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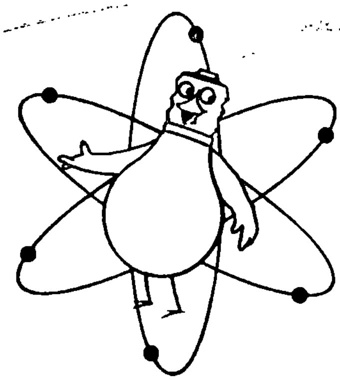
# DRESDEN NUCLEAR POWER STATION
# UNIT 2

SUPPLEMENT NO. 1 FOR

# TOPICAL REPORT TO DPR-19
# MODIFICATION 71-1
# REFUELING





Commonwealth Edison
Company

# DRESDEN NUCLEAR POWER STATION

## UNIT 2

## SUPPLEMENT NO. 1

## TO

## TOPICAL REPORT TO DPR - 19

## MODIFICATION 71-1 REFUELING

COMMONWEALTH EDISON COMPANY

3.1 QUESTION

Your response to Question 3, Amendment 12, regarding the performance of gadolinia-bearing fuel states that operating margins to incipient fuel melting and clad damage of the $Gd_2O_3$-$UO_2$ are always greater than the minimum values experienced between peak power standard $UO_2$ fuel rods. Provide supporting data to verify that fuel damage limits and operating margins are controlled between performance of the $UO_2$ fuel rods.

Specifically, provide current comparison data for the $UO_2$ fuel and $Gd_2O_3$-$UO_2$ fuel with respect to: (1) the several limits on peak fuel enthalpy in colories/gm and fuel rod power in kw/ft. corresponding to these limits to cause (a) vapor pressure in melted fuel to reach one atmosphere, (b) incipient fuel melting and (c) complete fuel melting, (2) transient conditions resulting in an MCHFR of one for the $UO_2$ rods, listing the corresponding MCHFR and peak kw/ft. for the $Gd_2O_3$-$UO_2$, and (3) peak fuel enthalpy generated, in calories/gm and corresponding fuel rod peak in kw/ft., for the control rod drop excursion analysis.

Your response to part (a) of the referenced question was incomplete with respect to power distribution as a function of burn-up for $Gd_2O_3$-$UO_2$. In addition, clarify the operating condition corresponding to 13.8 kw/ft., indicated as the peak power for the gadolinia-bearing fuel at anytime during life, in your response to part (c) of the referenced question.

3.1 ANSWER

The question mixes steady-state operating limits, abnormal operational transient limits and excursion accident limits. The following information and data compares predicted performance to the applicable limits in each of the three situations.

First consider a normal full power operating condition in which the maximum-powered assembly is type 2 (gadolinia-bearing), and the peak power per unit length is 17.5 kw/ft. Table 1 presents relative and absolute linear heat generation rates for the highest powered pure $UO_2$ rod and the highest powered $Gd_2O_3$-$UO_2$ rod as a function of exposure. Column 4 of Table 1 identifies the peak gadolinium-bearing rod power relative to the peak $UO_2$ rod. As shown, at the end of the operating cycle, this ratio is at its maximum value of 0.82. The resulting linear heat generation in the gadolinium-bearing rod is 13.8 kw/ft. The relationship shown in Table 1 is the result of fuel assembly design. The relative power between peak $UO_2$ rod and peak gadolinium-bearing rod will hold over the normal operating conditions and up through transients and accident excursions. In subsequent fuel cycles, when the assembly exposure is greater than 10,000 MWD/STU, the maximum linear heat generation in the gadolinia-bearing rod decreases due to the depletion of fissile isotopes; lower exposure reload fuel would be more limiting.



209.26

## TABLE - 1

MAXIMUM ROD POWERS IN MAXIMUM POWERED TYPE-2 ASSEMBLY. RELATION OF MAXIMUM $Gd_2O_5UO_2$ ROD TO MAXIMUM $UO_2$ ROD.

| 1<br>ASSEMBLY EXPOSURE MWD/STU | 2<br>MAXIMUM RELATIVE POWER IN $UO_2$ ROD | 3<br>MAXIMUM RELATIVE POWER IN $Gd_2O_3$-$UO_2$ ROD | 4<br>RATIO OF PEAK $Gd_2O_3$-$UO_2$ ROD TO PEAK $UO_2$ ROD | 5<br>RESULTING KW/FT IN $Gd_2O_3$-$UO_2$ ROD WHEN $UO_2$ ROD AT 17.5 KW/FT* |
|---|---|---|---|---|
| 0 | 1.24 | .28 | .23 | 4.0 |
| 500 | 1.25 | .31 | .25 | 4.3 |
| 1,000 | 1.26 | .35 | .28 | 4.9 |
| 1,500 | 1.27 | .40 | .31 | 5.5 |
| 2,000 | 1.26 | .44 | .35 | 6.1 |
| 3,000 | 1.25 | .53 | .42 | 7.4 |
| 5,000 | 1.20 | .72 | .60 | 10.2 |
| 7,000 | 1.20 | .86 | .72 | 12.2 |
| 10,000 | 1.18 | .97 | .82 | 13.8 |
| MAXIMUM $Gd_2O_3$ - $UO_2$ ROD VALUES | | 0.97 | .82 | 13.8 |

* For monitoring kw/ft. values, 1.24 local peaking is assigned to any assembly for which the calculated value is less than 1.24



209.27

3.1 **ANSWER** (Continued)

The second area of interest is that of thermal margin available for transients and uncertainty. Critical heat flux ratios and limits are unaffected by the inclusion of gadolinia in selected fuel rods. The minimum critical heat flux ratio is determined by mass flow, quality, pressure, and the maximum heat flux at the elevation of interest. A value of unity MCHFR is the damage limit for all rods in the assembly. Because of its lower heat flux, the gadolinia-bearing rod will always have a larger MCHFR than the limiting rod at the same elevation in the assembly. For example, if the operating safety limit were approached at the end of the cycle (when the gadolinia-bearing rod has peak heat flux relative to pure $UO_2$ rod), then the following condition would result:

| | Limiting $UO_2$ Rod | $Gd_2O_3$-$UO_2$ Rod |
|---|---|---|
| kw/ft. = | 23.5 | 19.3 |
| MCHFR = | 1.0 | 1.22 |

The MCHFR on the gadolinia-bearing rod is 1.22 as contrasted to 1.0 for the limiting $UO_2$ rod.

Table 2 presents data indicating the minimum margin to melting and the clad plastic strain damage limit. The related power entries are the most limiting conditions intended for steady-state operation of the two types of fuel rod. A power increase to 123% of rated power causes onset of melting in the limiting $UO_2$ rod, an additional percent increase produces the onset of melting in the gadolinia-bearing rod. A power of 160% of rated is required to reach the damage limit for the $UO_2$ rod; an additional twenty percent increase would be required to produce the same strain in the clad of the gadolinia-bearing rod. Thus, it may be concluded that the margin for transients and uncertainties is at least as large for the gadolinia-bearing rods as for the pure $UO_2$ rods. This is a result of the location of the gadolinia-bearing rods in the assembly, causing them to operate at lower power than the peak powered $UO_2$ rods, as delineated in column 4 of Table 1.

For very rapid excursions caused by, for example, a control rod drop, the $UO_2$ rods are also more nearly limiting. Table 3 compares the calculated peak enthalpies for the two rod types with the established limits based on avoiding fully molten fuel. Because both types of pellets must have enthalpy in excess of that which produces complete melting to create significant vapor pressure, it may be concluded that the use of gadolinia does not change capability of the fuel to prevent rapid transfer of the energy to the coolant.

In summary, the performance of the gadolinia-bearing rods does not compromise the overall fuel performance, nor are the gadolinia-bearing



209,28

3.1 ANSWER (Continued)

rods any closer to the respective design basis limits than are the pure $UO_2$ rods. Specific conclusions from the response to Question 3.1 are:

| | | |
|---|---|---|
| 1. | Relative margins to incipient fuel melting and clad damage - | Gadolinia-bearing rods have more margin due to placement in fuel assembly. |
| 2. | Relative power in gadolinium bearing rods-maximum linear heat generation. - | By design, gadolinia-bearing rods can only approach 82% of the rod power of the peak $UO_2$ rod. |
| 3. | Comparative transient conditions - | When limiting $UO_2$ rod is at MCHFR = 1.0, the gadolinia-bearing rod has MCHFR = 1.22. |
| 4. | Comparative material properties related to limits - | Gadolinia-bearing rods have lower values; however, lower power in gadolinia-bearing rods offsets this. |
| 5. | Comparative rod performance during control rod drop excursion - | Gadolinia-bearing rod has more margin relative to design basis limit. |
| 6. | Power distribution factor as a function of exposure for the gadolinia-bearing rods - | Displayed in Table 1 |



209.29

## TABLE 2

COMPARISON OF POWER MARGINS BETWEEN $UO_2$ RODS AND GADOLINIA-BEARING RODS

| DESCRIPTION | PERCENT OF RATED POWER | MAXIMUM POWER PER UNIT LENGTH | |
|---|---|---|---|
| | | $UO_2$ ROD | $Gd_2O_3$- $UO_2$ ROD |
| RATED POWER | 100 | 17.5 | 14 |
| ONSET OF MELTING | | | |
| $UO_2$ ROD | 123 | 21.5 | 17.2 |
| $Gd_2O_3$ ROD | 124 | 21.6 | 17.1 |
| DAMAGE (1% PLASTIC STRAIN) | | | |
| $UO_2$ ROD | 160 | 28.0 | 22.4 |
| $Gd_2O_3$ ROD | 160 | 31.5 | 25.2 |

Underline - indicates value which is the basis for percent power derivation

## TABLE 3

### EXCURSIONS

| DESCRIPTION | PEAK ENTHALPY, CAL/G | |
|---|---|---|
| | $UO_2$ROD | $Cd_2O_3$ - $UO_2$ROD |
| DESIGN BASIS LIMIT | 280 | 256 |
| RESULT OF WORST ROD DROP | 250 | 200 |
| MARGIN RELATIVE TO LIMIT | 30 CAL/GM | 56 CAL/GM |

### MATERIAL PROPERTIES

| T, $^{o}$F | ENTHALPY (CAL/GM) | CONDITION |
|---|---|---|
| 5080 | 220 | $UO_2$ MELTING STARTS |
| 5080 | 280 | $UO_2$ MELTING COMPLETE |
| 6880 | 360 | $UO_2$ 1 atmosphere of vapor pressure |
| 4530 | 196 | $Gd_2O_3$ - $UO_2$ MELTING STARTS |
| 4530 | 256 | $Gd_2O_3$ - $UO_2$ MELTING COMPLETE |
| ____ | 360* | $Gd_2O_3$ - $UO_2$- 1 atmosphere of vapor pressure |

* Vapor Pressure in gadolinia - bearing fuel not well determined. Expected value is slightly greater than pure $UO_2$. Because design basis is 280 cal/gm, this parameter has little significance.

3.2 QUESTION

Your FSAR does not explicitly describe a surveillance program for either the $UO_2$ fuel or the $Gd_2O_3$-$UO_2$ fuel. Relate your program for the $UO_2$ fuel to the program described for the Dresden plant in Dresden FSAR Amendments 16-17.

Separately describe your program for the $Gd_2O_3$-$UO_2$ fuel. Discuss how previous observations of $Gd_2O_3$-$UO_2$ burn-out in other General Electric BWR's were used to make estimates of the burn-out rates in the Quad-Cities Station. Indicate how your surveillance program will verify predicted burn-out performance.

3.2 ANSWER

The Fuel Surveillance Program committed to by General Electric has been described in the D2 FSAR amendment 16-17. This program provides for surveillance of the lead full length fuel rods with respect to exposure, linear heat generation rate, and the combination which operates beyond current production fuel experience in whichever reactor the lead performance is demonstrated. The program committed to in Dresden Amendment 16-17 will include the surveillance of lead performance gadolinia-bearing production fuel as well as the non-gadolinia-bearing production fuel and developmental fuel.

As discussed in section 4 of Amendment 9, the nuclear methods used on the $Gd_2O_3$-$UO_2$ rods in Quad-Cities fuel assemblies is the same basic method used on the gadolinia-bearing fuel rods in the Type V Dresden reload. The Type V minimum critical and the cycle operation of the Dresden 2 reactor were very close to prediction. The Dresden 1 cycle five operation is further amplified in Figure 1. Inspection of the figure shows that the predicted and observed control rod insertion are in close agreement. This plant data and similar plant data from Humboldt Unit 3 have served to verify that the predicted gadolinium burn-out is correctly matching the fuel depletion. The surveillance program includes the prediction of hot operating control rod patterns. As delineated in Section 3.3 of the D-2 Technical Specification and in the proposed Quad-Cities Technical Specification (Amendment 11), the actual and expected control rod configurations shall not differ by an amount exceeding 1% $\Delta$ k. This reactivity comparison at specified frequency assumes the timely identification of any anomaly and a reactor shutdown for thorough evaluation.

TABLE 4

PRODUCTION EXPERIENCE

GADOLINIA BEARING FUEL

| REACTOR | FUEL | TOTAL RODS | GD BEARING RODS | MAXIMUM ASSY EXPOSURE 7/1/71 | DESIGN PEAK LHGR (KW/FT) |
|---|---|---|---|---|---|
| DRESDEN I | | | | | |
| | TYPE III F | 3744 | 104 | 19,200 | 15.5 |
| | TYPE V | 3816 | 318 | 11,600 | 15.5 |
| BIG ROCK POINT | | | | | |
| | EG | 1694 | 88 | 5,400 | 17.7 |
| | EG | 1771 | 104 | | 17.7 |
| HUMBOLDT BAY | | | | | |
| | III | 1872 | 104 | 6,200 | 16.8 |
| | III | 1512 | 88 | 1,000 | 16.8 |



209,23

## ADDITIONAL INFORMATION

### Gadolinium Experience:

Table 4 presents experience in production reloads which employ gadolinia-bearing fuel rods. Exposure and design linear heat generation rates are indicated in Table 4 which are similar to Quad-Cities values.

Laboratory examinations of irradiated gadolinia-bearing rods have not revealed any indication of unsatisfactory mechanical performance relating to the use of gadolinium. These examinations have been summarized in Quad-Cities FSAR Amendment 9, Section C. These examinations not only serve to verify the mechanical integrity of the gadolinia-bearing fuel rods but have also identified the more detailed burn-up of gadolinium. Thus, the examinations have augmented the integral core surveillance of predicted gadolinium depletion.

### Loss of Coolant Accident:

The thermal response of the reactor core following a postulated loss of coolant accident is influenced by the local power distribution of the fuel. For the flooding mode the predicted fuel rod cladding peak temperature would occur essentially on the periphery of 49 rod bundle array and would be therefore affected by the peak linear power density. Therefore, the predicted peak cladding temperature would not be changed forthe flooding mode at the maximum rating of 17.5 kw/ft. The predicted thermal response of the cladding for the spray cooling mode is affected by the power density in the interior of the bundle. This result is due to the overall cooling mechanism of connection, radiation and channel wetting. Therefore, the peak clad temperature shifts from the outer high power density rods at spray initiation towards the central part of the bundle. The relative average power in the central nine fuel rods for the replacement fuel is 0.849*. [The corresponding value for the Dresden fuel central nine rods is 0.878**.] Application of these peaking factors to the calculated thermal response of the reactor core following a postulated loss of coolant accident would result in lower calculated fuel rod cladding peak temperatures for the replacement fuel under the spray cooling mode.

Therefore, in summary, the use of the replacement fuel for the predicted fuel rod cladding temperature response following a postulated LOCA would not increase the peak clad temperatures previously submitted for the Dresden 2-3 FSAR.

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* Figure 4 QC Units 1 & 2, Amendment 10.

** Figure 3.3.1 Dresden 2 & 3 FSAR.



209, 24

ADDITIONAL INFORMATION (Continued)

Clarification of Figure #1 in Submitted Topical Report to "DPR 19 Modification 71-1 Refueling Section 6.2

Section 6.2 describes the control modules used to analyze the refueled reactor. Figure 3 of that section identifies the five control modules used. When Figures 4 through 8 are inspected, it is noticed that fuel groupings can be identified which are different from the five control modules of Figure 3.

The control modules in Figure 3 are fuel groupings which satisfy all pertinent limits in the highest power zones of the reactor. Near the reactor periphery, deviations occur because there is greater neutron leakage and because it is not possible to produce maximum assembly power near the periphery.

This special situation occurs in most reactor loadings. For example, in the present Dresden 2 loading the basic fuel module is as shown at the upper left of Figure 3 - namely, two curtains adjacent to each fuel assembly. But, in the present Dresden 2 loading there exists at the periphery both one-curtained and uncurtained fuel assemblies.

The deviations from the basic control modules near the periphery have been analyzed through gross core analyses and they completely satisfy the reactivity and thermal limits. In fact, the reason for the special peripheral treatment is to improve overall plant operation by recognizing that greater reactivities can be loaded on the periphery than can be loaded in the high power regions of the core.



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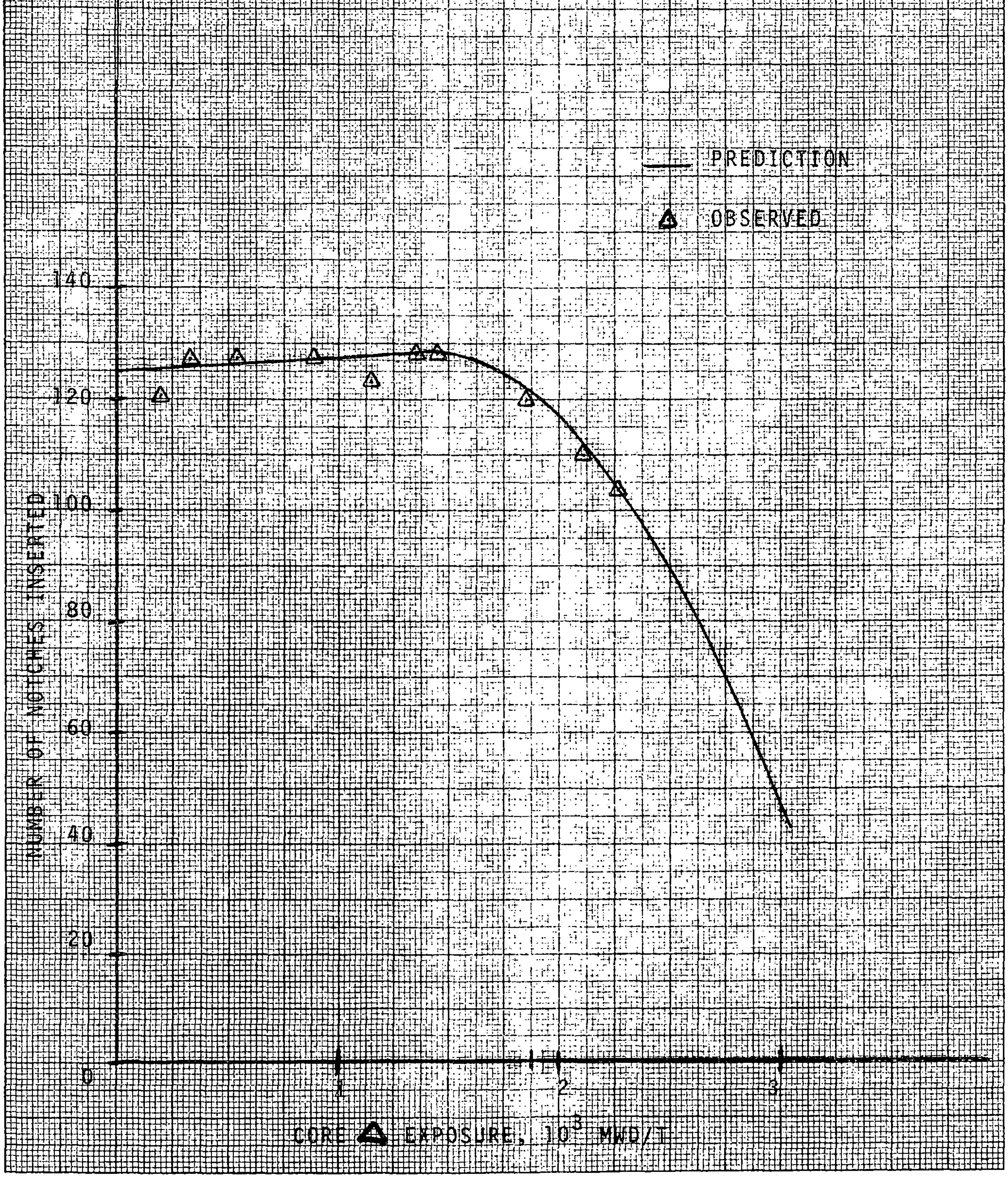
FIGURE 1

DRESDEN TYPE V PERFORMANCE





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