32	M7	0.10603D-05M8	0.14195D-04M9	0.0 D+00
ABA32	M10	0.12709D-01M11	0.83235D-02	
ABA33	M1	0.10166D-01M2	0.13835D-03M3	0.31641D-05
ABA33	M4	0.37683D-07M5	0.38070D-09M6	0.27190D-04
ABA33	M7	0.10413D-05M8	0.13770D-04M9	0.0 D+00
ABA33	M10	0.12709D-01M11	0.83235D-02	
ABA34	M1	0.10172D-01M2	0.13392D-03M3	0.29665D-05
ABA34	M4	0.34279D-07M5	0.33530D-09M6	0.27312D-04
ABA34	M7	0.10087D-05M8	0.13062D-04M9	0.0 D+00
ABA34	M10	0.12709D-01M11	0.83235D-02	
ABA35	M1	0.10179D-01M2	0.12750D-03M3	0.28896D-05
ABA35	M4	0.29673D-07M5	0.27627D-09M6	0.27491D-04
ABA35	M7	0.96108D-06M8	0.12069D-04M9	0.0 D+00
ABA35	M10	0.12709D-01M11	0.83235D-02	
ABA36	M1	0.10190D-01M2	0.11866D-03M3	0.23253D-05
ABA36	M4	0.23929D-07M5	0.20695D-09M6	0.27739D-04
ABA36	M7	0.89431D-06M8	0.10762D-04M9	0.0 D+00
ABA36	M10	0.12709D-01M11	0.83235D-02	
ABA37	M1	0.10205D-01M2	0.10533D-03M3	0.18125D-05
ABA37	M4	0.16506D-07M5	0.12555D-09M6	0.28122D-04
ABA37	M7	0.78990D-06M8	0.89278D-05M9	0.0 D+00
ABA37	M10	0.12709D-01M11	0.83235D-02	
ABB31	M1	0.10224D-01M2	0.88773D-04M3	0.12373D-05
ABB31	M4	0.92728D-08M5	0.57654D-10M6	0.28620D-04
ABB31	M7	0.65134D-06M8	0.68708D-05M9	0.0 D+00
ABB31	M10	0.12709D-01M11	0.83235D-02	
ABB32	M1	0.10243D-01M2	0.71458D-04M3	0.74392D-06
ABB32	M4	0.42755D-08M5	0.20271D-10M6	0.29148D-04
ABB32	M7	0.50279D-06M8	0.50228D-05M9	0.92000D-03
ABB32	M10	0.12709D-01M11	0.83235D-02	
ABC31	M1	0.10230D-01M2	0.83146D-04M3	0.11259D-05
ABC31	M4	0.82503D-08M5	0.50677D-10M6	0.28778D-04
ABC31	M7	0.60958D-06M8	0.62629D-05M9	0.0 D+00
ABC31	M10	0.12709D-01M1	0.83235D-02	
RB14	M1	0.11925D-01M2	0.56321D-04M3	0.45356D-06
RB14	M4	0.19871D-08M5	0.71746D-11M6	0.34502D-04
RB14	M7	0.42414D-06M8	0.31618D-05M9	0.0 D+00
RB14	M10	0.23619D-01M11	0.38902D-02	
RB24	M1	0.11945D-01M2	0.38150D-04M3	0.22056D-06
RB24	M4	0.68812D-09M5	0.17567D-11M6	0.34984D-04
RB24	M7	0.29814D-06M8	0.17322D-05M9	0.0 D+00
RB24	M10	0.23619D-01M11	0.38902D-02	
REFAX	M10	4.26485E-02M11	1.0952 E-02	
REFRD	M10	7.8857 E-02M11	1.65375E-03	

TABLE III. Energy Boundaries

Group	Lower Energy Boundary
1	1.35 MeV
2	183 keV
3	24.8 keV
4	4.31 keV
5	275 eV
6	10^{-5} eV

TABLE IV. M.O.C. k_{eff} Values

	Calculation	k_{eff}	Δk_{eff} Error
	2D	1.003480	——
1	TF 1,2,3,4,5	1.003058	0.000422
2	TF 1,3,5	1.003015	0.000465
3	TF 1,3,4	1.002893	0.000597
4	TF 1,2,5	1.002840	0.000640
5	TF 1,2,4	1.002893	0.000597
6	TF 1,5	1.002862	0.000618
7	TF 1	1.002476	0.001004

TABLE IV. M.O.C. k_{eff} Values

	Calculation	k_{eff}	Δk_{eff} error
	ZR	1.003480	——
1	TP 1,2,3,4,5	1.003058	0.000422
2	TP 1,3,5	1.003015	0.000465
3	TP 1,4,4	1.002895	0.000587
4	TP 1,2,5	1.002840	0.000640
5	TP 1,1,4	1.002893	0.000587
6	TP 1,5	1.002862	0.000618
7	TP 1	1.002476	0.001004

TABLE V. M.O.C. Synthesis Results

Calc.	k_{eff}	BR	Regional Breeding Ratios					
			C1	C2	AB1	AB2	RB1	RB2
DIF2D	1.003480	1.37081	0.50449	0.28833	0.24182	0.13552	0.11885	0.05181
5 T.F.	1.003058	1.37429	0.50592	0.28708	0.27193	0.13376	0.14979	0.05583
3 T.F.	1.003015	1.38121	0.50634	0.28673	0.24187	0.13375	0.14980	0.06272
1 T.F.	1.002440	1.39521	0.50886	0.28509	0.23832	0.13604	0.14903	0.07796

Calc.	k_{eff}	BR	Regional Power Fractions						P_{max} arbitrary units	P_{max} Location, cm	
			C1	C2	AB1	AB2	RB1	RB2		r	z
DIF2D	1.003480	1.37081	0.5071	0.3816	0.0515	0.0235	0.0311	0.0052	0.75254	1.266	3.810
5 T.F.	1.003058	1.37429	0.5087	0.3798	0.0514	0.0233	0.0312	0.0055	0.75798	1.266	3.810
3 T.F.	1.003015	1.38121	0.5092	0.3793	0.0514	0.0234	0.0312	0.0055	0.76197	1.266	3.810
1 T.F.	1.002440	1.39521	0.5115	0.3773	0.0499	0.0249	0.0310	0.0054	0.76933	1.266	3.810

TABLE VI. B.O.C. Synthesis Results[a]

Calc.	k_{eff}	BR	Regional Breeding Ratios					
			C1	C2	AB1	AB2	RB1	RB2
DIF2D	1.042968	1.46050	0.46276	0.28740	0.27912	0.17329	0.17703	0.08090
5 T.F.	1.040214	1.42670	0.47620	0.28065	0.28636	0.16808	0.14574	0.06966

Calc.	k_{eff}	BR	Regional Power Fractions						P_{max} arbitrary units	P_{max} Location, cm	
			C1	C2	AB1	AB2	RB1	RB2		r	z
DIF2D	1.042968	1.46050	0.4858	0.4112	0.0398	0.0238	0.0324	0.0069	0.69292	1.266	3.810
5 T.F.	1.040214	1.42670	0.4998	0.4016	0.0407	0.0233	0.0286	0.0061	0.69032	1.266	3.810

[a]Using M.O.C. trial functions.

TABLE VI. M.O.C. Synthesis Results[a]

Calc.	K_{eff}	BR	Regional Breeding Ratios					
			C1	C2	AB1	AB2	RB1	RB2
DIF2D	1.042298	1.46050	0.46276	0.28740	0.27812	0.17329	0.17705	0.08050
S T.F.	1.040214	1.42670	0.47620	0.28965	0.28636	0.16808	0.11571	0.06886

Calc.	K_{eff}	BR	Regional Power Fractions						F_{max} activity units	P_{max} Location, cm	
			C1	C2	AB1	AB2	RB1	RB2		i	j
DIF2D	1.042298	1.46050	0.4858	0.3172	0.0528	0.0258	0.0324	0.0069	0.052942	1.266	5.810
S T.F.	1.040214	1.42670	0.4898	0.4070	0.0407	0.0253	0.0286	0.0041	0.050342	1.205	3.810

[a]Using M.O.C. trial functions.

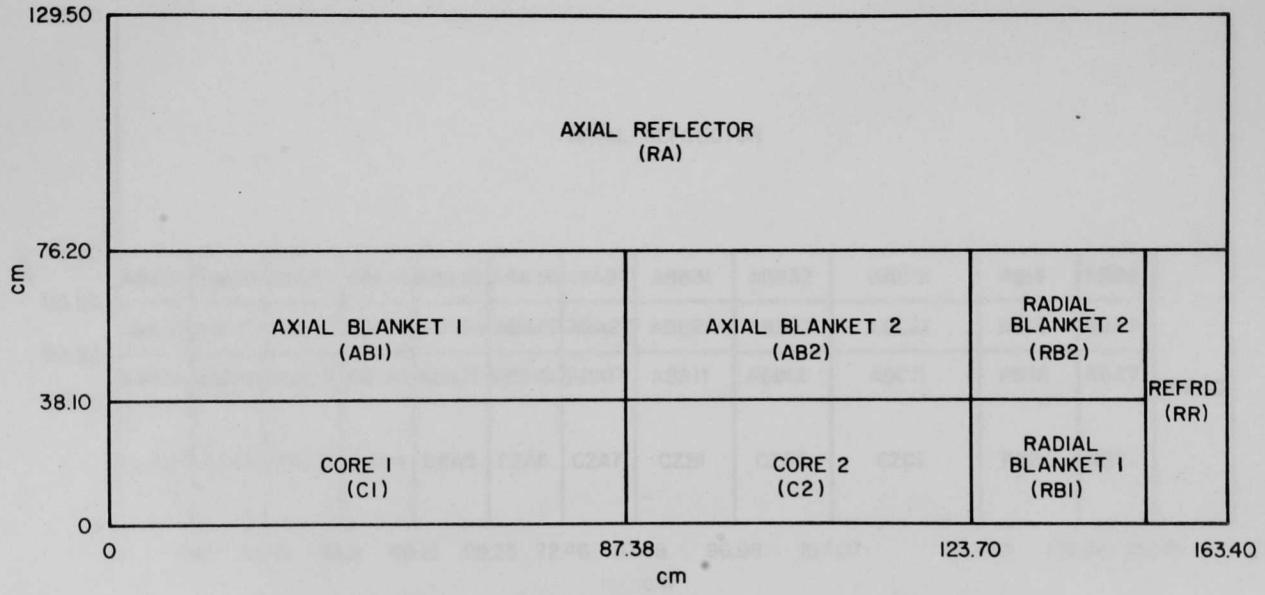


Fig. 1. Reactor Configuration (ANL Neg. No. 116-960 T-1)

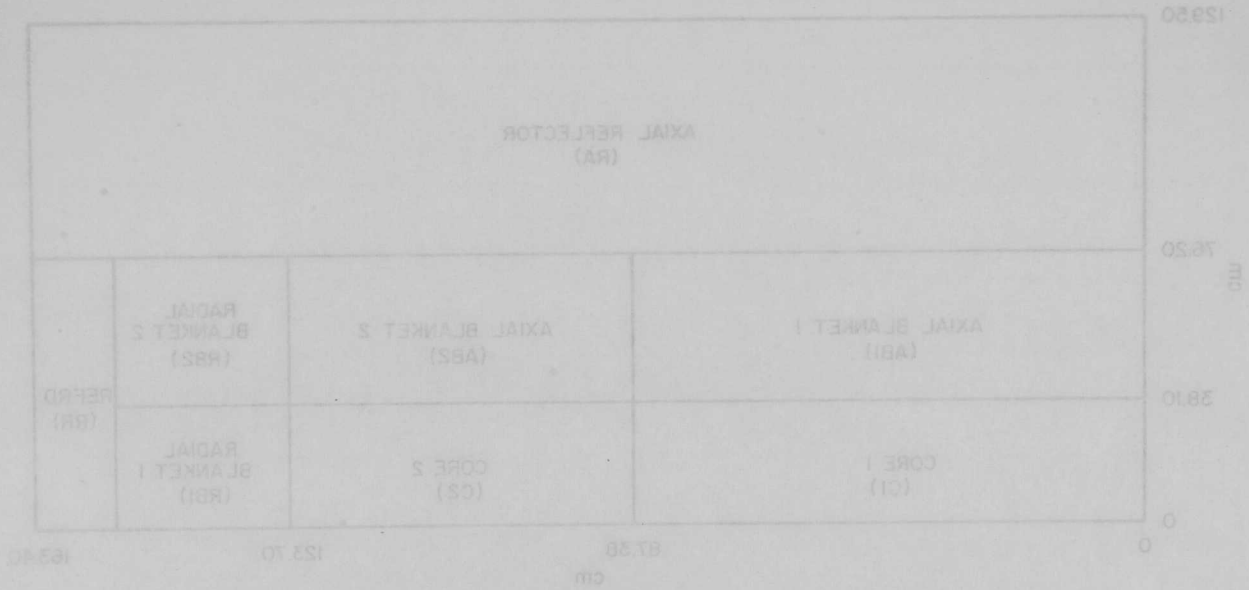


Fig. 1. Reactor Configuration (ANL Neg. No. 116-960 I-1)

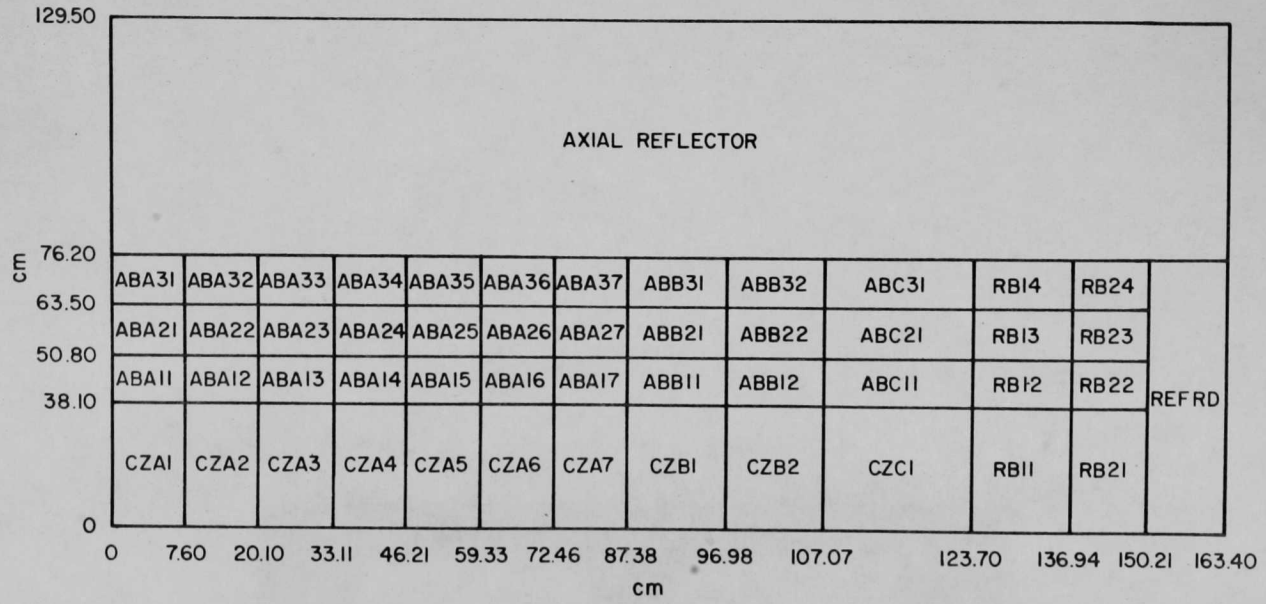


Fig. 2. Detailed Reactor Configuration (ANL Neg. No. 116-959 T-1)

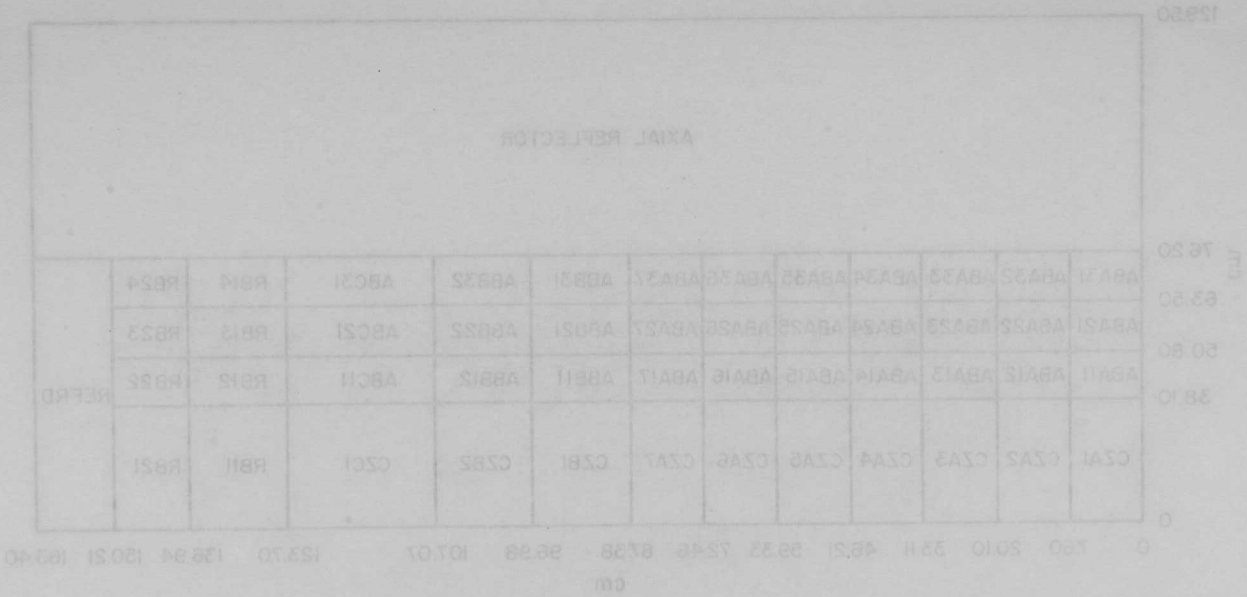
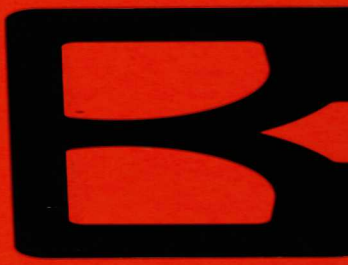


Fig. 2. Partial Reactor Configuration (ANL Neg. No. 116-959 T-1)

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