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Docket No. 50-346

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August 2, 1979

Director of Nuclear Reactor Regulation
Attention: Mr. Robert W. Reid, Chief
Operating Reactors Branch No. 4
Division of Operating Reactors
United States Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Reid:

This is in response to your letter dated July 2, 1979 requesting additional information concerning the determination of core parameters during the rod drop test at Davis-Besse Nuclear Power Station, Unit 1.

The requested information is attached.

Very truly yours,

LER:SCJ

Attachment

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Responses to NRC Questions on Davis-Besse Unit 1 Rod Drop Test

Since some of the questions posed are interrelated and redundant in nature, an attempt has been made to consolidate the answers. A discussion is presented below in which the contents answer many of the questions, but not in any specific order. For clarity, each of the individual questions is listed following the discussion and the answer is referred back to the discussion unless otherwise specified.

There are two methods used to calculate Linear Heat Rates (LHR) for the dropped rod test. One is by the process computer, the other by hand. The minimum DNBR is calculated by the computer only. The following will discuss the calculations and uncertainties used in both methods.

I. On Line Computer (OLC) LHR Calculations

Maximum linear heat rate = maximum total peak x average LHR
Maximum total peak = (1) maximum bundle power (measured) x (2) maximum axial peak in that bundle (measured) x (3) local pin peaking factor (calculated) x (4) uncertainties (constant)

(1) Maximum bundle power is calculated in the nuclear package

(2) The maximum axial peak is determined by evaluating the axial flux shape polynomial at approximately every two inches up the channel.

(3) The local pin peaking factor is calculated in subroutine LCFIT. The method of this calculation is discussed at length in the answer to Question 5.

(4) The total uncertainties applied to those measured and calculated values are as follows:

1.05	Radial peak uncertainty
1.05	Calculation uncertainty on pin peak*
1.016	Densification penalty (spiking factor)*
1.02	Core power uncertainty
1.024	Axial measurement uncertainty
1.026	Calculation uncertainty on axial peak
1.014	Mechanical hot channel factor

* These terms were formerly combined and labeled as an ultra conservative spike factor.

The OLC groups these LHR uncertainties as follows:

Maximum total peak = maximum bundle power (measured x 1.05) x maximum axial peak (maximum polynomial value x 1.026 x 1.024 x 1.014) x local pin peak (calculated x 1.05) x densification penalty (1.016 spiking).

II. Hand Calculations for Linear Heat Rates

The hand calculation of maximum LHR is basically the same as the computer calculations with the following exceptions:

1. Since the axial peak is based on the highest "segment" power, a 1.04 factor is applied to get the segment peak to average values. The OLC evaluation of axial flux every two inch precludes the need for this uncertainty.

2. A 1.02 slumping densification penalty constant is used.

3. The radial local peak is a constant 1.066 instead of the OLC calculated local x 1.05. (Since the OLC has a minimum 1.01 x 1.05 = 1.061 this will be the smallest value used).

4. The densification spike factor is a function of active length and not a constant as is in the OLC.

The remaining uncertainties are identical to the OLC values. For extreme conditions (e.g. dropped rod) the hand calculations are usually more conservative than the OLC calculations.

III. DNBR Calculation

All of the preceeding uncertainties that apply to pin power are incorporated in the Critical Heat Flux (CHF) evaluation. All of the uncertainties are incorporated in the actual heat flux. Additional DNBR conservatisms include:

1. Maximum system leakage on core flow approximately 5% of system flow

2. Isothermal maldistribution factor on hot assembly flow approximately 5% of calculated bundle flow

3. Reduction factor in hot assembly flow areas due to assumed bowing approximately 2% on area

4. Increased form loss coefficients in hot assembly due to bowing

5. Inlet temperature uncertainty + $2^{\circ}F$

6. FA - Mechanical hot channel flow area reduction factor approximately 2% on area

7. FQ - Uncertainty on local quality calculation approximately 1% on effective power

One final conservatism in this process lies in the fact that power 522 344
distribution is flatter at 100% power than at 40% (dropped rod power test level). This is more explicitly demonstrated in the answer to Question 1. The flatter power distribution would result in a smaller LHR and larger DNBR if a dropped rod were to occur at 100% power when compared to the extrapolated value. This has been shown to be on the order of 10% on LHR and approximately 20% on DNBR.

IV. Conclusion

The LHR and DNB calculations in the OLC are conservative. Every input to both calculations has some degree of conservatism. The total combination of all the uncertainties used (regardless of the breakdown) are substantially higher than those required by Technical Specifications.

Question 1:

Provide comparisons of calculated and measured radial peaking factors for the "dropped rod" tests at both the 50% and 0% withdrawn positions. It is preferable that these be submitted in the form of core maps.

Answer:

Core maps are provided giving the requested information for the Rod Drop test of 11/27/77. Both measured and predicted (FLAME 3) radial peaking factors are shown for the appropriate incore detector locations. The predicted and measured peak segment powers are noted in the lower left corner of the page. Figure 1 shows a comparison at equilibrium conditions (42% FP) at 8:30 a.m. Figure 2 shows the core at 11:06 a m. with the control rod in core location N-8 fully inserted. Figure 3 presents a similar comparison for the control rod at N-8 50% withdrawn which occurred at 12:18 p.m.

In addition to this data, cases were also run at 100% full power with the same control rod positions as those of the test (initial conditions and N-8 fully inserted). These calculations were done to contrast the resulting power peaks with those at the 40% FP level. Figure 4 shows the predicted radial powers for both of these cases. Predicted segment peaks are also shown in the lower left corner, and the nodal (6.0" axial length) peaks are shown in the lower right corner. The value for the peak node after the rod drop, if conservatively converted to Kw/ft as shown in Table 1 below, indicated a maximum linear heat rate (MLHR) of 17.5 Kw/ft, well below the fuel melt limit. This value is also well below both the hand calculation and computer calculation extrapolations of the 11/27/77 test results to 100% FP. Thus it is concluded that extrapolation of measured dropped rod peaks from 40% FP to 100% FP is extremely conservative due to feedback effects at the higher power level. For method of extrapolation, refer to the answer to Question 4.

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TABLE 1

CONVERSION OF FLAME 3 NODAL PEAK TO KILOWATTS/FOOT AT 100% FP

MLHR = Calculated Nodal Peak * Total Nuclear Uncertainty * Hot Channel Factor * Axial Local Factor (Grid Factor) * Radial Local Factor * Densification Power Spike Factor * Power Uncertainty * Densified Linear Heat Rate (100% FP)

= 2.274 * 1.075 * 1.014 * 1.026 * 1.066 * 1.023 * 1.02 * 6.20

= 17.5 Kw/ft

Question 2:

Provide the measured values of maximum linear heat rates and minimum DNBR for the "dropped rod" cases.

Answer:

The measured values of Maximum Linear Heat Rates (MLHR) and minimum DNBR are listed below.

Measured Values of MLHR and Minimum DNBR for Dropped Rod (51% Withdrawn)

1. Initial Conditions

Control Rod Positions:

Group 5	100% withdrawn
Group 6/7	69% withdrawn
Group 8	11% withdrawn
Assembly 5/7	51% withdrawn

Core Power	42.7% FP
Boron Concentration	1120 ppmB

2. Minimum DNBR 5.95

3. MLHR (by level)

Level	MLHR (Kw/ft) from OLC
1	4.357
2	6.551
3	8.279
4	8.300
5	5.720
6	3.237
7	1.366

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Measured Values of MLHR and Minimum DNBR for Dropped Rod (0% Withdrawn)

1. Initial Conditions

Control Rod Positions:

Group 5	100% withdrawn
Group 6/7	71% withdrawn
Group 8	11% withdrawn
Assembly 5/7	0% withdrawn

Core Power	42.5% FP
Boron Concentration	112) ppmB

2. Minimum DNBR 5.77

3. MLHR (by level)

Level	MLHR (Kw/ft) from OLC
1	4.407
2	6.585
3	8.511
4	8.895
5	6.396
6	3.782
7	1.54[illegible]

Question 3:

How did you account for the uncertainties in these measurements? Explain quantitatively what factors are accounted for in these uncertainties.

Answer:

See I. (4) in the discussion.

Question 4:

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How was the data measured at 40% power extrapolated to 100% power?

Answer:

1. To extrapolate the MLHR to 100% power, the measured values were multiplied by 100/(power level at which the test was conducted i.e. 40% power).

2. To extrapolate the minimum DNBR, the measured DNBR is plotted on Figure 5 (attached) and a curve parallel to the curve on Figure 5 is extended from the plotted point to the 100% power level. The resulting point gives the minimum DNBR extrapolated to 100% FP.

Question 5:

We have studied BAW-10123 Nuclear Application Software Package for 205-fuel assembly plants and assume that the radial local peaking factors are calculated in a similar manner for 177-fuel assembly plants. Describe in detail how radial local peaking factors are calculated for the "dropped rod" situation which is very different from "fuel-cycle design rod positions" as discussed in Section 3.8.2. If a multiplicative correction factor was used, please provide details as to how it was calculated. Also describe how you account for the uncertainties in the radial local peaking factor.

Answer:

The 177 FA Mark-B plant OLC calculates local peaks much differently than the methods described in BAW-10123. The basic method of the OLC calculations is as follows:

1. Determine the hottest bundle.

2. Set up a matrix of this bundle and the surrounding eight bundles (see Figure A).

3. The center location of each bundle will have a node value of its respective radial peak.

4. Each node is weighted to give most importance to the center bundle.

5. A surface fit is applied to the 9 nodes.

6. Any point on the surface fit inside the dashed lines on figure 1 that is greater than the hot bundle peak is taken as the radial local peak of the hot bundle.

7. If the local peak is less than 1.01 then the default value of 1.01 will be used.

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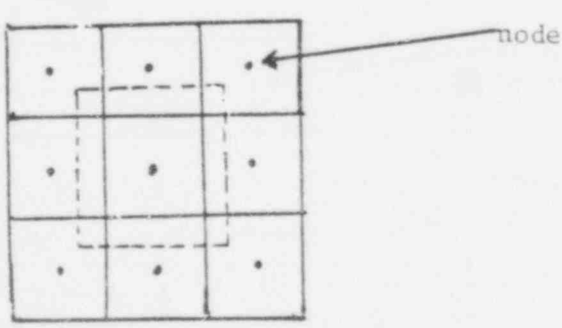

Figure A

Figure B shows a simplistic one-dimensional typical normal operation local peak calculation and a dropped rod local peak calculation. Based on this model, the local peaking factor calculation is usually nonconservative for dropped rod conditions. However, the <u>total</u> uncertainty is such that the final MLHR is a conservative value (refer to the discussion Section I).

Normal Operation   Dropped Rod

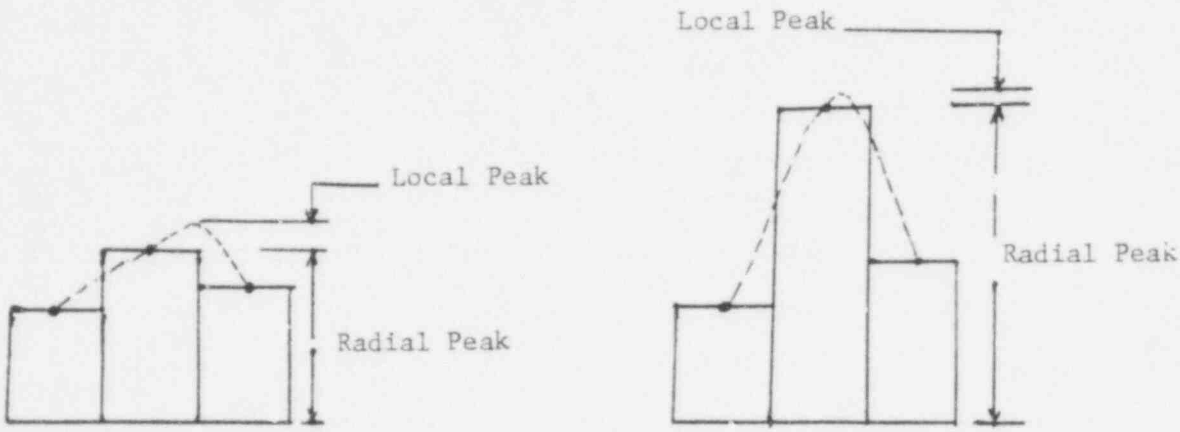

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Figure B

Question 6:

Are the values of radial local peaking factor conservative? If this is the case, justify this conclusion. If not, show how this is taken into account.

Answer:

See Section I and II of the discussion. Also see answer to Question 5.

Question 7:

It has been stated that there are other conservatisms in the process computer calculation. Explain in detail (quantitatively) what these conservatisms are and what assurance there is that credit for these has not and cannot be taken elsewhere.

Answer:

See Sections I and II of the discussion.

Question 8:

Are there other factors or parameters used in the process computer that may not be conservative? If so, explain how you justify the process computer calculation.

Answer

None of the other factors or parameters in the process com uter are nonconservative. See Section IV (conclusions) of the discussion.

bt b/8-11

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AE Instrumented Core Locations
Prior to Dropped Rod Test

X

CR 8 | N-8 10[illegible]D

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A															
B							1.160 1.096	1.342 1.327							
C						1.133 1.042			1.072 1.138	1.122 1.042			.533 .595		
D					.998 .969					.834 .935				.523 .555	
E				1.043 .969			1.096 1.142		1.106 1.142		.942 .958				
F			1.124 1.042				1.183 1.134	1.016 1.094				.855 .935	1.103 1.[illegible]2		
G		1.160 1.096			1.138 1.142	1.146 1.134			1.133 1.193		1.121 1.142		1.072 1.138		
H	.979 .967				1.210 1.144			1.388 1.359	1.316 1.195				1.243 1.191		
K					1.098 1.142						1.107 1.142	1.174 1.105			
L		1.084 1.12[illegible]	1.102 1.042			1.099 1.130					1.115 1.067		1.097 1.042		
M			.906 .953				1.102 1.142		1.080 1.142	1.086 1.067				.859 .832	
N				.857 .925				1.059 1.166	1.161 1.105						
O					.896 .953	1.102 1.042				1.127 1.042		.865 .824			
P						1.119 1.124									
R							.909 .897			.653 .632					

Z

Legend (upper value / lower value in each box):
Meas. 11/27/77 [illegible]
Calc. FLAME

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Meas. Segment Peak = 2.3749
N-8, Level 3

Calc. Segment Peak = 2.3160
N-8, Level 3

Figure 1

FIGURE 2.

Measured vs. Calculated RPD At Instrumented Core Locations During the Dropped Rod Test

X

CA θ | N-8 0.ETRO

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A															
B							1.279 1.248	1.538 1.515							
C						1.296 1.181			1.223 1.206	1.283 1.181			.600 .662		
D					1.141 1.088					.962 1.061				.603 .614	
E				1.177 1.076			1.223 1.259		1.234 1.259		1.064 1.073				
F			1.250 1.144				1.294 1.224	1.103 1.188				.964 1.035	1.223 1.144		
G		1.279 1.193			1.233 1.216	1.317 1.199			1.203 1.253		1.212 1.216		1.179 1.231		
H	1.071 1.044				1.277 1.187			1.305 1.379	1.355 1.212				1.346 1.273		
K					1.123 1.144						1.130 1.144	1.232 1.135			
L		1.146 1.179	.878 1.068			*.456 1.037					1.096 1.026		1.150 1.068		
M			.922 .943				.863 .876		.843 .875	.950 .907				[illegible] .894	
N				.816 .844				.436 .433	.780 .719						
O					.722 .792	.878 .805				.900 .806		.784 .724			
P						.892 .880									
R							.705 .667			.521 .501					

Z

Legend (upper value / lower value in each box):

Meas. 11/27/77 1106

Calc. FLAME

Fig 2. 522 352

Meas. Segment Peak = 2.5214
B-8, level 4

Calc. Segment Peak = 2.4546
B-8, level 4

* This location was receiving substitute signals from dropped rod location N-8.

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Measured vs. Calculated ...
At Inst...ented Core Locations
After Dropped Rod Test

X — CR 8 — N-8 51% WD

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A															
B							1.231 1.182	1.485 1.431							
C						1.249 1.120			1.180 1.225	1.236 1.120			.581 .636		
D					1.098 1.035					.925 .999				.581 .589	
E				1.136 1.027			1.185 1.213		1.196 1.213		1.029 1.017				
F			1.203 1.995				1.257 1.189	1.074 1.149				.926 .98	1.183 1.095		
G		1.231 1.145			1.204 1.185	1.267 1.173			1.178 1.232		.178 1.185		1.139 1.187		
H	1.030 1.005				1.249 1.168			1.381 1.374	1.334 1.208				1.304 1.231		
K					1.107 1.161						1.114 1.161	1.203 1.116			
L		1.114 1.145	.941 1.047			*.742 1.027					1.092 1.038		1.120 1.047		
M			.904 .941				.946 1.000		.927 1.000	.987 .972				.865 .883	
N				.820 .874				.742 .805	.927 .900						
O					.798 .861	.941 .909				.964 .909		.797 .766			
P						.961 .999									
R							.785 .776			.560 .574					

Z

Meas. 11/27/77 1218
Calc. FLAME

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Meas. Segment Peak = 2.4264
N-8, Level 4

Calc. Segment Peak = 2.4258
N-8, Level 3

Figure 3

* This location was receiving substitute signals from dropped rod location N-8.

POOR ORIGINAL

Calculated KFD at 100%FP

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A															
B							1.073 1.178	1.276 1.403							
C						1.038 1.137			1.129 1.233	1.038 1.137			.615 .655		
D					.980 1.070					.946 1.041				.573 .618	
E				.980 1.063			1.149 1.237		1.149 1.237		.973 1.066				
F			1.038 1.117				1.135 1.213	1.100 1.181				.946 1.025	1.038 1.117		
G		1.073 1.147			1.149 1.209	1.138 1.195			1.195 1.249		1.149 1.209		1.129 1.200		
H	.944 1.003				1.146 1.185			1.334 1.363	1.191 1.213				1.173 1.234		
K					1.149 1.156						1.149 1.156	1.105 1.133			
L		1.202 1.151	1.039 1.064			1.139 1.071					1.074 1.049		1.033 1.064		
M			.965 .963				1.149 .925		1.149 .925	1.074 .948				.[illegible] .859	
N				.944 .888				1.164 .469	1.105 .762						
O					.963 .848	1.038 .859				1.038 .859		.841 .770			
P						1.102 .934									
R							.877 .717			.653 .346					

CR at H-8 out
CR at H-8 in

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Calc. Segment Peak = 2.259
(H-8 out) G-8, Level 3

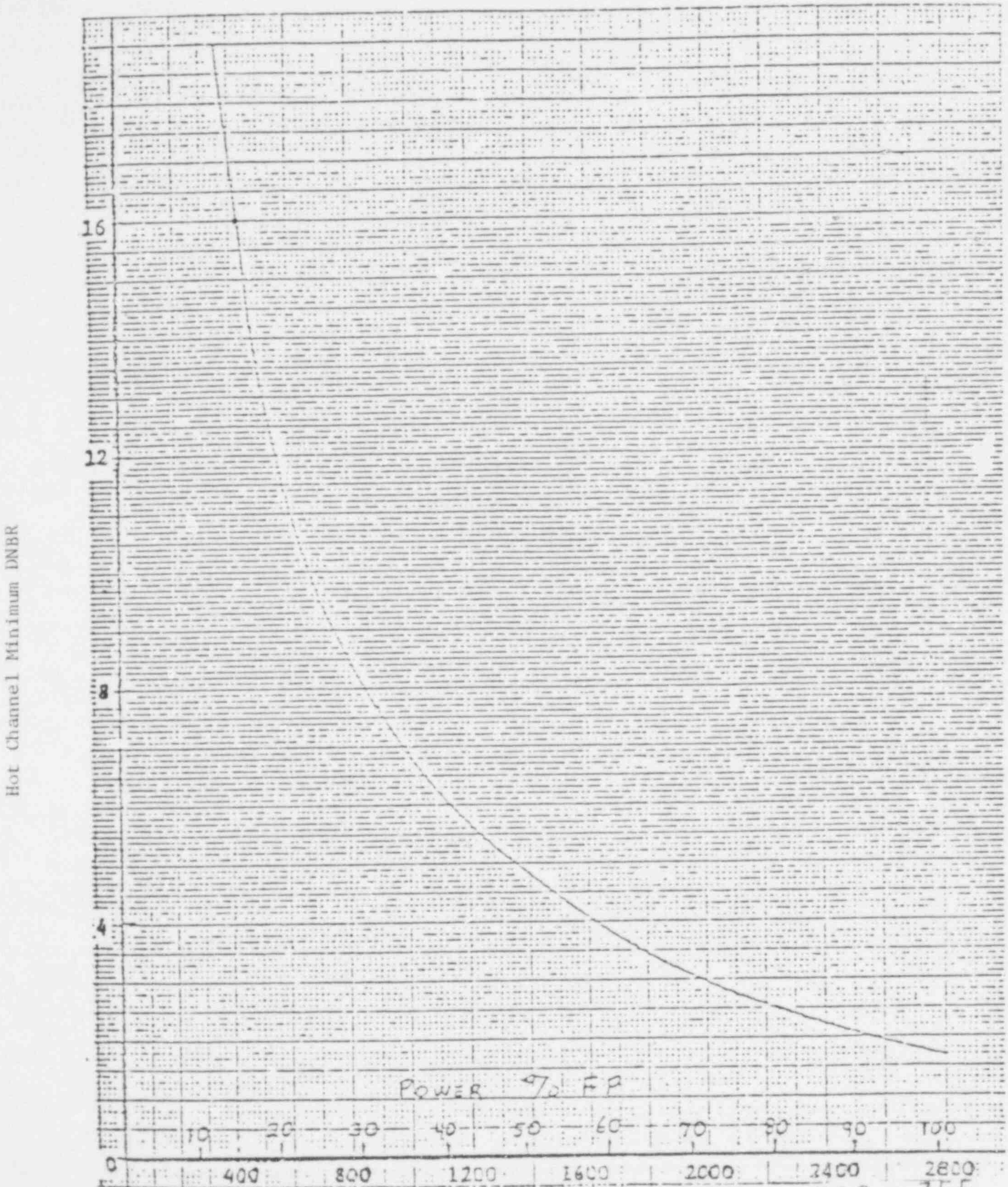
Calc. Segment Peak = 2.240
(H-8 in) G-8, Level 3

Calc. Nodal Peak = 2.2[illegible]
(H-8 out) G-8, node 10/24

Calc. Nodal Peak = 2.274
(H-8 in) G-8, node 10/24

FIGURE-4

Method to Extrapolate Minimum DNBR
(Minimum DNBR at the Overpower Trip Setpoint)



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Power, MW (Thermal)

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Figure 5