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Seabrook Station Fixed Incore Detector System Extended Operation

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ABSTRACT

This document satisfies the North Atlantic Energy Service Corporation commitment of adding Cycle 2, 3, and 4 comparisons of Movable Incore Detector System and Fixed Incore Detector System results to the initial methodology report. The work also demonstrates the continued accuracy of the calculational method and uncertainty analysis of the Fixed Incore Detector System currently in use at Seabrook Station. The results provided in this work augment those of the initial methodology report by adding more than two full cycles of operation of the system.

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1.0 INTRODUCTION

The Safety Evaluation Report[1] (SER) issued to allow fixed incore detectors to be used in addition to movable detectors for Technical Specification (TS) surveillance requested additional data for the following reasons:

1. First, there is a burnup dependence in the fixed/movable inferred measured Fxy and Fq. North Atlantic Energy Service Corporation provided information to respond to this concern that shows that the difference most likely is due to the inherent differences in the reactor physics methods used to predict the power distribution. While this may be true, it is important that the ratio be monitored in future cycles to ensure that the two methods do not continue to diverge which would indicate a problem with one of the systems.

2. The fraction of the total signal which is due to neutrons is approximate, is not a well known number, and it is not based on control experiments. It is important that more core burnup be achieved to ensure that this ratio does not change significantly with core life.

3. Third, there is little experience in the United States with a Fixed Platinum Detector System. Seabrook is the first plant to be approved to use this system of TS surveillance, and Seabrook is the first Westinghouse plant to employ a Fixed Incore Detector System to determine core peaking factors.

This report satisfies the commitment of North Atlantic Energy Service Corporation to the Nuclear Regulatory Commission[1], by collecting data from Cycles 2, 3, and 4, with the Movable Incore Detector System and comparing those results to data collected with the Fixed Incore Detector System. Additionally, this report confirms the continued accuracy of the Fixed Incore Detector System at Seabrook Station, which has now been operating for four full cycles. The initial methodology report[2], issued during the second cycle of operation, provided the Fixed Incore Detector System methodology, comparisons of data and an uncertainty analysis for Cycle 1 and a portion of Cycle 2.

The Fixed Incore Detector System has continued to demonstrate accuracy equal to or better than that stated in the initial methodology report. No noticeable reductions of detector signal strength have been observed nor have there been increases in measured-to-predicted signal differences. The entire system is operating in the same manner as analyzed previously, with no new detector failures.

This report includes a review of the data given with the initial methodology report and all data following that time, nearly 40 exposure points over four cycles of operation. Also included is a comparison of results determined with the Fixed Incore Detector System and the Movable Fission chamber Detector System, with a full description of differences between results from the two systems. Finally, a review of the uncertainty analysis with new data is included to support the original findings. A description of the analytical and processing methodology has not been included here. It was fully covered in the initial methodology report and has not changed.

2.0 BACKGROUND

Seabrook Station contains two complete and independent incore detector systems. The first is a Movable Incore Detector System, which uses movable fission chambers as designed by Westinghouse for reactors similar to Seabrook Station. The second detector system employs self-powered fixed platinum detectors. Both of these systems were installed during plant construction.

The Movable Incore Detector System uses 58 reactor core instrument thimbles as given in Figure 2-1. Each thimble is traversed by one or more of six movable fission chambers. The measurement of incore power requires the six movable fission chambers to be passed through the core at least 12 times. As the detector is passed through the core, the signals are collected and saved on the main plant computer as a neutron flux trace. Each detailed axial trace consists of 61 relative axial neutron flux measurements. These traces, which collectively make up a flux map, are then processed with analytical predictions of detector reaction rates and the core wide power distribution by INCORE-3[3] to infer the measured power distribution and corresponding peaking factors. The results are then compared to established limits to ensure that the core is operating within the limits specified in the Technical Specifications of Seabrook Station. To summarize, the Movable Incore Detector System may be used to generate flux maps and infer the incore power distribution via the monthly surveillance requirements in the Technical Specifications for Seabrook Station.

Currently, incore power distribution surveillance at Seabrook Station is performed with the Fixed Incore Detector System developed at Seabrook Station. The fixed incore detectors use the same 58 reactor core locations as shown in Figure 2-1. The Fixed Incore Detector System provides information on the combined gamma/neutron flux levels in the 58 instrumented assembly locations within the reactor core. These flux distributions, in conjunction with analytical predictions of the fluxes, are used to infer a three-dimensional power distribution. Once the power distribution has been inferred, the maximum local power peaking and hot channel factors can be derived and compared to established limits in a manner similar to the method used with the Movable Incore Detector System.

The fixed detectors used at Seabrook Station are self-powered, use platinum emitters and yield a signal proportional to the incident gamma and neutron flux. The Fixed Incore Detector System consists of 58 detector strings. Each string contains five self-powered platinum detectors for a total of 290 detectors in the core. These strings are an integral part of the instrument thimble. They are located in the same radial core locations as the movable fission chambers. Each detector consists of a 13.5 inch long platinum emitter within the core and is connected to its associated lead wire. A compensation lead wire which is identical to the emitter lead, runs parallel to the emitter lead within the sheath of each detector to correct for gamma induced background current. The emitter and leads are all packed in an Al_2O_3 dielectric insulator and bound in an inconel sheath. The wires for a detector string form a helix around a central inconel tube and are then bound by an inconel sheath. The central inconel tube is the path used by the movable fission chamber. Figure 2-3 shows this geometry in detail. The fixed incore detectors are spaced along the thimble so that they fall in the mid regions of the core between fuel assembly grids, as shown in Figure 2-4.

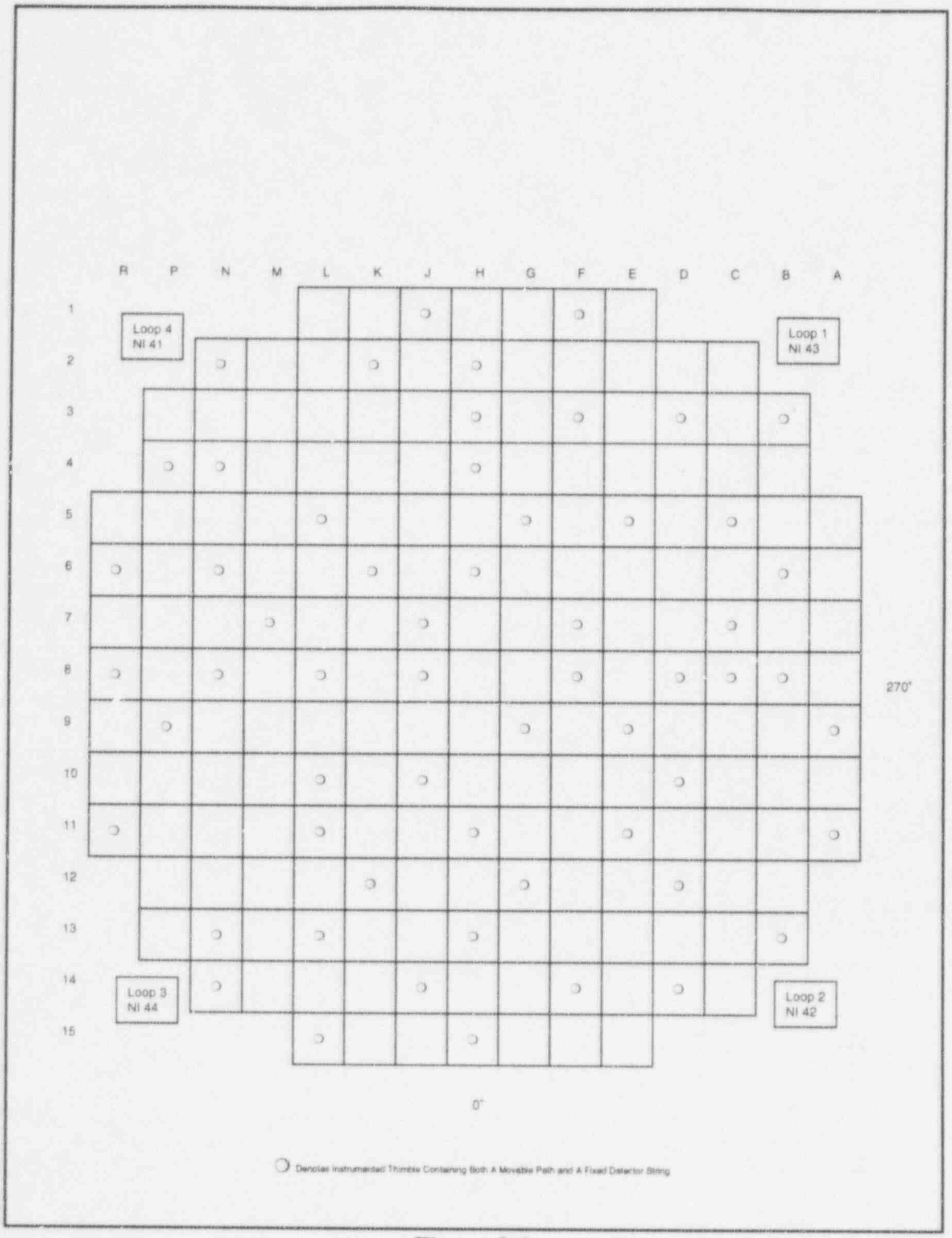

Figure 2-1

Seabrook Station Radial Locations of Instrument Thimbles

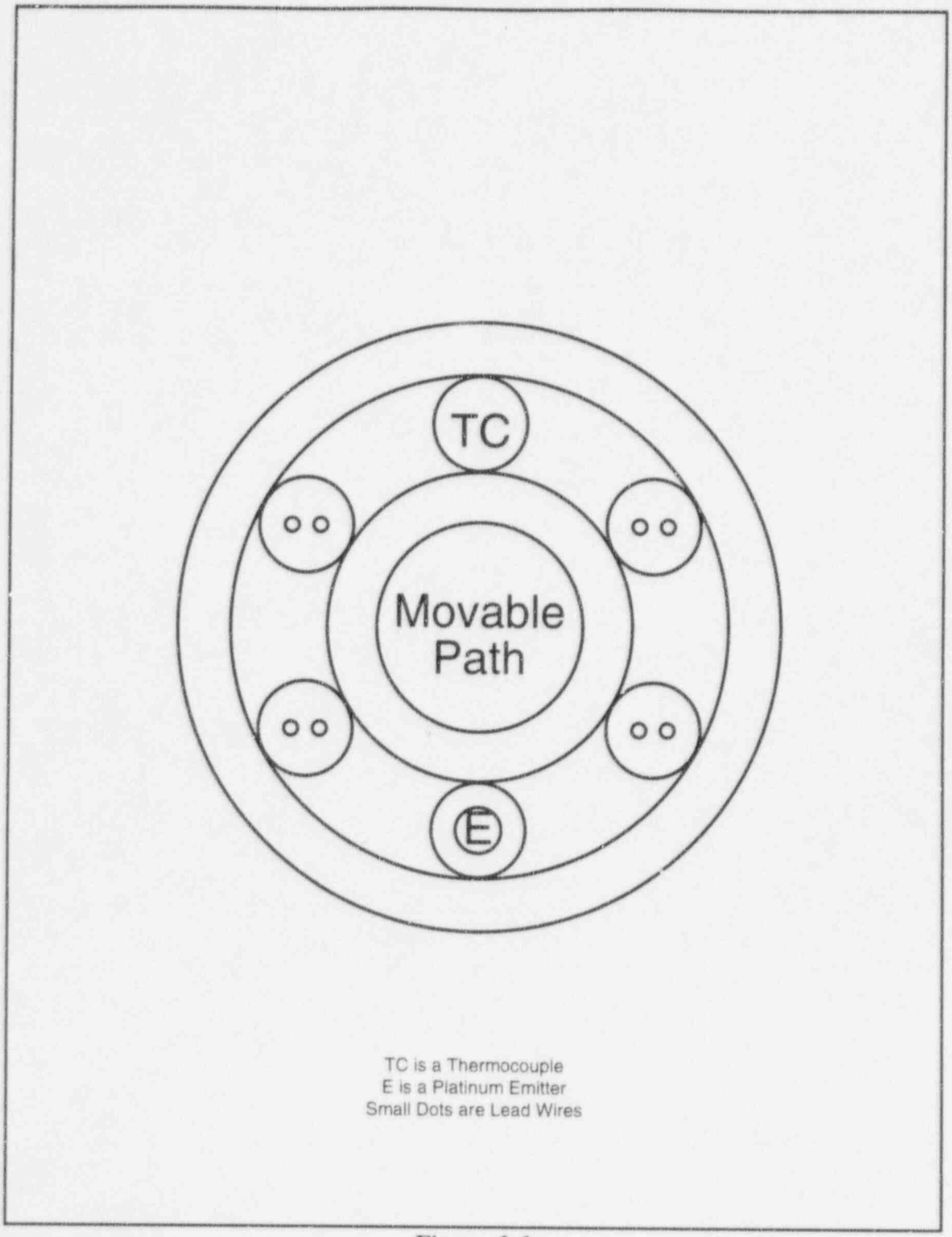

Figure 2-2

Instrument Thimble Internal Design

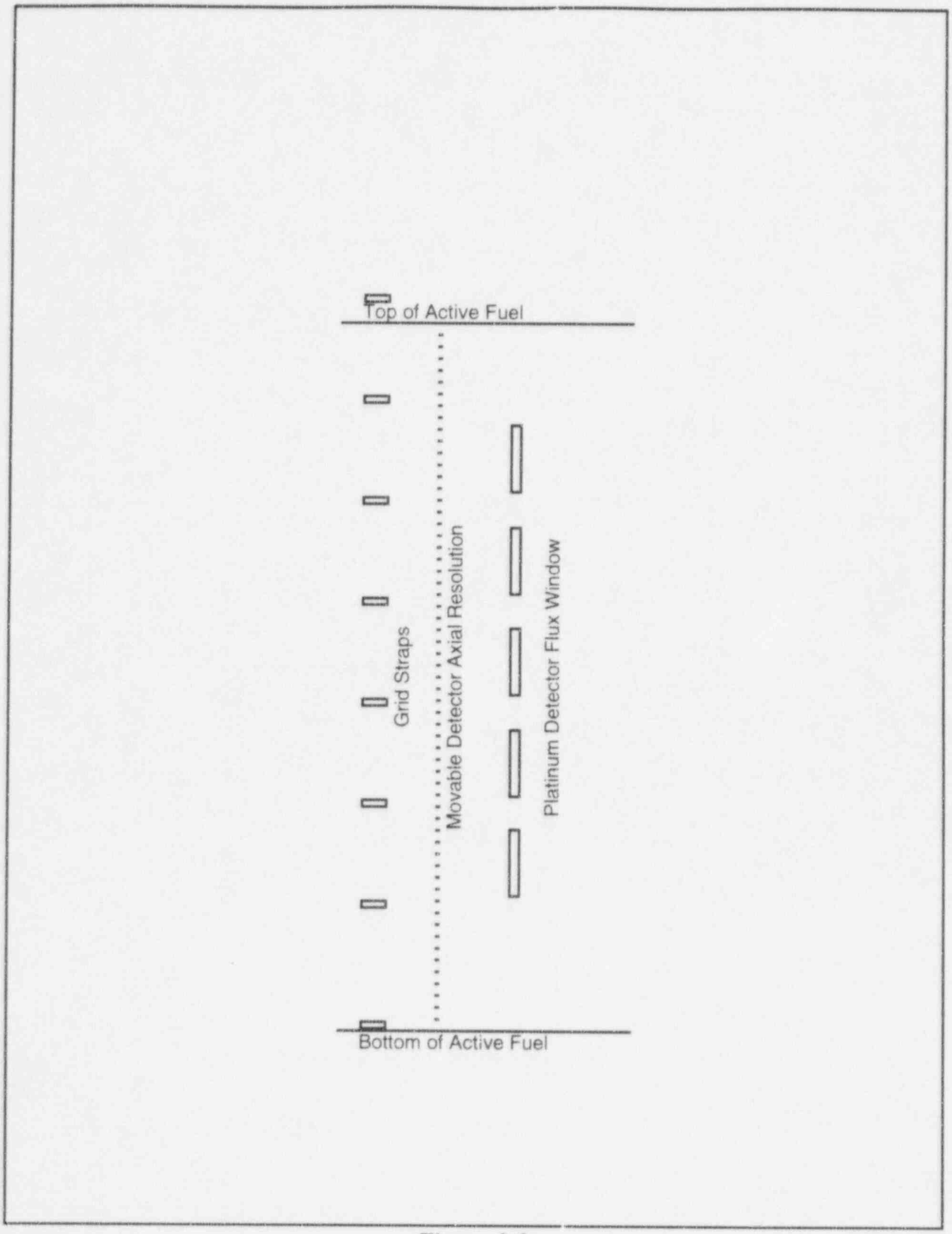

Figure 2-3

Axial Position of Platinum Incore Detectors

3.0 UNCERTAINTY ANALYSIS CONFIRMATION

The fixed incore detectors have been collecting data for over four full cycles of operation. The results of most of the first two cycles were used to determine the uncertainties in the system. Since that time, more than two full cycles of operational data has been added and applied to the same uncertainty analysis.

The uncertainty analysis used to license the Fixed Incore Detector System consisted of two uncertainty factors. The first is an uncertainty applied to the three-dimensional quantity of Fq. The three-dimensional or total system uncertainty as applied to Fq, is defined as:

$$k_t\sigma_t = \sqrt{(k_a\sigma_a)^2 + (k_b\sigma_b)^2 + (k_c\sigma_c)^2 + (k_d\sigma_d)^2} \qquad \text{Eq. (1)}$$

where:

σ_a is uncertainty due to signal reproducibility
σ_b is uncertainty due to analytical methods
σ_c is uncertainty due to axial signal power shape
σ_d is uncertainty due to total detector processing
k is the appropriate confidence multiplier for the data set

The second uncertainty factor is applied to the two-dimensional axially integrated quantity of Fdh. The radial or Fdh uncertainty requires the combination of three of the four uncertainty components. The axial power shape uncertainty is very small when applied to integrated radial parameters and the detector processing uncertainty contains only the axially integrated processing component for the same reason. The system two-dimensional uncertainty, as applied to Fdh, is defined as:

$$k_r\sigma_r = \sqrt{(k_a\sigma_a)^2 + (k_b\sigma_b)^2 + (k_e\sigma_e)^2} \qquad \text{Eq. (2)}$$

where:

σ_a is uncertainty due to signal reproducibility
σ_b is uncertainty due to analytical methods
σ_e is uncertainty due to integral detector processing
k is the appropriate confidence multiplier for the data set

The signal reproducibility, σ_a , was addressed extensively in the initial methodology report. The continued operation of the system for monthly or other surveillance for two additional cycles has shown no signal spikes or depressions. Since sets of detector signals for these analyses were chosen at random, it can be concluded that the signal reproducibility is equal to that given in the initial analysis.

The physics analysis method uncertainty, σ_b , has not changed. The methods used in the Fixed Incore Detector System analysis have not changed since the licensing of the system.

Axial power shape uncertainty, σ_c , was determined by comparing predicted and measured axial power shapes. Data from the SIMULATE-3 code[4] and movable fission chamber measurements were used to determine this component of uncertainty. Again, since the SIMULATE-3 has not been modified in this area, no change in this uncertainty components is expected.

The detector processing uncertainty in both the total system (σ_d) and radial calculations (σ_e) were determined from measured data collected through the first cycle and a portion of Cycle 2. This data set has grown and is included here to improve the statistics for the uncertainty calculation.

Previously, the total system component (σ_d) was determined from 23 core measurements for each of 290 detectors or 6670 data points. The average RMS difference between measured and predicted detector signals was given as 2.62%. Some 37 more surveillances have been taken since the initial report and the average RMS error for the total system is 2.61% for the new data. These results are given in Tables 3.1 and 3.2. This consistency in results demonstrates the accuracy of the total system processing as reported in the initial methodology report.

The same 37 surveillances have been used to determine a radial RMS difference (σ_e). The error for the new surveillances was averaged to be 1.98% RMS difference, as shown in Table 3.2. This is slightly less than the 2.11% RMS difference given in the original analysis. Thus, the system continues to operate to the level of uncertainty described previously.

In conclusion, no changes to the uncertainty values described in the initial methodology report are required and the existing values are still accurate.

Table 3.1
Cycles 1 and 2 Statistical Results

	Date	Exposure Mwd/Mtu	Radial RMS Percent Difference	Total System RMS Percent Difference
Cycle 1	07/10/90	480	2.673	3.323
	08//29/90	995	3.212	3.894
	08/29/90	1945	2.515	3.115
	09/26/90	2950	2.294	2.802
	10/10/90	3568	2.114	2.553
	11/08/90	4369	2.035	2.449
	12/05/90	4850	1.986	2.505
	01/04/91	5997	1.884	2.297
	02/05/91	7214	1.808	2.252
	03/18/91	8473	1.734	2.214
	04/16/91	9266	1.730	2.266
	05/20/91	10560	1.652	2.356
	06/18/91	11570	1.661	2.245
	06/18/91	12650	1.674	2.497
Cycle 2	11/01/91	415	2.591	2.868
	11/08/91	682	2.592	2.875
	12/04/91	1680	2.525	2.850
	01/08/92	2966	2.337	2.806
	02/04/92	3996	2.190	2.588
	03/04/92	5101	2.018	2.433
	04/01/92	6169	1.805	2.244
	05/05/92	7466	1.677	2.268
	06/02/92	8536	1.585	2.300
	07/06/92	9840	1.638	2.032
	08/07/92	11060	1.561	2.025

Table 3.2
Cycles 3 and 4 Statistical Results

	Date	Exposure Mwd/Mtu	Radial RMS Percent Difference	Total System RMS Percent Difference
Cycle 3	11/25/92	282	2.418	3.968
	12/23/92	1137	2.065	4.209
	01/07/93	1635	1.986	3.597
	01/27/93	2160	1.933	4.092
	02/11/93	2733	1.771	3.420
	03/03/93	3497	1.701	2.705
	03/24/93	4302	1.624	2.308
	04/21/93	5366	1.563	1.989
	06/02/93	6850	1.631	2.019
	06/24/93	7686	1.582	2.094
	07/21/93	8719	1.627	2.110
	08/26/93	9958	1.626	2.012
	09/15/93	10722	1.710	2.518
	10/13/93	11170	1.894	2.549
	12/15/93	13391	1.826	2.327
	01/12/94	14441	1.870	2.209
	01/25/94	14942	1.878	2.231
	03/02/94	15428	1.984	2.320
	03/16/94	15955	1.973	2.259
Cycle 4	08/05/94	102	2.411	3.316
	09/06/94	1321	2.117	3.096
	10/05/94	2430	2.069	2.673
	12/08/94	3500	2.006	2.334
	01/09/95	4871	1.976	2.404
	03/10/95	6098	1.958	2.613
	04/10/95	8380	1.841	2.633
	05/03/95	9566	1.850	2.368
	05/11/95	10440	1.883	2.531
	06/12/95	10744	1.865	2.334
	07/12/95	11967	1.962	2.461
	08/23/95	12495	1.917	2.368
	08/31/95	14101	1.997	2.659
	09/12/95	14402	2.010	2.361
	10/13/95	14856	2.430	2.802
		16042	2.088	2.545
RMS Percent Difference			1.976	2.608

4.0 FIXED AND MOVABLE DETECTOR RESULTS COMPARISONS

During normal operation of the plant, an incore detector analysis is performed to determine the incore power distribution on a monthly basis. The purpose of this analysis is to demonstrate that the maximum peaking factors, as determined by the incore power distribution, are less than the limits assumed in the safety analysis. Nearly forty incore power distributions have been processed by both the Fixed Incore Detector System and the Movable Incore Detector System for the same conditions. Data collected from both of these systems are compared in this work to show that both systems are reporting similar results for the same core conditions.

The primary parameters of concern for Technical Specification surveillance are the axial peak power in any pin, Fq, the integrated peak power in any pin, Fdh and core wide axial offset. Each of these three values have been compared for each surveillance made with both the Fixed Incore Detector System and the Movable Incore Detector System. Results for Cycles 1 through 4 are presented in Tables 4.1 through 4.4 and plotted in Figures 4-1 through 4-4, respectively.

Results for Cycle 1 and a portion of Cycle 2 were given in the initial methodology report. That data displayed a trend in which Fq from the Fixed Incore Detector System became lower or less than the value determined from the Movable Incore Detector System with increased cycle burnup. The data given here for Cycles 2, 3, and 4 also show this trend and this difference is discussed in the following section. The axial offset data from the Movable Incore Detector System is usally lower or more negative than the Fixed Incore Detector System data. This trend is also considered in the difference resolution given in the next section. All other data is in good agreement and confirms the accuracy of the Fixed Incore Detector System at determining the required surveillance parameters.

Table 4.1
Cycle 1 Results

Date	Exposure Mwd/Mtu	Fixed Incore Detector System			Movable Fission Chamber System		
		Axial Offset	Maximum Fdh	Maximum Fq	Axial Offset	Maximum Fdh	Maximum Fq
08/29/90	1945	-7.45	1.376	1.995	-5.08	1.361	1.949
09/26/90	2950	-5.15	1.355	1.879	-2.98	1.325	1.853
10/10/90	3468	-4.92	1.336	1.801	-3.08	1.316	1.788
11/08/90	4369	-3.79	1.312	1.731	-2.06	1.316	1.741
12/05/90	4850	-3.83	1.313	1.704	-2.13	1.309	1.712
01/04/91	5997	-3.25	1.299	1.667	-2.21	1.291	1.662
02/05/91	7214	-2.46	1.297	1.640	-2.03	1.283	1.632
03/18/91	8473	-1.64	1.297	1.630	-2.00	1.289	1.627
04/16/91	9266	-1.52	1.289	1.611	-1.44	1.278	1.621
05/20/91	10560	-0.70	1.279	1.575	-1.77	1.266	1.577
06/18/91	11570	-0.33	1.272	1.564	-1.85	1.261	1.582

Table 4.2
Cycle 2 Results

Date	Exposure Mwd/Mtu	Fixed Incore Detector System			Movable Fission Chamber System		
		Axial Offset	Maximum Fdh	Maximum Fq	Axial Offset	Maximum Fdh	Maximum Fq
11/01/91	415	1.94	1.473	1.842	2.87	1.442	1.832
11/08/91	682	5.56	1.468	1.901	5.40	1.433	1.892
12/04/91	1680	3.84	1.468	1.848	3.74	1.436	1.838
01/08/92	2966	1.10	1.464	1.768	0.72	1.429	1.767
02/04/92	3996	-0.30	1.454	1.749	-0.88	1.424	1.744
03/04/92	5101	-1.41	1.444	1.767	-2.37	1.420	1.786
04/01/92	6169	-1.66	1.436	1.774	-2.77	1.423	1.792
05/05/92	7466	-1.21	1.428	1.758	-2.68	1.413	1.781
06/02/92	8536	-0.83	1.419	1.734	-2.44	1.406	1.769
07/06/92	9840	-0.32	1.407	1.705	-2.21	1.409	1.767
08/07/92	11060	0.40	1.395	1.674	-1.92	1.399	1.739

Table 4.3
Cycle 3 Results

Date	Exposure Mwd/Mtu	Fixed Incore Detector System			Movable Fission Chamber System		
		Axial Offset	Maximum Fdh	Maximum Fq	Axial Offset	Maximum Fdh	Maximum Fq
11/25/92	277	-2.53	1.432	1.870	-1.64	1.443	1.865
12/22/92	1099	-2.73	1.420	1.921	-2.01	1.426	1.890
1/28/93	2206	-2.82	1.435	1.954	-2.39	1.444	1.943
2/23/93	3189	-2.84	1.437	1.948	-2.17	1.453	1.925
3/23/93	4259	-2.55	1.439	1.894	-2.10	1.447	1.910
4/22/93	5402	-2.52	1.448	1.849	-2.16	1.443	1.874
5/26/93	6577	-1.93	1.454	1.809	-1.54	1.440	1.822
6/23/93	7649	-1.26	1.454	1.787	-1.50	1.440	1.802
7/26/93	8909	-1.27	1.451	1.777	-1.01	1.448	1.787
8/24/93	9881	-0.35	1.449	1.751	-0.55	1.437	1.755
10/14/93	11211	-0.73	1.442	1.748	-1.13	1.455	1.749
12/10/93	13200	-1.37	1.432	1.757	-1.96	1.426	1.767

Table 4.4
Cycle 4 Results

Date	Exposure Mwd/Mtu	Fixed Incore Detector System			Movable Fission Chamber System		
		Axial Offset	Maximum Fdh	Maximum Fq	Axial Offset	Maximum Fdh	Maximum Fq
11/2/94	3499	-0.27	1.443	1.855	0.08	1.441	1.868
12/8/94	4869	-0.06	1.443	1.808	0.14	1.428	1.855
5/3/95	10439	-0.08	1.397	1.676	-1.53	1.404	1.721
8/31/95	14403	0.35	1.363	1.646	-2.29	1.375	1.683

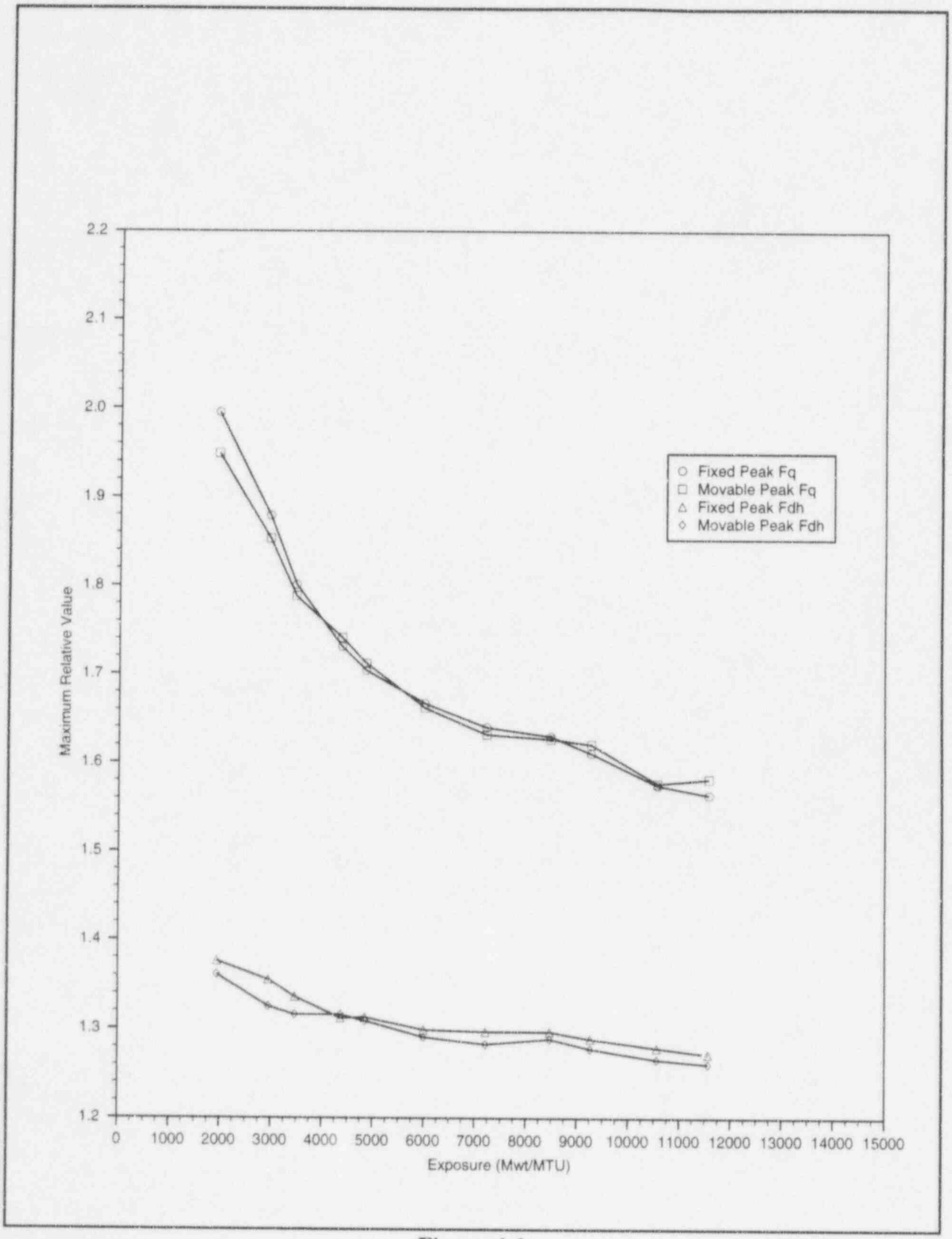

Figure 4-1

Seabrook Station Cycle 1 Fixed and Movable Detector Limit Results

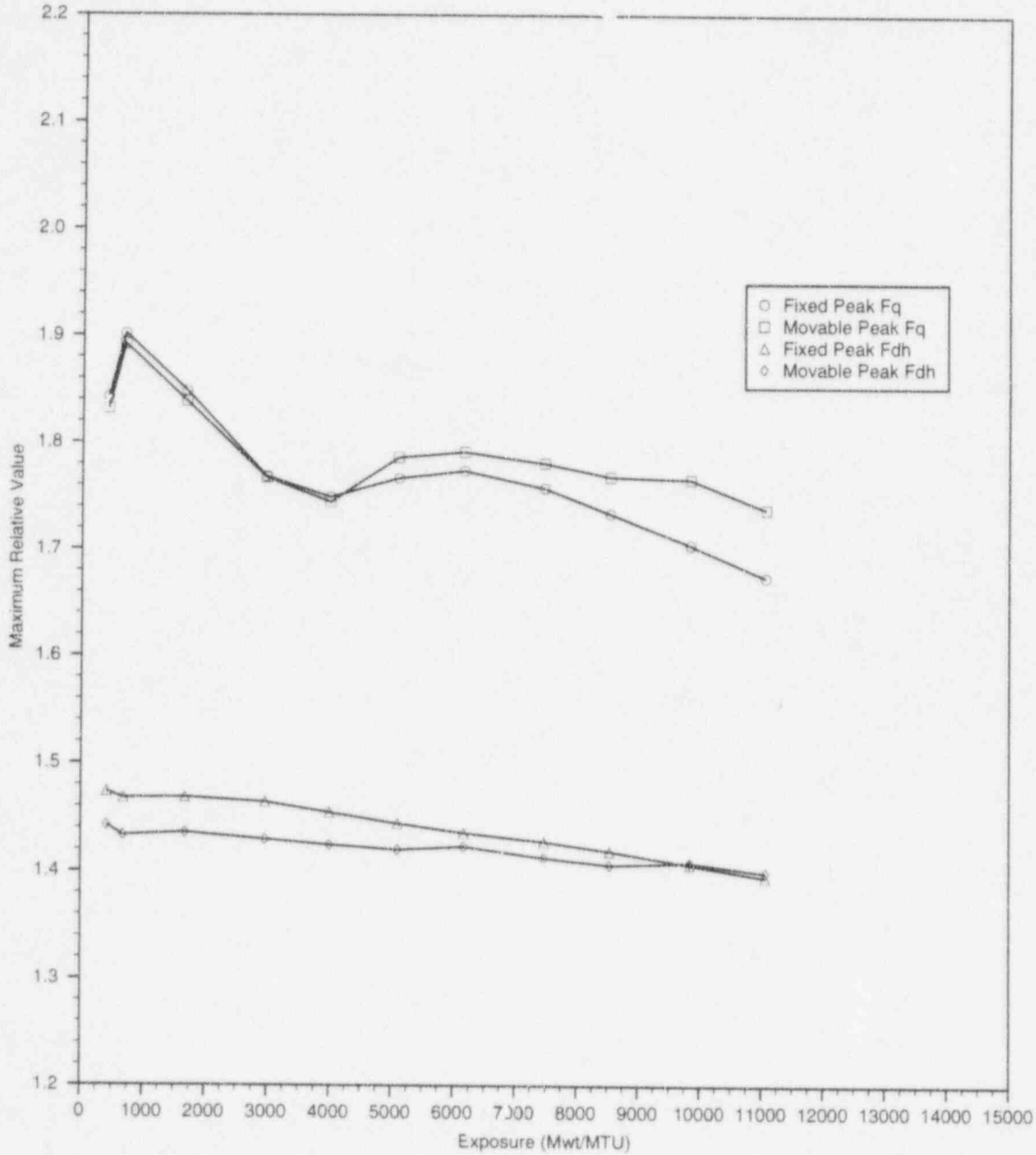

Figure 4-2

Seabrook Station Cycle 2 Fixed and Movable Detector Limit Results

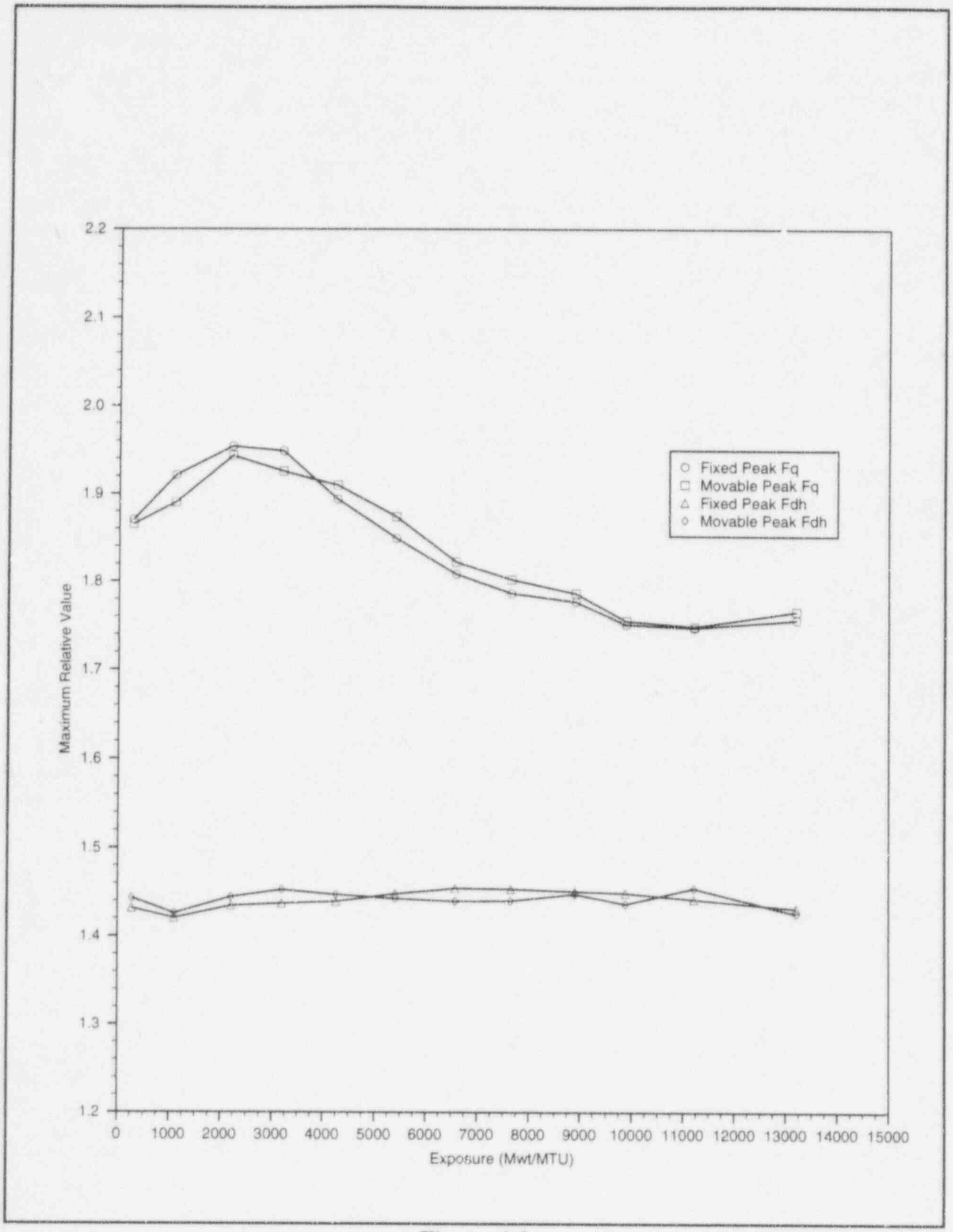

Figure 4-3

Seabrook Station Cycle 3 Fixed and Movable Detector Limit Results

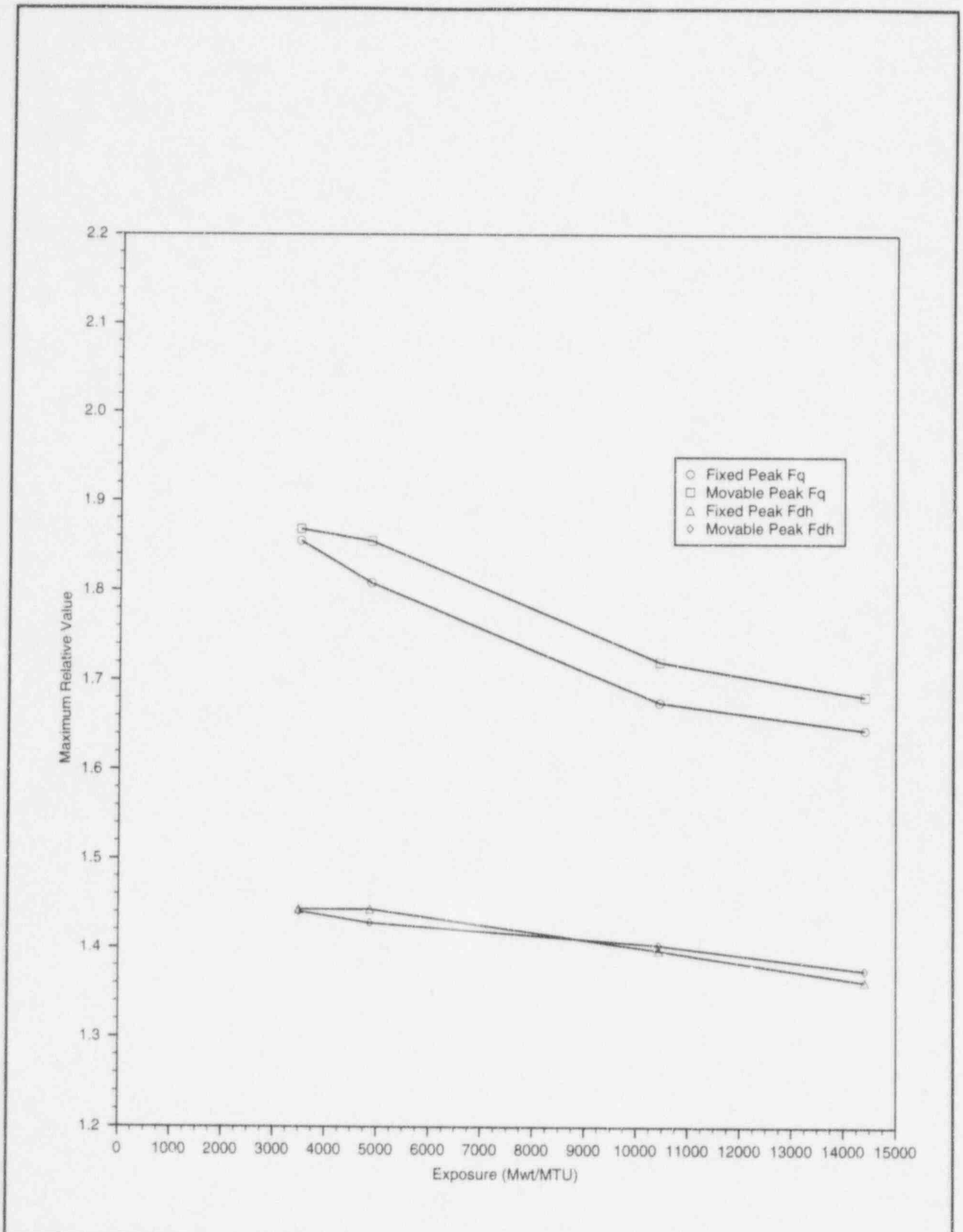

Figure 4-4

Seabrook Station Cycle 4 Fixed and Movable Detector Limit Results

5.0 DIFFERENCE RESOLUTION

As shown in Figures 4-2 and 4-4, there appears to be a burnup dependence on the Fq limit for Cycles 2 and 4 as measured with the Fixed and Movable Incore Detector Systems. This section will address this apparent burnup dependence.

The burnup dependence of measured Fq values between the Fixed Incore Detector System and the Movable Incore Detector System was noted in the SER and additional data was requested to quantify the effect. The differences are real and are derived from the methodological differences between the two measurement systems.

The measured value of Fq is separable into its radial and axial components (Fdh and Fz). As shown in Figures 4-1 through 4-4, the Fdh data from the two measurement systems is comparable for all four cycles. The Fz data, however, does not agree between the systems.

The Movable Incore Detector System uses a U235 fission chamber detector to measure the neutron flux axially through the core in each of the instrumented locations. The U235 fission chamber produces a current proportional to the fissions generated from the incident neutron flux on a U235 element. Thus, the Movable Incore Detector System measures the fission rate of U235 in the core as a function of axial core position.

The Movable Incore Detector System processing code, INCORE-3[3], is used to determine measured Fz from the Movable Incore Detector System data. At Seabrook Station, the INCORE-3 code normalizes the measured axial detector data and collapses them into an average plane. The ratio of a predicted axial integrated U235 fission rate to the measured integrated U235 fission rate is determined. This ratio is applied to the two dimensional average predicted power distribution to yield the inferred or measured radial power distribution. The measured radial power distribution is then used as radial factors (Fdh) and multiplied by the normalized axial U235 fission rate data, as axial peaking factors (Fz). The combination of Fz at each of 61 axial planes and the radial factor yield the axial Fq distribution.

The INCORE-3 code methodology uses Fz axial peaking factors, derived from the U235 axial fission rate shape to generate the axial power shape in the core. The use of U235 fission rate to approximate the incore axial power is acceptable, but not altogether accurate.

The axial power in the core is a combination of the fissions of all the isotopes in the core and not just U235. The U235 fission spectrum is not representative of all fissionable isotopes in the core, especially near the end of cycle when a substantial portion of the power is produced by plutonium isotopes. The actual axial power shape in the core is slightly different than that inferred from the U235 fission rate shape. The power shape generation method used in fixed incore detector processing code, FINC[2] yields a power shape which includes all the fissionable nuclides. Thus, the axial shape generated by FINC is different from that generated by INCORE-3.

The difference in the core axial power shapes from the two systems change with core burnup. At the beginning of the cycle, the fresh fuel dominates the core axial power shape

and the U235 fission rate shape is nearly the same as the axial power shape. However, as the cycle burnup increases, the contribution from other nuclides become more dominant. The axial power shape within the core also changes from the classic cosine shape to a double humped or dog bone shape. The double humped shape results from the depletion of the fuel in the central regions of the core and the compensation of the less depleted regions above and below the center of the core. The bottom of the core has a higher moderator density producing a softer spectrum, due to lower moderator temperature. The U235 fission chamber is more sensitive to the softer spectrum at the bottom of the core than the harder spectrum near the top of the core. Thus, the axial power shape generated by the U235 fission chamber will be more bottom peaked than the actual power shape.

From the data presented in Figures 4-1 through 4-4, Cycles 2 and 4 exhibit the trend in Fq described above; while the Cycle 1 and 3 Fq comparisons do not appear to exhibit the trend. Cycle 1 was a fresh core and most all fissions were from U235. Even by the end of the cycle the U235 fissions dominated the axial power shape. In Cycle 2, essentially two thirds of the core contained burned fuel from Cycle 1. A burnup dependence on Fq was observed near end of cycle. In Cycle 3, the peak Fq values do not appear to exhibit trend near end of cycle. In Cycle 3, the peak Fq location is not the same as the peak Fdh location. The Fdh in the peak Fq location was measured higher with the Fixed Incore Detector System than that measured by the Movable Incore Detector System. Thus, the decrease in Fz was compensated by an increase in Fdh. Cycle 4 showed the trend as expected and the peak Fdh values were in the same location as the peak Fq for most of the cycle. Although the Fq peak locations determined by each system were not the same, they are very near one another and have essentially the same axial power shape.

To graphically demonstrate the above concept, data near the end of Cycle 4 will be used in the discussion below.

A plot of the axial shape (Fz) of the maximum Fq pin inferred from the Movable Incore Detector System and the Fixed Incore Detector System, is given in Figure 5-1. The two shapes do not agree. Figure 5-1 shows that the Fz as determined by the Movable Incore Detector System is more bottom peaked and generally larger than the Fz determined by the Fixed Incore Detector System.

The discussion above states that the axial power shape determined from the Movable Incore Detector System is based on the axial fission rate from U235. For location N12, we can calculate the predicted axial fission rate, Fz, from U235 fissions using SIMULATE-3. This can be compared to the Fz determined from the Movable Incore Detector System in Location N12. Figure 5-2 shows the comparison. As can be seen, the axial shape determined by the Movable Incore Detector System is similar to the predicted U235 fission rate shape. Thus, the Movable Incore Detector System and the prediction agree when the U235 fission rate shape is used.

Figure 5-3 shows the SIMULATE-3 predicted axial power shape for location N12 when all fission nuclides are used compared to the axial power shape inferred by the Movable Incore Detector System . Here the prediction and the measurement disagree. This figure illustrates that the predicted axial power shape is not the same as the U235 fission rate shape

and looks more like that given in Figure 5-1. For comparison, the SIMULATE-3 predicted axial power shape for location N12 does agree with the Fixed Incore Detector System inferred axial power shape as shown in Figure 5-4.

The results demonstrate that, as the core depletes, the peak Fq from the Movable Incore Detector System using the INCORE-3 code is usually greater than that given by the Fixed Incore Detector System using the FINC code. The peak Fq from the Movable Incore Detector System is consistent with the U235 axial fission rate shape; while the peak Fq from the Fixed Incore Detector System is consistent with the axial power shape derived from all isotopes.

The single plane methodology of INCORE used for this analysis is not the latest in use at other plants with Movable Incore Detector Systems. The multi-plane methodology applied to the INCORE code has been developed to compensate for U235 reaction rate shape.

Although the value of Fxy is not used by the present safety analysis in place at Seabrook Station, the conclusions which apply to Fq are directly applicable to Fxy. The Fxy is derived directly from the inferred Fq in the INCORE methodology.

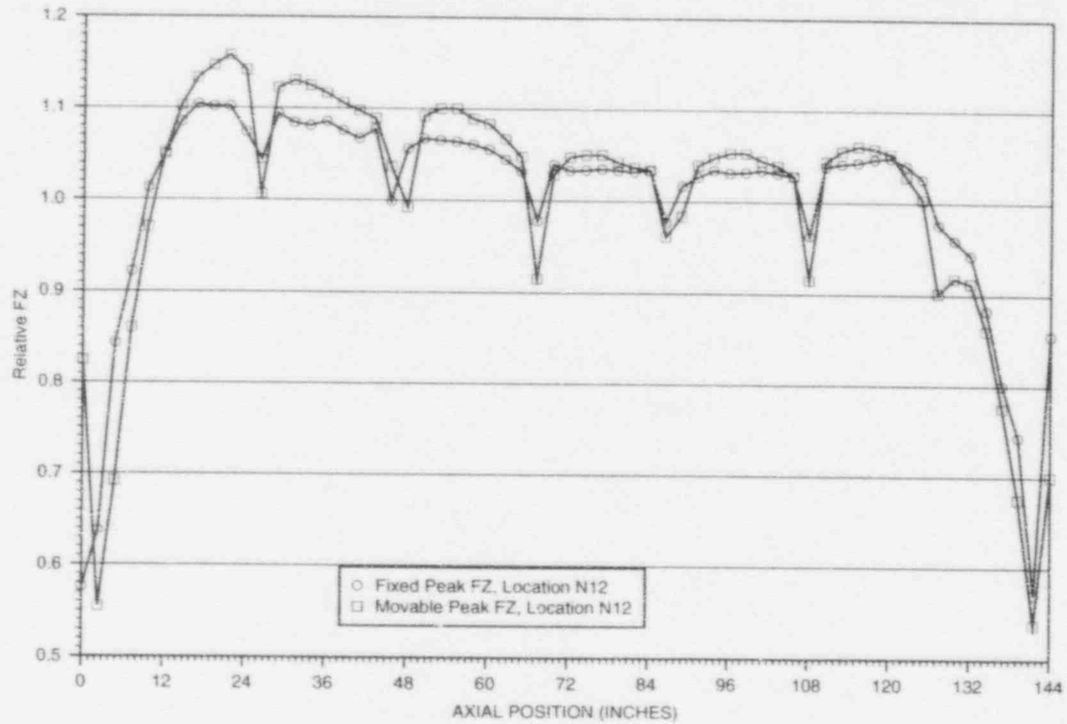

Figure 5-1

Seabrook Cycle 4 at 14402 Mwd/Mtu
Measured Fz Values
Movable Fission Chamber and Fixed Platinum Detectors

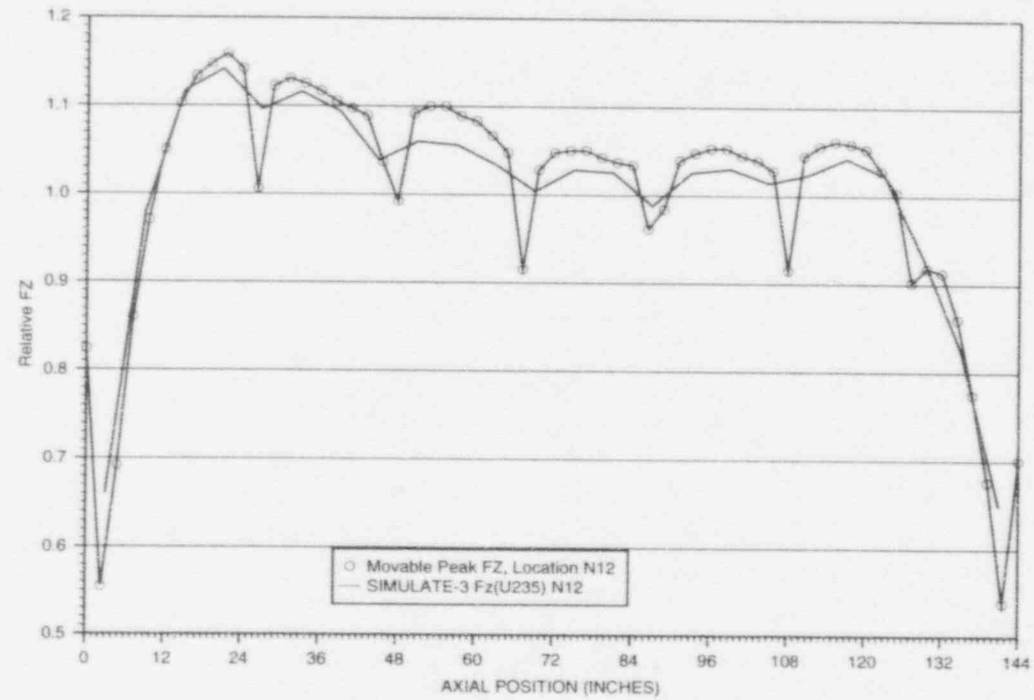

Figure 5-2

Seabrook Cycle 4 at 14402 Mwd/Mtu
Measured and Predicted Fz Values
Movable Fission Chamber Axial Power and SIMULATE-3 Predicted Fission Rates

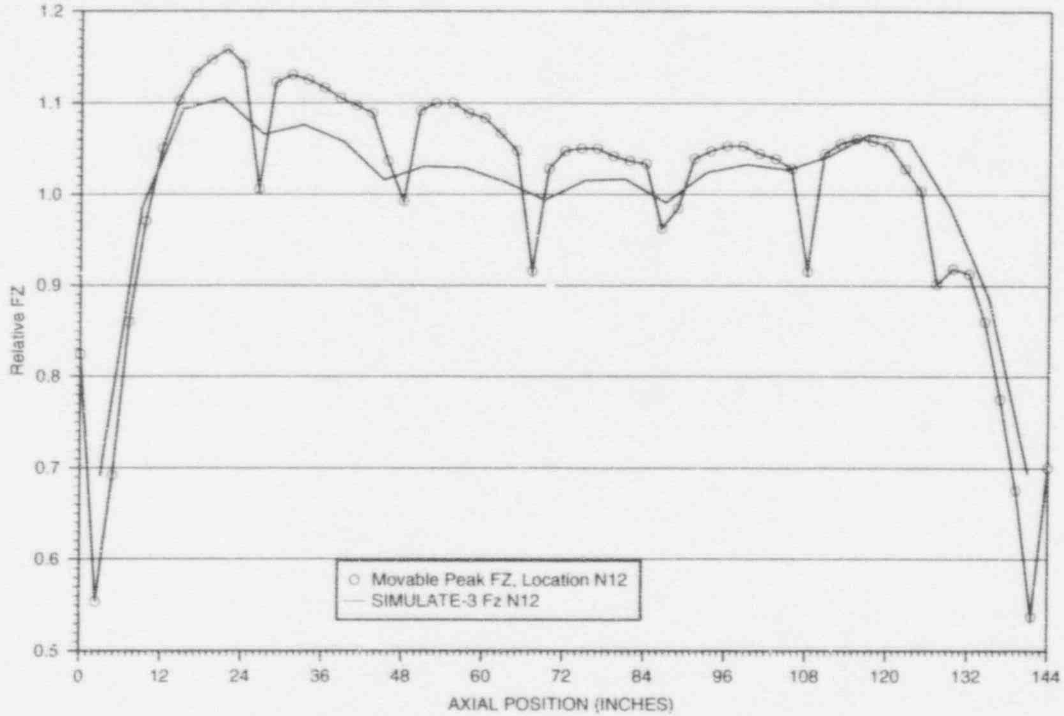

Figure 5-3

Seabrook Cycle 4 at 14402 Mwd/Mtu
Measured and Predicted Fz Values
Movable Fission Chamber vs SIMULATE-3

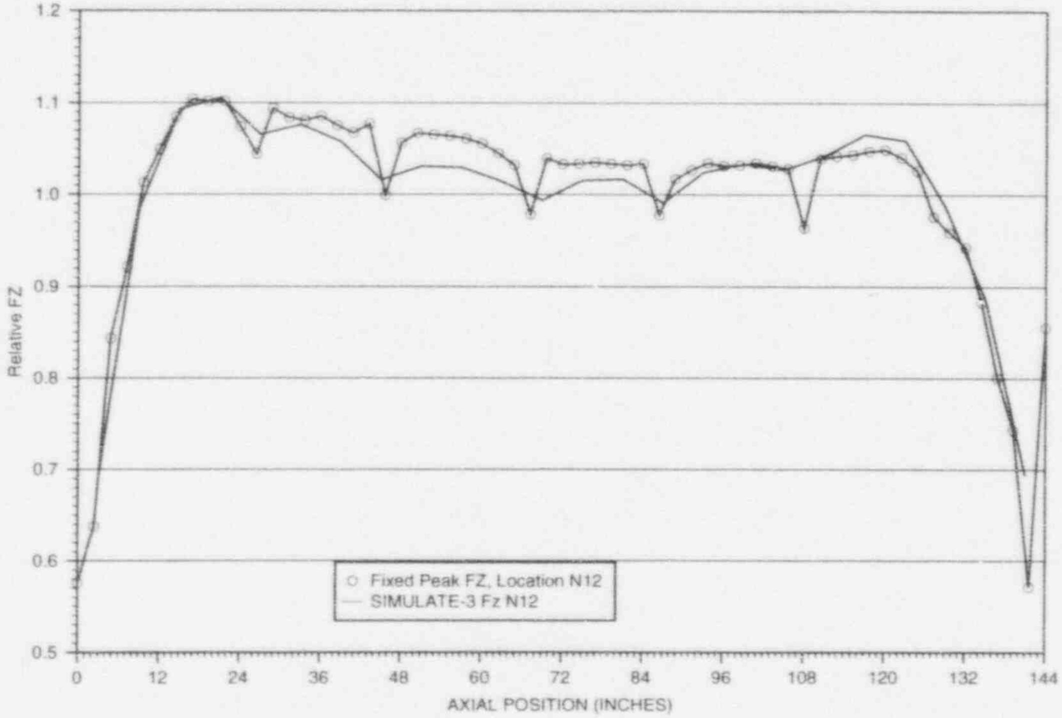

Figure 5-4

Seabrook Cycle 4 at 14402 Mwd/Mtu
Measured Fz Values
Fixed Platinum Detector System Measurements vs SIMULATE-3

6.0 CONCLUSIONS

This report addresses NRC concerns for additional benchmark data. Each of the concerns has been addressed in this work.

1. First, there is a burnup dependence in the fixed/movable inferred measured Fxy and Fq. North Atlantic Energy Service Corporation provided information to respond to this concern that shows that the difference most likely is due to the inherent differences in the reactor physics methods used to predict the power distribution. While this may be true, it is important that the ratio be monitored in future cycles to ensure that the two methods do not continue to diverge which would indicate a problem with one of the systems.

Differences in the Movable and Fixed Incore Detector System inferred Fq and Fxy values do exist and are expected, as described in Section 5. The difference is due to the methodological differences used to analyze the data. Axial power distributions using the Movable Incore Detector System are biased by the U235 fission spectrum using a single plane model to analyze the data. The methodology used in the analysis of Fixed Incore Detector System data considers fissions from all sources.

2. The fraction of the total signal which is due to neutrons is approximate, is not a well known number, and it is not based on control experiments. It is important that more core burnup be achieved to ensure that this ratio does not change significantly with core life.

The continuing performance of the Fixed Incore Detector System at Seabrook Station empirically demonstrates the validity of the platinum signal model used in SIMULTE-3. This is made evident in the confirmation of the uncertainty analysis provided in Section 3. The extended burnup data from Cycles 3 and 4 show that the system is accurate for long cycles and highly exposed fuel cores.

3. Third, there is little experience in the United States with a fixed platinum detector system. Seabrook is the first plant to be approved to use this system of TS surveillance, and Seabrook is the first Westinghouse plant to employ a Fixed Incore Detector System to determine core peaking factors.

The data given here clearly demonstrates the ability of the Fixed Incore Detector System at Seabrook Station to accurately and continuously measure the incore power distribution and associated limits.

The Fixed Incore Detector System at Seabrook Station has continued to demonstrate the same accuracy discussed in the original licensing analysis. No new detector failures or signal strength degradation has been seen. The raw millivolt signals given by the fixed detectors are about the same at the end of Cycle 4 as during Cycle 1 measurements.

Statistics of predicted to measured signal differences are still good. The axial or three dimensional component of uncertainty is unchanged after the addition of 40 detector maps,

while the radial uncertainty has decreased slightly. No changes to the uncertainty values used in surveillances made with this system are required.

A uniform set of analyses were performed at nearly 40 exposure points over four cycles of operation with two independent incore detector systems. Full incore analyses for each set of data collected with both movable fission chambers and fixed self powered platinum detectors show comparable results for radial peaking values. Axial peaking results differ between the systems as a function of cycle exposure. The difference in axial peak values is attributed to the limitations of the movable fission chamber system in its use of only the U235 fission rate to determine the axial power shape in the core.

The results of this report show the Fixed Incore Detector System to be a complete and independent system with accuracy and functionality expected for an incore detector system. The Fixed Incore Detector System should continue as a stand alone incore power surveillance system for Seabrook Station with the uncertainty factors of 4.12% for radial analyses (Fdh), and 5.21% for axial analyses (Fq).

7.0 REFERENCES

1 A.W. DeAgazio letter to T.C. Feigenbaum, Amendment No. 27 to Facility Operating License NPF-86: Incore Detector System - License Amendment Request 92-14 (TAC M85020), dated December 22, 1993.

2 J.P. Gorski, Seabrook Station Unit 1 Fixed Incore Detector System Analysis, YAEC-1855PA, October 1992.

3 A.J. Harris and H.A. Jones, The INCORE-3 Program, WCAP-8402, March 1975

4 A.S. DiGiovine and J.A. Umbarger, SIMULATE-3 Users Manual Studsvik/SOA-92/01, April 1992.