APPENDIX F

Evaluation of Fuel Element Powers, ^{235}U Masses, and Burnups from the Gamma-Scanning of Full-Sized Fuel Elements

The methods used to evaluate cycle-averaged fuel element powers and region-averaged ^{235}U masses and burnups from the gamma-scanning of full-sized fuel elements are discussed in Section 6.4. Results of these analyses arc given in Sections 7.7 and 7.8. The purpose of this appendix is to illustrate how the final results are obtained from the measured data. As a first example, gamma-scanning data for the LEU fuel element C024, fabricated by CERCA, will be used. Initially, this fuel element contained 340 g ^{235}U.

A summary of the power histories for each of the cores used in the ORR whole-core demonstration is given in Table F. 1. In this table TE(l,J) is the exposure time in full power days for the Jth startup of core 1, and TS(I,J) is the corresponding shutdown time in days measured from the 1/l/86 reference date. This information is needed in the evaluation of the 1401-a and ^{137}Cs buildup-decay factors (BDFs) discussed in Section 6.4.1. Also needed are decay constants and cumulative fission product yields. The values given below were taken from the ENDF/B Version V data file.

Isotope	Half Life Days	Error Percent	Decay Constant Days- I	Cumulative Fission Product Yield, %
^{140}Ba	1.2789E+01	0.047	5.4199E-02	6.271
^{140}La	1.6775E+00	0.050	4.1320E-01	6.276
^{137}Cs	1. 1020E+04	0.099	6.2899E-05	6.220

Table F.2 provides an evaluation of the ^{140}La gamma-scanning count rate data for each core in which fuel element C024 was irradiated. The counting locations given in this table are measured with respect to the top of the fuel column. The beginning time for each counting period is expressed in days relative to the l/l/86 reference date. CPSE(K) is the observed 1401-a counts per second at position K divided by the relative efficiency factor (see text, p. 60). Count rates from residual 1401-a activities from up to four previous irradiation cycles were evaluated from Eq. 3 on page 60 and are given in Table F.2 under the headings CPSR1(K), CPSR2(K), CPSR3(K), and CPSR4(K). The total residual count rate, CPSRT(K), is the sum of these four terms and is subtracted from CPSE(K) to get the net count rate, CPSN(K). BDF-LA(K) is the buildup-decay factor for ^{140}La and was calculated from Eq. (2) on p. 60 using times given in Tables F. I and F.2.

The next to the last column in Table F.2 has the heading (CRJBDF)/Y which is the net count rate divided by the product of the 1401-a buildup-decay factor and the 140Ba fission product yield. This quantity is proportional to the fission rate (Eq. 1, p. 60) and its average value (Eq. 4, p. 60) is proportional to the fuel element power. Finally, the last column in this C table is the product of the previous column and the total exposure time (in seconds) and is called TE(CR/BDF)/Y. This quantity is related to the total fissions which occurred in the fuel element and therefore is proportional to the 235U burnup (see Eqs. 5 and 10 in Section 6.4. 1).

For the first five cores the ^{140}La count rate data were recorded at only 12 locations along the length of the fuel column. Four additional counting locations were used for the last three irradiation cycles. For the first five cores in which C024 was irradiated, CPSE(K) was obtained at these four extra locations (K=2, 10, 14, and 16) by interpolation using the ^{137}Cs scanning data.

Table F. 1 Summary of Power Histories for the ORR Demonstration Cores

I	COR(I)	J	TE(I,J)-DAYS IRRADIATION	TS(I,J)-DAYS FROM 1/1/86
1	174C	1	16.84022	5.16667
2	174DE	1	12.85540	19.34722
		2	10.62284	31.00000
3	174F	1	11.28240	45.96042
		2	4.14575	50.12500
4	175A	1	7.05031	72.58958
		2	11.46776	84.08333
5	175B	1	20.30494	105.08333
6	175C	1	17.38908	122.97222
7	176A	1	0.00099	131.45972
		2	10.80045	142.34167
		3	0.00017	142.35417
		4	6.44282	150.64583
8	176B	1	15.81109	193.72778
		2	0.00008	193.75069
		3	6.05331	201.62500
9	176C	1	19.43568	222.00000
10	176D	1	19.44628	243.22708
11	177A	1	14.77308	268.12500
12	177B	1	18.51601	287.16667
13	177C	1	7.49794	295.20486
		2	4.12174	299.35069
		3	6.79107	306.16667
14	177D	1	15.33411	322.00000
15	178A	1	12.10057	339.46181
16	1788C	1	0.64447	342.43819
		2	11.13766	354.75000
17	178D	1	0.02916	355.01736
		2	0.16744	355.25694
		3	16.15898	372.07500
18	178H	1	0.06396	372.60208
		2	3.01563	376.35417
		3	0.07424	376.45694
		4	7,89992	384.37500
		5	2.93549	387.33333
		6	6.28731	393.64583
19	178J	1	2.94116	398.38264
		2	8.01454	406.42222
		3	2.92777	409.37708
		4	2.6~876	412.00000
20	179A	1	0.06706	428.83611
		2	0.05365	429.46181
		3	20.04798	449.68333

Table F.2 Evaluation of the ^{140}La Gamma Scan Count Rate Data

FUEL ELEMENT = C024 CORE = 174F GRID = A5 RELATIVE EFFICIENCY = 0.9162

K	LOC-IN	TIME-DAYS	CPSEM	CPSR1(K)	CPSR2(K)	CPSR3(K)	CPSR4(K	CPSRT(K)	CPSHM	BDF-LA(K)	(CR/BDF)/Y	TE(CR/BDF)/Y
1	0.3125	59.677	139.195	0.0	0.0	0.0	0.0	0.0	139.195	3.85465D-01	5.75839D+03	7.67589D+09
2	1.3125	59.681	l47.019	0.0	0.0	0.0	0.0	0.0	147.019	3.85386D-01	6.08331D+03	8.10900D+09
3	2.3125	59.685	166.658	0.0	0.0	0.0	0.0	D.0	166.658	3.85307D-01	6.89736D+03	9.19413D+09
4	q.3125	59.694	235.346	0.0	0.0	0.0	0.0	0.0	235.346	3.85128D-01	9.74462D+03	1.29895D+10
5	6.3125	59.703	299.484	0.0	0.0	0.0	0.0	0.0	299.484	3.8495OD-01	1.24060D+04	1.65371D+10
6	8.3125	59.713	363.432	0.0	0.0	0.0	0.0	0.0	363.432	3.84751D-01	1.50628D+04	2.00786D+10
7	10.3125	59.723	406.965	0.0	0.0	0.0	0.0	0.0	406.965	3.84553D-01	1.68758D+04	2.24953D+10
8	12.3125	59.734	427.990	0.0	0.0	0.0	0.0	0.0	427.990	3.84335D-01	1.77577D+04	2.36709D+10
9	14.3125	59.745	q33.258	0.0	0.0	0.0	0.0	0.0	433.258	3.84117D-01	1.79865D+04	2.39758D+10
10	15.3125	59.750	432.448	0.0	0.0	0.0	0.0	0.0	432.448	3.84008D-01	1.79579D+04	2.39378D+10
11	16.3125	59.756	414.874	0.0	0.0	0.0	0.0	0.0	414.874	3.83899D-01	1.72330D+04	2.29715D+10
12	18.3125	59.766	378.969	0.0	0.0	0.0	0.0	0.0	378.969	3.83702D-01	1.57497D+04	2.09943D+10
13	20.3125	59.777	317.916	0.0	0.0	0.0	0.0	0.0	317.946	3.83484D-01	1.32212D+04	1.76237D+10
l4	21.3125	59.782	291.042	0.0	0.0	0.0	0.0	0.0	291.042	3.83385D-01	1.21055D+04	1.61366D+10
15	22.3125	59.787	259.088	0.0	0.0	0.0	0.0	0.0	259.088	3.83286D-01	1.07792D+04	1.43686D+10
16	23.3125	59.792	297.280	0.0	0.0	0.0	0.0	0.0	297.280	3.83187D-01	1.23714D+04	1.64910D+10

NOTE: CPSE(k) OBTAINED BY INTERPOLATION USING THE CS-137 SCANNING DATA FOR K = 2, 10, 14, AND 16

Table F.2 Evaluation of the ^{140}La Gamma Scan Count Rate Data
(Continued)

FUEL ELEMENT = C024 CORE = 175B GRID = D3 RELATIVE EFFICIENCY = 0.9320

K	LOC-IU.	TME-DAYS	CPSE(K)	CPSR1(K)	CPSR2(K)	CPSR3(K)	CPSR4(K)	CPSRT(K)	CPSHM	BDF-LAM	(CR/BDF)/Y	TE(CR/BDF)/Y
1	0.3125	108.673	284.396	9.687	0.0	0.0	0.0	9.687	274.709	5.98002D-01	7.32544D+03	1.28514D+10
2	1.3125	108.678	284.127	10.230	0.0	0.0	0.0	10.230	273.896	5.97891D-01	7.30512D+03	1.28157D+10
3	2.3125	108.684	306.692	11.596	0.0	0.0	0.0	11.596	295.096	5.97780D-01	7.87200D+03	1.38102D+10
4	4.3125	108.695	409.419	16.373	0.0	0.0	0.0	16.373	393.046	5.97558D-01	1.04888D+04	1.84010D+10
5	6.3125	108.707	530.898	20.831	0.0	0.0	0.0	20.831	510.067	5.97316D-01	1.36172D+04	2.38892D+10
6	8.3125	108.721	651.144	25.273	0.0	0.0	0.0	25.273	625.871	5.97032D-01	1.67167D+04	2.93269D+10
7	10.3125	108.737	752.713	28.290	0.0	0.0	0.0	28.290	724.423	5.96706D-01	1.93595D+04	3.39633D+10
8	12.3125	108.755	810.597	29.740	0.0	0.0	0.0	29.740	780.857	5.96339D-01	2.08805D+04	3.66317D+10
10	15.3125	108.782	820.369	30.031	0.0	0.0	0.0	30.031	790.338	5.95786D-01	2.11537D+04	3.71109D+10
11	16.3125	108.791	792.345	28.805	0.0	0.0	0.0	28.805	763.540	5.95601D-01	2.04428D+04	3.58637D+10
12	18.3125	108.809	731.554	26.300	0.0	0.0	0.0	26.300	705.254	5.95230D-01	1.98940D+04	3.31466D+10
13	20.3125	108.826	628.811	2.2.057	0.0	0.0	0.0	22.057	606.754	5.94879D-01	1.62647D+04	2.85340D+10
14	21.3125	103.834	577.206	20.188	0.0	0.0	0.0	20.188	557.018	5.94723D-01	1.49356D+04	2.62019D+10
15	22.3125	108.841	515.587	17.969	0.0	0.0	0.0	17.969	497.618	5.94568D-01	1.33162D+04	2.34139D+10
16	23.3125	108.849	590.526	20.614	0.0	0.0	0.0	20.614	569.911	5.94412D-01	1.52891D+04	2.68224D+10

NOTE: CPSE(K) OBTAINED BY INTERPOLATIO14 USING THE CS-137 SCANNING DATA FOR K = 2. 10, 14, AND 16

Table F.2 Evaluation of the ^{140}La Gamma Scan Count Rate Data
(Continued)

FUEL ELEMENT = C024 CORE = 176A GRID = E4 RELATIVE EFFICIENCY = 1.0070

K	LOC-IN	TIME-DAYS	CPSE(K)	CPSR1(K)	CPSR2(K)	CPSR3(K)	CPSR4(K)	CPSRT(K)	CPSHM	BDF-LA(K)	(CR/BDF)/Y	TE(CR/BOF)/Y
1	0.3125	162.888	204.695	14.736	0.475	0.0	0.0	15.210	189.485		3.41286D-01	8.85357D+03 1.31911D+10
2	1.3125	162.892	209.860	14.721	0.501	0.0	0.0	15.222	194.638	3.41204D-01	9.09655D+03	1.35531D+10
3	2.3125	162.897	231.892	15.889	0.568	0.0	0.0	16.457	215.435	3.41123D-01	1.00709D+04	1.50O48D+10
4	4.3125	162.906	304.336	21.209	0.803	0.0	0.0	22.011	282.325	3.40959D-01	1.32041D404	1.96731D+10
5	6.3125	162.915	361.680	27.499	1.021	0.0	0.0	28.521	333.159	3.40796D-01	1.55891D+04	2.32265D+10
6	8.3125	162.925	399.960	33.726	1.239	0.0	0.0	34.965	364.995	3.40614D-01	1.70878D+04	2.54595D+10
7	10.3125	162.935	423.178	38.986	1.388	0.0	0.0	40.374	382.804	3.40433D-01	1.79311D+04	2.67159D+10
8	12.3125	162.946	430.033	41.985	1.459	0.0	0.0	43.445	386.588	3.40234D-01	1.81190D+04	2.69959D+10
9	14.3125	162.957	425.207	42.297	1.477	0.0	0.0	43.774	381.433	3.40035D-01	1.78879D404	2.66515D+10
10	15.3125	162.962	423.778	42.494	1.475	0.0	0.0	43.969	379.809	3.39944D-01	1.78164D+04	2.65451D+10
11	16.3125	162.967	405.920	41.044	1.415	0.0	0.0	42.459	363.461	3.39854D-01	1.70541D+04	2.54093D+10
12	18.3125	162.977	376.466	37.898	1.292	0.0	0.0	39.190	337.276	3.39673D-01	1.58339D+04	2.35912D*10
13	20.3125	162.998	324.119	32.575	1.084	0.0	0.0	33.659	290.460	3.39474D-01	1.36440D+04	2.03285D+10
14	21.3125	162.992	302.581	129.902	0.992	0.0	0.0	30.895	271.686	3.39392D-01	1.27652D+04	1.90191D+10
15	22.3125	162.997	275.793	26.711	0.883	0.0	0.0	27.594	248.199	3.39311D-01	1.16645D+04	1.73791D+10
16	23.3125	163.001	312.543	30.594	1.014	0.0	0.0	31.607	280.936	3.39230D-01	1.32061D+04	1.96761D+10

NOTE: CPSE(K) OBTAINED BY INTERPOLATION USING WE CS-137 SCANNING DATA FOR K = 2, 10. 14, AND 16

Table F.2 Evaluation of the ^{140}La Gamma Scan Count Rate Data
(Continued)

FUEL ELEMENT = C024 CORE = 176C GRID = B3 RELATIVE EFFICIENCY = 1.0243

K	LOC-IN.	TIME-DAYS	CPSE(K)	CPSRI(K)	CPSR2(K)	CPSR3(K)	CPSR4(K)	CPSRT(K)	CPSN(K)	BDF-LA(K)	(CR/BDF)/Y	TE(CR/BDF)/Y
1	0.3125	231.005	161.577	5.030	0.361	0.012	0.0	5.402	156.175	4.56441D-01	5.45619D+03	9.16226D+09
2	1.3125	231.009	163.647	5.156	0.361	0.012	0.0	5.529	158.118	4.56335D-01	5.52536D+03	9.27841D+09
3	2.3125	231.014	178.870	5.698	0.389	0.014	0.0	6.101	172.769	4.56230D-01	6.03872D+03	1.01405D+10
4	4.3125	231.023	236.077	7.478	0.520	0.020	0.0	8.017	228.060	4.56019D-01	7.97497D+03	1.33919D+10
5	6.3125	231.032	296.220	8.887	0.674	0.025	0.0	9.586	286.634	4.55809D-01	1.00279D+04	1.68392D+10
6	8.3125	231.042	374.002	9.827	0.826	0.030	0.0	10.684	363.318	4.55575D-01	1.27172D+04	2.13552D+10
7	10.31215	231.053	438.377	10.397	0.955	0.034	0.0	11.386	426.991	4.55317D-01	1.49544D+04	2.51120D+10
8	12.3125	231.064	484.111	10.565	1.029	0.036	0.0	11.630	472.481	4.55060D-01	1.65569D+04	2.78031D+10
9	14.31215	231.075	509.501	10.447	1.036	0.036	0.0	11.519	497.982	4.54803D-01	1.74604D+04	2.93202D+10
10	15.3125	231.081	517.804	10.411	1.041	0.036	0.0	11.488	506.316	4.54663D-01	1.77581D+04	2.98201D+10
11	16.3125	231.087	506.034	9.972	1.006	0.035	0.0	11.012	495.022	4.54522D-01	1.73673D+04	2.91639D+10
12	18.3125	231.099	482.483	9.247	0.928	0.032	0.0	10.207	472.275	4.54242D-01	1.65795D+04	2.78410D+10
13	20.3125	231.110	417.126	7.961	0.798	0.027	0.0	8.786	408.340	4.53985D-01	1.43101D+04	2.40856D+10
14	21.3125	231.115	385.061	7.432	0.733	0.024	0.0	8.188	376.873	4.53857D-01	1.32416D+04	2.22358D+10
15	22.3125	231.121	366.316	6.773	0.654	0.022	0.0	7.449	338.867	4.53728D-01	1.19096D+04	1.99991D+10
16	23.3125	231.126	395.223	7.675	0.749	0.025	0.0	8.450	386.774	4.53600D-01	1.35971D+04	2.28329D+10

NOTE:CPSEM OBTAINED BY INTERPOLATION USING WE CS-137 SCANNING DATA FOR K = 2, 10, 14, AND 16

LaGrange interpolation methods were used to obtain (CRIBDF)/Y values at the boundaries of the six axial fuel regions each of equal height (10.001 cm). These interpolated values are given in Table F.3 for each of the cores in which the fuel element C024 was exposed. In addition, this table contains the fitting coefficients for obtaining the 235U burnups from the measured total fissions (Eq. 11, p. 61.). Calculated transverse gradient correction factors (see Section 6.4.3 and Table C. 1), calculated cycle-averaged fuel element powers, and calculated EOC 235U masses are given at the end of Table F.3. These values are used to determine calculated-to-experiment (C/E) ratios.

Table FA lists the region- integrated quantities obtained from the 140La gamma-scanning data for the C024 fuel element. Numerical integrations were performed using the trapezoidal rule. Cycle-averaged fuel element powers were evaluated from Eq. 9 in the text (p. 61) where the value used for the geometric efficiency, G_L, is given at the top of Table FA and is discussed in Section 6.4.2. These cycle-averaged fuel element powers and corresponding C/E ratios are the values given in Table 37 of Section 7.7. ^{235}U burnup values were determined from Eqs. 5 and 11 in Section 6.4.1.

The evaluation of the ^{137}Cs gamma-scanning data for fuel element C024 is summarized in Table F.5. The BDF_c's (Eq. 7, p. 60) were calculated using the (CR/BDF)/Y values in Table F.2 for the $F(r)_j$ weighting functions. The last column in Table F.5 is the ^{137}CS count rate (CRc) divided by the product $BDF_c*Y_c*DC_c$, where Yc is the 137Cs fission product yield and DCc is the decay constant X_c. By numerically integrating these results the total number of fissions is determined from which the burnup is obtained (see Section 6.4. 1, Eqs. 8 and 11). The geometric efficiency ratio (G_c / G_L) given in Table F.5 was combined with the value given earlier for G_L to determine G_c (see 6.4.2). Based on this ^{137}Cs data, the final burnup for fuel element C024 is 51.20%, which is consistent with the value of 50.93% obtained earlier (Table FA) from the 140La data. Discharge values for the 235U masses and burnups given in Tables 38 (p. 136) and 43 (p. 147) of the text are based only on the 137Cs data.

For reasons discussed in Section 6.4.2, the fuel followers were gamma-scanned for ^{137}CS only. Before these measurements were completed, the Ge(Li)detector failed and so all eight LEU fuel followers were gamma-scanned using a 3" x 3" NaI detector (see Section 6.4.4). To illustrate the data analysis methods used for these elements, we consider the case of the UB002 LEU follower which was gamma-scanned with both detector systems.

Table F.6 shows the evaluation of the ^{137}Cs gamma-scanning data obtained with the Ge(Li) detector for the UB002 follower. After collecting the gamma-scanning data for all the followers, it was discovered that a 1/2-inch offset error had occurred in the location of the followers relative to the detector collimator. Linear interpolation methods were used to adjust the data to correspond to the 16 standard positions used in the analysis of all the 19-plate fuel elements, including C024 discussed above. Table F.6 includes these interpolated CPSE(K)
values. Since the followers were not scanned for 140La, calculated powers were used for the fission rate weighting function to determine the BDFc values (p. 60). The ^{235}U burnups for UB002 given in Table 43 of the text (p. 147) were obtained from the bottom entries in Table F.6.

Table F.7 shows the pulse height spectrum obtained with the NaI detector for the UB002 follower at location 09. This location reference corresponds to position K=6 in Table F.6. The first column of data in Table F.7 gives the channel numbers and the remaining columns the channel counts obtained in a 600-sccond counting time. Section 6.4.4 discusses the non-linear least squares method used to extract the 137Cs activity from the measured pulse height spectrum. Figure 18 (p. 71) compares the fitted spectrum (dotted curve) with the measured one (solid curve) taken from Table F.7. Table F.8 shows the results of this non-linear least squares analysis including the values obtained for the 137Cs count rate. The values for the 14 independent adjustable parameters obtained from the fitting procedure are given in Table F.8 under the Heading, "Final Approximate Solution". These parameters (see Table 22, p. 70) are given in the following order: b_l, b_2, b_3, b_4, b_5, W(^{137}Cs), a(^{106}Rh), a(^{l34}CS), a(^{137}Cs) , a(^{95}Nb), p(^{106}Rh), p($^{l\,34}$Cs, 605 keV), p(^{137}Cs), and p(^{134}Cs, 796 keV).

Table F.3 LaGrange interpolation, Burnup Fitting Coefficients, Calculated Transverse Gradients, Fuel Element Powers, and 235U Masses

LAGRANGE-INTERPOLATED VALUES FOR (CR/BDF)/Y FOR FUEL ELEMENT C024

CORE	X=0.0 INCH	X= 3.9375”	X= 7.8750”	X=11.8125"	X=15.7500”	X=19.6875”	X=23.6250”
174F	5.76698D+03	9.15937D+03	1.45246D+04	1.76093D+04	1.76962D+04	1.40191D+04	1.39621D+04
175B	7.46322D+03	9.90616D+03	1.60628D+04	2.06183D+04	2.09092D+04	1.71269D+04	1.72201D+04
176A	8.96753D+03	1.25894D+04	1.68240D+04	1.81206D+04	1.75329D+04	1.43204D+04	1.46826D+04
176C	5.54239D+03	7.56338D+03	1.21297D+04	1.62193D+04	1.76415D+04	1.50893D+04	1.52575D+04
177A	5.29726D+03	9.17029D+03	1.27074D+04	1.35552D+04	1.30360D+04	1.06398D+04	1.08252D+04
177C	7.90767D+03	9.418660*03	1.25193D+04	1.37725D+04	1.35672D+04	1.14196D+04	1.16940D+04
178A	8.02998D+03	1.23488D+04	1.66394D+04	1.77205D+04	1.71638D+04	1.45920D+04	1.51105D+04
178D	5.02153D+03	7.16371D+03	1.25510D+04	1.62002D+04	1.75024D+04	1.58766D+04	1.69696D+04

FITTING COEFFICIENTS FOR EVALUATION OF U235 BURNUP FROM TOTAL FISSIONS (TF)

(DELTA M(U235))/TF = A0 + A1*TF + A2*TF**2 + A3*TF**3 + A4*TF**4 + A5*TF**5

FIT	AD	Al	A2	A3	A4	A5
TOTAL FUEL	4.66564D+00	-1.34677D-02	1.32867D-03	-8.04212D-05	2.02123D-06	-1.82776D-08
FUEL SEGMENTS	4.67077D+00	-8.35366D-02	4.23953D-02	-1.2343OD-02	1.48777o-03	-6.46246D-05

NOTE: TF IS IN UNITS OF 1.OE+22

CORE	LOC	GROCF	CPWR-MW	CM25T-G	CM25A-G	CM2-5B-G	CM25C-G	CM25D-G	CM25E-G	CM25F-G
174F	A5	0.98338	1.20046	316.459	52.833	51.721	51.428	52.136	53.511	54.829
1758	D3	1.02282	1.25814	284.529	47.783	45.165	44.397	45.839	49.163	52.181
176A	E4	1.00518	1.17486	259.650	43.795	40.418	39.400	41.142	45.261	49.635
176C	B3	0.97750	1.03160	235.444	39.386	35.003	34.028	36.878	42.386	47.764
177A	A4	0.94701	0.85058	220.483	37.036	32.143	30.951	33.948	40.045	46.360
177C	D2	0.99916	0.98652	199.127	33.821	28.268	26.812	29.886	36.536	43.803
178A	C5	0.98008	1.17804	182.693	31.170	25.238	23.637	26.773	33.853	42.021
1780	D5	0.98299	1.06726	163.075	27.324	21.077	19.555	23.111	31.434	40.575

In this manner ^{137}Cs count rates, CPSE(K), were obtained from the NaI spectra measured at each of the 16 locations along the height of the UB002 fuel column. The results of these analyses and the subsequent evaluations of the ^{235}U masses and burnups arc shown in Table F.9. These masses and burnups are in reasonable agreement with those obtained with tile Ge(Li) detector given in Table F.6. Because of the superior resolution of the Ge(Li) detector system, these are the preferred results. However, the results obtained with the 3" x 3" NaI detector system are very acceptable.

Figure F.1 compares the UB002 axial distribution of the ^{137}Cs activities measured with both the Ge(Li) and the NaI detection systems. To make the results independent of detector efficiency, the (CR/BDF)/Y*DC values given in Tables F.6 and F.9 have been normalized to their integrated average values. That is, the (CR/BDF)/Y*DC values have been divided by N where

$$N = \int_{ZL}^{ZU} [(CR / BDF)Y * DC](z)dz \Big/ \int_{ZL}^{ZU} dz$$

Figure FA shows that the two distributions are in reasonable agreement, which demonstrates the validity of the nonlinear least squares method used to obtain ^{137}Cs activities from the spectra measured with the NaI detector system.

It was pointed out in Section 7.8 that 129 of the 132 HEU fuel elements used in the demonstration were irradiated in various cores before the beginning of the demonstration. Since no gamma-scanning measurements on full-sized fuel elements were made before the shutdown of core 174D, the first core to contain some LEU fuel, these irradiated HEU fuel elements had an uncertain ^{235}U mass at the start of the demonstration. However, most of the HEU fuel elements used in the transition cores were gamma-scanned for both ^{140}La and ^{137}Cs activities. The ^{140}La data was used to determine the cycle-averaged fuel element powers while the ^{137}Cs data are the final burnup status of the element. By combining information from both sets of data, the ^{235}U content of the HEU elements at the beginning of the demonstration was determined. This type of data analysis is illustrated here for the HEU fuel element T507.

Table F.10 provides a summary of the power histories for those ORR cores in which the HEU fuel elements used in the demonstration were previously irradiated. As Table 40 (p. 142) shows, fuel element T507 was used in eight pre-demonstration cores, namely: 171A, 171E, 172A, 172D, 172F, 172H, 173D, and 174C. Core 174C was the all-HEU reference core with which the demonstration began. Information from Table F.10 was used to evaluate buildup-decay factors for ^{137}Cs.

The ^{140}La activity data for T507 is summarized in Table F. 11. An estimate of the residual lanthanum, count rates from the previous irradiation in core 174C is given under the heading CPSRO(K). Table F.12 gives the LaGrange-interpolated (CR/BDF)/Y values at the axial boundaries of the fuel element segments. At the bottom of this table are the calculated values for the transverse gradient correction factors (see Table C.1) and the REBUS-3 values for the cycle-averaged fuel element powers and the EOC ^{235}U masses for each of the demonstration cores in which T507 was irradiated. Table F.13 summarizes the results obtained from the 1401-a gamma-scanning data. The cycle-averaged fuel element powers and corresponding C/E ratios in this table are those given in Table 37 (pp. 1121-115) of the text.

Table F.14 summarizes the ^{137}Cs gamma-scanning data and the results obtained from them. Experimental values for the final ^{235}U masses and burnups and the corresponding C/E ratios given in this table are the same as those shown earlier in Table 40 (p.142) for the HEU fuel element T507. The lanthanum data (Table F.13) determines how much ^{235}U was consumed in this fuel element from irradiation in these three demonstration cores. Adding this value to the final mass gives the experimental value for the ^{235}U mass in T507 at the beginning of the demonstration.

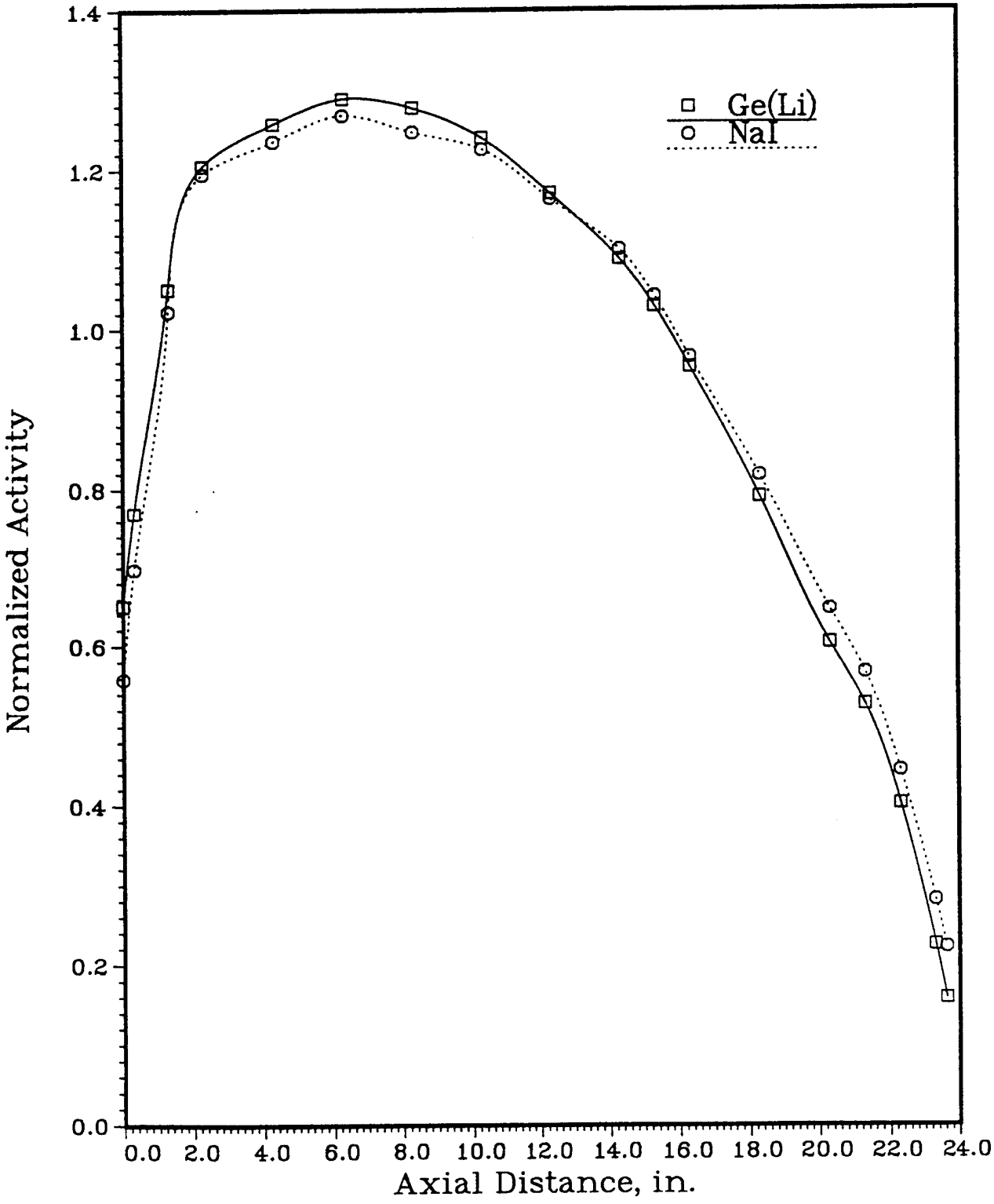
UB002 Normalized Cs–137 Activity Distributions
Ge(Li)
NaI
Normalized Activity
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0
Axial Distance, in.

Fig. F.1

Table F. 10 Summary of Power Histories for Some ORR Pre-Demonstration Cores

K	BCORE(K)	TEB(K)-DAYS IRRADIATION	TSB(K)-DAYS FROM 1/1/86
1	165A	12-30969	-866.00000
2	165C	13.36315	-838.00000
3	165F	12.74233	-796.00000
4	165G	11.60450	-783.00000
5	166A	2.74311	-776.00000
6	166C	4.25450	-769.00000
7	1660	13.63004	-755.00000
8	166E	12.48590	-741.00000
9	166F	13.44644	-727.00000
10	166G	12.66404	-712.00000
11	166H	13.28615	-698.00000
12	167A	16.66011	-677.00000
13	167C	24.84469	-644.00000
14	167D	24.86076	-618.00000
15	168A	19.30483	-588.00000
16	168B	19.47486	-568.00000
17	1680	16.20806	-547.00000
18	168E	9.25601	-538.00000
19	168F	3.26954	-534.00000
20	168G	1.72119	-532.00000
21	168H	3.69854	-527.00000
22	169A	16.71353	-504.00000
23	169C	16.31512	-486.00000
24	169D	2.41179	-482.00000
25	169E	14.21083	-466.00000
26	169F	6.74582	-459.00000
27	169G	19.53403	-439.00000
28	169H	3.19407	-436.00000

Table F.10 Summary of Power Histories for Some ORR Pre -Demonstration Cores (Continued)

K	BCORE(K)	TEB(K)-DAYS IRRADIATION	TSB(K)-DAYS FROM 1/1/86
29	170A	18.20389	-411.00000
30	1708	8.11810	-397.00000
31	170C	12.62156	-377.00000
32	170D	20.468l5	-356.00000
33	170E	10.82360	-345.00000
34	171A	15.43517	-313.00000
35	171B	12.61278	-292.00000
36	171C	19.49819	-272.00000
37	171D	2.65235	-269.00000
38	171E	7.43064	-259.00000
39	171F	14.34115	-244.00000
40	172A	11.54885	-229.00000
41	172B	13.46974	-215.00000
42	172C	7.36282	-207.00000
43	172D	2.29017	-204.00000
44	172E	15.30338	-188.00000
45	172F	12.10643	-173.00000
46	172G	11.33104	-160.00000
47	172H	13.08496	-145.00000
48	173A	12.90138	-117.00000
49	173B	12.63424	-103.00000
50	173C	12.30005	-89.87500
51	173D	13.41946	-75.87500
52	173E	17.00518	-58.33333
53	174B	15.36189	-18.99028
54	174C	16.77853	5.16667

Table F. 12 LaGrange Interpolation, Burnup Fitting Coefficients, Calculated Transverse Gradients, Fuel Element Powers, and 235U Masses for HEU Fuel Elements

LAGRANGE - INT ER POLATED VALUES FOR (CR/BDF)/Y FOR FUEL ELEMENT T507

CORE	X=0.0	INCH X= 3.9375"	X= 7.8750”	X=11.8125”	X=15.7500”	X=19.6875”	X=23.6250”
174E	5.099610+03	8.897550+03	1.690000+04	1.945230+04	1.971240+04	1.709490+04	1.267070+04
176B	4.583610+03	6.217580+03	7.663340+03	8.1679~0+03	8.094590+03	7.275400+03	5.518230+03
177C	3.904320+03	9.422800+03	1.3765qD+04	1.47A840+04	1.474770+04	1.380980+04	1.073980+04

FITTING COEFFICIENTS FOR EVALUATION OF U235 BURNUP FRO11 TOTAL FISSIONS (TF)

DELTA M(U235) = AD + A1*TF + A2*TF**2 + A3*TF**3 + A4*TF**4 + A5*TF**5

FIT	A0	A1	A2	A3	A4	A5
TOTAL FUEL	-9.25120D-04	4.689460+00	-1.63870D-03	2.58510D-05	-5.50236D-07	2.47418D-09
FUEL SEGMENTS	3.42-578D-04	4.68379D+00	-3.78094D-03	-1.18506D-03	1.690211D-04	-9.86020D-06

TF=A0 + A1*DELM25 + A2*DELM25**2 + A3*0ELM25**3 + A4*DELM25**4 + A5*DELM25**5

FIT	A0	A1	A2	A3	A4	A5
TOTAL FUEL	1.92109D-04	2.13246D-01	1.58549D-05	-5.1210D-08	2.32330D-10	-1.87301D-13
FUEL SEGMENTS	-7.65582D-05	2.13516D-01	3.28953D-05	2.85210D-06	-8.77314D-08	1.10841D-09

NOTE: TF IS IN UNITS OF 1.0E+22

CORE	LOC	GRDCF	CPWR-MW	CM2ST-G	CH25A-G	CH25B-G	CN25C-G	CM250-G	CH25E-G	CM25F-G
174E	C4	0.99963	1.15519	159.650	27.043	22.060	20.732	23.565	29.762	36.488
176B	A2	0.98204	0.52198	145.218	24.651	19.378	18.004	20.924	27.462	34.799
177C	D5	1.01535	0.92164	123.804	20.744	15.208	13.817	16.821	24.309	32.903