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Omaha Public Power District

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April 24, 1981

RECEIVED MAY 01 1981 U.S. NUCLEAR REGULATORY COMMISSION

Mr. Charles M. Trammell
Project Manager
U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Licensing
Operating Reactors Branch No. 3
Washington, D.C. 20555

Reference: Docket No. 50-285

Dear Mr. Trammell:

The Commission's letter to the Omaha Public Power District dated February 2, 1981, forwarded Amendment No. 55 to the Fort Calhoun Station Facility Operating License. This amendment added Interim Special Technical Specification (ISTS) 6.4, allowing continued operation with less than 75% operable incore nuclear detectors. The Commission's Safety Evaluation of the amendment specified that the District furnish the NRC Project Manager with the results of the 31 EFPD measurement for uncertainty factors required by ISTS 6.4. Attachment 1 summarizes the results of the measurement. Attachment 2 details the methodology employed in the determination of peaking factor uncertainties.

Please note that Attachment 2 is a proprietary Combustion Engineering report and includes the affadavit supporting a request for withholding this information from public disclosure, pursuant to 10 CFR Chapter 2.790, paragraph (b)(4).

Sincerely,

W. C. Jones
Division Manager
Production Operations

WCJ/KJM/TLP:jmm

Attachments

cc: Mr. Dennis Kelley-NRC
LeBoeuf, Lamb, Leiby & MacRae

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ATTACHMENT 1

EVALUATION OF PEAKING UNCERTAINTIES

With less than 75% of the incore detector strings operable, Interim Special Technical Specification (ISTS) 6.4 requires that the total planar radial peaking factor uncertainty (U_{xy}), the total integrated radial peaking factor uncertainty (U_R), and the total peaking factor uncertainty (U_q) be assessed every 31 EFPD. Attachment 2 recommends that the previous total uncertainties be increased by 1% to:

7% for F_R

8% for F_{xy}, F_q

An analysis performed by Combustion Engineering, Inc. showed that a failure of up to 80% of all incore detectors resulted in an additional uncertainty of less than 1%, so the use of a 1% increase in the peaking factor uncertainties as above is conservative.

Attachment 2 also recommends that, rather than assess the total uncertainties every 31 EFPD, the measured pooled uncertainties should be calculated and compared to the pooled limit values in Table III (of this attachment). If the measured pooled uncertainties are less than the pooled limit values, then the overall uncertainties are in compliance.

In addition to assessing the peaking factor uncertainties every 31 EFPD's, ISTS 6.4 requires that the CECOR measured untilted radial peaking factors F_R^M and F_{xy}^M be corrected and be shown to be within their respective Technical Specification limits of 1.52 and 1.57. The correction is performed by:

$$F_R = 1.01\, F_R^M$$

$$F_{xy} = 1.01\, F_{xy}^M$$

On January 26, 1981, the limit of having less than 75% of the strings operable was reached. On February 2, 1981, ISTS 6.4 was issued, with a Cycle 6 burnup of 5830 MWD/MTU. At the time of ISTS implementation, the measured pooled uncertainties and peaking factors were less than the upper limits. Thirty-one EFPD corresponds to 965 MWD/MTU, so the next required surveillance would be at 6795 MWD/MTU. This surveillance was performed at 6500 MWD/MTU and the measured pooled values of SF_{xy}, SF_R, and S_q found to be 0.02690, 0.01905, and 0.02693 which are less than their respective limits of 0.03210, 0.02691, and 0.03211. Table 1 shows a continuation of Table II from Attachment 2; i.e., measured pooled uncertainties for F_R, F_{xy}, and F_q versus burnup. The values of F_R and F_{xy} were 1.43 and 1.47 which have margins 0.09 and 0.10 to their Technical Specification limits.

Figures 1 and 2 show plots of the measured F_{xy} and F_R values versus fuel burnup for Cycle 6. The step change upward (triangular points to circular points) indicates the change to less than 75% of the strings operable and, consequently, the application of a 1.01 multiplier on the CECOR $F_{xy}{}^M$ and $F_R{}^M$ values. These data show decreasing peaking factor values with fuel burnup and increasing margins to Technical Specification limits. This trend is expected to continue for the remainder of Cycle 6.

Figures 3, 4, and 5 show plots of $S_{F_{xy}}$, S_{F_R}, and S_{F_q} versus Cycle 6 burnup. These values show a decreasing trend which is consistent with the failure of older detectors (with increased sensitivity uncertainties) and are less than the pooled limit values since the issuance of ISTS 6.4.

TABLE I

Ft. Calhoun Unit 1 Cycle 6

Summary of Measurement Uncertainty for All Timepoints

SFXY

Burnup	Level 1	N(1)-1	Level 2	N(2)-1	Level 3	N(3)-1	Level 4	N(4)-1
300 MWD/T	.03450	26	.02848	27	.03459	26	.03124	24
500 MWD/T	.03825	26	.02928	27	.03335	26	.03141	24
1000 MWD/T	.03388	25	.03226	27	.03959	25	.03440	23
2000 MWD/T	.02619	25	.02893	27	.03698	23	.03130	22
3000 MWD/T	.02745	24	.02657	26	.02901	21	.03002	21
4000 MWD/T	.02701	24	.02948	24	.03501	21	.03208	20
5000 MWD/T	.02639	24	.03046	24	.03130	19	.03178	19
5800 MWD/T	.02594	24	.02807	22	.03144	19	.02652	18
6500 MWD/T	.02773	23	.02480	19	.02752	19	.02754	16

Burnup	SFXY Pooled	NDEG	SFQ	NDEG	SFR	NDEG
300 MWD/T	.03229	103	.03228	103	.02692	22
500 MWD/T	.03324	103	.03315	103	.02675	22
1000 MWD/T	.03510	100	.03518	100	.03023	19
2000 MWD/T	.03092	97	.03098	97	.02578	18
3000 MWD/T	.02817	92	.02818	92	.02361	14
Pooled	.03210	495	.03211	495	.02691	95
4000 MWD/T	.03085	89	.03079	89	.02772	12
5000 MWD/T	.02988	86	.02982	86	.02341	11
5800 MWD/T	.02797	83	.02796	83	.02183	11
6500 MWD/T	.02690	77	.02693	77	.01905	9

CYCLE BURNUP (MWD/MTU)

Figure 3

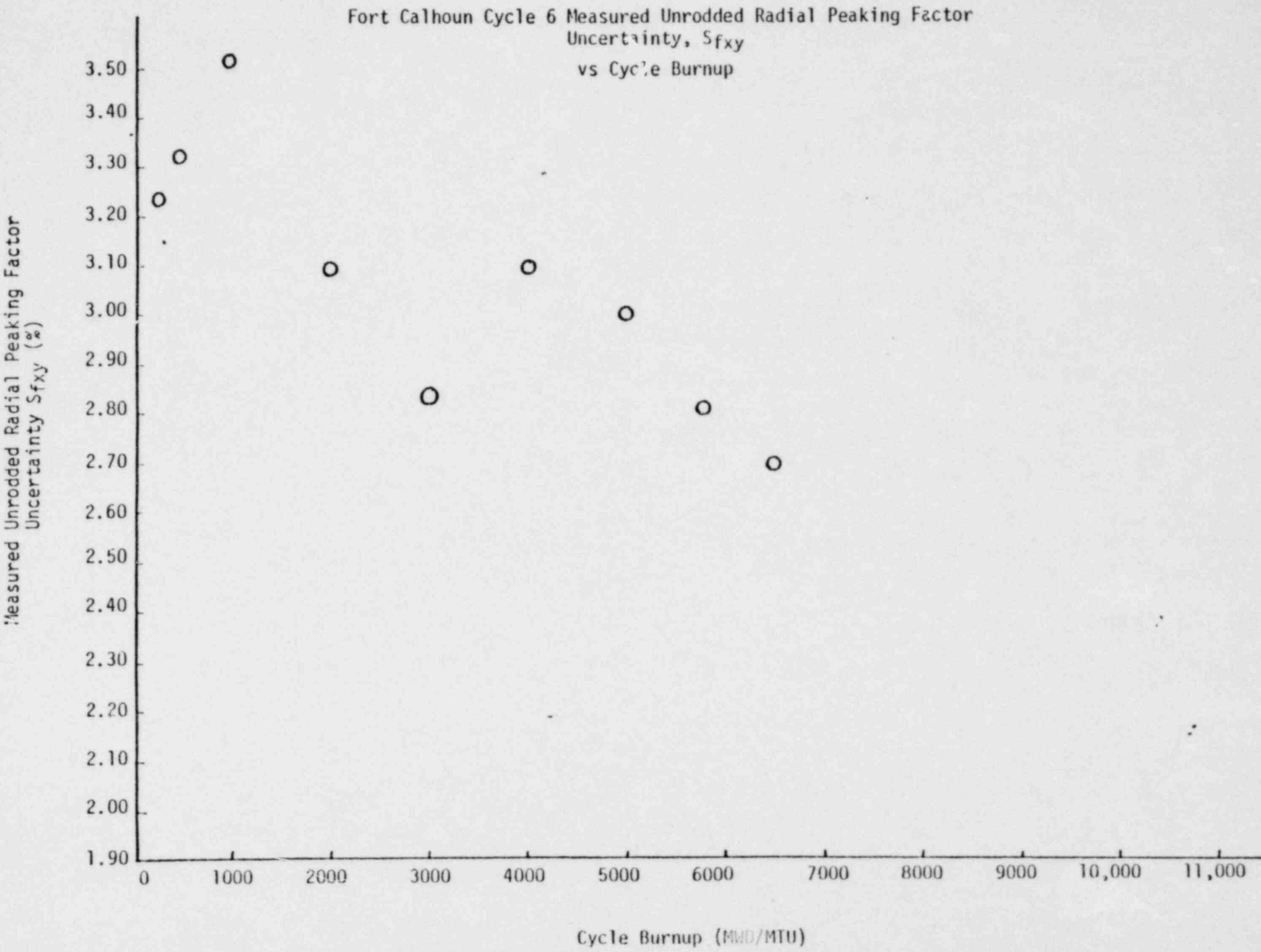

Fort Calhoun Cycle 6 Measured Unrodded Radial Peaking Factor
Uncertainty, S_{fxy}
vs Cycle Burnup
Measured Unrodded Radial Peaking Factor
Uncertainty S_{fxy} (%)
3.50
3.40
3.30
3.20
3.10
3.00
2.90
2.80
2.70
2.60
2.50
2.40
2.30
2.20
2.10
2.00
1.90
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
Cycle Burnup (MWD/MTU)

Figure 4

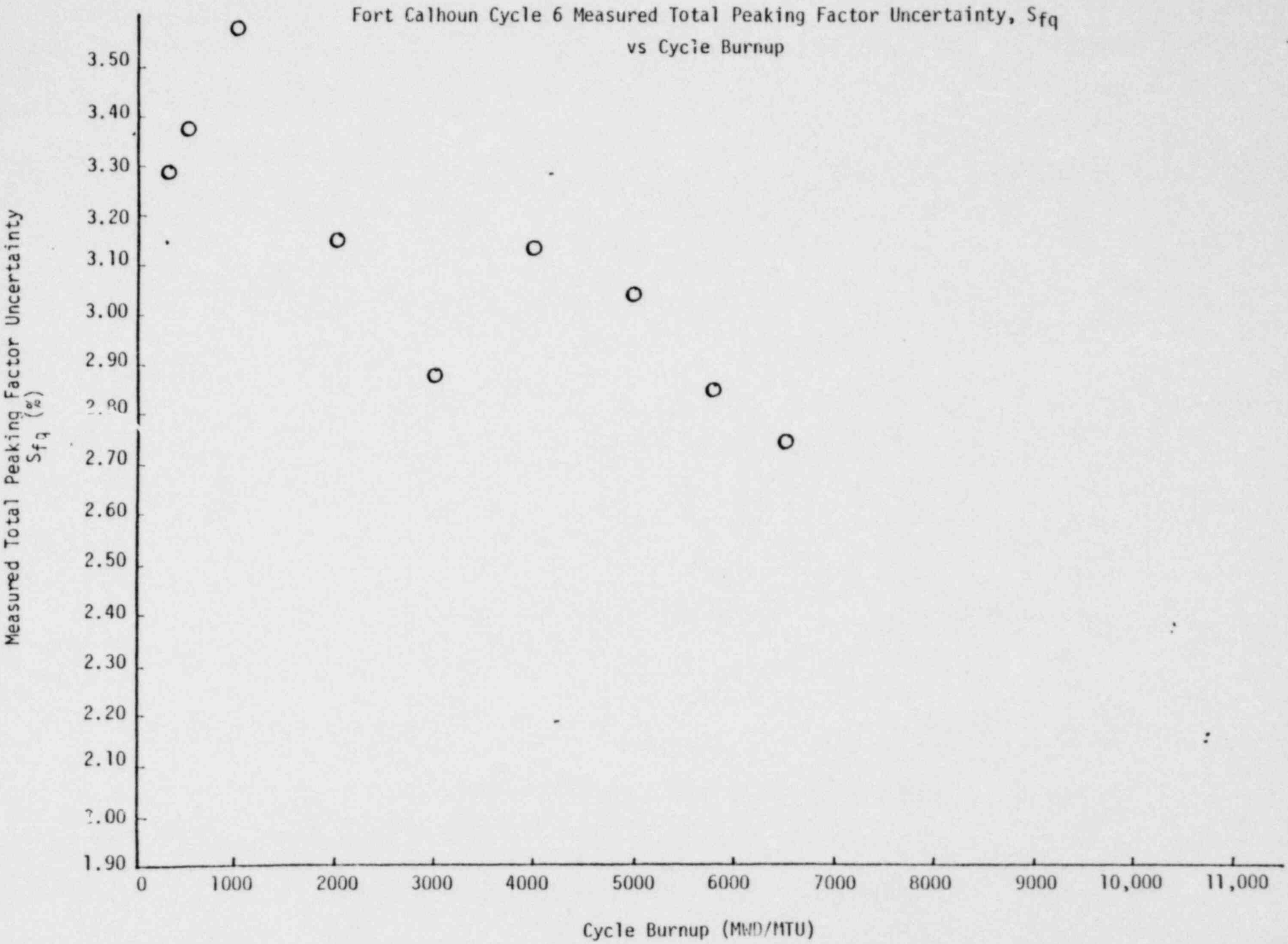
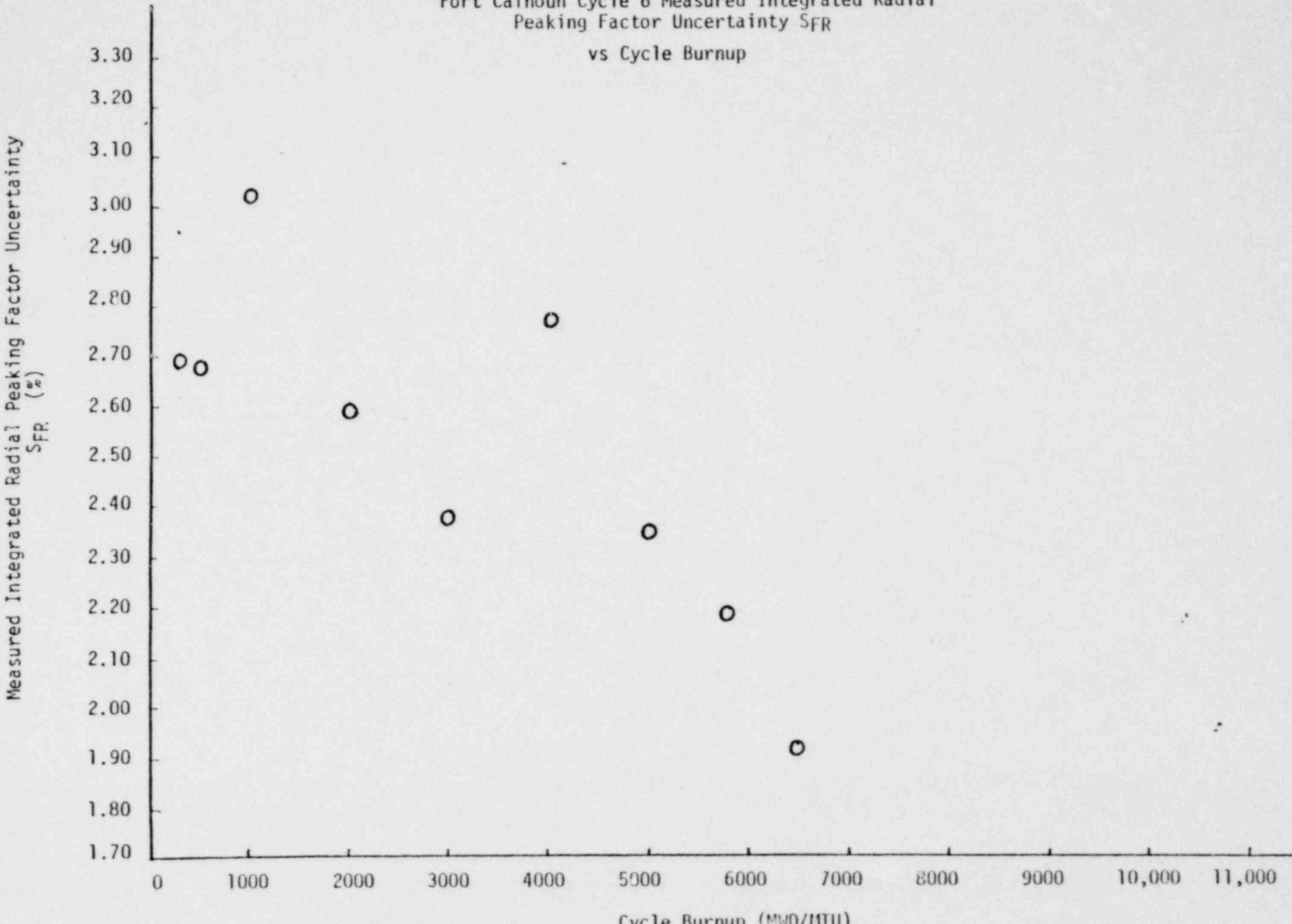

Fort Calhoun Cycle 6 Measured Total Peaking Factor Uncertainty, Sfq
vs Cycle Burnup
Measured Total Peaking Factor Uncertainty
Sfq (%)
3.50
3.40
3.30
3.20
3.10
3.00
2.90
2.80
2.70
2.60
2.50
2.40
2.30
2.20
2.10
2.00
1.90
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
Cycle Burnup (MWD/MTU)

Figure 5

Fort Calhoun Cycle 6 Measured Integrated Radial Peaking Factor Uncertainty S_{FR} vs Cycle Burnup



ATTACHMENT 2

AFFIDAVIT PURSUANT

TO 10 CFR 2.790

Combustion Engineering, Inc.)
State of Connecticut)
County of Hartford) SS.:

I, P. L. McGill depose and say that I am the Vice President, Commercial of Combustion Engineering, Inc., duly authorized to make this affidavit, and have reviewed or caused to have reviewed the information which is identified as proprietary and referenced in the paragraph immediately below. I am submitting this affidavit in conformance with the provisions of 10 CFR 2.790 of the Commission's regulations and in conjunction with the application of Omaha Public Power District, for withholding this information.

The information for which proprietary treatment is sought is contained in the following document:

CEN-150(O) - P, Analysis of CECOR Power Peaking Uncertainties For Ft. Calhoun Unit 1 Cycle 6, February, 1981.

This document has been appropriately designated as proprietary.

I have personal knowledge of the criteria and procedures utilized by Combustion Engineering in designating information as a trade secret, privileged or as confidential commercial or financial information.

Pursuant to the provisions of paragraph (b) (4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the above referenced document, should be withheld.

1. The information sought to be withheld from public disclosure are the methodology related to the determination of power distribution measurement uncertainties and the statistical models used to determine the uncertainty estimate, which is owned and has been held in confidence by Combustion Engineering.

2. The information consists of test data or other similar data concerning a process, method or component, the application of which results in a substantial competitive advantage to Combustion Engineering.

3. The information is of a type customarily held in confidence by Combustion Engineering and not customarily disclosed to the public. Combustion Engineering has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The details of the aforementioned system were provided to the Nuclear Regulatory Commission via letter DP-537 from F.M. Stern to Frank Schroeder dated December 2, 1974. This system was applied in determining that the subject documents herein are proprietary.

4. The information is being transmitted to the Commission in confidence under the provisions of 10 CFR 2.790 with the understanding that it is to be received in confidence by the Commission.

5. The information, to the best of my knowledge and belief, is not available in public sources, and any disclosure to third parties has been made pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence.

6. Public disclosure of the information is likely to cause substantial harm to the competitive position of Combustion Engineering because:

a. A similar product is manufactured and sold by major pressurized water reactors competitors of Combustion Engineering.

b. Development of this information by C-E required tens of thousands of manhours of effort and hundreds of thousands of dollars. To the best of my knowledge and belief a competitor would have to undergo similar expense in generating equivalent information.

c. In order to acquire such information, a competitor would also require considerable time and inconvenience related to the development of methods and statistical models for determining power distribution measurement uncertainties.

d. The information required significant effort and expense to obtain the licensing approvals necessary for application of the information. Avoidance of this expense would decrease a competitor's cost in applying the information and marketing the product to which the information is applicable.

e. The information consists of methods and statistical models for the determination of power distribution measurement uncertainties, the application of which provides a competitive economic advantage. The availability of such information to competitors would enable them to modify their product to better compete with Combustion Engineering, take marketing or other actions to improve their product's position or impair the position of Combustion Engineering's product, and avoid developing similar data and analyses in support of their processes, methods or apparatus.

f. In pricing Combustion Engineering's products and services, significant research, development, engineering, analytical, manufacturing, licensing, quality assurance and other costs and expenses must be included.

The ability of Combustion Engineering's competitors to utilize such information without similar expenditure of resources may enable them to sell at prices reflecting significantly lower costs.

g. Use of the information by competitors in the international marketplace would increase their ability to market nuclear steam supply systems by reducing the costs associated with their technology development. In addition, disclosure would have an adverse economic impact on Combustion Engineering's potential for obtaining or maintaining foreign licensees.

Further the deponent sayeth not.

P. L. McGill
Vice President
Commercial

Sworn to before me

this 20th day of March 1981

Notary Public

CAREY J. WENZEL, NOTARY PUBLIC
State of Connecticut No. 59962
Commission Expires March 31, 1985

COMBUSTION ENGINEERING, INC.

Report CEN-150(O)-NP

Analysis of CECOR Power Peaking Uncertainties For Ft. Calhoun Unit 1 Cycle 6

February 1981

LEGAL NOTICE

This report was prepared as an account of work sponsored by Combustion Engineering, Inc. Neither Combustion Engineering nor any person acting on its behalf:

A. Makes any warranty or representation, expressed or implied including the warranties of fitness for a particular purpose or merchantability, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

1.0 Introduction

This report presents the results of an analysis of the CECOR power peaking uncertainties for Ft. Calhoun Unit 1 Cycle 6. The analysis was performed to assist The Omaha Public Power District (OPPD) in establishing a program for compliance with requirements of the Interim Special Technical Specifications (Reference 1) approved in February 1981. The revised technical specifications allow for an increased number of failed in-core detector strings (up to 80% of the total) and at the same time impose a periodic requirement to evaluate of the CECOR uncertainties.

The analysis of the CECOR power peaking uncertainties is based on calculational and operating data for Ft. Calhoun Unit 1 Cycle 6 available up to December 1980. At that time 5 of 28 (or 18% of total) detector strings had failed.+ In view of the history of detector failures for Cycle 6, the analysis considered both the observed failures and extrapolated future failures to determine the expected effect on the CECOR uncertainties.

The analysis was performed in three parts: The first part evaluated the basic measurement uncertainties for F_r, F_q and F_{xy} based on core-follow calculations for Cycle 6. The second part evaluated the box synthesis uncertainties for the configuration with all observed failed detectors, and for configurations with extrapolated failed detectors. The final part of the analysis evaluated the overall CECOR uncertainties using results of the first two parts and the methodology in Reference 2. The overall uncertainties were compared against the present Cycle 6 Technical Specification values of

6% for F_r,
7% for F_q, F_{xy}

+ A detector string is defined as failed if two detectors in the axial string have failed signals.

In addition, the expected effect of extrapolated detector failures on the overall uncertainty was evaluated. Recommendations for conservative compliance with the Interim Special Technical Specifications were developed based on the results of the analysis.

1.1 Summary of Results

A detailed description of the analysis is given in Chapter 2. The major results are as follow:

i) The calculation of the overall CECOR uncertainties based on observed failed detectors and operating data through 3000 MWD/T cycle burnup indicates compliance with the Technical Specifications. The calculated uncertainties are

[ ] for F_r,
for F_q,
for F_{xy}.

ii) The basic measurement uncertainty values show a decreasing trend after 1000 MWD/T cycle burnup. This may be attributable to the more likely failure of instruments (e.g., the most aged instruments) which have greater than average errors in calculated sensitivity. This trend is expected to continue through Cycle 6.

iii) The box synthesis uncertainties were found to increase by less than [ ] above reference calculation values for substantial extrapolated detector failures. The combined CECOR uncertainties showed an increase of [ ] or less for the extrapolated failure analysis.

1.2 Recommendations

Based on the results of the analysis, the following recommendations are made for complying with the Interim Special Technical Specifications:

i) Increase the CECOR uncertainties used for Cycle 6 to 1% above the values in the Technical Specifications. This will conservatively allow for increased synthesis errors due to future detector failures. The recommended CECOR uncertainty values are

$$7\% \text{ for } Fr,$$
$$8\% \text{ for } F_q, F_{xy}.$$

ii) Calculate the basic measurement uncertainties at the periodic intervals required. If the measurement uncertainties do not exceed the values in the reference calculation (Section 2.1), it is then conservative to conclude that the overall CECOR uncertainties are within the recommended values above, provided that expected normal core operation is maintained. This procedure replaces the need to periodically calculate the synthesis and combined uncertainties. In the event that either the measurement uncertainties exceed the reference calculation values, the core power distribution departs significantly from nominal, or detector failures approach the limits in the Interim Special Technical Specifications, then the synthesis and combined uncertainty calculations should be performed.

2.0 Analysis

The loading and instrument pattern for Ft. Calhoun Unit 1 Cycle 6 is shown in Figure 1 and the history of failed instruments through December 1980 is given in Table I. These data show the detector failures to be concentrated among the most aged instruments (MOC2/BOC3 batches) and in the BOC5 batch. Additionally, it is seen that over half (15 of 28) of the in-core locations for Cycle 6 have MOC2/BOC3 batch detectors, while six locations have BOC5 batch detectors. In this analysis, extrapolated future failures through Cycle 6 were considered to be within these instrument batches.

2.1 Basic Measurement Uncertainty

The basic measurement uncertainty values were obtained from instrument box power comparisons of ROCS and CECOR calculations, following the method described in Part I of Reference 2. The ROCS and CECOR calculations used represent the Cycle 6 core operation from 300 to 3000 MWD/T, as indicated in Table II. The 3000 MWD/T time point includes all detector failures through October 1980.

The ROCS-CECOR comparison results over instrumented locations for the five time points are summarized in Table III. These results show that the greatest measurement uncertainty values occur at the 1000 MWD/T time point, while the values decrease for both the 2000 and 3000 MWD/T time points. [

]

The [ ] measurement uncertainty values are given in Table IV. The values for each parameter include the estimated standard deviation (S), number of degrees of freedom, the 95/95 probability/confidence factor ($k_{95/95}$) and upper tolerance limit (kS). The standard deviation values are given in units of percent of peak assembly value. [

] The [ ] values were used in the calculation of combined CECOR uncertainties described in Section 2.3. The $k_{95/95}$ factors shown in Table IV were obtained using Reference 4.

Additional ROCS-CECOR instrument location comparisons were performed for extrapolated detector failures in the MOC2/BOC3 and BOC5 batches. The results showed lower uncertainty values than the reference calculation above, consistent with the expectation that the basic measurement uncertainty may improve slightly by elimination of instruments with greater than average errors in calculated sensitivity. The actual core-follow calculations for Cycle 6 show a decreasing trend in the basic measurement uncertainty with burnup, as indicated in Table III.

2.2 Box Power Synthesis Uncertainty

The box power synthesis analysis was performed using a reference design ROCS depletion calculation and CECOR synthesis calculations representing various failed detector configurations. The methodology used for the synthesis analysis is described in Part II of Reference 2.

The ROCS reference calculation was a three-dimensional, quarter-core, nominal depletion calculation to 10,000 MWD/T based on the core configuration shown in Figure 1. A full core CECOR synthesis model was constructed which utilized the ROCS calculation depletion structure [

] The first CECOR synthesis calculation treated all detectors listed in Table I as failed throughout the depletion. This case is the source of the basic synthesis uncertainty values used in the combined uncertainty analysis in Section 2.3. Additional synthesis calculations were performed for extrapolated detector failures in the MOC2/BOC3 and BOC5 batches.

The synthesis uncertainty estimates for F_r, F_q and F_{xy} were obtained by comparing the CECOR synthesis and ROCS reference calculation box power distributions at each depletion time point in accordance with the procedures in Reference 2. The ROCS-CECOR comparison results for the basic synthesis case using all observed failed detectors are summarized in Table V. The worst-case time point value [

] is indicated for each parameter. The synthesis uncertainty values for Cycle 6 derived from these data are given in Table VI. [

]

The values of standard deviation (S), bias ($\bar{D}$) and the number of degrees of freedom given in Table VI were used in the combined uncertainty analysis in Section 2.3. The S and $\bar{D}$ values are quoted in units of percent of peak box value. [

] The probability/confidence factor ($k_{95/95}$) values were obtained using Reference 4.

Additional synthesis comparisons were made for cases extrapolating extensive failures among the MOC2/BOC3 and BOC5 instrument batches. The ROCS-CECOR comparison results for these cases showed small, progressive synthesis errors due to additional failed detectors. The case with the maximum extrapolated failures treated all MOC2/BOC3 and BOC5 batch instruments, or 3/4 of all detectors, as failed. The results of the ROCS-CECOR comparisons for this case are summarized in Table VII. Comparison of these results against the results for the case of observed failures in Table V show that the maximum synthesis errors attributable to

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[ ]

the extrapolated detector failures are about [ ] for F_q, [ ] for F_r and [ ] for F_{xy}. These errors are considered small in magnitude, and may be indicative of more separable radial and axial power distributions for Ft. Calhoun Unit 1 Cycle 6 than for the larger later cycle cores used for the data base in Reference 2.

2.3 Combined Uncertainty.

The combined uncertainty analysis was performed using the basic measurement and synthesis uncertainty results described in Sections 2.1 and 2.2, and the procedure given in Part III of Reference 2. The pin peak calculative and synthesis uncertainty components from Reference 2, which are not affected by detector failures, were included in the combined uncertainty calculations.

The values of the components used for the combined uncertainty calculation representing the operation of Ft. Calhoun Unit 1 Cycle 6 up to December 1980 are given in Table VIII. The overall CECOR uncertainties are given by the 95/95 probability/confidence upper one-sided tolerance limit $(\bar{D}+kS)$ for each parameter. The values,

[ ] for F_r,
for F_q,
for F_{xy},

are within the Technical Specification values of 6% for F_r and 7% for F_q and F_{xy}.

The combined uncertainties were also analyzed for cases with extrapolated failed detectors. These evaluations assumed no change in the basic measurement uncertainties, based on the analysis described in Section 2.1, and incorporated synthesis calculation results for extrapolated detector failures. The results of this analysis projected a maximum increase in the overall uncertainty value of [ ] for F_q, [ ] for F_r, and [ ] for F_{xy} for extrapolated failures in the MOC2/BOC3 and BOC5 instrument batches. Based on this analysis it is judged conservative to allow for increased synthesis errors in the event of future detector failures in Cycle 6 by adding a 1% penalty to the existing uncertainty values for F_r, F_q and F_{xy}.

2.4 Compliance

Based on the analysis in this report it is recommended that the following procedures be adopted by OPPD for compliance with the Interim Special Technical Specifications (ISTS): First, as a conservative measure to allow for expected future in-core detector failures, the overall CECOR uncertainties should be increased uniformly by 1% above the ISTS values. Thus it is recommended that the uncertainty values utilized in the ISTS be assigned values of

7% for U_r,
8% for U_q, U_{xy}.

The basic measurement uncertainties should be evaluated periodically (every 31 EFPD of operation) using the procedure in Section 2.1. If the standard deviation values obtained do not exceed the reference [ ] values in Table III, then it can be reported , on the basis of the analysis in Sections 2.2 and 2.3, that the overall uncertainties are less then the above recommended values, in compliance with the ISTS requirement. This measure eliminates the need to periodically reevaluate the synthesis uncertainties for future expected normal core operation of Cycle 6. If the basic measurement uncertainty values obtained exceed the reference values in Table III, then it would be necessary to perform the synthesis and combined uncertainty calculations as in Sections 2.2 and 2.3 to comply with the ISTS.

3.0 References

1. "Application For Amendment of Operating License," U.S. NRC Docket No. 50-285, Omaha Public Power District, January 1981.

   "Safety Evaluation by the Office of Nuclear Reactor Regulation Supporting Amendment No. 55 to Facility Operating License No. DPR-40, Omaha Public Power District, Fort Calhoun Station, Unit No. 1, Docket No. 50-285," U. S. NRC, February 2, 1981.

2. A. Jonsson, W. B. Terney and M. W. Crump, "Evaluation of Uncertainty in the Nuclear Power Peaking Measured by the Self-Powered Fixed In-core Detector System," CENPD-153-P, Rev. 1-P-A, May 1980.

3. W. J. Dixon, F. J. Massey, Jr., "Introduction to Statistical Analysis," McGraw Hill Book Co., 1969.

4. "Factors for One-Sided Tolerance Limits and for Variables Sampling Plans, " Sandia Corporation Monograph, SCR-607, 1963.

TABLE I

INCORE DETECTOR FAILURES

December, 1980

Date Failed	Instr.# -Level	Batch #
BOC6	3-4	Cycle 5 (BOC5)
BOC6	10-1	Cycle 3 (BOC3)
BOC6	14-4	Cycle 3 (BOC3)
BOC6	20-3	Cycle 3 (BOC3)
6/16/80	21-4	Cycle 5 (BOC5)
7/11/80	17-4	Cycle 5 (BOC5)
7/15/80	25-3	Cycle 3 (BOC3)
7/16/80	18-1	Cycle 3 (BOC3)
8/20/80	21-3	Cycle 5 (BOC5)
8/22/80	3-3	Cycle 5 (BOC5)
8/25/80	12-4	Cycle 5 (BOC5)
9/1/80	26-3- erratic	Cycle 2 (MOC2)
9/8/80	23-3	Cycle 5 (BOC5)
9/8/80	7-1- erratic	Cycle 3 (BOC3)
9/23/80	4-4	Cycle 2 (MOC2)
10/6/80	18-2	Cycle 3 (BOC3)
11/11/80	20-2	Cycle 3 (BOC3)
12/3/80	17-3	Cycle 5 (BOC5)

TABLE II

Fort Calhoun Unit 1 Cycle 6

Comparison Snapshot Operating Data

			Failed Detectors			
Burnup	Power Level	Rod * Insertion	Level 1	Level 2	Level 3	Level 4
300	99%	0%	10	none	20	3, 14, 21
500	100%	0%	10	none	20	3, 14, 21
1000	100%	0%	10, 18	none	20, 25	3, 14, 17, 21
2000	99%	0%	10, 18	none	3, 20, 21, 25	3, 12, 14, 17, 21
3000	66%	0%	7, 10, 18	18	3, 20, 21, 23, 25, 26	3, 4, 12, 14, 17, 21

* All rods out

TABLE III

Ft. Calhoun Unit 1 Cycle 6

Summary of Measurement Uncertainty for All Timepoints

SFXY

Burnup	Level 1	N(1)-1	Level 2	N(2)-1	Level 3	N(3)-1	Level 4	N(4)-1
300 MWD/T	[ ]	26	[ ]	27	[ ]	26	[ ]	24
500 MWD/T	[ ]	26	[ ]	27	[ ]	26	[ ]	24
1000 MWD/T	[ ]	25	[ ]	27	[ ]	25	[ ]	23
2000 MWD/T	[ ]	25	[ ]	27	[ ]	23	[ ]	22
3000 MWD/T	[ ]	24	[ ]	26	[ ]	21	[ ]	21

Burnup	SFXY [ ]	NDEG	SFQ	NDEG	SFR	NDEG
300 MWD/T	[ ]	103	[ ]	103	[ ]	22
500 MWD/T	[ ]	103	[ ]	103	[ ]	22
1000 MWD/T	[ ]	100	[ ]	100	[ ]	19
2000 MWD/T	[ ]	97	[ ]	97	[ ]	18
3000 MWD/T	[ ]	92	[ ]	92	[ ]	14
[ ]	[ ]	495	[ ]	495	[ ]	95

TABLE IV

Summary of Uncertainties*
For the Measurement of Peak Assembly Power

Quantity	S	Number of Degrees of Freedom	$k_{95/95}$	kS
F_r				
F_{xy}				
F_q				

* Quoted in percent of peak assembly value

TABLE V

Ft. Calhoun Unit 1 Cycle 6 Synthesis - Observed Failed Instruments

Bias and Standard Deviation of Difference Between ROCS and CECOR Calculations

Burnup	F_q			F_r			F_{xy}		
(MWD/T)	$\bar{D}$	S	N	$\bar{D}$	S	N	$\bar{D}$	S	N
500			133			133			11
1000			133			133			11
2000			133			133			11
3000			133			133			11
4000			133			133			11
5000			133			133			11
6000			133			133			11
7000			133			133			11
8000			133			133			11
9000			133			133			11
10000			133			133			11

+ Worst-case Value

TABLE VI

Summary of Synthesis Uncertainties *

Box Power[+]	$\bar{D}$	S	Number of Degrees of Freedom	k95/95	$\bar{D}$ + kS
F_r					
F_{xy}					
F_q					

* Quoted in percent of peak box value.

TABLE VII

Ft. Calhoun Unit 1 Cycle 6 Synthesis - Extrapolated Failed Instruments

Bias and Standard Deviation of Difference Between ROCS and CECOR Calculations

	F_q			F_r			F_{xy}		
Burnup (MWD/T)	$\bar{D}$	S	N	$\bar{D}$	S	N	D	S	N
500			133			133			11
1000			133			133			11
2000			133			133			11
3000			133			133			11
4000			133			133			11
5000			133			133			11
6000			133			133			11
7000			133			133			11
8000			133			133			11
9000			133			133			11
10000			133			133			11

+ Worst-case Value

TABLE VIII

Ft. Calhoun Unit 1 Cycle 6

Summary of Uncertainty Components

Parameter			$\overline{D}$ (%)	S (%)	f	k95/95	$\overline{D}$+kS (%)
F_q	Box	Meas.	[ ]	[ ]	[ ]	[ ]	[ ]
		Synth.					
	Pin	Calc.					
		Synth					
	Combined		[ ]	[ ]	[ ]	[ ]	[ ]
F_r	Box	Meas.	[ ]	[ ]	[ ]	[ ]	[ ]
		Synth.					
	Pin	Calc.					
		Synth.					
	Combined		[ ]	[ ]	[ ]	[ ]	[ ]
F_{xy}	Box	Meas.	[ ]	[ ]	[ ]	[ ]	[ ]
		Synth.					
	Pin	Calc.					
		Synth.					
	Combined		[ ]	[ ]	[ ]	[ ]	[ ]

Figure 1

LOADING & INSTRUMENT PATTERN

FORT CALHOUN UNIT 1 CYCLE 6