AD. 2344

SNE-119

**^{238}Pu PRODUCTION IN COMMERCIAL WATER
REACTORS EXPERIMENTAL AND ANALYTICAL
PROGRAM**

July 1972

Southern Nuclear Engineering, Incorporated
Dunedin, Florida

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PLUTONIUM-238 PRODUCTION
IN COMMERCIAL WATER REACTORS
EXPERIMENTAL AND ANALYTICAL PROGRAM

Kenneth E. Roach
William L. Mullett
Gilbert M. Brown
William A. Maxwell
Stanley E. Turner
Walter Mitchell, III

July 1972

Prepared for the U.S. Atomic Energy Commission
Under Contract No. AT(29-2)-2741

Southern Nuclear Engineering, Inc.

Dunedin, Florida

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ACKNOWLEDGEMENTS

Several industrial organizations, as well as the U. S. Government, have made this program possible. Credit for success of the program is due to the Connecticut Yankee Atomic Power Company, Battelle Columbus Laboratories, Nuclear Materials and Equipment Corporation, the Savannah River Laboratories of the USAEC, and the Space Nuclear Systems Office of the USAEC. Individuals due special credit are Mr. James Tribble, New England Electric System; Mr. Rudy Grube, Yankee Atomic Electric Company; Mr. Owen Kruger, Battelle Columbus Laboratories; Messrs. Bob Traggio, Stan Fleming, and Wes Hartley of Connecticut Yankee Atomic Power Company; Mr. Mel Bleiberg, Nuclear Materials and Equipment Corporation; and Mr. Mike Gaitanis of the Space Nuclear Systems Office, USAEC.

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I. INTRODUCTION AND SUMMARY

Since 1969, Southern Nuclear Engineering, Inc. has been conducting an analytical and experimental program to evaluate the feasibility of producing plutonium-238 in commercial light water reactors. Early calculations performed by Southern Nuclear indicated that plutonium-238 could be produced in significant quantities and, perhaps, very economically by replacing some of the burnable poison rods in a conventional pressurized water reactor with rods fabricated with neptunium-237. The early study was limited by the restrictions of the one-dimensional reactor physics model that was used and by the lack of experimental data on the behavior of neptunium targets exposed to a neutron spectrum characteristic of that in a light water reactor. In 1970, Southern Nuclear started a program to irradiate neptunium in an actual power reactor and to generate a multi-dimensional reactor model for (1) analyzing the results of the irradiation program and (2) refining the simpler one-dimensional calculations performed earlier. A number of electric utilities with operating reactors were contacted by Southern Nuclear Engineering (SNE), and all of the utilities expressed interest in participating in a proposed irradiation program. Because of scheduling and other items of convenience, it was decided that the Connecticut Yankee reactor, owned by Connecticut Yankee Atomic Power Company (CYAPC), would be used for

the irradiation. CYAPC was quite interested in the program from the start and agreed to make space available for test specimens in its Connecticut Yankee reactor. SNE obtained a no-cost agreement with CYAPC for the irradiation of Government-furnished neptunium-237 targets; the agreement was signed, and on January 20, 1971 it was approved by the USAEC. Battelle Columbus Laboratories (BCL) was selected to fabricate the neptunium-237 targets. SNE designed the targets, and approval of the design drawings was obtained in early-December, 1970 from the USAEC, BCL, and CYAPC. Prior to approval of the drawings, a location in the Connecticut Yankee reactor core was selected for the neptunium irradiation.

A complete description of the targets, including design drawings and pellet specifications, is given in Ref. 1.

The targets were fabricated at BCL and were installed on March 17, 1971 in the fuel assembly to be irradiated in Core 3 of the Connecticut Yankee reactor. Core 3, with the target-containing fuel assembly, attained full power on June 1, 1971 and was shut down for a fuel shuffle on June 9, 1972. The fuel assembly containing the targets was removed following that shutdown. Thus, the targets were in the core for approximately one year. On June 25, 1972 the targets were removed from the fuel assembly and placed in a storage container (designed and built by Southern Nuclear) in the fuel storage pool at the Connecticut Yankee site. Visual inspection

of the targets as they were removed from the fuel assembly indicated no cladding damage, swelling, or other visible effect that might have been detrimental to the experiment. The targets were scheduled to be shipped to Battelle Columbus Laboratories sometime in late July, 1972 for post-irradiation inspection and destructive testing. Metallurgical evaluations will be carried out, and samples selected on the basis of gamma scans will be analyzed for neptunium-237 and plutonium isotopes, including plutonium-236.

Concurrent with the effort leading to the neptunium irradiation, SNE developed a multi-dimensional model for the analysis of pressurized water reactor cores containing neptunium targets. Core 3 of Connecticut Yankee was modeled in three dimensions, and the burnup of the neptunium targets was followed on a monthly basis during FY 72. At the same time, a two-dimensional parametric study, which utilized a pressurized water reactor of current design as a base, was started in order to refine the earlier one-dimensional calculations. Four two-dimensional problems have been completed, and these calculations have given a feasible arrangement of neptunium rods mixed with burnable poison rods. Further calculations with the two-dimensional model in FY 73 will optimize the neptunium loading (concentration) per rod; it is possible that the loading optimization may require re-evaluation of the spatial arrangement.

Month-by-month calculations were performed for Core 3 of Connecticut Yankee to follow the behavior of the targets with burnup and to estimate the neptunium and plutonium concentrations in the targets at the end of the cycle. At the beginning of the tenth month, an oscillation in the calculated axial power distribution was observed. At first, it was thought that too large a value of the convergence parameter was causing the problem. However, when the calculation was repeated using a smaller value of the convergence parameter, the calculated axial power distribution did not change. Further investigation indicated that a xenon oscillation is causing the problem. Analysis of the problem will continue in the early months of FY 73 and, hopefully, it will be resolved. Calculated concentrations of neptunium and plutonium isotopes in the targets should be available before the first measurements are completed.

II. TWO- AND THREE-DIMENSIONAL MODELING

Preliminary two- and three-dimensional modeling for refining the earlier one-dimensional calculations and for following the neptunium irradiation in the Connecticut Yankee reactor was completed in FY 71.¹ Tasks to be continued in FY 72 included a comparison of three-dimensional versus two-dimensional calculations for following the target irradiation, a detailed investigation of self-shielding factors in two dimensions, monthly calculations of Connecticut Yankee Core 3 using either the two-dimensional or three-dimensional model, the completion of several problems in the two-dimensional parametric study, and preliminary work on neptunium irradiation in the equilibrium cycle of the reference reactor.

A. Three-Dimensional Versus Two-Dimensional Calculations for Following Target Behavior

A three-dimensional calculation that included all of the neptunium targets was made for the beginning-of-life case on Core 3 of Connecticut Yankee. At the same time, a two-dimensional calculation was performed in order to compare the cost of computer time for four two-dimensional calculations with one three-dimensional calculation. Either a single three-dimensional calculation or four two-dimensional calculations would be required to follow the behavior of the neptunium targets. It was found that the three-dimensional calculation was the more economical approach in terms of

computer time, so the three-dimensional model was adopted for use in following the target behavior in Connecticut Yankee.

B. Self-Shielding Factors for Np-237, Pu-238, and B-10

Equivalent diffusion-theory constants for the fuel rods and for the neptunium target rods in assembly E-08 in the Connecticut Yankee reactor were calculated with the self-shielding factor program CNRØD. It was assumed that the neutron spectrum in the neptunium cell was the same as that in the surrounding fuel cells. The calculated constants were then used to prepare the input to a two-dimensional cell calculation for the PDQ-07 program,² explicitly describing the neptunium target rod and each fuel pin individually. The geometrical configuration (one-quarter assembly), shown in Fig. 1, represented each rod in rectangular geometry, maintaining actual rod cross-sectional areas in order to preserve actual neutron reaction rates. The PDQ-07 calculation gave local power and flux distributions in the fuel assembly in two dimensions. Self-shielding factors for the neptunium target rods obtained from the two-dimensional PDQ-07 calculations are compared in Table I with those calculated by the simpler one-region cell approximation used previously. The two-dimensional results show good agreement with results of the previous calculations for single, isolated neptunium rods. The two-dimensional geometrical model is sufficiently general to be used for a study of the two-dimensional self-shielding factors and mutual interactions

when the fuel assembly contains a number of neptunium rods or when it contains both neptunium rods and burnable poison rods.

Table I COMPARISON OF CALCULATED SELF-SHIELDING FACTORS FOR NEPTUNIUM TARGET RODS

Np loading, atoms/cm ³	Two-dimensional		Cell approximation	
	Epithermal group	Thermal group	Epithermal group	Thermal group
2.606 x 10 ²¹	0.7198	0.9129	0.7205	0.8877
3.38 x 10 ²¹	0.6225	0.7664	0.6006	0.7668
6.76 x 10 ²¹	0.5243	0.5774	0.5348	0.5893
1.475 x 10 ²²	0.4216	0.3718	0.4211	0.3718

The relative fuel rod power distribution in the assembly (normalized to an average of 1.00) is shown in Fig. 2 for an assembly without neptunium. A local (intra-assembly) power peaking factor of 1.068 appears on this figure. Figures 3, 4, 5, and 6 show assembly power distributions when the assembly contains neptunium rods of various loadings. No large change in local power peaking is evident, although the location of the hottest fuel pin is shifted.

Figures 7 through 16 give the thermal-group neutron flux distribution, diagonally through the assembly and across the row which includes the neptunium rod. These figures show: (1) the flux peaking in the water holes;

(2) the local flux depressions through the fuel pins and Np target rods; and
(3) the increasing flux depression in the neptunium target rods as the neptunium loading increases.

Two-dimensional calculations were made for intra-assembly power distributions and self-shielding factors in the reference reactor. Figure 17 shows the calculated fuel rod power distribution in an average fuel assembly without any burnable poison rods. Figures 18 and 19 are similar distributions calculated for assemblies containing twelve and sixteen burnable poison rods, respectively. It is apparent from the figures that the local power peaking (intra-assembly) increases when the burnable poison rods are installed. For the unrodded case, the power peak (1.057) occurs for fuel rods C5, D5, E3, and E4. With twelve and sixteen poison rods present, the power peak is shifted to rods A2 and B1, and the magnitude of the peak increases to 1.157 for twelve rods and to 1.168 for sixteen rods.

Self-shielding factors from the two-dimensional calculations (in two neutron energy groups) are compared to the self-shielding factors as calculated with the simple one-dimensional model in Table II. These results show good agreement between the values calculated by the different techniques and tend to confirm that the self-shielding factors from the simple one-dimensional program are adequate. When calculations were performed for assemblies containing both burnable poison rods and neptunium rods, the

self-shielding factors calculated by the simple one-dimensional model are about 8% low. In the two-dimensional array, the marked thermal neutron flux depression in the vicinity of the boron rods leads to an enhanced thermal flux in the vicinity of the more weakly absorbing neptunium rods (relative to the assembly-averaged thermal flux). Hence, the presence of boron rods in the same assembly as the neptunium rods leads to a value of the neptunium self-shielding factor that is higher than the value for the case in which there are no boron rods in the same assembly; calculations show the difference to be about 8%.

Table II BORON BURNABLE POISON
SELF-SHIELDING FACTORS

	<u>Epithermal group</u>	<u>Thermal group</u>
1-D case	0.9742	0.5376
2-D, 12 BP rods	0.9638	0.5258
2-D, 16 BP rods	0.9640	0.5336

The results of two-dimensional calculations of self-shielding factors as a function of the number of burnable poison rods present are given in Table III. The effect of the presence of boron burnable poison rods is clearly evident. With eight to sixteen boron rods present, the self-shielding factors are approximately constant. The boron self-shielding factor, derived from an analytical fit used in other calculations, is appropriate for the two-dimensional parametric

problems. The calculations would suggest that the self-shielding factor for neptunium be increased slightly. However, the increase would be within the accuracy of the one-dimensional calculations.

Table III RESULTS OF TWO-DIMENSIONAL
CALCULATIONS OF SELF-SHIELDING FACTORS

	Epithermal group		Thermal group	
	<u>Boron rod(s)</u>	<u>Np rod(s)</u>	<u>Boron rod(s)</u>	<u>Np rod(s)</u>
Single rod (One-dimensional calculation)	0.860 (0.862)	--- (0.733)	0.448 (0.484)	--- (0.924)
5 boron rods	0.872	---	0.495	---
8 boron, 10 Np rods	0.881	0.746	0.535	0.973
10 boron, 6 Np rods	0.881	0.748	0.529	0.980
12 boron rods	---	---	0.527	---
14 boron, 6 Np rods	0.882	0.747	0.540	0.990
16 boron rods	---	---	0.531	---
(Analytic fit, as currently used)	(0.882)	(0.694)	(0.547)	(0.904)

As a result of the detailed two-dimensional study of self-shielding factors, it was concluded that self-shielding factors calculated with the simple one-dimensional program are adequate.

C. Monthly Calculations of Connecticut Yankee Core 3

A three-dimensional model of the Connecticut Yankee reactor was set up for the PDQ-07 program to follow the operation of Core 3. Approximately

two-thirds of the fuel in Core 3 was partially-spent fuel from Cores 1 and 2. Core 2 contained two demonstration test assemblies clad with Zircaloy and two demonstration test assemblies clad with stainless steel; these assemblies were cycled again in Core 3. Two additional fresh Zircaloy-clad demonstration test assemblies were used in Core 3. A two-dimensional, quarter-core representation of Core 3, showing the various types of fuel, is given in Fig. 20.

To conserve computer time, quarter core (x,y) symmetry was chosen. Forty mesh points in the x dimension and forty mesh points in the y dimension seemed adequate to represent the x,y flux distribution. Seven plane groupings were used to describe the top reflector, the four neptunium target volumes, a bottom core volume, and the bottom reflector. Figure 21 is an isometric drawing of the three-dimensional geometric model.

The reactor physics methods described in Ref. 3 were used to calculate microscopic and macroscopic cross sections for each of the fuel types seen in Fig. 20. The HARMONY program⁴ was used to calculate changes in isotopic compositions.

Data were obtained from the Connecticut Yankee reactor operating staff on a monthly basis. These data included the soluble boron concentration at the beginning of the month and the total thermal energy produced during the month. Table IV gives the data obtained from the operating staff. Note that the reactor reached full power on June 1, 1971 and was shut down on June 9, 1972.

Table IV CONNECTICUT YANKEE REACTOR CORE 3
MONTHLY SOLUBLE BORON CONCENTRATION
AND THERMAL ENERGY PRODUCTION

<u>Date</u>	<u>Critical boron concentration, ppm</u>	<u>Energy increment, Mwd/mtU</u>	<u>Total energy, Mwd/mtU</u>
May 26, 1971	1360	0.0	0.0
July 1	870	843.9	843.9
Aug. 1	796	820.5	1664.4
Sept. 1	748	827.6	2492
Oct. 1	655	815.5	3307.5
Nov. 1	544	810.5	4118
Dec. 1	473	840.4	4958.4
Jan. 1, 1972	373	829.6	5788
Feb. 1	287	842.0	6630
Mar. 1	191	779.0	7409
Apr. 1	91	860.0	8269
May 1	19	833.0	9102
June 9	0	1090.0	10,192

Calculations were performed with a power input of 456.25 Mw for the quarter core, and time intervals such that the average core energy production was the value obtained from the operations staff at CYAPC.

The calculated variation in the assembly-wise relative power density during the lifetime of Core 3 is seen in Figs. 22, 23, and 24. Figures 25 through 36 show the monthly assembly-wise relative power densities by plane grouping. The geometry associated with the plane groupings may be seen in the isometric drawing of the three-dimensional model, Fig. 21. One can see from the assembly-wise power distributions by plane groupings that, after February (Fig. 33), a large oscillation occurred in the axial power. It was thought that too large a value in the convergence parameter caused the problem, but, when calculations were repeated using smaller values of the parameter, no change was observed in the power distribution. Further investigation indicated that a xenon oscillation was causing the problem, though the reason for the xenon oscillation is not fully understood. It may be that the number of planes in the axial dimension (Fig. 21) is too small; in any event, study will continue in the early months of FY 73 and, hopefully, the problem will be resolved.

Masses of the various isotopes of importance within the targets are given on a monthly basis in Table V. As mentioned earlier, the calculations seemed reasonable until February, when the xenon oscillation was encountered.

Table V CALCULATED MASSES OF ISOTOPES
IN TARGETS, BY MONTH

Target	Mwd/mtU	Masses in grams of isotopes in targets				<u>Pu-236</u>
		<u>Np-237</u>	<u>Pu-238</u>	<u>Pu-239</u>	<u>Pu-240</u>	<u>Pu-238</u> <u>ppm</u>
Initial values						
D	0.0	109.8	0.0	0.0	0.0	0.0
C	0.0	49.81	0.0	0.0	0.0	0.0
B	0.0	100.0	0.0	0.0	0.0	0.0
A	0.0	207.2	0.0	0.0	0.0	0.0
Total	————	466.8	0.0	0.0	0.0	0.0
As of June 30, 1971						
D	770.2	107.9	1.765	0.02197	0.0001359	5.221
C	1244	48.57	1.100	0.01143	0.0001894	6.313
B	1111	98.20	1.612	0.01234	0.0001830	7.799
A	911.1	205.0	1.926	0.008973	0.0001099	11.13
Total	————	459.7	6.403	0.05471	0.0006182	————
As of July 31, 1971						
D	1650	105.7	3.867	0.06220	0.001443	4.953
C	2286	47.48	2.164	0.04282	0.001359	6.030
B	2114	96.59	3.192	0.04649	0.001324	7.446
A	1833	202.8	4.035	0.03768	0.0009455	10.62
Total	————	452.6	13.26	0.1892	0.005071	————
As of August 31, 1971						
D	2556	103.47	5.972	0.1466	0.005245	4.774
C	3455	46.44	3.149	0.08893	0.004066	5.843
B	3107	95.02	4.701	0.09824	0.004066	7.214
A	2766	200.67	6.138	0.08371	0.002500	10.26
Total	————	445.60	19.96	0.4174	0.0159	————

Table V (Continued)

Target	Exposure Mwd/mtU	Masses in grams of isotopes in targets				Pu-236
		Np-237	Pu-238	Pu-239	Pu-240	Pu-238 ppm
As of September 30, 1971						
D	3475	101.27	8.020	0.2620	0.01261	4.678
C	4486	45.47	4.049	0.1444	0.008417	5.742
B	4063	93.53	6.116	0.1623	0.008634	7.085
A	3689	198.54	8.186	0.1435	0.006509	10.05
Total	————	438.81	26.371	0.7122	0.03617	————
As of October 31, 1971						
D	4444	99.01	10.07	0.4108	0.02503	4.588
C	5425	44.60	4.845	0.2035	0.01407	5.649
B	4953	92.16	7.397	0.2320	0.01476	6.965
A	4566	196.53	10.11	0.2115	0.01218	9.856
Total	————	432.30	32.42	1.058	0.06604	————
As of November 30, 1971						
D	5471	96.67	12.15	0.5945	0.04412	4.500
C	6295	43.81	5.561	0.2642	0.02083	5.557
B	5803	90.85	8.608	0.3079	0.02257	6.847
A	5458	194.51	12.02	0.2990	0.01997	9.675
Total	————	425.84	38.34	1.467	0.1075	————
As of December 31, 1971						
D	6485	94.41	14.13	0.7973	0.06931	4.412
C	7106	43.08	6.204	0.3253	0.02846	5.471
B	6631	89.60	9.745	0.3877	0.03191	6.740
A	6334	192.54	13.86	0.3749	0.02966	9.511
Total	————	419.63	43.94	1.885	0.1593	————

Table V (Continued)

Target	Exposure Mwd/mtU	Masses in grams of isotopes in targets				Pu-236
		Np-237	Pu-238	Pu-239	Pu-240	Pu-238 ppm
As of January 31, 1972						
D	7568	92.04	16.12	1.033	0.1037	4.329
C	7843	42.42	6.777	0.3840	0.03654	5.383
B	7395	88.45	10.78	0.4663	0.04212	6.629
A	7155	190.70	15.58	0.4607	0.04066	9.339
Total	————	413.61	49.26	2.344	0.2230	————
As of February 29, 1972						
D	8425	90.19	17.67	1.231	0.1362	4.253
C	8492	41.85	7.265	0.4378	0.04452	5.306
B	8149	87.33	11.76	0.5477	0.05369	6.536
A	8019	188.8	17.32	0.5561	0.05421	9.192
Total	————	408.15	54.01	2.773	0.2886	————
As of March 31, 1972						
D	9928	87.05	20.06	1.594	0.2061	4.180
C	9087	41.33	7.709	0.4888	0.05260	5.217
B	8656	86.59	12.46	0.6046	0.06231	6.412
A	8478	187.76	18.35	0.6092	0.06224	8.998
Total	————	402.73	58.58	3.297	0.3832	————
As of April 30, 1972						
D	10122	86.62	20.65	1.644	0.2004	4.078
C	9561	40.92	8.056	0.5302	0.05950	5.132
B	9549	85.29	13.52	0.7074	0.07913	6.336
A	9826	184.82	20.80	0.7693	0.08924	8.901
Total	————	397.65	63.03	3.650	0.4282	————

Table V (Continued)

<u>Target</u>	<u>Exposure</u> <u>Mwd/mtU</u>	<u>Masses in grams of isotopes in targets</u>				<u>Pu-236</u>
		<u>Np-237</u>	<u>Pu-238</u>	<u>Pu-239</u>	<u>Pu-240</u>	<u>Pu-238</u>
						<u>ppm</u>
As of June 9, 1972						
D	10386	86.06	21.08	1.712	0.1931	3.986
C	10201	40.37	8.495	0.5871	0.06979	5.023
B	10752	83.57	14.97	0.8504	0.1056	6.199
A	11634	180.95	24.22	0.9944	0.1337	8.666
Total	————	390.95	68.76	4.144	0.5022	————

Exposures (in Mwd/mtU) given in Table V refer to the exposures in the respective volumes containing the targets (see Fig. 21). The exposures were calculated from the concentrations of fission products within each volume. Even though the xenon oscillations occurred, it is interesting to note that the final exposures (June 9, 1972) compare reasonably well with the reported core average exposure of 10,192 Mwd/mtU. It should be pointed out that the concentrations reported in Table V are correct for the corresponding exposures given in the table, even though the power distribution may be incorrect because of the xenon oscillations.

D. Two-Dimensional Parametric Study

The first calculation in the series was for the base, or reference, reactor (Indian Point Unit No. 2). Figure 37 shows the calculated critical boron concentration in the moderator as a function of burnup, and includes results

from the one-dimensional point model as well as those from the two-dimensional model. Figure 38 gives the assembly-wise average power distribution as a function of burnup in the reference reactor. Good agreement was seen when the initial power distribution was compared with values given in the Final Safety Analysis Report for Indian Point Unit No. 2.⁵ (See Fig. 22 in Ref. 1.)

Arriving at an optimum spatial distribution of neptunium target rods and boron burnable poison rods can be accomplished only through a trial-and-error process. Direct substitution of neptunium rods for boron rods, on the basis of initial thermal absorption cross sections, is not acceptable because the two elements behave differently with burnup. While thermal absorption in the neptunium remains nearly constant with burnup, absorption decreases in the boron as burnup progresses. This difference in behavior is shown in Fig. 39, which is based on a two-group, zero-dimensional calculation for a single assembly. During the trial-and-error process of determining locations of target rods and burnable poison rods, the spatial distribution in neutron flux and fuel burnup throughout the core must be considered, as well as the differences in single-rod burnup characteristics exhibited by neptunium and boron.

In addition to the differences in behavior of boron and neptunium rods, there are several rather vague constraints that should also be considered.

From earlier studies,³ it is known that a better Pu-238 production rate results from a relatively-low initial Np-237 loading per rod. There are 20 lattice positions potentially available in each rodded assembly, so it is desirable to use as many of these positions as possible to minimize the individual neptunium rod loading. Furthermore, it is intuitively felt that the economics of neptunium rod fabrication dictate that the number of different neptunium rod loadings and the number of assembly types or configurations be kept to a minimum. For the initial calculations, a single neptunium loading of 148 grams per rod was adopted; this corresponds, approximately, to the "best" value obtained in the earlier one-dimensional study.³ Several combinations of target and burnable poison rods are necessary, however, although an effort was made to keep the number of combinations to a minimum. Table VI lists a number of possible combinations, together with the approximate initial thermal-group absorption cross-sections (assembly-homogenized). Note that only even numbers of rods were considered in order to preserve intra-assembly symmetry and to avoid unacceptable local power peaking.

The first parametric problem (PP1) was set up to represent the practical problem described in Ref. 3. The calculation gave power peaking near the center of the core (1.33) that was somewhat greater than the reference case value (1.24); Fig. 40 shows the assembly-wise average power distribution throughout burnup, as taken from parametric problem PP1. The power distribution is probably unacceptable, since there are substantial variations with burnup.

Table VI SOME POSSIBLE COMBINATIONS
OF BORON AND NEPTUNIUM RODS

<u>Assembly combinations boron rods/neptunium rods</u>	<u>Initial thermal-group absorption cross-section (cm⁻¹)</u>
16/0*	0.0184
14/6	0.0179
14/4	0.0173
12/8	0.0162
12/6	0.0156
12/0*	0.0138
10/10	0.0145
10/8	0.0139
10/6	0.0133
8/12	0.0128
8/10	0.0122
6/14	0.0111
6/0*	0.0069
2/6	0.0041
2/4	0.0035

* Boron rods only, as originally specified for the reference reactor.

To compensate, the assembly combinations in the center assemblies of the core were modified to increase the initial absorption. This case (PP2) overcompensated, leading to an initial power peaking (1.35 max.) in some of the outer fuel assemblies. (See Fig. 41 for PP2 assembly-wise relative power distribution versus burnup.) The PP2 rod arrangement was considered unsatisfactory because it caused a sharp change in relative power density for some assemblies over the first time interval.

Several single-fuel-assembly calculations were performed, using small time steps whose sum was equal to the first interval in PP2. These calculations confirmed the results obtained from the two-dimensional model, and it was concluded that the PP2 calculation was correct.

In order to minimize power peaking and the large change in relative power density, a third model (PP3) was prepared. The overcompensation of PP2 was partially corrected in PP3. A sharp change in relative power density also occurred in this problem, although the change was not as great as that in PP2. Figure 42 gives assembly-wise average relative power distribution as a function of burnup for PP3.

The fourth parametric problem (PP4) was developed with a dual purpose: (1) achieving further improvement in power distribution, and (2) utilizing more of the potentially-available lattice positions for neptunium rods. The desired improvement was obtained. The power distribution in PP4 (see Fig. 43)

was better than that for the reference reactor, for no assembly-wise relative power was as large as the maximum value (1.31) calculated for the reference reactor at the beginning of life.

Since PP4 used more of the potentially-available assembly lattice positions than did the earlier problems, more neptunium was irradiated; consequently, the boron concentration as a function of burnup differed somewhat from the values obtained in earlier problems. The calculated boron concentration versus core burnup is given in Fig. 44 for all parametric problems, as well as for the reference reactor.

All core arrangements used in the parametric study are shown in Fig. 45, along with the respective thermal-group absorption cross-sections. Figures 46 through 49 show the assembly-wise burnup and isotopic masses in the neptunium target rods at a burnup of 16,000 Mwd/mtU for the four parametric problems.

We have, in PP4, a practical situation for the spatial distribution of neptunium rods within the core. Future calculations (in FY 73) will include an investigation of the neptunium loading per rod. Significant changes in neptunium concentration may require re-evaluation of the core spatial arrangement, but this will depend upon the magnitude of the effects seen in the future calculations.

One of the two-dimensional calculations to be performed in FY 73 will give information on the equilibrium cycle in the reference reactor, with

that reactor containing neptunium targets. The first cycle average core burnup in the reference reactor is estimated⁵ to be 14,500 Mwd/mtU. The equilibrium discharge burnup is estimated to be 33,000 Mwd/mtU, with an equilibrium feed enrichment of 3.2 wt.%. The calculations will involve determining diffusion equation coefficients for the expected fuel pattern in the equilibrium core, fitting them according to the methods described in Ref. 1, and using them in a two-dimensional model for the equilibrium cycle.

Burnable poison is not used in the equilibrium cycle, so there is not the option of replacing burnable poison rods with neptunium rods. However, it is considered necessary to evaluate both the feasibility and the cost of a straightforward irradiation of neptunium in the equilibrium cycle.

III. PRELIMINARY PLANNING OF POST-IRRADIATION TESTS

In planning the tests to be performed on the targets following their removal from the reactor, the consideration of calorimetric measurements made it necessary to have good estimates of the energy release in the targets subsequent to their removal from the reactor. In earlier calculations, it was assumed that all isotopes beyond Pu-238 in the target isotope production chains were Pu-239. In order to predict more accurately the energy release and target decay heats, Pu-239, Pu-240, Pu-241, and Pu-242 were added to the production chains in the one-dimensional model.

Table VII shows energy release rates based on calculations using the extended chains. The energy release from fission-product decay one week

Table VII POWER GENERATED IN TARGETS
ONE WEEK AFTER REACTOR SHUTDOWN
(Based on an exposure of 12,000 Mwd/mtU)

Target	Power generated (watts/cm ³)			Volume (cm ³)	Total watts
	Fission products*	Pu-238	Total		
A	0.461	0.395	0.856	17.863	15.29
B	0.399	0.246	0.645	18.819	12.14
C	0.289	0.143	0.432	18.761	8.10
D	0.190	0.082	0.272	81.445	22.15
Totals in one target rod	—	—	—	—	57.68

* Includes fission products from Np-237, Np-238, Pu-238, Pu-239, and Pu-241.

after shutdown is greater than that from Pu-238 decay. Therefore, gross calorimetric measurements on the targets would be difficult to interpret; on this basis, such tests were eliminated from the post-irradiation program.

After the targets have been packaged and shipped from the reactor site to hot cells at Battelle Columbus Laboratories, a post-irradiation program consisting of the items listed below is planned.

1. Physical measurements on targets.
2. A gamma scan of each target and perhaps differential pulse height measurements.
3. Cover gas analysis on each target in one target rod.
4. Metallography on several sections of targets, including cladding.
5. An electron microprobe analysis of certain pellets in one rod.
This analysis will determine the Np-Pu ratio as a function of pellet radius and height.
6. On cladding surrounding each selected pellet, wedding-band measurements of cobalt-60 and manganese-54 activities for flux-time estimates.
7. For all pellets surrounded by the wedding bands in item 6, a chemical analysis on dissolved pellets to determine total neptunium, plutonium, and zirconium (pellet-sized samples if at all possible).

8. Mass spectrograph measurements on all samples in item 7 to determine the following mass ratios: Pu-239/Pu-238, Pu-240/Pu-238, Pu-241/Pu-238, and Pu-242/Pu-238. Also, an alpha pulse height measurement to determine the Pu-236/Pu-238 ratio.
9. Confirmation of the Pu-236/Pu-238 ratio by independent measurements (alpha pulse height) at one or more facilities other than Battelle Columbus Laboratories.
10. Preservation of historical samples as indicated.
11. Perhaps a measurement of the specific activity of zirconium from the samples indicated in item 7 for possible use as a burnup indicator.
12. Disposal of waste.

IV. DESIGN AND CONSTRUCTION OF STORAGE CONTAINER FOR NEPTUNIUM TARGETS

The targets could not be removed from the spent fuel pool in the fuel handling building at Connecticut Yankee until charging of Core 4 was completed. It was felt that bringing the shipping cask (BMI-1) into the pool and performing the necessary operations would cause confusion that could lead to delays in startup of Core 4. Consequently, a container was needed for storing the target assembly from the time it was removed from the fuel assembly until the time it was placed in the shipping cask.

SNE agreed to design and fabricate a storage container for the target assembly. SNE Drawing 69-646-14B (Fig. 50) shows the design of the container. Materials were furnished by Southern Nuclear at no cost to the Government.

On May 3, 1972, the completed storage container was shipped to the Connecticut Yankee site. At the site, certain checkout procedures, listed below, were performed on the container prior to its use for storing the targets:

- Trial fitting at the upper frame of the short, new-fuel handling tool (2 ft long).
- Trial fitting at the upper frame of the long, irradiated-fuel handling tool (27 ft long).

- Checking for proper support on the support lugs by trial fitting of a spare flow-mixer device within the upper end.
- Checking the flow-mixer handling tool (30 ft long) to verify its fitting with the upper end of the container as well as its ability to grapple, insert, and remove the spare flow-mixer device.
- Trial fitting of the container in a typical spent-fuel-pit storage rack position and in the new-fuel elevator.

The checkout procedures went smoothly, and the Connecticut Yankee Plant Superintendent indicated that there were no difficulties in handling the container with any of the Connecticut Yankee tools.

On June 25, 1972, the assembly containing the targets was removed from the reactor and the targets themselves were removed and placed in the storage container. No problems were encountered.

V. REMOVAL OF THE NEPTUNIUM TARGETS FROM THE REACTOR

On June 25, 1972, fuel assembly E-08, containing the targets, was transferred from the reactor to the spent fuel pool in the fuel handling building. Southern Nuclear's Senior Mechanical Engineer was at the reactor site to observe and monitor the transfer of the assembly, the subsequent removal and visual inspection of the targets, and the positioning of the targets in the target rod storage container.

Binoculars were used for gross visual inspection of the targets. A more detailed inspection of the exterior surface of each target was accomplished by use of an underwater television camera made available through the courtesy of Gulf United Nuclear Corporation. A video-tape recording of the inspection was made, using Gulf's equipment. A copy of that tape will be available to SNE at a future date.

The following observations were made as a result of visual inspection of the target removal:

- There was no indication of sticking or other problems when the target rods were withdrawn.
- Neither target rod showed evidence of loss of material from the bottom end. Both rods were the same length.

- The black oxide film associated with the long-term exposure of Type 304 stainless steel in high-temperature, high-pressure water was evident.
- No change was observed in the target cladding diameter relative to the diameter of the target rod end connectors (solid bar). There was no indication of cladding collapse or swelling.
- The target cladding showed no visible evidence of cracking, spalling, or flaking, nor were there signs of penetration of the cladding.
- The underwater television display revealed apparent minor pitting on the surface of the cladding of targets A and B. Since an instant replay of the video-tape was not possible, no conclusions could be drawn concerning this pitting.

No difficulties were encountered in placing the targets in the storage container. The container, with the targets in place, is now located in a compartment of the spent fuel storage rack. It will remain there until completion of the refueling of the reactor. It is estimated that late in July, 1972, the targets will be appropriately sectioned, packaged, and shipped to Battelle Columbus Laboratories in the BMI-1 shipping cask.

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5. Consolidated Edison Company of New York, Inc., USAEC Docket No. 50-247, Exhibit B-8, Vol. 1, Indian Point Nuclear Generating Unit No. 2 Final Facility Description and Safety Analysis Report.

Fig. 2 Relative power density with no neptunium targets.

Fig. 3 Relative power density with an initial neptunium concentration of 2.606×10^{21} atoms/cm³ in targets.

Fig. 4 Relative power density with an initial neptunium concentration of 3.38×10^{21} atoms/cm³ in targets.

Fig. 5 Relative power density with an initial neptunium concentration of 6.76×10^{21} atoms/cm³ in targets.

Fig. 6 Relative power density with an initial neptunium concentration of 1.475×10^{22} atoms/cm³ in targets.

Fig. 7 Point-wise flux at row 27 with no neptunium targets.

Fig. 8 Point-wise flux at diagonal with no neptunium targets.

Fig. 9 Point-wise flux at row 27 with an initial neptunium concentration of 2.606×10^{21} atoms/cm³ in targets.

Fig. 10 Point-wise flux at diagonal with an initial neptunium concentration of 2.606×10^{21} atoms/cm³ in targets.

Fig. 11 Point-wise flux at row 27 with an initial neptunium concentration of 3.38×10^{21} atoms/cm³ in targets.

Fig. 12 Point-wise flux at diagonal with an initial neptunium concentration of 3.38×10^{21} atoms/cm³ in targets.

Fig. 13 Point-wise flux at row 27 with an initial neptunium concentration of 6.76×10^{21} atoms/cm³ in targets.

Fig. 14 Point-wise flux at diagonal with an initial neptunium concentration of 6.76×10^{21} atoms/cm³ in targets.

Fig. 15 Point-wise flux at row 27 with an initial neptunium concentration of 1.475×10^{22} atoms/cm³ in targets.

Fig. 16 Point-wise flux at diagonal with an initial neptunium concentration of 1.475×10^{22} atoms/cm³ in targets.

Fig. 17 Relative power distribution in average reference fuel assembly - No burnable poison rods present.

Fig. 18 Relative power distribution in average reference fuel assembly - 12 boron rods per assembly.

Fig. 19 Relative power distribution in average reference fuel assembly - 16 boron rods per assembly.

enrichment w/o	clad material	first irradiation cycle
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3.24	SS	1
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3.67	SS	1
------	----	---

3.67	SS	2
------	----	---

3.67	SS (test)	2
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3.00	Zircaloy	2
------	----------	---

3.25	Zircaloy	3
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4.00	SS	3
------	----	---

Fig. 20 Fuel types in Connecticut Yankee Core 3
(assuming quarter-core symmetry).

Fig. 21 Three-dimensional geometric model of the Connecticut Yankee reactor used in PDQ-07 calculations.

Fig. 22 Connecticut Yankee Core 3 — Assembly-wise relative power density as a function of burnup, through 1664 Mwd/mtU.

.7462	.9763	.7859	1.056	.8822	1.068	.8407	.7674
.7496	.9772	.7859	1.052	.8812	1.070	.8485	.7853
.7490	.9734	.7829	1.045	.8780	1.070	.8558	.8053
.7479	.9698	.7792	1.037	.8732	1.067	.8592	.8197
.7425	.9607	.7719	1.026	.8660	1.063	.8636	.8385
.9761	.8588	1.062	.9472	1.109	.9588	1.133	.8043
.9769	.8584	1.057	.9434	1.105	.9600	1.140	.8235
.9730	.8542	1.049	.9369	1.098	.9599	1.148	.8462
.9696	.8499	1.041	.9300	1.090	.9577	1.152	.8635
.9605	.8410	1.028	.9195	1.080	.9545	1.157	.8869
.7856	1.061	1.051	.9373	1.109	.8885	1.079	Np Targets
.7854	1.056	1.045	.9339	1.103	.8883	1.087	
.7821	1.048	1.036	.9285	1.095	.8881	1.099	
.7786	1.040	1.027	.9229	1.087	.8869	1.107	
.7716	1.028	1.015	.9143	1.078	.8860	1.120	
1.057	.9472	.9302	.9044	1.129	1.241	.8920	
1.052	.9424	.9266	.9013	1.120	1.234	.9021	
1.044	.9354	.9210	.8970	1.111	1.231	.9168	
1.037	.9287	.9156	.8929	1.104	1.229	.9295	
1.027	.9190	.9076	.8872	1.097	1.229	.9485	
.9004	1.117	1.112	1.130	1.065	1.012		
.8972	1.110	1.104	1.120	1.058	1.017		
.8928	1.102	1.095	1.111	1.053	1.027		
.8884	1.095	1.088	1.104	1.049	1.036		
.8825	1.086	1.080	1.097	1.048	1.052		
.9983	.9915	.8989	1.246	1.014			
.9989	.9901	.8969	1.239	1.018			
.9990	.9882	.8953	1.234	1.028			
.9993	.9872	.8949	1.232	1.037			
.9990	.9858	.8951	1.233	1.054			
.8746	1.193	1.104	.9005				
.8784	1.196	1.110	.9090				
.8826	1.199	1.118	.9224				
.8875	1.206	1.129	.9359				
.8935	1.214	1.143	.9560				
.8575	.8222	— 2492	— Burnup, Mwd/mtU				
.8714	.8374	— 3308					
.8876	.8565	— 4118					
.9045	.8753	— 4958					
.9253	.9000	— 5788					

Fig. 23 Connecticut Yankee Core 3 — Assembly-wise relative power density as a function of burnup, continued through 5788 Mwd/mtU.

.7314	.9452	.7595	1.009	.8553	1.057	.8679	.8605
.7257	.9349	.7507	.9929	.8408	1.037	.8502	.8419
.6999	.9049	.7293	.9765	.8395	1.063	.9007	.9362
.7132	.9172	.7356	.9717	.8263	1.029	.8603	.8904
.9452	.8265	1.010	.9045	1.067	.9498	1.165	.9152
.9359	.8174	.9955	.8905	1.048	.9341	1.144	.9145
.9037	.7896	.9681	.8744	1.046	.9559	1.218	1.009
.9177	.7998	.9724	.8709	1.029	.9275	1.156	.9632
.7596	1.010	.9974	.9017	1.067	.8847	1.133	Np Targets
.7539	.9982	.9844	.8915	1.052	.8777	1.138	
.7258	.9643	.9558	.8746	1.049	.8928	1.201	
.7375	.9740	.9605	.8740	1.036	.8777	1.167	
1.011	.9051	.8958	.8786	1.089	1.233	.9736	
1.004	.8981	.8901	.8740	1.081	1.232	.9912	
.9678	.8666	.8639	.8572	1.076	1.252	1.045	
.9791	.8759	.8713	.8602	1.069	1.244	1.031	
.8738	1.074	1.070	1.090	1.048	1.074		
.8730	1.071	1.067	1.088	1.050	1.094		
.8425	1.036	1.038	1.070	1.049	1.131		
.8538	1.048	1.048	1.075	1.049	1.126		
.9982	.9842	.8958	1.239	1.076			
1.006	.9912	.9041	1.251	1.103			
.9771	.9646	.8853	1.241	1.125			
.9918	.9814	.9019	1.262	1.133			
.9012	1.227	1.164	.9831				
.9178	1.250	1.194	1.017				
.8995	1.232	1.194	1.035				
.9233	1.267	1.223	1.055				
.9517	.9315	6630 — Burnup, Mwd/mtU					
.9872	.9717	7409					
.9905	.9853	8269					
1.024	1.015	9102					

Fig. 24 Connecticut Yankee Core 3 — Assembly-wise relative power density as a function of burnup, continued through 9102 Mwd/mtU.

.7072	.9397	.7513	1.007	.8058	.9326	.6814	.5600
1.118	1.491	1.190	1.603	1.281	1.492	1.093	.9160
1.024	1.365	1.088	1.465	1.167	1.352	.9822	.8232
.8414	1.122	.8941	1.202	.9569	1.107	.8042	.6729
.5046	.6674	.5350	.7130	.5711	.6541	.4754	.3813
.9425	.8310	1.038	.9056	1.027	.8373	.9272	.5877
1.496	1.316	1.652	1.439	1.642	1.339	1.495	.9618
1.370	1.205	1.512	1.315	1.497	1.212	1.335	.8633
1.126	.9900	1.242	1.079	1.227	.9933	1.096	.7061
.6697	.5923	.7358	.6433	.7242	.5891	.6454	.4007
.7603	1.047	1.034	.8925	1.037	.7822	.8759	Np Targets
1.206	1.667	1.647	1.420	1.664	1.258	1.429	
1.104	1.527	1.507	1.298	1.518	1.144	1.292	
.9073	1.254	1.238	1.066	1.245	.9366	1.057	
.5424	.7428	.7343	.6352	.7313	.5501	.6039	
1.036	.9265	.8968	.8523	1.060	1.110	.7160	
1.654	1.476	1.429	1.363	1.713	1.811	1.179	
1.515	1.352	1.308	1.246	1.565	1.652	1.073	
1.245	1.110	1.074	1.022	1.282	1.352	.8781	
.7360	.6604	.6397	.6069	.7459	.7715	.4920	
.8562	1.076	1.067	1.076	.9880	.8584		
1.371	1.730	1.719	1.741	1.609	1.415		
1.256	1.585	1.574	1.594	1.471	1.293		
1.031	1.301	1.291	1.306	1.205	1.058		
.6099	.7627	.7563	.7591	.6926	.5928		
.8976	.9046	.8208	1.143	.8715			
1.457	1.463	1.329	1.872	1.439			
1.335	1.340	1.217	1.714	1.317			
1.095	1.098	.9974	1.404	1.078			
.6323	.6412	.5816	.7989	.6035			
.7558	1.035	.9405	.7484				
1.231	1.698	1.549	1.239				
1.128	1.555	1.419	1.138				
.9241	1.274	1.163	.9293				
.5337	.7247	.6552	.5183				
.6846	.6454	— 2	Plane Groupings				
1.130	1.070	— 3					
1.035	.9799	— 4					
.8479	.8025	— 5					
.4772	.4477	— 6					

Fig. 25 Connecticut Yankee Core 3 - Assembly-wise relative power density - BOL, no Xe, equilibrium Sm.

.7395	.9701	.7839	1.056	.8755	1.048	.8094	.7124
.8819	1.167	.9424	1.285	1.070	1.305	1.021	.9356
.8097	1.071	.8641	1.176	.9768	1.184	.9200	.8422
.7432	.9842	.7935	1.080	.8947	1.084	.8412	.7680
.5827	.7644	.6202	.8329	.6918	.8212	.6313	.5403
.9705	.8576	1.067	.9502	1.104	.9415	1.090	.7470
1.168	1.028	1.292	1.152	1.362	1.171	1.392	.9822
1.072	.9436	1.183	1.055	1.243	1.062	1.243	.8833
.9852	.8673	1.089	.9688	1.140	.9727	1.142	.8066
.7650	.6787	.8414	.7522	.8683	.7400	.8486	.5672
.7856	1.068	1.060	.9389	1.109	.8744	1.033	Np Targets
.9459	1.295	1.287	1.144	1.376	1.096	1.341	
.8677	1.186	1.179	1.048	1.256	.9980	1.212	
.7973	1.092	1.085	.9613	1.153	.9137	1.169	
.6222	.8430	.8387	.7443	.8726	.6862	.7942	
1.064	.9551	.9340	.9035	1.131	1.222	.8494	
1.300	1.161	1.140	1.113	1.421	1.572	1.117	
1.191	1.065	1.045	1.019	1.298	1.431	1.016	
1.095	.9787	.9589	.9341	1.192	1.313	.9298	
.8410	.7575	.7414	.7160	.8883	.9474	.6485	
.9025	1.122	1.117	1.135	1.063	.9801		
1.112	1.398	1.392	1.428	1.355	1.286		
1.019	1.275	1.274	1.036	1.237	1.172		
.9349	1.171	1.170	1.200	1.137	1.075		
.7144	.8852	.8813	.8925	.8310	.7517		
.9813	.9805	.8896	1.233	.9839			
1.245	1.234	1.123	1.591	1.293			
1.140	1.130	1.028	1.452	1.180			
1.043	1.035	.9416	1.333	1.082			
.7659	.7713	.7002	.9580	.7558			
.8500	1.156	1.065	.8618				
1.087	1.500	1.394	1.139				
.9952	1.370	1.273	1.041				
.9096	1.254	1.166	.9528				
.6650	.8965	.8212	.6604				
.8060	.7702	—	2	Plane Groupings			
1.062	1.022	—	3				
.9705	.9345	—	4				
.8859	.8534	—	5				
.6206	.5896	—	6				

Fig. 26 Connecticut Yankee Core 3 — Assembly-wise relative power density - July, 1971, 844 MwD/mtU.

.7564	.9909	.7978	1.070	.8884	1.065	.8284	.7383
.8468	1.115	.8980	1.218	1.017	1.245	.9830	.9150
.7973	1.049	.8440	1.141	.9507	1.155	.9049	.8408
.7451	.9821	.7897	1.069	.8882	1.079	.8448	.7833
.6125	.8012	.6474	.8666	.7206	.8579	.6638	.5756
.9911	.8737	1.080	.9611	1.117	.9567	1.114	.7737
1.116	.9800	1.224	1.091	1.290	1.116	1.337	.9602
1.049	.9222	1.149	1.023	1.204	1.036	1.220	.8816
.9829	.8635	1.078	.9581	1.128	.9680	1.146	.8223
.8017	.7093	.8755	.7813	.9029	.7726	.8930	.6041
.7988	1.081	1.070	.9493	1.118	.8859	1.056	Np Targets
.9004	1.225	1.215	1.083	1.298	1.042	1.289	
.8465	1.151	1.140	1.015	1.213	.9697	1.189	
.7926	1.080	1.070	.9502	1.137	.9071	1.114	
.6489	.8766	.8699	.7727	.9045	.7146	.8356	
1.075	.9640	.9436	.9128	1.136	1.233	.8687	
1.228	1.097	1.078	1.053	1.336	1.488	1.076	
1.152	1.030	1.011	.9860	1.247	1.382	.9987	
1.081	.9658	.9470	.9229	1.172	1.299	.9352	
.8730	.7852	.7690	.7429	.9183	.9850	.6829	
.9115	1.131	1.124	1.139	1.067	.9949		
1.052	1.313	1.310	1.342	1.275	1.227		
.9864	1.230	1.226	1.254	1.189	1.142		
.9236	1.154	1.151	1.179	1.118	1.072		
.7408	.9169	.9120	.9221	.8593	.7863		
.9967	.9932	.8997	1.243	.9985			
1.186	1.172	1.065	1.503	1.233			
1.109	1.097	.9957	1.400	1.148			
1.037	1.026	.9326	1.317	1.079			
.7995	.8029	.7279	.9952	.7903			
.8660	1.177	1.086	.8805				
1.040	1.434	1.336	1.095				
.9722	1.337	1.245	1.020				
.9084	1.252	1.167	.9568				
.6960	.9326	.8620	.6949				
.8315	.7951	2 — Plane Groupings					
1.032	.9948	3					
.9614	.9273	4					
.8973	.8659	5					
.6577	.6257	6					

Fig. 27 Connecticut Yankee Core 3 — Assembly-wise relative power density - August, 1971, 1664 Mwd/mtU.

.7723	1.009	.8114	1.086	.9060	1.092	.8553	.7707
.8065	1.058	.8521	1.152	.9676	1.190	.9488	.8946
.7736	1.014	.8158	1.100	.9208	1.123	.8880	.8351
.7383	.9698	.7800	1.054	.8808	1.076	.8512	.7997
.6373	.8324	.6715	.8995	.7514	.9012	.7032	.6175
1.008	.8877	1.094	.9750	1.136	.9794	1.149	.8069
1.058	.9283	1.155	1.032	1.223	1.066	1.287	.9384
1.014	.8899	1.104	.9855	1.162	1.007	1.194	.8753
.9699	.8514	1.059	.9441	1.115	.9649	1.153	.8391
.8323	.7350	.9058	.8096	.9403	.8104	.9462	.6476
.8106	1.093	1.082	.9629	1.133	.9041	1.087	Np Targets
.8528	1.154	1.144	1.024	1.227	.9931	1.239	
.8163	1.104	1.094	.9774	1.166	.9395	1.162	
.7808	1.060	1.050	.9362	1.120	.9016	1.118	
.6713	.9052	.8979	.8005	.9391	.7470	.8831	
1.086	.9735	.9549	.9254	1.148	1.252	.8927	
1.156	1.033	1.017	.9951	1.258	1.408	1.034	
1.104	.9874	.9712	.9485	1.194	1.330	.9751	
1.060	.9468	.9305	.9089	1.151	1.284	.9382	
.9005	.8093	.7944	.7694	.9505	1.023	.7205	
.9209	1.141	1.134	1.148	1.077	1.013		
.9916	1.235	1.232	1.260	1.200	1.168		
.9463	1.176	1.172	1.197	1.137	1.104		
.9067	1.130	1.127	1.154	1.098	1.065		
.7642	.9455	.9408	.9514	.8888	.8218		
1.012	1.007	.9115	1.256	1.014			
1.123	1.108	1.007	1.416	1.170			
1.068	1.054	.9567	1.339	1.107			
1.024	1.011	.9189	1.295	1.068			
.8299	.8320	.7540	1.031	.8234			
.8828	1.200	1.106	.8988				
.9905	1.364	1.271	1.045				
.9402	1.290	1.202	.9885				
.9011	1.241	1.158	.9522				
.7256	.9806	.9003	.7270				
.8570	.8192	2 — Plane Groupings					
.9942	.9592	3					
.9400	.9071	4					
.9008	.8699	5					
.6939	.6602	6					

Fig. 28 Connecticut Yankee Core 3 — Assembly-wise relative power density - September, 1971, 2492 Mwd/mtU.

.8200	1.067	.8573	1.143	.9548	1.152	.9089	.8294
.7350	.9599	.7735	1.042	.8782	1.084	.8735	.8386
.7152	.9334	.7513	1.009	.8478	1.037	.8283	.7929
.6978	.9131	.7346	.9897	.8306	1.019	.8155	.7807
.6570	.8564	.6897	.9224	.7728	.9314	.7329	.6534
1.067	.9376	1.151	1.025	1.194	1.034	1.218	.8687
.9598	.8418	1.043	.9329	1.106	.9718	1.181	.8810
.9333	.8187	1.012	.9040	1.067	.9300	1.110	.8323
.9131	.8010	.9931	.8863	1.048	.9144	1.102	.8202
.8561	.7546	.9277	.8293	.9654	.8371	.9860	.6854
.8561	1.150	1.136	1.013	1.188	.9528	1.153	Np Targets
.7736	1.042	1.032	.9268	1.109	.9049	1.142	
.7516	1.012	1.001	.8974	1.069	.8675	1.084	
.7351	.9931	.9833	.8797	1.052	.8541	1.073	
.6889	.9266	.9180	.8304	.9622	.7702	.9205	
1.142	1.023	1.004	.9735	1.201	1.314	.9503	
1.044	.9337	.9205	.9020	1.136	1.278	.9585	
1.012	.9053	.8916	.8716	1.093	1.223	.9151	
.9936	.8880	.8741	.8553	1.080	1.213	.9046	
.9216	.8276	.8134	.7888	.9722	1.056	.7525	
.9686	1.197	1.188	1.201	1.128	1.072		
.8994	1.116	1.113	1.138	1.087	1.074		
.8703	1.078	1.074	1.095	1.044	1.028		
.8535	1.061	1.058	1.083	1.034	1.019		
.7828	.9673	.9619	.9721	.9103	.8521		
1.068	1.060	.9593	1.316	1.073			
1.025	1.009	.9166	1.284	1.076			
.9879	.9728	.8822	1.230	1.031			
.9704	.9560	.8687	1.221	1.021			
.8552	.8553	.7747	1.058	.8530			
.9348	1.268	1.172	.9555				
.9093	1.249	1.169	.9674				
.8739	1.196	1.119	.9261				
.8589	1.181	1.107	.9160				
.7504	1.014	.9336	.7570				
.9178	.8787	— 2 —	Plane Groupings				
.9262	.8790	— 3 —					
.8861	.8583	— 4 —					
.8716	.8449	— 5 —					
.7271	.6931	— 6 —					

Fig. 29 Connecticut Yankee Core 3 — Assembly-wise relative power density - October, 1971, 3308 Mwd/mtU.

.8343	1.083	.8695	1.156	.9687	1.173	.9333	.8669
.6500	.8454	.6822	.9155	.7754	.9604	.7830	.7674
.6633	.8625	.6949	.9303	.7846	.9634	.7776	.7597
.6757	.8810	.7094	.9530	.8034	.9907	.8022	.7846
.7239	.9415	.7573	1.011	.8487	1.028	.8153	.7387
1.082	.9499	1.163	1.037	1.209	1.053	1.248	.9093
.8454	.7413	.9151	.8205	.9737	.8622	1.056	.8088
.8624	.7561	.9317	.8338	.9844	.8644	1.040	.8002
.8809	.7724	.9547	.8537	1.011	.8893	1.082	.8268
.9409	.8280	1.015	.9080	1.058	.9230	1.096	.7756
.8683	1.162	1.147	1.026	1.202	.9706	1.187	Np Targets
.6823	.9148	.9060	.8164	.9761	.8038	1.028	
.6950	.9314	.9216	.8286	.9862	.8072	1.023	
.7096	.9545	.9447	.8483	1.015	.8312	1.060	
.7557	1.013	1.003	.8984	1.053	.8479	1.025	
1.155	1.034	1.017	.9874	1.215	1.335	.9845	
.9179	.8212	.8109	.7962	1.001	1.133	.8706	
.9329	.8347	.8231	.8061	1.009	1.135	.8703	
.9558	.8547	.8425	.8262	1.042	1.178	.9004	
1.007	.9042	.8899	.8639	1.062	1.159	.8406	
.9825	1.211	1.202	1.214	1.144	1.104		
.7945	.9824	.9793	1.002	.9622	.9690		
.8053	.9946	.9901	1.011	.9677	.9717		
.8244	1.021	1.019	1.044	1.002	1.007		
.8561	1.056	1.050	1.061	.9963	.9454		
1.090	1.080	.9768	1.338	1.105			
.9120	.8958	.8141	1.138	.9706			
.9201	.9039	.8200	1.141	.9735			
.9440	.9278	.8436	1.184	1.009			
.9397	.9377	.8491	1.159	.9450			
.9588	1.299	1.206	.9894				
.8143	1.115	1.051	.8782				
.8184	1.118	1.054	.8796				
.8404	1.154	1.089	.9096				
.8271	1.117	1.033	.8421				
.9552	.9179	— 2	Plane Groupings				
.8429	.8214	— 3					
.8429	.8216	— 4					
.8670	.8456	— 5					
.8118	.7764	— 6					

Fig. 30 Connecticut Yankee Core 3 - Assembly-wise
relative power density - November, 1971, 4118 Mwd/mtU.

.8280	1.073	.8604	1.142	.9585	1.166	.9333	.8803
.6142	.7960	.6424	.8585	.7288	.9034	.7416	.7362
.6499	.8423	.6786	.9048	.7643	.9393	.7626	.7546
.6700	.8706	.7012	.9383	.7929	.9797	.7993	.7926
.7666	.9959	.7993	1.066	.8958	1.090	.8704	.8004
1.072	.9395	1.148	1.024	1.195	1.046	1.248	.9256
.7960	.6978	.8582	.7699	.9127	.8118	.9968	.7787
.8423	.7379	.9064	.8111	.9567	.8433	1.017	.7975
.8705	.7629	.9398	.8409	.9955	.8800	1.076	.8377
.9953	.8738	1.070	.9561	1.117	.9782	1.172	.8417
.8596	1.147	1.132	1.015	1.189	.9656	1.194	Np Targets
.6428	.8582	.8493	.7670	.9152	.7582	.9769	
.6789	.9063	.8959	.8068	.9582	.7884	1.007	
.7014	.9396	.9294	.8364	.9988	.8233	1.059	
.7975	1.068	1.056	.9470	1.110	.8982	1.097	
1.142	1.022	1.007	.9788	1.203	1.330	.9965	
.8614	.7710	.7621	.7491	.9393	1.067	.8340	
.9079	.8123	.8016	.7856	.9807	1.108	.8630	
.9412	.8419	.8308	.8156	1.026	1.164	.9056	
1.062	.9517	.9379	.9114	1.119	1.229	.9038	
.9736	1.199	1.190	1.203	1.138	1.112		
.7480	.9221	.9191	.9405	.9061	.9244		
.7854	.9675	.9627	.9825	.9432	.9594		
.8140	1.006	1.003	1.028	.9896	1.007		
.9024	1.113	1.106	1.117	1.053	1.011		
1.087	1.076	.9737	1.334	1.114			
.8620	.8459	.7693	1.072	.9264			
.9003	.8834	.8019	1.114	.9615			
.9361	.9188	.8359	1.171	1.009			
.9963	.9922	.8985	1.227	1.010			
.9622	1.304	1.215	1.003				
.7742	1.058	1.002	.8425				
.8047	1.098	1.039	.8730				
.8378	1.148	1.089	.9151				
.8804	1.191	1.104	.9046				
.9733	.9379	— 2 —	Plane Groupings				
.8110	.7934	— 3 —					
.8394	.8205	— 4 —					
.8749	.8566	— 5 —					
.8766	.8401	— 6 —					

Fig. 31 Connecticut Yankee Core 3 - Assembly-wise
relative power density - December, 1971, 4958 Mwd/mtU.

.8625	1.115	.8943	1.185	.9974	1.219	.9840	.9459
.5433	.7018	.5673	.7560	.6446	.8021	.6658	.6745
.5831	.7535	.6079	.8086	.6859	.8464	.6944	.7013
.6105	.7906	.6378	.8513	.7229	.8973	.7408	.7500
.7857	1.020	.8175	1.090	.9183	1.125	.9065	.8494
1.115	.9754	1.190	1.062	1.242	1.093	1.315	.9986
.7019	.6154	.7549	.6786	.8056	.7219	.8928	.7175
.7535	.6600	.8089	.7253	.8569	.7607	.9251	.7453
.7906	.6928	.8514	.7635	.9055	.8071	.9955	.7967
1.019	.8927	1.092	.9764	1.144	1.009	1.222	.8957
.8942	1.190	1.173	1.055	1.238	1.013	1.268	Np Targets
.5680	.7552	.7477	.6777	.8094	.6770	.8848	
.6083	.8091	.7999	.7229	.8595	.7136	.9250	
.6381	.8513	.8423	.7609	.9096	.7571	.9883	
.8154	1.090	1.077	.9685	1.137	.9269	1.149	
1.186	1.062	1.048	1.022	1.256	1.399	1.070	
.7597	.6805	.6739	.6644	.8334	.9537	.7645	
.8120	.7269	.7187	.7063	.8821	1.004	.8017	
.8542	.7646	.7560	.7444	.9366	1.071	.8543	
1.084	.9711	.9587	.9339	1.147	1.269	.9518	
1.016	1.250	1.241	1.257	1.195	1.188		
.6637	.8158	.8140	.8351	.8096	.8432		
.7063	.8679	.8643	.8840	.8538	.8866		
.7428	.9152	.9130	.9381	.9091	.9448		
.9235	1.139	1.132	1.145	1.084	1.058		
1.144	1.130	1.025	1.406	1.191			
.7706	.7554	.6885	.9601	.8455			
.8156	.7991	.7268	1.011	.8889			
.8604	.8433	.7686	1.077	.9466			
1.027	1.021	.9252	1.266	1.056			
1.020	1.383	1.297	1.080				
.6980	.9530	.9107	.7737				
.7344	1.002	.9564	.8117				
.7760	1.062	1.016	.8630				
.9122	1.235	1.151	.9506				
1.050	1.017	2 — Plane Groupings					
.7437	.7331	3					
.7783	.7674	4					
.8243	.8130	5					
.9233	.8886	6					

Fig. 32 Connecticut Yankee Core 3 — Assembly-wise relative power density - January, 1972, 5788 Mwd/mtU.

.7181	.9274	.7440	.9867	.8337	1.027	.8393	.8280
.5113	.6587	.5331	.7087	.6065	.7570	.6343	.6547
.6151	.7929	.6403	.8499	.7234	.8957	.7418	.7635
.6841	.8833	.7135	.9501	.8102	1.010	.8431	.8701
1.002	1.300	1.041	1.387	1.172	1.446	1.176	1.122
.9277	.8103	.9888	.8837	1.039	.9222	1.124	.8796
.6589	.5777	.7070	.6368	.7566	.6825	.8492	.7009
.7930	.6945	.8495	.7628	.9026	.8062	.9875	.8165
.8834	.7741	.9491	.8527	1.013	.9098	1.132	.9298
1.299	1.135	1.388	1.241	1.460	1.296	1.589	1.188
.7449	.9893	.9758	.8814	1.039	.8593	1.098	Np Targets
.5342	.7078	.7008	.6374	.7620	.6430	.8521	
.6412	.8501	.8405	.7619	.9071	.7595	.9988	
.7141	.9492	.9394	.8516	1.019	.8564	1.135	
1.038	1.385	1.368	1.233	1.452	1.192	1.500	
.9908	.8860	.8768	.8584	1.059	1.196	.9389	
.7136	.6397	.6346	.6274	.7873	.9083	.7454	
.8548	.7655	.7581	.7470	.8339	1.072	.8759	
.9541	.8546	.8465	.8359	1.053	1.214	.9915	
1.380	1.235	1.221	1.192	1.467	1.637	1.251	
.8546	1.051	1.045	1.063	1.018	1.037		
.6272	.7690	.7682	.7899	.7705	.8189		
.7472	.9163	.9136	.9366	.9102	.9646		
.8340	1.025	1.024	1.055	1.029	1.091		
1.178	1.452	1.444	1.464	1.393	1.382		
.9742	.9610	.8739	1.206	1.041			
.7335	.7186	.6566	.9166	.8221			
.8686	.8506	.7756	1.081	.9677			
.9726	.9526	.8705	1.221	1.093			
1.319	1.310	1.189	1.632	1.380			
.8792	1.196	1.131	.9520				
.6703	.9149	.8820	.7569				
.7887	1.076	1.037	.8887				
.8846	1.211	1.168	1.002				
1.180	1.601	1.501	1.249				
.9268	.9041	2 — Plane Groupings					
.7261	.7212	3					
.8499	.8443	4					
.9558	.9494	5					
1.216	1.175	6					

Fig. 33 Connecticut Yankee Core 3 — Assembly-wise relative power density - February, 1972, 6630 Mwd/mtU.

1.159	1.493	1.197	1.580	1.334	1.638	1.335	1.309
.4219	.5419	.4390	.5820	.4995	.6245	.5259	.5457
.3717	.4778	.3863	.5112	.4362	.5409	.4496	.4650
.3285	.4227	.3419	.4535	.3877	.4834	.4048	.4196
.4251	.5514	.4406	.5882	.4977	.6196	.5074	.4917
1.494	1.305	1.586	1.417	1.661	1.475	1.794	1.420
.5426	.4758	.5809	.5240	.6230	.5652	.7071	.5981
.4784	.4188	.5112	.4596	.5440	.4885	.6014	.5093
.4233	.3709	.4533	.4079	.4843	.4370	.5447	.4591
.5517	.4808	.5883	.5261	.6222	.5563	.6926	.5322
1.202	1.591	1.567	1.417	1.667	1.384	1.778	Np Targets
.4416	.5832	.5775	.5269	.6310	.5375	.7242	
.3885	.5131	.5073	.4614	.5498	.4644	.6205	
.3438	.4549	.4501	.4095	.4900	.4153	.5579	
.4416	.5890	.5811	.5259	.6222	.5163	.6657	
1.597	1.429	1.415	1.387	1.707	1.936	1.543	
.5909	.5302	.5269	.5227	.6576	.7662	.6464	
.5190	.4651	.4614	.4559	.5705	.6608	.5549	
.4602	.4125	.4093	.4053	.5100	.5927	.4978	
.5914	.5280	.5234	.5132	.6347	.7188	.5668	
1.384	1.698	1.690	1.719	1.653	1.706		
.5244	.6415	.6420	.6629	.6517	.7100		
.4584	.5607	.5596	.5754	.5628	.6112		
.4068	.4984	.4982	.5142	.5045	.5479		
.5097	.6288	.6262	.6371	.6116	.6246		
1.586	1.565	1.427	1.969	1.720			
.6204	.6075	.5569	.7803	.7161			
.5390	.5274	.4821	.6733	.6164			
.4801	.4697	.4300	.6032	.5524			
.5820	.5761	.5241	.7251	.6273			
1.445	1.965	1.869	1.584				
.5740	.7843	.7652	.6650				
.4952	.6763	.6588	.5715				
.4419	.6045	.5894	.5118				
.5282	.7204	.6821	.5749				
1.545	1.514	2 — Plane Groupings					
.6357	.6377	3					
.5454	.5471	4					
.4878	.4892	5					
.5614	.5475	6					

Fig. 34 Connecticut Yankee Core 3 — Assembly-wise relative power density - March, 1972, 7409 Mwd/mtU.

.1314	.1703	.1372	.1848	.1593	.2045	.1755	.1925
.3291	.4225	.3440	.4581	.3974	.5032	.4335	.4729
.6325	.8130	.6609	.8807	.7617	.9616	.8224	.8979
.9224	1.187	.9652	1.289	1.119	1.424	1.232	1.347
2.089	2.707	2.172	2.912	2.492	3.148	2.640	2.647
.1704	.1482	.1827	.1653	.2001	.1841	.2382	.2098
.4224	.3706	.4536	.4123	.4946	.4553	.5794	.5156
.8124	.7122	.8725	.7916	.9484	.8681	1.095	.9769
1.186	1.041	1.276	1.159	1.394	1.287	1.655	1.463
2.702	2.358	2.889	2.602	3.103	2.823	3.588	2.832
.1373	.1828	.1814	.1669	.2027	.1749	.2451	Np Targets
.3437	.4532	.4504	.4148	.5007	.4336	.6014	
.6595	.8707	.8649	.7947	.9586	.8260	1.142	
.9619	1.273	1.265	1.163	1.409	1.221	1.701	
2.157	2.874	2.844	2.594	3.091	2.605	3.424	
.1858	.1658	.1660	.1662	.2117	.2531	.2206	
.4588	.4123	.4118	.4119	.5221	.6187	.5433	
.8793	.7893	.7876	.7865	.9968	1.179	1.032	
1.283	1.152	1.150	1.151	1.468	1.742	1.526	
2.870	2.567	2.556	2.523	3.139	3.600	2.903	
.1644	.2029	.2040	.2122	.2115	.2388		
.4088	.4994	.5018	.5219	.5202	.5884		
.7794	.9535	.9574	.9949	.9898	1.117		
1.137	1.393	1.401	1.462	1.460	1.647		
2.468	3.043	3.042	3.113	3.019	3.141		
.1970	.1933	.1780	.2548	.2393			
.4866	.4766	.4393	.6202	.5884			
.9236	.9045	.8333	1.177	1.115			
1.350	1.322	1.221	1.733	1.641			
2.812	2.791	2.553	3.548	3.117			
.1845	.2562	.2529	.2232				
.4537	.6215	.6168	.5466				
.8574	1.176	1.166	1.033				
1.256	1.725	1.712	1.518				
2.567	3.503	3.342	2.848				
.2124	.2145	2 — Plane Groupings					
.5139	.5226	3					
.9690	.9852	4					
1.422	1.445	5					
2.762	2.705	6					

Fig. 35 Connecticut Yankee Core 3 — Assembly-wise relative power density - April, 1972, 8269 Mwd/mtU.

1.473	1.895	1.519	2.006	1.703	2.118	1.765	1.816
.2960	.3789	.3075	.4068	.3518	.4443	.3837	.4176
.1579	.2021	.1637	.2160	.1855	.2319	.1969	.2128
.0767	.0981	.0794	.1045	.0896	.1117	.0949	.1024
.0392	.0511	.0404	.0542	.0458	.0586	.0496	.0531
1.896	1.652	2.008	1.797	2.121	1.908	2.372	1.962
.3793	.3327	.4051	.3667	.4377	.4031	.5137	.4565
.2024	.1771	.2156	.1944	.2307	.2098	.2625	.2327
.0983	.0860	.1045	.0941	.1115	.1012	.1265	.1120
.0512	.0441	.0543	.0483	.0579	.0526	.0691	.0582
1.522	2.011	1.982	1.802	2.134	1.803	2.386	Np Targets
.3088	.4062	.4026	.3695	.4446	.3857	.5347	
.1646	.2163	.2139	.1956	.2336	.2003	.2744	
.0800	.1051	.1038	.0948	.1130	.0969	.1325	
.0408	.0546	.0537	.0487	.0585	.0497	.0691	
2.019	1.806	1.796	1.772	2.198	2.553	2.101	
.4116	.3700	.3690	.3682	.4660	.5531	.4849	
.2192	.1966	.1956	.1941	.2433	.2861	.2492	
.1066	.0956	.0950	.0942	.1179	.1386	.1206	
.0555	.0492	.0489	.0484	.0609	.0723	.0616	
1.757	2.156	2.156	2.210	2.152	2.295		
.3677	.4487	.4509	.4690	.4669	.5271		
.1949	.2377	.2376	.2453	.2422	.2721		
.0949	.1156	.1155	.1193	.1177	.1320		
.0485	.0601	.0600	.0617	.0607	.0672		
2.034	2.015	1.851	2.588	2.310			
.4395	.4309	.3978	.5616	.5308			
.2311	.2262	.2078	.2914	.2743			
.1127	.1103	.1013	.1419	.1335			
.0576	.0567	.0519	.0742	.0680			
1.892	2.597	2.498	2.148				
.4134	.5665	.5617	.4967				
.2151	.2944	.2909	.2565				
.1050	.1436	.1418	.1250				
.0538	.0753	.0734	.0640				
2.093	2.068	2	Plane Groupings				
.4708	.4783	3					
.2430	.2468	4					
.1185	.1204	5					
.0620	.0620	6					

Fig. 36 Connecticut Yankee Core 3 - Assembly-wise relative power density - May 1972, 9102 Mwd/mtU.

Fig. 37 Calculated critical boron concentration as a function of average core burnup for the reference reactor.

1.239	1.187	1.285	1.181	1.223	1.121	0.980	0.749
1.275	1.235	1.305	1.212	1.225	1.122	0.960	0.728
1.170	1.190	1.184	1.185	1.155	1.128	0.960	0.744
1.021	1.071	1.038	1.104	1.077	1.126	0.981	0.795
0.815	0.865	0.839	0.933	0.946	1.074	1.023	0.933
0.856	0.903	0.867	0.946	0.944	1.060	1.014	0.951
1.187	1.287	1.287	1.275	1.200	1.122	0.988	0.774
1.235	1.311	1.314	1.283	1.212	1.114	0.974	0.749
1.190	1.185	1.235	1.181	1.191	1.089	1.010	0.763
1.071	1.029	1.102	1.064	1.141	1.070	1.068	0.811
0.865	0.824	0.895	0.892	1.014	1.025	1.148	0.949
0.903	0.858	0.919	0.902	1.006	1.011	1.136	0.963
1.285	1.287	1.310	1.238	1.174	1.053	0.905	0.663
1.305	1.314	1.317	1.255	1.176	1.057	0.890	0.649
1.184	1.235	1.195	1.217	1.139	1.092	0.913	0.680
1.038	1.102	1.058	1.140	1.094	1.123	0.954	0.743
0.839	0.895	0.872	0.980	0.995	1.115	1.031	0.907
0.867	0.919	0.887	0.979	0.981	1.093	1.021	0.927
1.181	1.275	1.238	1.185	1.028	0.984	0.853	0.551
1.212	1.283	1.255	1.191	1.045	0.980	0.840	0.546
1.185	1.181	1.217	1.153	1.107	1.016	0.898	0.585
1.104	1.064	1.140	1.102	1.150	1.056	0.979	0.656
0.933	0.892	0.980	0.988	1.118	1.091	1.124	0.844
0.946	0.902	0.979	0.976	1.092	1.068	1.118	0.874
1.223	1.200	1.174	1.028	1.135	0.832	0.775	
1.225	1.212	1.176	1.045	1.120	0.832	0.759	
1.155	1.191	1.139	1.107	1.151	0.925	0.813	
1.077	1.141	1.094	1.150	1.187	1.032	0.895	
0.946	1.014	0.995	1.118	1.192	1.165	1.072	
0.944	1.006	0.981	1.092	1.155	1.141	1.076	
1.121	1.122	1.053	0.984	0.832	0.894	0.499	
1.122	1.114	1.057	0.980	0.832	0.866	0.494	
1.128	1.089	1.092	1.016	0.925	0.923	0.548	
1.126	1.070	1.123	1.056	1.032	1.003	0.632	
1.074	1.025	1.115	1.091	1.165	1.156	0.836	
1.060	1.011	1.093	1.068	1.141	1.136	0.864	
0.980	0.988	0.905	0.853	0.775	0.499		
0.960	0.974	0.890	0.840	0.759	0.494		
0.960	1.010	0.913	0.898	0.813	0.548		
0.981	1.068	0.954	0.979	0.895	0.632		
1.023	1.148	1.031	1.124	1.072	0.836		
1.014	1.136	1.021	1.118	1.076	0.864		
0.749	0.774	0.663	0.551	0.0	Core Average Burnup - Mwd/mtU		
0.728	0.749	0.649	0.546	1,000			
0.744	0.763	0.680	0.585	5,000			
0.795	0.811	0.743	0.656	9,000			
0.933	0.949	0.907	0.844	14,500			
0.951	0.963	0.927	0.874	16,000			

Fig. 38 Reference PWR — Assembly-wise average power distribution as a function of burnup.

Fig. 39 Macroscopic absorption cross-section per rod and change in reactivity (single assembly).

1.327	1.318	1.299	1.187	1.198	1.143	.9949	.7829
1.105	1.154	1.123	1.156	1.118	1.113	.9564	.7673
.9791	1.041	1.009	1.094	1.055	1.098	.9625	.8043
.7587	.8107	.7943	.8930	.9050	1.030	1.012	.9956
.7993	.8495	.8237	.9097	.9085	1.021	1.004	1.017
1.318	1.331	1.321	1.248	1.202	1.113	1.055	.8009
1.154	1.117	1.177	1.132	1.163	1.069	1.042	.7835
1.041	.9929	1.071	1.044	1.118	1.046	1.068	.8168
.8107	.7733	.8449	.8508	.9662	.9871	1.137	1.005
.8495	.8080	.8716	.8648	.9655	.9774	1.124	1.023
1.299	1.321	1.289	1.228	1.129	1.055	.9067	.6865
1.123	1.177	1.136	1.181	1.113	1.093	.9219	.7107
1.009	1.071	1.034	1.122	1.080	1.109	.9459	.7596
.7943	.8449	.8287	.9331	.9551	1.078	1.029	.9797
.8237	.8716	.8464	.9371	.9466	1.058	1.016	.9988
1.187	1.248	1.228	1.121	.9823	.9390	.8873	.5705
1.156	1.132	1.181	1.127	1.110	1.023	.9505	.6265
1.094	1.044	1.122	1.097	1.156	1.059	1.003	.6849
.8930	.8508	.9331	.9501	1.084	1.074	1.146	.9439
.9097	.8648	.9371	.9414	1.060	1.047	1.128	.9758
1.198	1.202	1.129	.9823	1.051	.7917	.7652	
1.118	1.163	1.113	1.110	1.166	.9574	.8685	
1.055	1.118	1.080	1.156	1.206	1.061	.9394	
.9050	.9662	.9551	1.084	1.173	1.179	1.157	
.9085	.9655	.9466	1.060	1.134	1.143	1.153	
1.143	1.113	1.055	.9390	.7917	.8460	.4987	
1.113	1.069	1.093	1.023	.9574	.9741	.6108	
1.098	1.046	1.109	1.059	1.061	1.050	.6956	
1.030	.9871	1.078	1.074	1.179	1.218	.9886	
1.021	.9774	1.058	1.047	1.143	1.186	1.012	
.9949	1.055	.9067	.8873	.7652	.4987		
.9564	1.042	.9219	.9505	.8685	.6108		
.9625	1.068	.9459	1.003	.9394	.6956		
1.012	1.137	1.029	1.146	1.157	.9886		
1.004	1.124	1.016	1.128	1.153	1.012		
.7829	.8009	.6865	.5705	0.0	— Burnup, Mwd/mtU		
.7673	.7835	.7107	.6265	5000			
.8043	.8168	.7596	.6849	9000			
.9956	1.005	.9797	.9439	16000			
1.017	1.023	.9988	.9758	17000			

Fig. 40 PPI — Assembly-wise average power distribution as a function of burnup.

.7880	.7834	.8740	.9496	1.135	1.247	1.232	1.047
1.366	1.352	1.308	1.254	1.153	1.075	.8734	.6862
1.248	1.289	1.203	1.200	1.080	1.050	.8730	.7123
.7616	.8146	.7994	.8891	.8960	1.005	.9638	.9289
.8313	.8824	.8523	.9247	.9111	1.003	.9569	.9449
.7834	.8321	.8676	1.014	1.145	1.219	1.354	1.043
1.352	1.338	1.308	1.243	1.197	1.029	.9822	.6965
1.289	1.226	1.247	1.147	1.141	1.000	.9886	.7256
.8146	.7809	.8541	.8534	.9625	.9696	1.098	.9529
.8824	.8418	.9038	.8835	.9720	.9637	1.083	.9660
.8740	.8676	.8713	1.057	1.094	1.140	1.082	.8857
1.308	1.308	1.281	1.273	1.133	1.048	.8434	.6435
1.203	1.247	1.174	1.201	1.090	1.061	.8696	.6875
.7994	.8541	.8391	.9433	.9640	1.079	1.013	.9453
.8523	.9038	.8744	.9592	.9600	1.058	.9950	.9544
.9496	1.014	1.057	1.037	.9831	1.013	1.018	.6874
1.254	1.243	1.273	1.176	1.103	.9697	.8708	.5629
1.200	1.147	1.201	1.130	1.143	1.010	.9324	.6262
.8891	.8534	.9433	.9671	1.110	1.097	1.161	.9443
.9247	.8835	.9592	.9628	1.081	1.061	1.129	.9639
1.135	1.145	1.094	.9831	1.099	.8675	.8742	
1.153	1.197	1.133	1.103	1.125	.9049	.7999	
1.080	1.141	1.090	1.143	1.167	1.009	.8797	
.8960	.9625	.9640	1.110	1.210	1.216	1.186	
.9111	.9720	.9600	1.081	1.159	1.162	1.162	
1.247	1.219	1.140	1.013	.8675	.9607	.5971	
1.075	1.029	1.048	.9697	.9049	.9100	.5801	
1.050	1.000	1.061	1.010	1.009	.9926	.6625	
1.005	.9696	1.079	1.097	1.216	1.253	1.007	
1.003	.9637	1.058	1.061	1.162	1.196	1.006	
1.232	1.354	1.082	1.018	.8742	.5971		
.8734	.9822	.8434	.8708	.7999	.5801		
.8730	.9886	.8696	.9324	.8797	.6225		
.9638	1.098	1.013	1.161	1.186	1.007		
.9569	1.083	.9950	1.129	1.162	1.006		
1.047	1.043	.8857	.6874	0.0	Burnup, Mwd/mtU		
.6862	.6965	.6435	.5629	5000			
.7123	.7256	.6875	.6262	9000			
.9289	.9529	.9453	.9443	16000			
.9449	.9660	.9544	.9639	17000			

Fig. 41 PP2 — Assembly-wise relative power distribution as a function of burnup.

.9356	.9432	1.005	1.005	1.082	1.131	1.095	.9342
1.315	1.319	1.276	1.231	1.143	1.089	.9188	.7375
1.144	1.190	1.132	1.165	1.090	1.091	.9361	.7739
.8006	.8518	.8321	.9247	.9318	1.039	.9966	.9562
.8485	.8976	.8669	.9451	.9367	1.030	.9876	.9729
.9432	.9896	1.010	1.055	1.067	1.115	1.180	.9350
1.319	1.300	1.295	1.214	1.161	1.044	1.008	.7428
1.190	1.138	1.180	1.115	1.137	1.038	1.041	.7826
.8518	.8143	.8818	.8826	.9907	.9962	1.122	.9744
.8976	.8553	.9136	.8997	.9913	.9863	1.107	.9895
1.005	1.010	1.062	1.087	1.081	1.085	1.007	.8195
1.276	1.295	1.245	1.232	1.114	1.049	.8683	.6752
1.132	1.180	1.121	1.166	1.087	1.079	.9056	.7265
.8321	.8818	.8607	.9585	.9734	1.079	1.014	.9478
.8669	.9136	.8823	.9652	.9659	1.060	1.000	.9621
1.005	1.055	1.087	1.078	1.034	1.035	1.000	.6621
1.231	1.214	1.232	1.146	1.092	.9723	.8797	.5786
1.165	1.115	1.166	1.107	1.132	1.013	.9441	.6451
.9247	.8826	.9585	.9669	1.091	1.067	1.125	.9237
.9451	.8997	.9652	.9599	1.067	1.040	1.106	.9522
1.082	1.067	1.081	1.034	1.195	.9678	.9217	
1.143	1.161	1.114	1.092	1.121	.9231	.8071	
1.090	1.137	1.087	1.132	1.154	1.008	.8810	
.9318	.9907	.9734	1.091	1.164	1.154	1.130	
.9367	.9913	.9659	1.067	1.126	1.118	1.123	
1.131	1.115	1.085	1.035	.9678	1.066	.6497	
1.089	1.044	1.049	.9723	.9231	.9152	.5826	
1.091	1.038	1.079	1.013	1.008	.9847	.6596	
1.039	.9962	1.079	1.067	1.154	1.180	.9524	
1.030	.9863	1.060	1.040	1.118	1.146	.9682	
1.095	1.180	1.007	1.000	.9217	.6497		
.9188	1.008	.8683	.8797	.8071	.5826		
.9361	1.041	.9056	.9441	.8810	.6596		
.9966	1.122	1.014	1.125	1.130	.9524		
.9876	1.107	1.000	1.106	1.123	.9682		
.9342	.9350	.8195	.6621	0.0	Burnup - Mwd/mtU		
.7375	.7428	.6752	.5786	5,000			
.7739	.7826	.7265	.6451	9,000			
.9562	.9744	.9478	.9237	16,000			
.9729	.9895	.9621	.9522	17,000			

Fig. 42 PP3 — Assembly-wise relative power distribution as a function of burnup.

1.021	1.008	1.068	1.046	1.103	1.112	1.058	.8917
1.282	1.289	1.246	1.213	1.133	1.083	.9255	.7441
1.123	1.166	1.105	1.146	1.078	1.087	.9439	.7814
.8126	.8601	.8329	.9260	.9297	1.040	1.004	.9615
.8555	.9008	.8635	.9434	.9330	1.031	.9949	.9787
1.008	1.059	1.089	1.096	1.106	1.103	1.139	.8990
1.289	1.266	1.277	1.192	1.162	1.045	1.013	.7536
1.166	1.110	1.153	1.095	1.129	1.038	1.047	.7935
.8601	.8167	.8800	.8808	.9885	.9975	1.126	.9815
.9008	.8531	.9079	.8951	.9878	.9872	1.112	.9975
1.068	1.089	1.105	1.103	1.087	1.067	.9336	.7915
1.246	1.277	1.217	1.210	1.111	1.051	.8800	.6844
1.105	1.153	1.097	1.151	1.086	1.082	.9154	.7342
.8329	.8800	.8589	.9597	.9757	1.080	1.015	.9468
.8635	.9079	.8772	.9642	.9673	1.061	1.002	.9627
1.046	1.096	1.103	1.084	1.030	1.022	.9791	.6510
1.213	1.192	1.210	1.142	1.101	.9862	.8878	.5929
1.146	1.095	1.151	1.110	1.146	1.027	.9456	.6564
.9260	.8808	.9597	.9746	1.100	1.068	1.107	.9228
.9434	.8951	.9642	.9664	1.076	1.043	1.090	.9536
1.103	1.106	1.087	1.030	1.179	.9441	.9040	
1.133	1.162	1.111	1.101	1.139	.9353	.8253	
1.078	1.129	1.086	1.146	1.174	1.021	.8958	
.9297	.9885	.9757	1.100	1.169	1.151	1.126	
.9330	.9878	.9673	1.076	1.133	1.117	1.121	
1.112	1.103	1.067	1.022	.9441	1.035	.6270	
1.083	1.045	1.051	.9862	.9353	.9332	.5917	
1.087	1.038	1.082	1.027	1.021	1.001	.6674	
1.040	.9975	1.080	1.068	1.151	1.176	.9430	
1.031	.9872	1.061	1.043	1.117	1.145	.9618	
1.058	1.139	.9836	.9791	.9040	.6270		
.9255	1.013	.8800	.8878	.8253	.5917		
.9439	1.047	.9154	.9456	.8958	.6674		
1.004	1.126	1.015	1.107	1.126	.9430		
.9949	1.112	1.002	1.090	1.121	.9618		
.8917	.8990	.7915	.6510	0.0	Burnup, Mwd/mtU		
.7441	.7536	.6844	.5929	5,000			
.7814	.7935	.7342	.6564	9,000			
.9615	.9815	.9468	.9228	16,000			
.9787	.9975	.9627	.9536	17,000			

Fig. 43 PP4 — Assembly-wise relative power distribution as a function of burnup.

Fig. 44 Calculated critical boron concentration as a function of average core burnup for the reference reactor and parametric problems.

16/0-.0184 12/6-.0156 14/6-.0179		16/0-.0184 14/4-.0173 14/6-.0179		12/0-.0138 10/6-.0133 10/6-.0133		6/0-.0069 6/0-.0069 2/4-.0035	
14/6-.0179		14/6-.0179		10/8-.0139		2/4-.0035	
14/6-.0179		14/6-.0179		10/10-.0145		2/6-.0041	
	12/0-.0138 10/6-.0133 14/6-.0179 12/6-.0156 10/10-.0145		12/0-.0138 10/6-.0133 10/6-.0133 12/6-.0156 10/10-.0145		16/0-.0184 12/8-.0162 8/10-.0122 10/8-.0139 10/10-.0145		
		12/0-.0138 10/6-.0133 10/6-.0133 10/8-.0139 10/10-.0145		12/0-.0138 10/6-.0133 10/6-.0133 10/8-.0139 10/10-.0145		6/0-.0069 6/0-.0069 2/4-.0035 2/4-.0035 2/6-.0041	
			16/0-.0184 14/6-.0179 14/6-.0179 14/6-.0179 14/6-.0179		12/0-.0138 8/10-.0122 8/10-.0122 8/12-.0128 6/14-.0111		
				16/0-.0184 14/6-.0179 14/6-.0179 12/6-.0156 12/8-.0162			
					6/0-.0069 6/0-.0069 2/4-.0035 2/4-.0035 2/6-.0041	Ref PP1 PP2 PP3 PP4	

Sample Entry

2/6 - .0041

Boron Rods
Np Rods

Thermal-Group Absorption
Cross-Section, cm⁻¹

Fig. 45 Core arrangement of different assembly combinations used in 2-D calculations.

17990	18380	18120	18120	17900	17730	15630	12550
	508.8		341.7		520.0		
	280.5		186.2		275.0		
	40.69		26.73		39.20		
	9.530		6.217		8.988		
	3.636		3.681		3.654		
18380	18150	18670	18140	18340	17230	16770	12780
508.8		504.0		509.5		744.9	
280.5		282.5		279.9		344.1	
40.69		41.32		40.59		44.31	
9.530		9.809		9.547		9.025	
3.636		3.621		3.641		3.842	
18120	18670	18290	18570	17700	17300	14940	11560
	504.0		505.7		527.5		
	282.5		281.6		271.2		
	41.32		41.10		38.19		
	9.809		9.739		8.595		
	3.621		3.636		3.671		
18120	18140	18570	17840	17350	16260	15140	10110
341.7		505.7		525.5		979.8	
186.2		281.6		273.2		400.7	
26.73		41.10		38.35		48.85	
6.217		9.739		8.641		9.352	
3.681		3.636		3.741		3.828	
17900	18340	17700	17350	18200	15210	13750	
	509.5		525.5		562.8		
	279.9		273.2		254.0		
	40.59		38.35		33.18		
	9.547		8.641		6.772		
	3.641		3.741		3.822		
17730	17230	17300	16260	15210	15350	9790	
520.0		527.5		562.8			
275.0		271.3		254.0			
39.20		38.19		33.18			
8.988		8.595		6.772			
3.654		3.671		3.822			
15630	16770	14940	15140	13750	9790	Assem. burnup -Mwd/mtU	
	744.9		979.8			— Np-237 mass gms	
	344.1		400.7			— Pu-238 mass gms	
	44.31		48.85			— Pu-239 mass gms	
	9.025		9.352			— Pu-240 mass gms	
	3.842		3.828			— Pu-236/Pu-238 ratio ppm	
12550	12780	11560	10110	Total masses in core at 16,000 Mwd/mtU			
				Np-237 - 44.36 kg			
				Pu-238 - 22.06 kg			
				Pu-239 - 3.03 kg			
				Pu-240 - 0.67 kg			
				Pu-236/Pu-238 ratio 3.72 ppm			

Fig. 46 Assembly-wise burnup and isotopic masses in neptunium target rods in PP1 at an average core burnup of 16,000 Mwd/mtU.

18150	18200	18040	18030	17900	17780	15890	12880
	511.2		513.9		519.1		420.7
	279.6		278.6		275.4		141.3
	40.24		39.91		39.32		15.66
	9.734		9.231		9.029		2.810
	3.752		3.726		3.635		3.600
18200	18100	18160	18100	18350	17300	17410	12990
511.2		511.8		509.4		915.0	
279.6		279.4		279.9		437.9	
40.24		40.17		40.61		57.86	
9.734		9.335		9.544		12.09	
3.752		3.740		3.648		3.743	
18040	18160	18210	18610	17680	17230	14990	11760
	511.8		505.0		528.7		434.2
	279.4		281.8		270.7		132.2
	40.17		41.19		38.03		13.83
	9.335		9.753		8.549		2.317
	3.740		3.662		3.656		3.626
18030	18100	18610	17840	17250	16100	14990	10030
513.9		505.0		527.3		983.9	
278.6		281.8		272.3		398.4	
39.91		41.19		38.11		48.27	
9.231		9.753		8.538		9.121	
3.726		3.662		3.738		3.805	
17900	18350	17680	17250	18020	15030	13610	
	509.4		527.3		566.0		
	279.9		272.3		252.3		
	40.61		38.11		32.74		
	9.544		8.538		6.613		
	3.648		3.738		3.808		
17780	17300	17230	16100	15030	15270	9920	
519.1		528.7		566.0		458.6	
275.4		270.7		252.3		114.4	
39.32		38.03		32.74		10.72	
9.029		8.549		6.613		1.637	
3.635		3.656		3.808		3.525	
15890	17410	14990	14990	13610	9920	Assem. burnup - Mwd/mtU	
	915.0		983.9		458.6	Np-237 mass gms	
	437.9		398.4		114.4	Pu-238 mass gms	
	57.86		48.27		10.72	Pu-239 mass gms	
	12.09		9.121		1.637	Pu-240 mass gms	
	3.743		3.805		3.525	Pu-236/Pu-238 ratio ppm	
12880	12990	11760	10030	Total masses in core at 16,000 Mwd/mtU			
420.7		434.2		Np-237 - 55.38 kg			
141.3		132.2		Pu-238 - 25.65 kg			
15.66		13.83		Pu-239 - 3.433 kg			
2.810		2.317		Pu-240 - .7432 kg			
3.600		3.626		Pu-236/Pu-238 ratio 3.712 ppm			

Fig. 47 Assembly-wise burnup and isotopic masses in neptunium target rods in PP2 at an average core burnup of 16,000 Mwd/mtU.

18060	8190	18090	17980	17660	17530	15810	12950
	511.2		514.7		697.7		419.9
	279.9		278.3		364.7		141.8
	40.26		39.80		51.68		15.78
	9.346		9.169		11.69		2.848
	3.719		3.715		3.666		3.625
18190	18140	18350	17970	17820	17090	17050	13030
511.2		508.6		517.6		738.7	
279.9		280.9		276.7		347.4	
40.26		40.61		39.41		45.17	
9.346		9.510		9.062		9.311	
3.719		3.695		3.693		3.805	
18090	18350	18170	18370	17520	17070	14960	11830
	508.6		678.7		708.5		433.4
	280.9		373.6		359.4		132.8
	40.61		54.21		50.22		13.93
	9.510		12.68		11.16		2.349
	3.695		3.667		3.676		3.638
17980	17970	18370	17770	17370	16240	15010	10100
514.7		678.7		525.1		1180.	
278.3		373.6		273.4		478.8	
39.80		54.21		38.40		58.04	
9.169		12.68		8.630		10.94	
3.715		3.667		3.727		3.816	
17660	17820	17520	17370	18390	15580	13880	
	517.6		525.1		556.2		
	276.7		273.4		257.6		
	39.41		38.40		34.11		
	9.062		8.630		7.067		
	3.693		3.727		3.766		
17530	17090	17070	16240	15580	15740	10160	
697.7		708.5		556.2		455.6	
364.7		359.4		257.6		116.7	
51.68		50.22		34.11		11.11	
11.69		11.16		7.067		1.728	
3.666		3.676		3.766		3.516	
15810	17050	14960	15010	13880	10160	Assem. burnup- Mwd/mtU	
	738.7		1180.		455.6	Np-237 mass gms	
	347.4		478.8		116.7	Pu-238 mass gms	
	45.17		58.04		11.11	Pu-239 mass gms	
	9.311		10.94		1.728	Pu-240 mass gms	
	3.805		3.816		3.516	Pu-236/Pu-238 ratio ppm	
12950	13030	11830	10100	Total masses in core at 16,000 Mwd/mtU			
419.9		433.4		Np-237 — 58.99 kg			
141.8		132.8		Pu-238 — 27.44 kg			
15.78		13.93		Pu-239 — 3.672 kg			
2.848		2.349		Pu-240 — .7917 kg			
3.625		3.638		Pu-236/Pu-238 ratio, 3.717 ppm			

Fig. 48 Assembly-wise burnup and isotopic masses in neptunium target rods in PP3 at an average core burnup of 16,000 Mwd/mtU.

18120	18230	18100	17990	17640	17380	15700	12820
	510.5		514.6		876.4		632.1
	280.2		278.4		454.1		211.3
	40.35		39.81		64.02		23.35
	9.365		9.169		14.37		4.171
	3.712		3.707		3.678		3.641
18230	18160	18450	17950	17930	17030	16900	12970
510.5		845.6		860.3		927.3	
280.2		468.6		461.7		432.3	
40.35		68.12		66.17		55.92	
9.365		15.92		15.19		11.42	
3.712		3.670		3.673		3.821	
18100	18450	18100	18240	17530	17000	14950	11780
	845.6		851.6		887.2		650.9
	468.6		465.8		448.7		198.7
	68.12		67.34		62.55		20.79
	15.92		15.62		13.86		3.483
	3.670		3.673		3.686		3.654
17990	17950	18240	17800	17480	16320	14950	10170
514.6		851.6		523.1		1376.	
278.4		465.8		274.4		559.3	
39.81		67.34		38.67		67.38	
9.169		15.62		8.719		12.69	
3.707		3.673		3.728		3.837	
17640	17930	17530	17480	18510	15590	13960	
	360.3		523.1		741.2		
	461.7		274.4		343.8		
	66.17		38.67		45.53		
	15.19		8.719		9.419		
	3.673		3.728		3.781		
17380	17030	17000	16320	15590	15770	10130	
876.4		887.2		741.2		683.7	
454.1		448.7		343.8		174.8	
64.02		62.55		45.53		16.61	
14.37		13.86		9.419		2.573	
3.678		3.686		3.781		3.531	
15700	16900	14950	14950	13960	10130	Assem. burnup-Mwd/mtU	
	927.3		1376.		683.7	Np-237 mass gms	
	432.3		559.3		174.8	Pu-238 mass gms	
	55.92		67.38		16.61	Pu-239 mass gms	
	11.42		12.69		2.573	Pu-240 mass gms	
	3.821		3.837		3.531	Pu-236/Pu-238 ratio ppm	
12820	12970	11780	10170	Total masses in core at 16,000 Mwd/mtU			
632.1		650.9		Np-237 — 76.91 kg			
211.3		198.7		Pu-238 — 35.52 kg			
23.35		20.79		Pu-239 — 4.743 kg			
4.171		3.483		Pu-240 — 1.019 kg			
3.641		3.654		Pu-236/Pu-238 ratio 3.716 ppm			

Fig. 49 Assembly-wise burnup and isotopic masses in neptunium target rods in PP4 at an average core burnup of 16,000 Mwd/mtU.

ITEM NO.	TITLE	MATERIAL SPECIFICATION	NO REQD
1	TARGET ROD ASSEMBLY	SNE DWG NO 69-646-10	REF.
2	UPPER FRAME	TYPE 304 STAINLESS STL	1
3	SUPPORT LUG	TYPE 304 STAINLESS STL	8
4	#6-32 UNC FLAT HEAD MACHINE SCREW	TYPE 304 STAINLESS STL	16
5	SUPPORT BLOCK	TYPE 304 STAINLESS STL	4
6	SHROUD HALF	16 GAGE (0.051) TYPE 304 STAINLESS STEEL W/2B FINISH	2
7	LOWER END PLATE	TYPE 304 STAINLESS STL	1

NOTES:
 1 CONTAINER WEIGHT 98 LBS
 WITHOUT TARGET ROD ASSEMBLY
 2 DEBURR ALL SHARP EDGES
 1/64" MAX

② UPPER FRAME

③ SUPPORT LUG

⑤ SUPPORT BLOCK

⑦ LOWER END PLATE

⑥ SHROUD HALF

B	5272	REVISED DIMENSIONS TO REFLECT AS BUILT CONDITIONS - ADDED WELDING NOTES
A	7473	REVISED THROUGH SUPPORT LUGS ADDED THROUGH DETAIL - MADE MINOR DIMENSIONAL CHANGES
REV	DATE	DESCRIPTION
SOUTHERN NUCLEAR ENGINEERING, INC AFFILIATE OF REYNOLDS SMITH & HILLS DUNEDIN, FLORIDA PU 238 COMMERCIAL PRODUCTION		
DRAWN	R. COLE	2-11-72
CHECKED		
APPROVED	CMJL	5/7/72
TARGET ROD ASSEMBLY STORAGE CONTAINER		HALF SIZE 69-646-14 B

Fig. 50