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THRU: D. L. Ziemann, Chief, ORB #2, DRL

BIG ROCK POINT - RELOAD F AND "TYPE J-1" FUEL (CONSUMERS POWER COMPANY)

INTRODUCTION

Consumers Power Company has requested, by letters dated December 15 and 17, 1970, that the Technical Specifications be changed to permit reactor operation with Reload F (Proposed Change No. 21) and "Type J-1" (Proposed Change No. 22) fuel assemblies in the core. We have reviewed these proposed changes, discussed by telephone with Consumers Power Company representatives (12/30/70),

1. the elimination of Reload D type fuel in Table 5.1 without an accompanying justification;

2. small omissions and typographical errors which we have corrected in the revised Technical Specifications (i.e., in Section 5, Part A, there are six types of fuel not twelve; there is no Figure 5.13 or instrumented fuel bundle; the note (1) in Table 5.1 should include F fuel bundles and be applied to Reload E and E-G and F special fuel rods per bundle; note (2) should begin with fuel bundles, etc.);

3. the status of the additional emergency core spray system for the Big Rock Point reactor vessel (According to a telecon of January 25, 1971, Consumers plans to submit the additional information we have requested relating to the proposed emergency core spray system in anticipation of having the new core spray system in service when operation is resumed following the February 1971 refueling outage.);

4. the basis for addition of a short diffuser to the "Type J-1" inlet tie plate to improve the flow distribution at the entrance of the bundle; and

5. justification for changing fuel temperature calculational methods with the result that the peak center fuel temperature is 5203°F at 122% power where in the past no fuel

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melting was calculated at heat fluxes of 500,000 Btu/hr-ft^2, the maximum value permitted by the Technical Specifications at 122% power level;

and have met with Jersey Nuclear Corporation and Consumers Power Company representatives (1/21/71) to discuss quality assurance and review gadolinium poison technology, fuel rod spacers and inlet diffuser design.

DISCUSSION

The Reload F fuel assembly, the fifth(1) subassembly type designed and fabricated b- General Electric Company for refueling the Big Rock Point nuclear reactor since the initiation of reactor operation in 1962, is the result of a continuing effort to increase the power output of each fuel assembly, i.e., longer fuel life at the rated reactor power level. The first reload(2) fuel substituted zircaloy 2 for 304 SS to clad the oxide fuel, reduced the number of fuel rods per bundle from 144 to 121 and used two different U-235 enrichments to reduce local peaking. The second reload fuel type(3) was similar to the first reload type except that vibratory compacted UO_2 powder was used in place of pellets and bundle U-235 enrichment was increased to about the level used in the original core fuel assemblies. The third reload fuel assembly type(4) reduced the number of fuel rods per bundle to 81 using larger diameter rods and three enrichment zones. The fourth reload fuel type(5) was identical physically to the preceding fuel assembly but included gadolinium oxide burnable poison in four fuel rods to provide the supplemental reactivity control for the approximate 23% increase in uranium enrichment and resultant 33% increase in expected fuel lifetime.

Reload F fuel continues this evolutionary process of fuel assembly optimization, but the changes are more subtle. The burnable gadolinia oxide poison concentration is reduced by about 36% below the concentration in the Reload E-G fuel assemblies, four tie rods have been moved from peak power regions, and the U-235 distribution within the bundle has been adjusted to improve power distribution. Conspicuous in the description of the Reload F fuel is the significant reduction in the burnable gadolinium oxide poison compared to Reload E-G fuel assemblies while the total weight of U-235 per bundle is unchanged. As already noted, the substantial increase in the U-235 content of the Reload E-G bundle was balanced by the introduction of burnable gadolinium oxide poison. It was expected that the gadolinium poison would be burned to near zero(6) neutron absorption prior to the end of the first operating cycle that the fuel is in the reactor. Presented below is an abbreviated summary of significant design changes to the reload fuel assemblies since startup of the Big Rock Point Nuclear Reactor in 1962.

BIG ROCK POINT - ORIGINAL AND RELOAD FUEL

	Reload A	Reload B	Reload C	Reload E	Reload E-G	Reload F	"Type J-1"
Fuel Rod Active Fuel Length - Inches	70	70	70	70	70	70	68
Fuel Clad	304 SS	Zr-2	Zr-2	Zr-2	Zr-2	Zr-2	Zr-2
Enrichment	3.2%	2.98% calc	3.62%	2.90% calc	3.52% calc	3.52% calc	3.53%
Wt UO_2/bundle - lbs	344.5 calc	328.8	305	341.4	346	346	346
Wt $U_{235}O_2$/bundle - lbs	11.02	9.8	11.02	9.9	12.2	12.2	12.2
Moderator/Fuel	2.7	2.65	2.6	2.39	2.39	2.39	2.39 approx
Fuel Lifetime MWd/tu	10,000	-	-	15,000	20,000	-	23,000 (a)
Av Gd w% calc	0	0	0	0	1.51 (2% in 54")	0.974 (1.25% in 54")	0.765 (1% in 52")
Wt Gd/Bundle - lbs	0	0	0	0	0.272	0.175	0 .137
Flow Adapter at entrance plate	No	No	No	No	No	No	Yes
Reference	Table 8.1 SAR	Consumers letter Change 8 12/23/65	Consumers Change 10 7/29/66 Table 1	Consumers Change 14 2/6/68 Change 16 1/22/69 Table I	Consumers Change 16 1/22/69 Table I	Consumers Change 21 Table 1 Figure 1 12/15/70	Consumers Change 22 12/17/70

(a) Meeting with Jersey Nuclear 1/21/71

Type "J-1" fuel assemblies designed and fabricated by Jersey Nuclear Company are described as being essentially identical to the Reload E-G fuel developed by GE.

By telecons on December 30, 1970, and January 4, 1971, with G. Walke of Consumers Power Company, it was revealed that only two "Type J-1" fuel assemblies will be inserted into the Big Rock Point core during the planned reactor outage in February 1971, that these two fuel assemblies were actually fabricated in the Battelle Northwest Laboratories, that the gadolinium oxide poison in the four poison rods has been reduced to 1%, in the 52" length and that the quality assurance requirements of 10 CFR Part 50, Appendix B, were met.

The only difference between "Type J-1" fuel and Reload E-G fuel assemblies that was called out in the proposed change is the addition of a short diffuser to the inlet tie plate to improve flow distribution at the entrance of the bundle causing about a two-inch reduction in the active fuel length with negligible effects on the power generation within the bundle according to the Consumers Power Company. We have observed, however, that the four fuel rods with burnable gadolinium poison are located in the diagonal positions next to the cobalt rods instead of in the second rod along the sides as in the Reload E-G fuel assemblies and that the burnable poison concentration is reduced by 50%.

EVALUATION

According to Consumers Power Company, the Reload F and "Type J-1" fuel assemblies are essentially identical to Reload E-G fuel assemblies which have been approved by DRL for the Big Rock Point nuclear reactor. We have nevertheless identified three areas for more intensive evaluation. The first involves the Consumers Power Company statement in referring to Reload F fuel that "the combined effect indicates that K_∞ is almost identical to the 'E-G' fuel". The burnable gadolinium oxide poison has been reduced by about 36% for Reload F and 50% for "Type J-1" without an equivalent reduction in the bundle U-235 content (E-G and F and J-1 fuel bundles each contain 12.2 pounds of U-235 compared with E which contains 9.9 pounds and no burnable poison). Therefore, the basis for the reported GE conclusion that K_∞ is nearly identical for the Reload E-G and F fuel assemblies containing significant differences in the amounts of burnable poison is not evident. During telecons with Consumers Power Company (12/30/70 and 1/5/71) and General Electric Company (1/6/71), it was agreed that GE would submit additional information responsive to our interest in Reload F vs Reload E-G fuel assembly reactivity. In a TWX from Consumers Power Company dated January 19, 1971, it was stated that the reactivity of the

Reload E-G fuel was overpredicted and there was not as much gadolinia burnup in one year as expected. GE emphasized that the early Reload E-G fuel gadolinia calculations were crude because of the small number of fuel assemblies involved at the time, but over the last two years the analytical methods have been improved to include 10 concentric sections of the gadolinia containing fuel rods in the calculational model. This latter feature alone is considered to have great significance because of the local shielding effects of the gadolinia. It has been confirmed that an excessive amount of gadolinia was used in the Reload E-G fuel, according to a GE telecon on 1/20/71, by irradiated gadolinia fuel rods in which the burnable gadolinia poison was not depleted until 9000 $\frac{MWd}{ton}$ or 2 2/3 fuel cycles. The TWX also clarified the comparison of K_∞ by the statement "The uncontrolled reactivities at the beginning of life now calculated for the F-fuel containing 1.25 w/o Gd_2O_3 and reported in the application for using 'F' fuel are very close to the reactivities originally calculated and reported in the application for the EG fuel containing 2.0% w/o Gd_2O_3.

Consumers Power Company had agreed earlier to show comparative power distribution data for the three fuel assembly types to illustrate the effect of moving the burnable poison rods from the second row on the side of the fuel assembly as in the GE fabricated bundles to the diagonal position next to the cobalt rods as they are in the Jersey Nuclear "Type J-1" bundles. This was accomplished during the January 21, 1971 meeting by scanning the results of computer solutions for the core thermal hydraulics behavior with F and J-1 fuel in equivalent core positions. Differences were negligible.

The second area of concern to us involves the reported increase in the end of cycle center fuel temperatures at 500,000 Btu/hr-ft^2 heat fluxes. It is especially noteworthy because the reported temperature, 5203°F, is above the fuel melting temperature (5020°F for irradiated fuel at the end of the first cycle) although for the same conditions, corresponding to the Technical Specification heat flux limit of 500,000 Btu/hr-ft^2, at the beginning of the fuel cycle the center fuel temperature is 5051°F, below the 5080°F incipient melting temperature of unirradiated UO_2. This is the second time that a noticeable amount of melting, reported to be 4% of the cross sectional area of the fuel, has been calculated for a reload fuel assembly at 500,000 Btu/hr-ft^2. The first time about the same amount of melting was reported for low density, low enrichment fuel in Reload E fuel assemblies where the temperature was explained by low $\int k\,d\theta$ listed as 85.5 w/cm instead of 93 w/cm, the value used for Reload F fuel. For the low density Reload E fuel, however, it was stated that the maximum overpower heat flux, 465,000 Btu/hr-ft^2 corresponding to 122% power level, occurred at the end of the second operating cycle and therefore no fuel melting was expected. Similar statements by GE note that the operating peak heat flux has been about 375,000 Btu/hr-ft^2 compared to the license limit of 410,000 Btu/hr-ft^2 at rated power and therefore at the 122% overpower condition peak temperatures would in reality be 4830°F, 200°F below melting. The calculated increase in fuel temperature at 500,000 Btu/hr-ft^2 has been explained by "... calculations at peak heat flux formerly were made with the assumption that the pellet-clad gap was closed which improved the heat transfer across this gap. Present calculations do not take credit for improved gap conductance so, consequently, the fuel temperature is higher". The heat transfer coefficient between fuel and cladding previously had been reported(7) as 1000 Btu/hr-ft^2°F for pellet-type fuel and 3000 Btu/hr-ft^2°F(8) for vibratory compacted UO_2 powder. During the January 6, 1971 telecon, GE representatives emphasized that the Reload F fuel performance predictions were made using the calculational methods currently accepted for the large BWR product line fuel. We were also informed that the local peaking factors have not been reduced considering fuel depletion at the end of the first cycle. Since the calculated increase in fuel temperature at the end of the first cycle is very small and barely above the fuel melting temperature for 500,000 Btu/hr-ft^2 and since it is predicted that heat fluxes at 122% overpower will not exceed 460,000 Btu/hr-ft^2 or 4830°F and melting will not occur, we have determined that the calculated expected thermal performance and related fuel integrity is acceptable. Under the circumstances, the difference in calculated fuel temperature at 500,000 Btu/hr-ft^2 is somewhat academic and need not be explained as a condition for approving the proposed change to allow the use of Reload F (or "Type J-1") fuel. In contrast to the fuel melting temperature calculated by GE, Jersey Nuclear reported during the 1/21/71 meeting that fuel melting temperatures would not be attained at 500,000 Btu/hr-ft^2 heat flux at any time during the J-1 fuel irradiation. (Nominal fuel-clad diametral clearance was revealed to be 0.009 inch nominal slightly larger than the .007 inch for GE fuel. Max clad strain in J-1 fuel rods was identified as 0.75% and maximum clad temperature as 765°F with an allowable crud accumulation of 1.5 mils/cycle.) Aware of these small calculational differences, we nevertheless continue to believe that evaluation at 500,000 Btu/hr-ft^2 and 122% power is desirable because such calculations show the steady-state operating margin, permit comparative evaluation of fuel, and indicate the margin for misplaced high enrichment rods in low enrichment regions; although with recent GE product line fuel assemblies, this is not mechanically possible.

The third area of concern involves quality assurance during fuel fabrication and assembly. Consumers admits that they have little control over the GE quality assurance but insists that quality assurance has been purchased with the new "Type J-1" fuel because such requirements were "spelled out" in the fuel purchase specification that Consumers prepared for Jersey Nuclear Corporation. Consumers freely admits that contractual arrangements with GE and the Company Confidential label pinned on fuel fabrication methods by GE does not give Consumers the direct supervision of quality assurance programs that they have with the Jersey Nuclear Corporation. Indirectly, there is limited evidence that the GE quality assurance program is effective since they have provided essentially all of the reload fuel for the Big Rock Point reactor (about 8 years) up to the present time. The Reload F fuel is in fact the fifth improved reload fuel type for the Big Rock Point reactor and confidence in the GE design and fabrication, based on demonstrated performance at Big Rock Point and numerous other operating reactors, has been reasonably established.

In contrast, however, Jersey Nuclear Corporation is offering with its initial fuel "Type J-1" for the Big Rock Point core essentially the latest version of the fuel which GE has perfected. Without the heritage of demonstrated fuel performance, quality assurance in the design and fabrication of the Jersey Nuclear fuel "Type J-1" assumes a greater proportion of our evaluation. At the January 21, 1971 meeting with Consumers and Jersey Nuclear Corporation this and other design factors of J-1 fuel were examined more closely. Responsive to our interests, Jersey Nuclear representatives outlined the company organization and discussed the quality control and quality assurance that is built into their nuclear fuel products. A written manual, that can be made available for review if requested, specifically identifies the quality assurance measures that were followed by Jersey Nuclear Corporation during the design and fabrication of the "Type J-1" fuel assemblies for Big Rock Point. The division of responsibility between Jersey Nuclear and Battelle Northwest for the design and manufacture of the "Type J-1" fuel was described as one where the technical design expertise was provided by Battelle on a consulting basis (a relationship which is to continue for an indefinite time) and Battelle fabrication facilities plus certain new presses and other equipment provided on a load basis by Jersey Nuclear were used by Battelle personnel under direct supervision of Jersey Nuclear management to fabricate the Big Rock Point fuel assemblies. The quality control and quality assurance responsibilities were held by Jersey Nuclear. Although we have not confirmed the existence of a quality assurance organization, or witnessed the effectiveness of the quality assurance procedures, ample evidence was provided by the Jersey Nuclear Corporation representatives that extensive written procedures have been prepared and are in use so that further effort in this area is not considered necessary at this time. We also have heard Consumers Power Company representatives describe their quality assurance audits. (Consumers representatives made six trips to the various suppliers and fabricators including BNW to audit quality assurance records and were satisfied that all of the necessary records were being kept in accordance with the written procedures and could be recovered if necessary.) Jersey Nuclear Corporation recently forwarded all of the quality assurance records generated by the Jersey Nuclear Corporation (records that begin with the receipt of the enriched uranium hexafluoride, zircaloy tubing, and assembled fuel rod spacers) to Consumers Power Company. Repetitive emphasis by the various speakers that Jersey Nuclear Corporation is new in the design and fabrication of nuclear fuel and places a very high value on quality assurance to successfully enter the very competitive business of providing reload cores for nuclear power plants made a favorable impression. Although without first hand knowledge of the Jersey Nuclear Corporation fuel design and fabrication quality assurance program and based solely on the informative presentations of the Jersey Nuclear Corporation management, we are satisfied with the level of importance attached to product quality assurances. Jersey Nuclear Corporation is continuing to perfect the quality assurance procedures and will use them at the various fabrication sites so that the experience can be used to improve their own design and fabrication facilities which are nearing completion (one assembly line predicted to be ready about May 1971).

The diffuser at the entrance to the "Type J-1" fuel assembly can be more accurately described as an adapter to smooth the coolant flow as it makes the transition from a circular to the square geometry of the subassembly. It is evident, from a picture, that any effect on the subassembly coolant flow rate by the diffuser will be negligible. The Jersey Nuclear representatives indicated that the crud deposit, if it still exists, may be reduced as a result of this flow transition device especially in the lower regions where most failures resulting from crud accumulation have occurred. The fuel has been designed to accommodate a 1.5 $\frac{\text{mil}}{\text{cycle}}$ crud build up without causing excessive clad temperature.

The stainless steel, containing inconel clips, fuel rod spacers have been provided in the assembled condition by an unnamed supplier. According to Jersey Nuclear the spacers are similar to the GE spacers. There have been no hydraulic tests to confirm spacer mechanical design features, but thermal hydraulic test results show good agreement with the GE Hench Levy heat transfer correlations. We requested copies of the data and comparison with the Hench Levy predictions which were shown to us at the meeting and Jersey Nuclear agreed to provide the information.

In attempting to resolve the difference between the Reload F and "Type J-1" Gd_2O_3 concentration 1.25% vs 1% in the poisoned section of the fuel rods and the difference in the location of the poison fuel rods, it was implied that the lumped Gadolinium analysis might have been used by GE and that such a treatment is not sensitive to the wide differences in the Gd_{155} and Gd_{157} isotopes which are present. The neutron cross sections and self-shielding properties are such that while one depletes rapidly, the absorption of neutrons by the other increases significantly over the first 1500 MWd/ton of fuel depletion before decreasing again. Related to the self-shielding characteristics it was also reported that the low enrichment, 2.55%, caused a 10% flux depression at the center of the rod compared with a 20% reduction for the highly enriched (4.5%) fuel rods. In contrast, the middle enrichment fuel (3.53%) containing 1% gadolinia burnable poison caused a 30% flux depression at the center. In partial justification for the reduced gadolinium concentration (1%), it was noted that the reactivity hold down capability of gadolinia drops off very noticeably at a level just above 1% or possibly as high as 2%. In other words, an increase above this level in the gadolinia concentration would not reduce the initial bundle reactivity significantly.

We have considered the explanations provided by GE and Jersey Nuclear Corporation to account for the difference in gadolinia concentration between the "Type J-1" and Reload F fuel assemblies and have concluded that the differences are accountable by the differences in basic properties of the gadolinia and the more refined calculational methods. We have concluded that these differences are small enough that reactor safety is not significantly affected.

Each of the fuel assembly types contains gadolinia fuel rods which can be removed for examination, if visual observations warrant, whenever the reactor is shut down for refueling. Visual observations and fuel rod dimensional measurements will reveal abnormal crud accumulation on fuel rods, excessive dimensional changes, or unusual conditions that might be attributed to the fuel spacers or the flow adapter at the entrance. With this capability to check the fuel assembly at the end of the first fuel cycle and satisfaction that the design differences are small, we have concluded that the use of Reload F or "Type J-1" fuel assemblies does not increase the hazards of operation or result in an unacceptable degree of risk to the public and that these two reload fuel assembly types can be used safely at the discretion of Consumers Power Company.

CONCLUSION

General Electric has provided information to show that the original Reload E-G fuel poison concentration was (conservatively) too high and that the burnable gadolinium oxide poison was not burned out by the end of the first fuel cycle as predicted. As a result, power generation, heat fluxes, and fuel temperatures were lower than originally calculated. We are satisfied with the Jersey Nuclear Corporation explanation of fuel design uncertainties that contribute to the small gadolinia differences between the Reload F and "Type J-1" fuel assemblies and agree that these and other small differences in calculated peak center fuel temperature do not have safety significance. Quality assurance for Jersey Nuclear fuel is specified in a written manual which has been offered for our review. All of the quality assurance records for the two "Type J-1" fuel assemblies have been forwarded to Consumers Power Company. It was evident from the Jersey Nuclear Corporation's oral presentation describing their quality assurance program that they do satisfy the intent of 10 CFR 50 Appendix B, Quality Assurance Criteria. Further evaluation of the quality assurance program is not considered warranted as a condition for inserting the "Type J-1" fuel assemblies.

We have concluded that since all A (original core loading) and D type fuel assemblies have been removed from the Big Rock Point core and there are no plans to again insert this type of fuel into the core, all references in the Technical Specifications to these fuel types can be deleted. We agree that Section 8 of the Technical Specifications, as it now exists, is obsolete and that the proposed reorganization to isolate research and development programs from basic reactor operation is acceptable. We have also concluded that the differences between Reload E-G, Reload F and "Type J-1" fuel assemblies are minor and that Reload F and/or "Type J-1" fuel will not increase the probability of an accident which could release fission products from the primary system, impair the effectiveness of the installed engineered safety features, or change the consequences of the design basis accident which assumes that all fission product gases are released from the fuel matrix without a lifetime dependence. Therefore, the proposed change does not present significant hazards considerations not described or implicit in the safety analysis report and there is reasonable assurance that operation of Big Rock Point reactor in the manner proposed will not endanger the health and safety of the public. Therefore, the Technical Specifications should be revised as requested.

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REFERENCES

(1) Type A fuel assemblies made up the original Big Rock Point core. Type D fuel consisted of 15 developmental fuel assemblies with clad variations from .010 to .030 inch and 304 SS, Zr-2, inconel 600 and incoloy clad material.

All of the A and D type fuel assemblies have been permanently removed from the Core (G. Walke telecon 12/30/70).

Reload B, C, E, and E-G fuel assemblies were approved for general use in the Big Rock Point nuclear reactor during the period between reactor start up in 1962 and February 27, 1969.

(2) Reload B fuel using zircaloy clad UO_2 in place of stainless steel clad fuel used in the original core ("A" fuel), 121 instead of 144 rods per bundle, and inclusion of cobalt targets was approved for the Big Rock Point core by DRL letter dated April 14, 1966. (Change No. 8). The duel U-235 enrichment with the high enrichment in the inside rods was expected to provide significant improvement in local peaking factors. The average enrichment was lower than the original SS clad "A" type fuel.

(3) Reload C fuel assemblies approved by DRL letter dated October 7, 1966 (Change No. 10), used vibratory compacted UO_2 powder instead of pelleted UO_2 fuel used in the original core. The U-235 enrichment of the inside fuel rods was increased slightly from 4.2% to 5.2% while the outer assembly rod enrichment was increased from 2.6% in the Reload B fuel to 2.9% to compensate in part for the reduced fuel density of the vibratory compacted Reload C fuel. However, the average enrichment was greater than Reload B fuel and about the same as the original SS clad fuel.

(4) Reload E fuel assemblies, approved by DRL letter dated July 2, 1968 (Change No. 14), incorporated the General Electric product line features. The bundles contained 81 larger diameter pelleted fuel rods instead of the 121 rods in Reload B and C fuel assemblies. (Reload C fuel rods contained vibratory compacted UO_2 powder). Three different fuel enrichments were used in contrast to two for Reload B and C fuel to further improve heat generation characteristics of the fuel assembly. The total weight of U-235 per bundle remained unchanged from the Reload B fuel.

(5) Reload E-G fuel assemblies, approved for the Big Rock Point core by DRL letter dated February 27, 1969 (Change No. 16), redistributed the enriched uranium within the fuel assembly, increased the total average enrichment from 2.9% to 3.55% and introduced gadolinium oxide burnable poison to four fuel rods to partially compensate for the increased enrichment to extend the fuel depletion 15,000 MWd/T for Reload E fuel to 20,000 MWd/T for the Reload E-G fuel.

(6) From Consumers Power Company, Proposed Change No. 16 dated January 22, 1969:

"The principal nuclear characteristics of the Reload 'E-G' fuel have been calculated and are compared to Reload 'E' fuel on Table 3. The reactivity values for the 'E-G' fuel at all conditions are lower than for 'E' fuel resulting in ample core shutdown margin" . . . "The core will be most reactive at the start of the cycle when there is calculated to be ample shutdown margin. The gadolinia initially controls 9% K_∞ of a bundle. A reference core containing 20 'E-G' fuel bundles has been analyzed. Approximately 3% Δk_{eff} core is initially controlled by the gadolinia. The gadolinia is designed to burn to near zero neutron absorption prior to the end of the first operating cycle that the fuel is in the reactor. Calculations show a slight decrease in core reactivity through the depletion of the gadolinia and a normal decrease thereafter. At no time does the core reactivity increase during burnup of the gadolinia."

(7) Table 2 of Consumers Proposed Change No. 10 dated July 29, 1966.

(8) Consumers Power Company, Proposed Change No. 14 dated February 6, 1968.