November 1, 1979
GQL 1335

TMI-2 Support
Three Mile Island Nuclear Station
Attn: John T. Collins
U. S. Nuclear Regulatory Commission
Middletown, Pennsylvania 17057

Dear Sir:

Three Mile Island Nuclear Station, Unit 2 (TMI-2)
License No. DPR-73
Docket No. 50-320
Core Thermocouple Averaging

Attached is a report explaining the statistical bases for the Incore Thermocouple Averaging Method used at TMI-2. This letter is being submitted in response to the request for information in your letter of October 22, 1979.

Sincerely,

Signed J. G. Herbein

J. G. Herbein
Vice President-Nuclear Operations

JGH:LWH:tas

Attachment

cc: Mark Greenberg, NRC

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INTRODUCTION

Provided herein is documentation of the basis for the existing method of core thermocouple averaging, justification for using the assumption of a normally distributed data set, and the basis for application of [illegible] calculated average value with conservative margins and uncertainties in the plant operating procedures. Specifically, B&W has provided a computer program which employs a statistical technique for elimination of core thermocouple data outliers and which in turn provides an "on-line" average temperature to the operator. Subsequently, B&W applied conservative margins to cover uncertainties in this "on-line" calculated average value. This adjusted value is then used as a basis for judging whether natural circulation is no longer cooling the core and a switch to alternate Cooling Modes is required.

AVERAGING TECHNIQUE

Assumption: The data set must be normally distributed. (Justification for this assumption is provided in the "Normality Test" section of this memo).

This method requires that the data be rank ordered, that the mean and standard deviation be calculated, and that a sample statistic be calculated to test the hypothesis that the most extreme data point (high or low) is from the same population. Individual detailed steps follow:

1) Rank order the data in increasing order, i.e., $T_1 < T_2 --- < T_n$

2) Calculate the sample mean, where

$$\overline{T} = \frac{\sum_{i=1}^{n} T_i}{n}$$

3) Calculate the standard deviation, where

$$S = \left(\frac{\sum_{i=1}^{n} (T_i)^2 - n\overline{T}^2}{n-1} \right)^{1/2}$$

Note: Use all values of T in the calculation of $\overline{T}$ and s.

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4) Calculate the sample statistic, X_n and X_1, where

$$X_n = \frac{T_n - \bar{T}}{S} \quad \text{and} \quad \frac{\bar{T} - T_1}{S}$$

5) Compare X_n and X_1 with the value of Table 1 corresponding to the total number of data points, n. If X_n or X_1 exceeds the value given in Table 1 for the number of data points in the sample, then T_n is too large or T_1 is too small and should be eliminated prior to averaging. Table 1 gives you [illegible]% assurance that you are not eliminating a good data point. If both X_1 and X_n are too large, reject T_i which produces the largest X_i value.

6) Procedure steps 2-5 should be repeated to ensure that the remaining data doesn't include an outlier. The rejected value of T_i should not be used in the calculation of $\bar{T}$ and S.

7) Determine the core average temperature by determining the mean of the remaining, "good" data points.

NORMALITY TEST

A sample data set of incore temperatures was obtained in the control room, 10/10/79. The data set was tested for normality using the W test described in ANSI Standard N15.15-1974-Assessment of the assumption of normality.

The data set provided a test statistic of 0.888 (calculated from the sample) and the hypothesis of normality must be rejected, for this sample of 49. At the 1% level of significance the critical value is 0.929, and comparison of .888 to this value leads to rejection. The outlier rejection technique does assume that the underlying incore temperature readings are normally distributed, as do other outlier rejection methods suitable for computer applications.

The data set at hand was subjected to the current outlier criteria ($(\bar{X}_n - X)/s = (230-171.57)/17.17 = 3.40 > 3.13$) and the 230° reading rejected. The new average is 170.354° for 48 observations. ($\bar{T}$ for 49 data points is 171.57).

The minimal impact of rejecting a single data point suggests that continued use of the current rejection criteria as an automated data editor technique is justifiable, particularly when the objective is to provide capability to eliminate outliers on-line. However, continued review of the core thermocouple values must be made to assure the validity of the continued use of the outlier rejection criteria.

Attached for reference is a core thermocouple map from October 10, 1979 and calculation sheets showing a test for normality on that data.

APPLICATION OF CALCULATED AVERAGE TEMPERATURE

The average temperature calculated above has been used to determine when the plant operator should prepare to use the Decay Heat Removal System. [illegible] has recommended that, "If the average temperature of the incore thermocouples increases to 235°F, or if RC pressure approaches 325 psig, then, under the direction of R. C. Arnold or J. G. Herbein, make immediate preparation for placing a Decay Heat Removal System (Normal Decay Heat, Alternate Decay Heat or Mini Decay Heat System) in operation by [illegible] [illegible]-1 and [illegible]-1/1."

The temperature criterion of 235° F has the following bases:

1) 44° F/Hr maximum core water volume heatup rate for total loss of natural circulation (at time of calculation). The current worst case core heatup rate is less than 30° F/Hr, and the best estimate is 11.4° F/Hr. (These values are based on simple ratioing of earlier values by the present decay heat rate), i.e., October 12, 1979.

2) An allowance of one hour to get on the Decay Heat Removal System prior to reaching a bulk core outlet temperature of 300°F, which is the normal Decay Heat Removal System design temperature.

3) 10°F margin.

4) 10°F uncertainty on the average core outlet temperature. (The 10°F uncertainty represents the possible deviation of the true average temperature from the calculated sample average temperature, and also considers the expected error which would be introduced assuming that one high data point is eliminated when in fact the data point is good).

   More specifically, 10°F uncertainty has two sub-components: 8.1°F and 1.4°F (9.5°F total $\sim$ 10.0).

   The 8.1°F uncertainty represents ≥ three standard deviations about the mean of the data set (determined in August 1979). The 1.4°F uncertainty represents the reduction in calculated average temperature which resulted in August 1979 by the averaging routine's rejection of the hottest incore thermocouple. This 1.4°F uncertainty assumes that the highest value was erroneously rejected.

   Hence 300°F - 10°F - 10°F - 44°F $\cong$ 235°F.

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TABLE I

TWO SIDED ELIMINATION

(5% Significance)

N	CRITICAL VALUE
3	1.15
4	1.48
5	1.71
6	1.89
7	2.02
8	2.13
9	2.21
10	2.29
11	2.38
12	2.41
13	2.46
14	2.51
15	2.55
16	2.59
17	2.62
18	2.65
19	2.68
20	2.71
21	2.73
22	2.76
23	2.78
24	2.80
25	2.82
30	2.91
35	2.93
40	3.04
45	3.09
50	3.13

Reference:

John L. Jaech, Statistical Methods in Nuclear Material Control, Technical Information Center, Office of Information Services, Atomic Energy Commission, 1973, page 393.

CALCULATIONS RELATED TO NORMALITY TESTING (W TEST)

THE DATA FROM THE CORE MAP WAS RANKED (ORDERED) TO CONFORM TO CALCULATIONAL NEEDS. THE NECESSARY DIFFERENCES WERE MULTIPLIED BY THE FACTORS IN THE STANDARD FOR THE SAMPLE SIZE OF 49. THE MEAN, STANDARD DEVIATION AND THE SUM OF SQUARES OF DEVIATIONS FROM THE MEAN ARE ALSO CALCULATED. THE W TEST [illegible] THE [illegible] OF NORMALITY IF THE TEST STATISTICS IS LESS THAN THE CRITICAL (TABLE) VALUE FOR THE APPROPRIATE SAMPLE SIZE AND LEVEL OF SIGNIFICANCE.

THE OUTLIER CRITERION IS APPLIED, AND AN OBSERVATION IS REJECTED. THE NEW MEAN IS THEN CALCULATED TO SHOW THE IMPACT ON CORE AVERAGE TEMPERATURE.

W TEST FOR NORMALITY

(ANSI N15.15-1974)

RANK	READING	RANK	READING
1	142	26	169
2	143	27	169
3	149	28	170
4	152	29	170
5	155	30	171
6	156	31	171
7	158	32	171
8	158	33	173
9	158	34	174
10	158	35	175
11	160	36	175
12	161	37	176
13	162	38	176
14	164	39	177
15	165	40	179
16	165	41	182
17	165	42	184
18	166	43	188
19	167	44	189
20	167	45	193
21	167	46	209
22	168	47	210
23	168	48	215
24	168	49	230
25	169		

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b= (230-142) .377 + (215-143).2589 + (210-149) .2271 + (209-152).2038 +(193-155).1

+ (189-156).1692 + (188-158).1553 + (184-158).1427 + (182-158).1312

+ (179-158).1205 + (177-160).1105 + (176-161).101 + (176-162).0919

+ (175-164).0832 + (175-165).0748 + (174-165).0667 + (173-165).0588

+ (171-166).0511 + (171-167).0436 + (171-167).0361 + (170-167).0288

+ (170-168).0215 + (169-168).0143 + (169-168).0071 = 112.0915

b^2= 12554.50

THE AVERAGE IS 171.57143 (=8407./49)

THE STANDARD DEVIATION IS 17.16828

S^2 FOR THE W TEST IS (n-1) (STANDARD DEVIATION)^2 = 48(17.17)^2

= 14148

W = b^2/S^2 = .888 IS THE TEST STATISTIC. THIS SHOULD BE COMPARED WITH THE CRITICAL VALUE (TABLE 2 OF ANSI N15.15-1974). IF THE TEST STATISTIC IS GREATER THAN THE CRITICAL VALUE, THE HYPOTHESIS OF NORMALITY IS NOT REJECTED.

FOR n=49, THE 1% LEVEL OF SIGNIFICANCE CRITICAL VALUE IS 0.929. THE HYPOTHESIS OF NORMALITY IS THEREFORE REJECTED.

APPLICATION OF THE OUTLIER REJECTION CRITERIA TO THE ATTACHED DATA SET CALLS FOR CALCULATION OF

$$\frac{X_{49} - \bar{X}}{S} = \frac{230-171.571}{17.168} = 3.4 \quad > 3.13$$

AND THE REJECTION OF THE 230° READING IS CALLED FOR. FOR THE REMAINING 49 DATA POINTS, THE AVERAGE IS THEN CALCULATED TO BE 170.354. THE REJECTION OF OUTLIERS WOULD STOP AT ONE IN THIS CASE.

10/10/79
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