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February 27, 1984

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Quad Cities Station Unit 2
Information Concerning Cycle 7
Shutdown Margin Demonstration
NRC Docket No. 50-265

Dear Mr. Denton:

This transmittal provides information requested by the Core Performance Eranch and the Quad Cities Project Manager (R. Bevan) during a conference call with Commonwealth Edison and General Electric personnel on February 24, 1984. The subject of the call was the results of the shutdown margin (SDM) demonstrations performed on February 17, 1984 following completion of the Quad Cities Unit 2 End-of-Cycle 6 refueling and maintenance outage.

During the performance of a local SDM test on the reloaded (Cycle 7) core, a larger than expected reactivity insertion was observed which corresponded to a 0.977%Δk difference from predicted results. This observed reactivity difference was accommodated by the 1%ΔK margin used in the design process to account for analytical and measurement uncertainties. As a result of this inherent design margin the Technical Specification shutdown margin requirement was satisfied. Attachment 1 provides a chronology of the detailed sequence of events (as discussed on the conference call).

Results of Local Testing and Immediate Investigations

The demonstrated SDM was determined to be 1.30%ΔK compared to a required value of 1.23%ΔK for beginning of cycle (i.e. including the cycle R factor and the residual penalty for inverted B_4C tubes). Attachment 2 provides calculational details. Although the Technical Specification requirement was demonstrated, the large mismatch between predicted and measured resulted in prompt notification of off-site support personnel in both GE's core management area and CECo's Nuclear Fuel Services Department. Several additional investigations were then undertaken prior to startup of the unit. These were:

a. Independent verification by off-site personnel of the site's calculations.

b. A review of the core loading verification videotape which assured proper location and orientation of the fuel in the vicinity of the local test.

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c. A review of the control blade exposure accounting records which assured that blades in the vicinity of the test did not have excessive fluence relative to the current lifetime criterion (34% boron depletion).

d. Performance of a second local SDM test in a symmetric core location with a similar fuel configuration which again demonstrated the required SDM and showed consistent behavior (reactivity within 0.15%ΔK) with respect to the symmetric area. Refer to Attachment 2.

All of these added measures provided assurance that the deviation from predicted behavior during the initial test did not represent a physical abnormality.

Preliminary Assessment and Results of In-Sequence Test

The results of the immediate investigations also supported General Electric's preliminary assessment that the deviation most likely represents an analytical problem in modeling the unique local fuel configuration in the control cells involved. Attachment 3 describes the atypical configuration and potential ways it may have contributed to increased modeling uncertainty.

Attachment 4 is the General Electric letter recommending that the plant proceed to perform the in-sequence critical demonstration in order to confirm that the modeling discrepancy was merely a local phenomenon as opposed to a core wide anomaly. Based on the above evidence that no physical problem existed and on the successful demonstration of adequate SDM, the control rods were withdrawn for the distributed critical. With appropriate period and temperature corrections, this third test produced excellent agreement with the predicted core reactivity (a difference of less than .1%Δk). This confirmed that no core-wide anomaly existed and further supported General Electric's preliminary assessment.

Although the calculated SDM from this third test showed substantial margin to the required BOC value of 1.23% (Attachment 5), the in-sequence SDM method is dependent on the predicted worth of the strongest rod. Since the local tests indicated a significant underprediction of the worth for this rod (due to difficulty in modeling the atypical adjacent fuel configuration), the in-sequence SDM result is not considered as reliable for this reload. The locally demonstrated values (1.30% for the first test and 1.45% for the second test) are therefore considered the most accurate.

Subsequent Investigations

Subsequent to the completion of these tests, additional reviews by GE have been completed which confirmed that the original lattice physics data (libraries and intermediate results) were correctly applied in the nodal code to calculate the initial k_{eff} and rod worth data. Rerunning the cases produced the same results and therefore eliminated input errors as the source

of the local discrepancy. General Electric has also indicated their intent to perform further investigations of their underprediction of the local reactivity. The effects of any fuel exposure or reactivity uncertainties are being examined in more detail in order to quantify their impact on the local demonstration. Should the ongoing investigation produce new information significantly different than that presented herein, a supplemental report will be provided.

While General Electric's investigations continue, Edison intends to monitor the Unit 2 core with normal procedures to assure compliance with all core power distribution limits. The four strongest control rods are only targeted for 25% withdrawal at full power BOC conditions, with full withdrawal not occurring until near end-of-cycle in order to facilitate the test program discussed in Attachment 3.

In summary, the shutdown margin testing demonstrated that the Quad Cities Unit 2 reloaded core was in compliance with Technical Specifications and startup was allowed to proceed.

If you have any questions concerning this matter, please contact this office.

One signed original and forty (40) copies of this letter and its attachments are enclosed for your use.

Very truly yours,

B. Rybak
Nuclear Licensing Administrator

BR:HEB:lm
ID:2168N

cc: NRC Resident Inspector - Quad Cities
R. Bevan - NRR

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ATTACHMENT 1

Shutdown Margin Demonstration Events
Quad Cities Unit 2
February 17-18, 1984

Background

The test performed was a local SDM demonstration as is described in bases Section 3.3 of the DPR-30 Technical Specifications.

The demonstration involved the highest worth rod and two diagonally adjacent rods.

The cell with the highest worth rod contains four high enrichment and high gadolinia content, once burned barrier fuel bundles. This fuel will be part of the end-of-cycle 7 barrier fuel ramp demonstration.

Test Procedure

The test is performed to a permanent station procedure, which describes the rod movements in detail, and to a special rod maneuver review sheet describing the target rod positions and the amount of SDM demonstrated.

The target rod positions for this demonstration had the highest worth rod and the first diagonal rod at 48 and the second diagonal rod at 24. This rod pattern would have demonstrated 0.0026Δk more SDM at 68^{o}F than what is required by Technical Specifications.

Event Chronology

2-17-84

0405 Rod pulls begun for local SDM demonstration.

0925 With the first two rods at 48 and the second diagonal at 16, the SRM's indicated that the reactor was near critical. The SRM and IRM charts were switched to fast speed. Calculations showed that this rod pattern did not demonstrate the required SDM. The decision was made to proceed with the test.

0937 With the first two rods at 48 and the second diagonal at 18, the SRM's indicated criticality on a 175 second period. After prompt effects decayed, the period settled out at 325 seconds. Reactor temperature was 177^{o}F.

0947 Started manual rod insertions as prescribed by the SDM procedure in the event of criticality.

0950 All rods at 00.

0951 Mode switch was locked in shutdown pending the results of an On-Site Review of the situation. These two actions are also prescribed by the procedure.

At approximately 1010 hours a conference call was initiated with Nuclear Fuel Services, at which time they were informed of the situation and given the initial data. It was determined that although the reactor went critical, the demonstration did prove ~.06%Δk more than the minimum SDM required by the Technical Specifications. It was also calculated that the local critical predicted by General Electric was about 0.01Δk different than what was demonstrated.

At approximately 1030, the NRC was notified via the ENS red phone of the manual scram (following all rods in) caused by moving the mode switch to shutdown.

At approximately 1100, the Nuclear Stations Division and GE in San Jose were notified of the SDM test criticality.

In the ensu hours:

GE confirmed that the Technical Specification SDM had been successfully demonstrated. GE also suggested at this point that a local core model code inadequacy might be responsible for the 0.01Δk difference between the predicted and actual criticals.

NFS made preliminary recommendations to re-examine the core verification video-tapes and check control rod exposures in the vicinity of the highest worth rod. This was done, and no core loading error or excessive control rod exposure was seen.

NFS suggested that a second SDM demonstration in a symmetric cell might be advisable since this would help determine if a local core anomaly was the cause of the critical.

GE agreed on the principle of a second demonstration, but recommended that we proceed with the whole core critical.

1600 The On-Site Review Committee met and decided that a second demonstration would be done in a cell 180° mirror symmetric to the first cell.

1700 A telecopied letter was received from GE stating their position and documenting that the rod worth curves for the highest worth rod also applied to the symmetric cell.

1837 The second demonstration was begun.

2328 The reactor went critical with the first two rods at 48 and the second diagonal at 22. The period was 500 seconds and the reactor temperature was 176°F. It was felt that this was exactly the response expected from a symmetric core.

2-18-84

0043 Began pulling rods in-sequence.

0303 Reactor went critical.

0330 NFS and GE were notified of the results of the second SDM demonstratio and the in-sequence critical. The calculated difference between GE's predicted critical and the actual critical was 0.0008Δk.

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ATTACHMENT 2

Required SDM for Q2 BOC7 : 0.25 %
+ 0.934% (R)
+ 0.05 % (Inverted tube penalty)
1.234 % ΔK (at 68°F)

A. Initial Local SDM Test

1.0002 Keff on ~ 325 sec. period @ 177°F
+ .0036 ΔK Temperature Correction to 68°F
1.0038 Keff @ 68°F, 325 sec. period with D-8 and E-7 at pos. 48 and E-9 at pos. 18

.0114 ΔK Worth of E-7
+ .0054 ΔK Worth of E-9 to pos. 18
.0168 ΔK Reactivity inserted beyond strongest rod

1.0038
- .0168 ΔK worth of E-7 and E-9 withdrawn
.9870 Keff @ 68°F with strongest rod (D-8) out

1.0000
- .9870
.0130 ΔK SDM @ 68°F ∴

Demonstrated SDM for Q2 BOC7 (D-8 location) = **1.307% ΔK** (at 68°F)

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.9870 Keff @ 68°F with strongest rod (D-8) out

1.0000
-.9870
.0130 ΔK SDM @ 68°F ∴

Demonstrated SDM for Q2 BOC7 (D-8 location) = **1.30% ΔK** (at 68°F)

ATTACHMENT 2 (cont'd)

B. Second Local SDM Test (mirror symmetric)

1.0001	Keff on ~500 sec period @ 176°F
+ .0036	ΔK Temperature Correction to 68°F
1.0037	Keff @ 68°F, ~500 sec period with M-8 and L-7 at 48 and L-9 at 22

.0114 ΔK	Worth of L-7
.0068 ΔK	Worth of L-9 at pos. 22
.0182 ΔK	Reactivity inserted beyond M-8

1.0037	
-.0182	ΔK worth of L-7 and L-9 withdrawn
.9855	Keff @ 68°F with rod M-8 out

1.0000	
-.9855	
.0145	ΔK SDM @ 68°F ∴

Demonstrated SDM for Q2B0C7 = **1.45 %Δk** (at 68°F)
(M-8 location)

ATTACHMENT 3

A. Fuel Configuration for Q2C7 Special Control Cells (D-8, M-8, H-4, and H-12)

The strongest worth control rod used in each of the two local SDM tests (D-8 and M-8, respectively) is surrounded by a unique and atypical fuel configuration. This configuration consists of four, once-burned (~6000 MWD/T) assemblies grouped together in a single control cell to facilitate the ongoing Barrier Fuel Demonstration Program. There are a total of four of these specially loaded control cells, one on each of the quadrant axes.

Normally, a control cell consists of four assemblies which are either,

a) a mixture of high reactivity and low reactivity fuel (most cells in conventional loadings and cells which are uncontrolled in mono-sequence loadings), or

b) all low reactivity fuel (controlled cells in mono sequence loadings).

The barrier fuel testing program, however, requires special test cells which contain four high reactivity barrier assemblies grouped together. Fresh fuel was used in these cells for the completed Cycle 6 demonstration while once-burned fuel is used for the planned Cycle 7 demonstration. Grouping the special barrier assemblies is necessary in order to confirm their pellet-clad interaction (PCI) resistance during the end-of-cycle. high power ramp testing while not impacting non-barrier fuel. The fuel in these test cells needs to be high reactivity in order to produce local power levels during the ramp test which are sufficient to challenge the barrier's PCI resistance.

B. Impact on Modeling Uncertainties

Due to this concentration of higher reactivity fuel in a single control cell, the sensitivity to even a small exposure bias is high (~.5%ΔK per 500 MWD/T). That is, the self-correcting aspects of a mixed cell loading are not available to dampen exposure uncertainties.

In addition, the residual gadolinia content of low burnup fuel contributes to modeling uncertainty. This could also be aggravated by the concentrated loading of four similar assemblies in a single cell.

Since the reactivity of the fuel peaks at approximately 9000 MWD/ST, it is believed that any biases either in exposure or reactivity which would cause an underprediction in reactivity for the BOC demonstration would also cause an overprediction in the amount of shutdown margin decrease through the cycle (R value). Thus, the minimum shutdown margin during the cycle has been calculated with an R value which, if anything, is conservative given the results of the BOC demonstration.

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Attachment 4

① this → CF

② cc → ~~JAS~~

JRW

GENERAL ELECTRIC

NUCLEAR ENERGY BUSINESS OPERATIONS
GENERAL ELECTRIC COMPANY • 175 CURTNER AVENUE • SAN JOSE, CALIFORNIA 95125

February 17, 1984
REP:84-029

cc: A. F. De Vita
N. J. Kalivianakis
L. J. Scott

Dr. H. E. Bliss, Director
Nuclear Fuel Services
COMMONWEALTH EDISON COMPANY
922 Edison Building
P. O. Box 767
Chicago, IL 60690

SUBJECT: Quad Cities 2 Cycle 7 Shutdown Margin Results and Startup Recommendations

REFERENCE: "Quad Cities 2 Cycle 7 Startup Package", A. F. De Vita to L. J. Scott, December 23, 1983.

Dear Dr. Bliss:

The following are General Electric's calculations and recommendation related to the beginning-of-Cycle 7 startup at Quad Cities 2 (see attached Figure).

1. Using the information provided in the attached Figure and the Reference letter, General Electric has calculated the demonstrated shutdown margin to be:

$$\Delta k(SDM) = \Delta k(\text{rod worth}) - \Delta k(\text{temperature}) - \Delta k(\text{period}) - R$$

$$= 0.0167 - 0.0036 - .0002 - .0093 = .0036$$ −.0005 (B4C slumping penalty) JAS

This calculation shows that the Technical Specification shutdown margin requirement of 0.0025 Δk has been demonstrated.

2. The next strongest control rod is calculated to be at location 18-39 (E-10). This rod is strongest at beginning-of-cycle. The shutdown margin at beginning-of-cycle, with this rod fully withdrawn, is calculated to be .0306 Δk as compared to the .0135 Δk worth for rod 14-31 (D-8). Because there is a greater than 0.01 Δk difference between the first and second high worth rod, there is negligible risk that the second highest worth rod could be of greater worth than the high worth rod.

3. The Quad Cities 2 Cycle 7 core has been loaded in an octal symmetric fashion, therefore, the diagonally adjacent rod worth curves provided in the reference letter can be used to calculate the rod worths for the symmetric rods for the case where rod 46-31 (M-8) and its diagonally adjacent rods are being withdrawn.

Bill ~~from~~ Paul Knospel
@ QC2 2/17/84 GDG

QUAD CITIES 1-2 DRESDEN 2-3

DATE _____ @ _____

RP _____ WT _____

PR _____ DHS _____

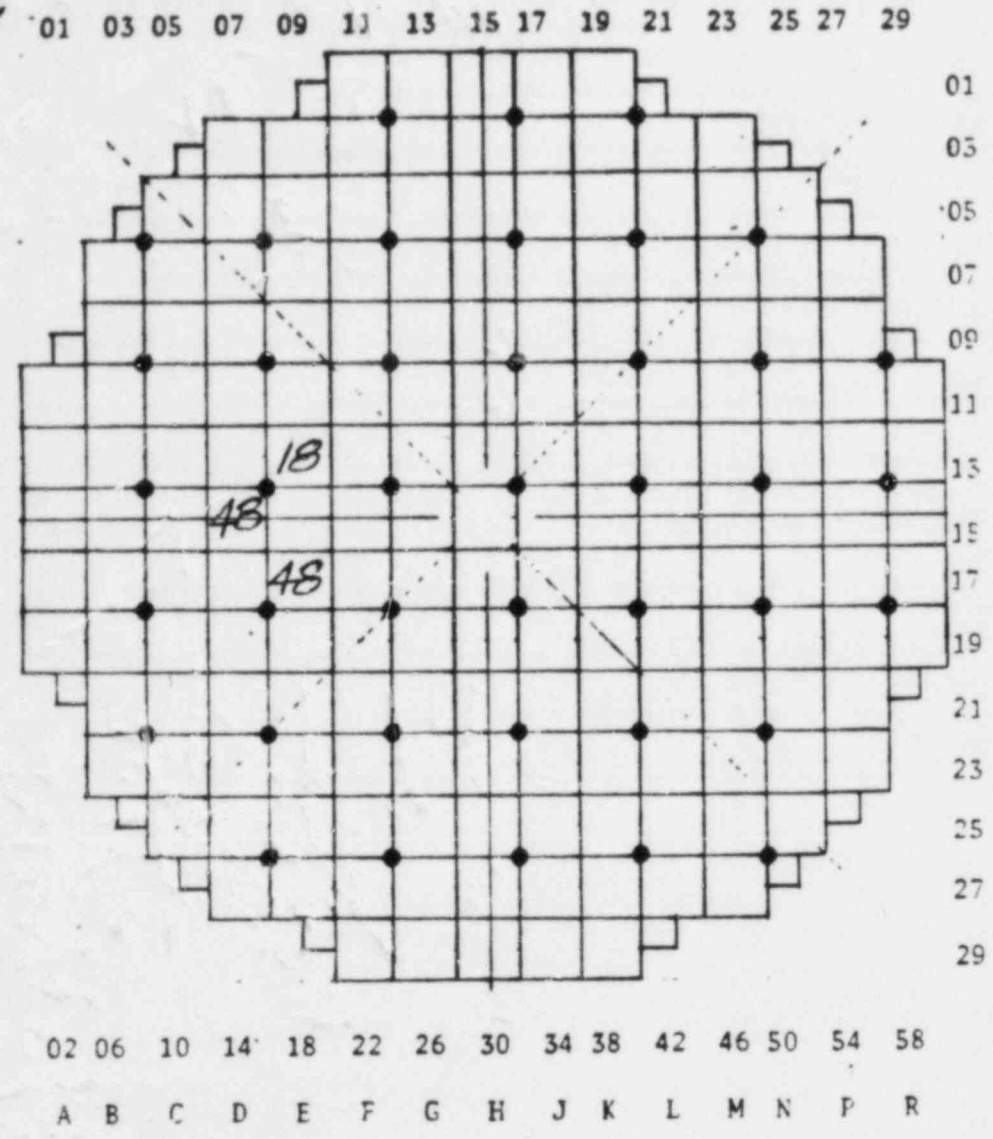
CYCLE EXP. _____

MCPR _____ @ _____

MFLPD _____ @ _____

MAPRAT _____ @ _____

AXIAL POWER: 12 _____
11 _____
10 _____
9 _____
8 _____
7 _____
6 _____
5 _____
4 _____
3 _____
2 _____
1 _____



COMMENTS: QC2 BOC7 Local Shutdown Margin Demonstration:

Reactor went critical with above Rod Pattern

T = 177°F

period ≅ 300 sec

Rev. 2
08/81

ATTACHMENT 5

In-Sequence Critical SDM Test

1.0006 Keff, @ 170°F, Critical Rod Pattern (CRP), τ = 92 sec.
0.0014 ΔK, Temperature Correction to 68°F
1.0020 Keff, @ 68°F, CRP

0.05554 ΔK, Groups 1 and 2 (44 Rods 00 → 48)
0.00134 ΔK, Group 3 (24 Rods 00 → 04)
0.00420 ΔK, To 19th Rod Group 4 (19 Rods 04 → 08)
0.06108 ΔK, Rods Withdrawn

1.0020 Keff @ 68°F, CRP
- 0.0611 ΔK, Rods Withdrawn
0.9409 Keff @ 68°F, ARI

Note: 0.9409 Keff (Measured)
0.9401 keff (GE Predicted)
0.0008 ΔK

0.9409 Keff @ 68°F, ARI
+ 0.0370 ΔK Worth of Strongest Rod (D-8) *
0.9779 Keff @ 68°F, ARI except D-8 @ 48

⇒ The core is **2.21 % ΔK*** Shutdown
(at 68°F)

* Does not Account for Underprediction of Rod D-8 Worth