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September 29, 1982

Director
Office of Nuclear Reactor Regulation
U S Nuclear Regulatory Commission
Washington, DC 20555

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
Docket Nos. 50-282 License Nos. DPR-42
50-306 DPR-60

Response to NRC Concerns on Monitoring of
Core Power Distributions in Prairie Island 1, Cycle 7

On August 16, 1982 (and subsequent dates) discussions were held between NSP and the Core Performance Branch on methods of monitoring core power distributions. In response to staff concerns, the attached response is submitted for information.

Please call us if you have further questions concerning this subject.

David Musolf
Manager of Nuclear Support Services

DMM/TMP/js

NRR Regional Admin-III
NRR Proj Mgr, NRC
NRC Resident Inspector
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A015

RESPONSE TO NRC CONCERNS ON MONITORING OF CORE POWER DISTRIBUTIONS IN PRAIRIE ISLAND 1, CYCLE 7

Ref: 1. Letter from J S Holm (ENC) to R Anderson (NSP), August 13, 1982, "Use of the Symmetry Option in the Detector Routine of the Conform Package for Prairie Island 1, Cycle 7"

2. NSP Topical Report NSPNAD8101P, "Qualification of Reactor Physics Methods for Application to PI Units", December 1981.

Reference 1 is Exxon Nuclear's (ENC) justification for using the symmetry option of the DETECTOR code for monitoring core power distributions for PI1, Cycle 7. The main point of their letter is that the symmetry option of the DETECTOR code can be used for core monitoring as long as core symmetry can be shown to be within some small degree uncertainty. They show this by comparing the differences between symmetric measured reaction rate locations. The option is acceptable as long as symmetry can be shown. It should be noted that all measured reaction rates are used in determining core power distributions using this option. For more details on the justification, see Reference 1 attached.

The NSP DP5 program, described in detail in Reference 2, was also used to analyze the core power distributions in PI1, Cycle 7. The DP5 program calculates reaction rates, power distributions, temperature distributions, etc. for all assemblies in the core (full core representation). The calculation is done in three dimensions, thus incorporating all feedback effects. The program is normalized at BOC to a two-dimensional ¼ core PDQ depleted over the cycle length. Comparisons have been made at various state points over the cycle between calculated DP5 reaction rates and monitored reaction rates (raw data i.e. the DETECTOR code has not manipulated or calculated this data). Figure 1 gives the results of this comparison for MAP 107-27, the mean is 1.24 and the standard deviation is 1.01. Figure 2 gives the comparison of the DP5 calculated $F_{\Delta H}$ to the DETECTOR calculated $F_{\Delta H}$ using the symmetry option. The technical specification limit is also indicated. The uncertainty associated with the DP5 calculation of $F_{\Delta H}$ is well established (see Reference 2) and is given as ± .06 of the calculated value. This uncertainty includes uncertainty in calculation as well as in measurement. (When this uncertainty was established over several cycles of operation, the measurement uncertainty was never subtracted out). Figure 3 shows a comparison of the DP5 calculated $F_{\Delta H}$'s to the DETECTOR calculated $F_{\Delta H}$'s using the 'nearest neighbor option.'

The DP5 program accounts for asymmetries in assembly exposure distributions only. Other asymmetries such as flow induced, etc. are not accounted for. Therefore a significant deviation between the comparison of the calculated to measured reaction rates in a few monitored assemblies would indicate an asymetric core. The comparisons shown in Figure 1 are all within 1% to 2% in the interior of the core thus indicating that the core is symmetrically loaded which corroborates the ENC conclusion. Furthermore, the DP5 program calculates the power distributions in the unmonitored assemblies to within the same degree of accuracy as it does for the monitored assemblies. In this mode, DP5 is calculating the power in unmonitored assemblies in a much more accurate but similar method to the DETECTOR code 'nearest neighbor option.' The coupling factors are inherent in the basic methodology of DP5, whereas for DETECTOR, they are explicitly determined and applied in an algorithim to distribute power to the unmonitored assemblies with no feedback effects accounted for. Plant procedures require that DETECTOR and DP5 are to be run to determine a peak $F_{\Delta H}$ for the core. For conservatism, the largest value from either code would be used for compliance. The DP5 program will be run at the plant conditions at the time the flux map, which was input to DETECTOR, was run. The results from DP5 are compared to the measured reaction rates. Acceptance criteria is then applied to this comparison. As long as the DP5 data is within the acceptance criteria, the DP5 results can be used to determine the peak $F_{\Delta H}$ in monitored and unmonitored assemblies. It should be noted that DP5 used in this manner is completely independent of the DETECTOR code.

A simpler way to use DP5 in the monitoring mode would be to use the measured reaction rates as input to DP5 and from this calculate assembly power distributions, in a sense, run DP5 backward. Running the program in this manner would eliminate the need to make the comparison outlined above. This would be the only difference between the two methods of running DP5 in the monitoring mode. In the near future the Nuclear Analysis Department intends to produce a topical report on this mode of running DP5 for NRC review. When this review is complete and the plant has reviewed and approved these methods, then NSP intends to use DP5 as the monitoring tool for technical specification compliance for both Prairie Island plants.

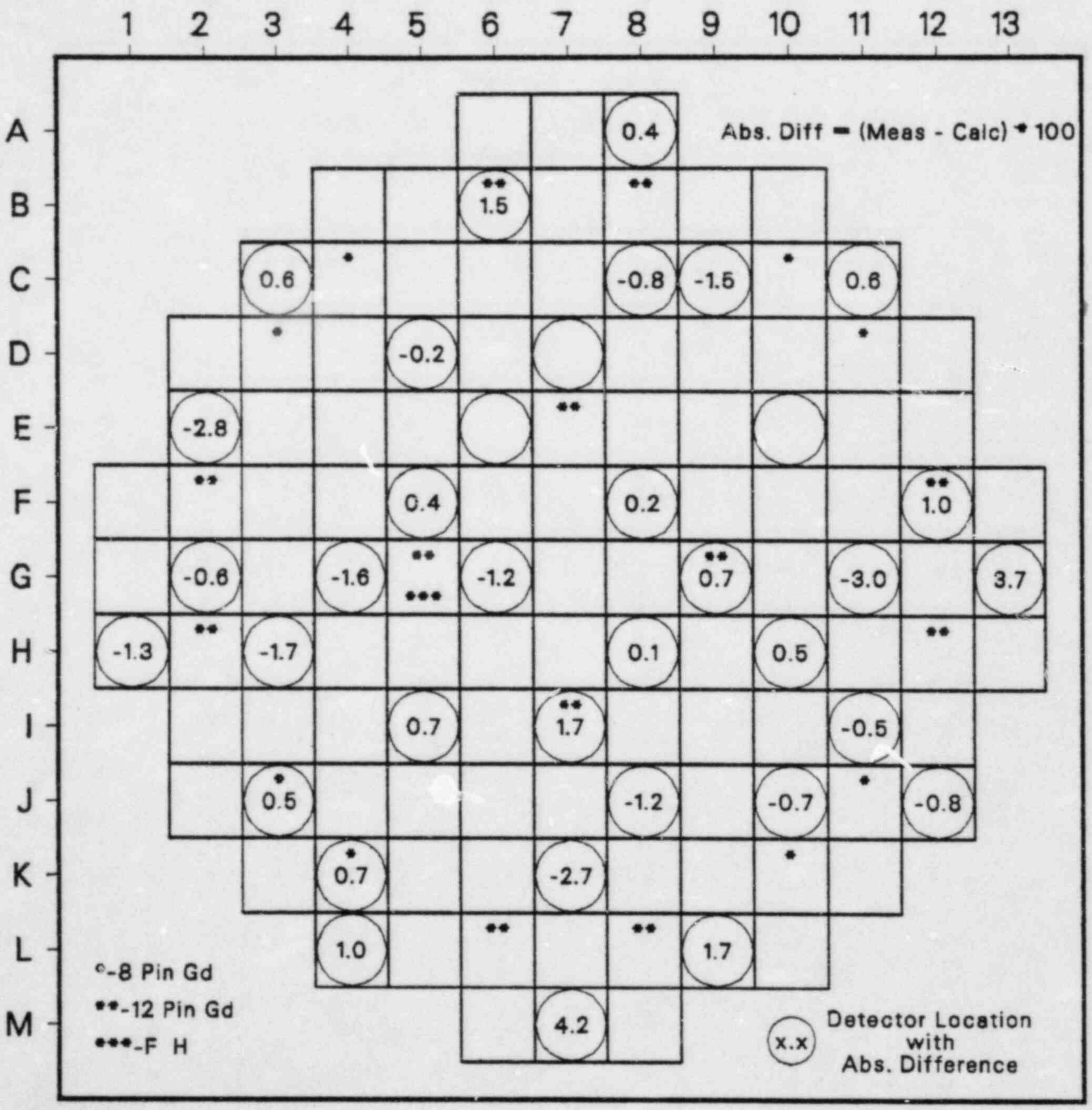
Measured and Calculated Integrated Detector Responses

PI 1 CYCLE 7 HFP,10.105 GWD/MTU, ARO, EQ XENON

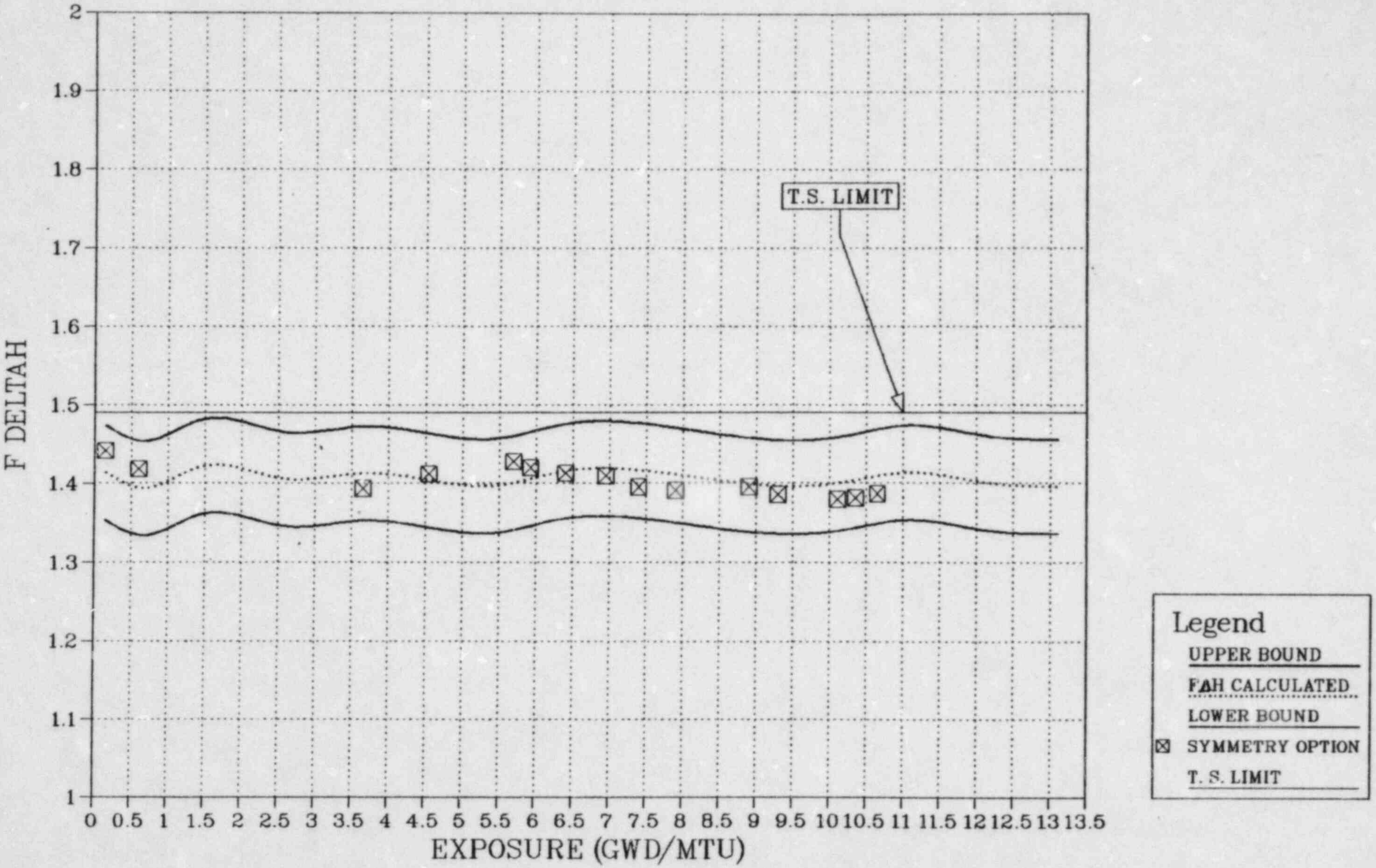
Absolute Differences

FIGURE 1

MAP 107-27

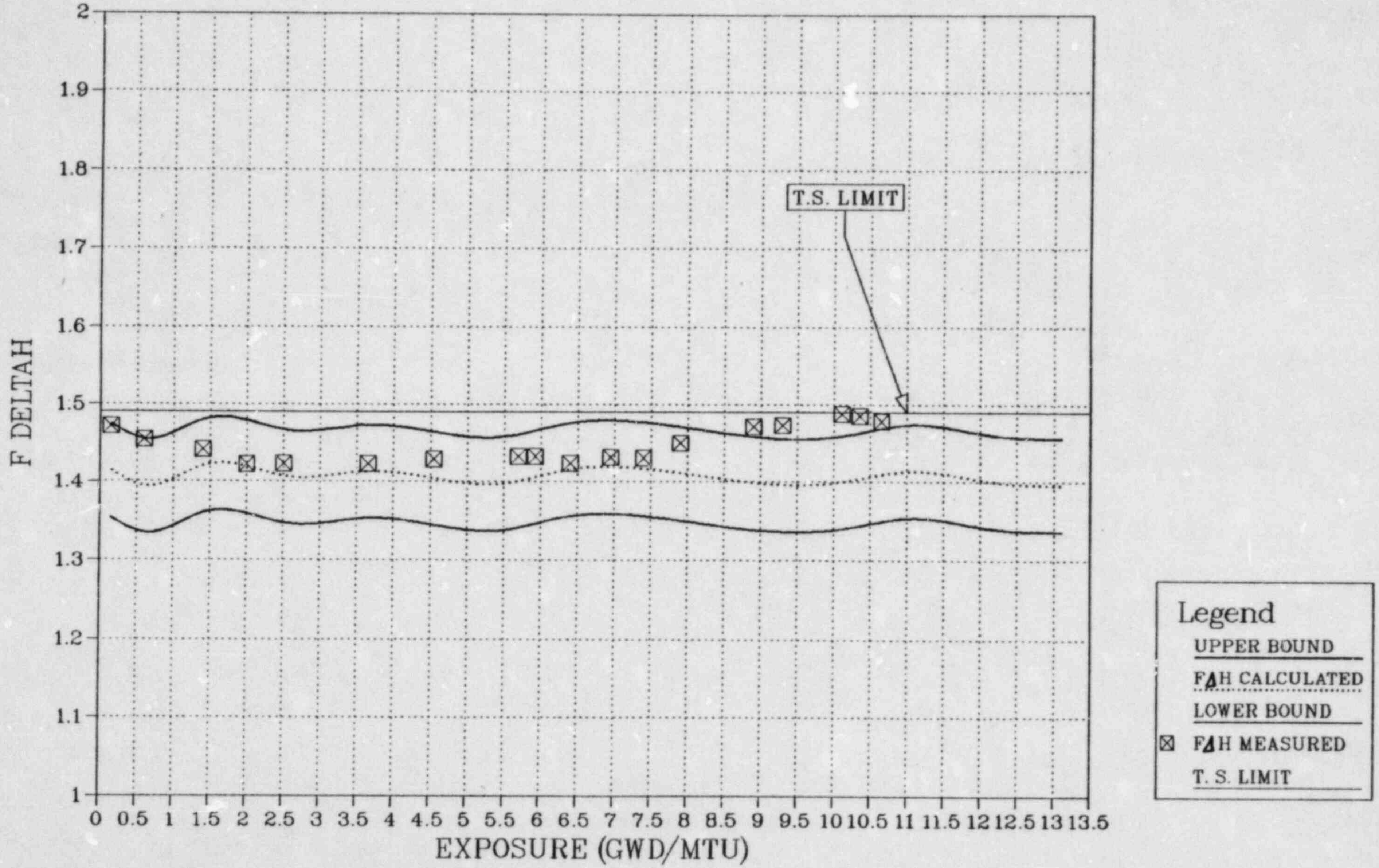


PRAIRIE ISLAND 1 CYCLE 7
FΔH MEAS VS CALC
FIGURE 2



NSP–NUCLEAR ANALYSIS DEPT.

PRAIRIE ISLAND 1 CYCLE 7
FΔH MEAS VS CALC
FIGURE 3



NSP-NUCLEAR ANALYSIS DEPT.

EXXON NUCLEAR COMPANY, Inc.

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August 13, 1982

File
LB/JSH:020:82

Mr. Roger Anderson
General Superintendant of Nuclear Analyses
Northern States Power
414 Nicollett Mall Plaza
Minneapolis, MN 55401

Dear Mr. Anderson:

Subject: Use of the Symmetry Option in the DETECTOR Routine of the CONFORM Package for Prairie Island Unit 1 Cycle 7

Reference 1: Letter to Matt Klee (NSP) from MR Killgore (ENC) July 22, 1982.

Reference 2: J. S. Holm, "Exxon Nuclear Analysis of Power Distribution Measurement Uncertainty for Westinghouse PWRs", ENC, July 1979.

In Reference 1 it is recommended that the symmetry option in DETECTOR be utilized in the monitoring of the core power distribution in Prairie Island Unit 1 Cycle 7. This recommendation has been made based upon the fact that ENC believes that the DETECTOR option currently utilizied in the monitoring of the Prairie Island Unit 1 Cycle 7 core power distribution is overly conservative. The use of the symmetry option in DETECTOR will result in a more accurate measurement of the peak $F_{\Delta H}$ in the core for Cycle 7. The supporting argument for this recommendation is provided below.

The suitability of utilizing the symmetry option depends on the assumption of core quadrant symmetry with regard to the core assembly power distribution. The measurement of the assembly power in any one of four symmetric core locations provides a measurement of all four locations when quadrant symmetry exists in the core. To demonstrate that the use of the symmetry option for Prairie Island Unit 1 Cycle 7 is suitable a comparison of one-eighth core measured reaction rates in symmetric locations has been made. One-eighth core symmetric comparisons are made since there are few one-quarter core symmetric measured locations. In Figure 1 the differences between the measured and calculated reaction rates in the unrodded plane are shown. In Figure 2 these differences have been folded into an eighth core map to compare the differences between calculated and measured powers in symmetric locations. The one-eighth core values are subtracted and the results shown in Figure 2 to represent the difference between measured reaction rates in symmetric locations with the expected eighth core asymmetries removed. The maximum difference between symmetric measured reaction rates as shown in Figure 2 is 1.9% with a standard deviation of 0.93%. The relative standard deviation is calculated assuming that each difference represents two data points, one positive and one negative. In Reference 2, the relative standard deviation with regard to the measurement of a single assembly reaction rate is shown to be .65%. The expected relative standard deviation for a symmetric core with regard to the difference between two measured reaction rates is, therefore, $(2 \times .65^2)^{1/2} = .92\%$. The relative standard deviation for the differences between symmetric measured reaction rates shown in Figure 2 is consistent with the expected relative standard deviation for a symmetric core.

The uncertainty in $F_{\Delta H}$ (and similarly F_Q^N) as calculated by DETECTOR using the symmetry option can be estimated from the data in Reference 2 for cores which have symmetric power distributions. The peaking factor $F_{\Delta H}$ has three components when determined by DETECTOR using the symmetry option. The three components are the measured reaction rate, the calculated reaction rate to assembly power ratio and the calculated local peaking factor. $F_{\Delta H}$ is defined (with suitable normalization) as the measured reaction rate divided by the ratio of the calculated reaction rate to assembly power ratio and multiplied by the calculated local peaking factor. The uncertainty in $F_{\Delta H}$ as determined by DETECTOR using the symmetry option can be expressed as a combination of the uncertainties in the components of $F_{\Delta H}$. Using the nomenclature of Reference 2, the uncertainty in $F_{\Delta H}$, $S_{P^m_{xy}}$, is defined as:

$$S_{P^m_{xy}} / P^m_{xy} = \left((S_{APR}/APR)^2 + (S_{A^m_{xy}} / A^m_{xy})^2 + (S_{L^c}/L^c)^2 \right)^{1/2} \qquad (1)$$

where

$S_{P^m_{xy}} / P^m_{xy}$ = Relative standard deviation in $F_{\Delta H}$

$S_{A^m_{xy}} / A^m_{xy}$ = Relative standard deviation in the measured assembly reaction rate

S_{APR}/APR = Relative standard deviation in the ratio of the calculated reaction rate to assembly power

S_{L^c}/L^c = Relative standard deviation in the local power peaking factor

The values determined in Reference 2 for $S_{A^m_{xy}} / A^m_{xy}$ and S_{L^c}/L^c are .65% and 1.35%, respectively. The value of S_{APP}/APR can be determined from Equation 4.7 in Reference 2 for S_{CF}/CF (S_{CF}/CF = 2.058).

$$S_{CF}/CF = \left((S_R/R)^2 + 2\,(S_{APR}/APR)^2 \right)^{1/2} \qquad (2)$$

where

S_{CF}/CF = Relative standard deviation in the ratio of the calculated reaction rates in two assemblies

S_R/R = Relative standard deviation in the ratio of the calculated assembly power in two assemblies.

it is reasonable to assume that the uncertainty in the ratio of the calculated assembly powers between two assemblies, S_R/R, is greater than the uncertainty in the ratio of the calculated reaction rate to calculated assembly power in one assembly. A conservative estimate of S_{APR}/APR can be obtained by substituting S_{APR}/APR for S_R/R in Equation 2.

$S_{APR}/APR = (S_{CF}/CF)^2/3)^{1/2} = 1.19\%$.

The relative standard deviation for $F_{\Delta H}$, $S_{P^m_{xy}}/P^m_{xy}$ can be determined from Equation 1 with the values 1.19%, .65% and 1.35% substituted for S_{APR}/APR, $S_{A^m_{xy}}/A^m_{xy}$ and S_{L^C}/L^C, respectively. The resultant value for $S_{P^m_{xy}}/P^m_{xy}$ is 1.91%. The one sided 95-95 tolerance limit is then 1.72 * 1.91% = 3.29% assuming that the tolerance limit factor in Reference 2 is appropriate for $S_{P^m_{xy}}/P^m_{xy}$ defined by Equation 1.

The current Technical Specification value for the uncertainty in $F_{\Delta H}$ is applicable to the use of the DETECTOR code with the symmetry option since 3.29% is less than 4.0%.

Sincerely,

J S Holm

J. S. Holm, Unit Manager
BWR Neutronics

JSH/mar
cc: Matt Klee
DH Peterson
LC O'Malley
Cliff Bonneau ✓
RB Stout
GA Sofer
FB Skogen

Figure 1 Prairie Island Unit 1 Cycle 7 Map 107-27
Relative Reaction Rate Differences
Configuration 2 only - 10,100 MWD/MT

	M	L	K	J	I	H	G	F	E	D	C	B	A
1						4.4							
2							1.4		-4.9				
3				5.8		-0.1					4.2		
4		4.2	6.2				-5.0						
5					-2.0			-5.4		-3.5			
6							-5.1		NA			3.0	
7	-4.2		-0.5		3.1								
8				-1.4		-2.5		-1.9			-0.9		2.5
9		-3.5					3.7				1.3		
10				-2.3		-2.8			NA				
11					0.7		0.3				4.4		
12				5.0				3.7					
13							4.2						

$\bar{X} = 3.2$
$\sigma = 1.7$

	G	F	E	D	C	B	A
7		-5.1(3) NA	3.1(2) 3.7(3) 0.6		-0.5(2) 0.3(3) 0.8	1.4(1) NA	-4.2(2) -4.2(3) 0.0
8		-1.9(4) -2.5(3) -6	-5.4(1) NA	-1.4(3) 02.8(3) 1.4	-0.9(4) -0.1(2) 0.8	3.0(1) 3.7(4) 0.7	2.5(4) 4.4(2) 1.9
9			-2.0(2)	-3.5(1) NA	1.3(4) 0.7(3) 0.6	-3.5(3) -4.9(1) 1.4	
10				-2.3(3)	6.2(2) 5.8(2) 0.4	4.2(2) 5.0(3) 0.8	
11					4.4(4) 4.2(1) .2		
12							
13							

Reaction Rate Differences (Quadrant)

Absolute Difference Between Reaction Rate Differences d_i

$$\sigma = [\sum_i^N d_i^2/N]$$

$$= .93$$

Quadrant Key

2	1
3	4

Figure 2 Prairie Island Unit 1 Cycle 7 Map 107-27, 10,100 MWD/MT Relative Reaction Rate Differences Folded into an Eighth Core