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

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RELOAD G AND NFS-DA 11 x 11 ROD BUNDLES WITH UNPOWERED RODS AND PLUTONIUM

Discussion

Consumers Power Company (CPCo) has requested approval (1) to begin the transition to Reload G fuel by inserting two lead bundles into the Big Rock Point core during the February - March 1973 refueling outage and approximately 21 additional Reload G assemblies in February 1974 (cycle 11) and each succeeding refueling thereafter[2] and (2) to insert four Nuclear Fuel Service - Demonstration Assembly (NFS-DA) fuel bundles into the Big Rock Point reactor during the February - March 1973 refueling outage[3]. Each Reload G bundle contains one unpowered solid zircaloy center rod and 24 plutonium-uranium oxide fuel rods arranged in a 5 x 5 array in the center of an 11 x 11 fuel bundle rod array (about 1.4 kg of recycled plutonium per bundle). Each NFS fuel bundle contains approximately 1.85 kilograms of fissile plutonium or about three times the normal end of life self generation level. The NFS fuel bundles are described by CPCo[1] as a new type of fuel bundle using an 11 x 11 fuel rod array with eight hollow unpowered rods, four at the corners and four in diagonal positions next to the center rod that will enable Big Rock Point to meet the AEC Interim Acceptance Criteria for Emergency Core Cooling Systems with future reloads of this type. For the NFS fuel bundles, the calculated maximum fuel clad temperature resulting from a loss-of-coolant accident is reported to be 2129°F in contrast to 2740°F for Type F fuel with 9 x 9 fuel rod arrays that is currently used as reload fuel (through February - March 1973 refueling).

Both proposed fuel bundles employ 11 x 11 fuel rod arrays with reduced rod diameter to lower the linear heat generation rate. Both the NFS and Reload G fuel bundles will use cobalt target rods in the corners as is the current practice. As noted, NFS-DA was originally described[1] with unpowered hollow rods in the corners as well as the diagonals next to the center rod. However, since the heat generation in the cobalt targets is negligibly small compared with fuel rods and since the importance of corner rods as a heat sink following a LOCA is relatively low, we have attached no safety significance to the substitution of cobalt target rods in the corner positions of NFS fuel bundles[3] in place of hollow rods. The safety aspects of the target cobalt rods were evaluated previously by us and determined to have no safety significance. Target rods similar to those in the NFS and Reload G bundles have been in use at Big Rock Point for several years without incident. No further evaluation of cobalt target rods is contemplated at this time.

We met with representatives of CPCo and Jersey Nuclear Company on November 2, 1972, to discuss calculational methods and other design features of the proposals. The following table, Table 1, prepared from information readily available in the Big Rock Point files shows that:

1. The total weight of fuel and clad for 11 x 11 and 9 x 9 rod arrays are approximately the same.

2. The average linear power generation in the B Fuel, NFS-DA, and Reload G fuel rods is $\frac{81}{121}$, or (67%) of the power generated in Reload F, J-1, J-2, and EEI fuel rods.

3. The total fuel rod heat transfer surface per bundle is increased by $\frac{121\ (.449)}{81\ (.5625)} - 1$ or 19%.

Reduced power generation per rod results in less peak energy stored within the fuel rods during rated power conditions and consequently more heat storage capacity following a loss-of-coolant accident.

Table 1

Type Fuel	B Fuel	NFS-DA	Reload G	J-1	J-2	EEI	Reload F
Rod diameter inches	0.449	0.449	0.449	0.5625	0.5625	0.5625	0.5625
**Clad thickness inches	0.034	0.034	0.034	0.040	0.050 0.040	0.040	0.040
Rod array	11 x 11	11 x 11	11 x 11	9 x 9	9 x 9	9 x 9	9 x 9
Metal/water ratio	0.915	0.915	0.915	0.99	0.99	0.99	0.99
Wt PuO_2 and UO_2 kg		*125.07	144.8	----	NA	NA	-----
Wt UO_2 kg	149	-----	-----	148.5	-----	-----	NA
Wt Pu (fissile/bundle kg)	0	1.85	1.4	0	1.5	5.33	0
Wt bundle lb	NA	NA	445	453	NA	NA	NA

*Pu and U metal

Type Fuel	B Fuel	NFS-DA	Reload G	J-1	J-2	DEI	Reload F
Gadolinium rods/bundle	0	0	4	4		NA	4
Diametral gap in L/D	0.008	.0085	0.0095				
Pellet L/D		1.61	0.75				

NA - not available.

**Clad weight per bundle same for 11 x 11 and 9 x 9.

Shortly after the Big Rock Point reactor was started up in 1965, operation with Type B (11 x 11 fuel rod) fuel was authorized. Thirty Type B fuel bundles were irradiated for the design lifetime (3 refueling cycles) without failure. The trend following completion of Type B fuel bundle irradiation was towards fuel bundles with fewer rods per bundle. This trend is now being reversed with the two Reload G and four NFS-DA bundles to be inserted during the February - March 1973 refueling outage. The mechanical differences between the fuel bundles with 11 x 11 fuel rod arrays originally irradiated in the Big Rock Point core and the Reload G and NFS-DA fuel bundles involve;

a. an inert Zr center rod that retains the 3 axial rod spacers in Reload G bundles,

b. an upper tie plate design that facilitates underwater disassembly and replacement of Reload G bundle rods,

c. the use of the tubes in corner positions of NFS-DA as structural members to tie the assembly together, as capture rods for the five spacer grids and as cobalt target rods, and

d. four non-fueled tubes positioned diagonally next to the center rod of the NFS-DA fuel bundles.

The Reload G and NFS-DA assemblies also differ from previous 11 x 11 fuel bundles in that these recent designs use recycle plutonium fuel. There are 24 PuO_2-UO_2 fuel rods with 4.3% fissile plutonium in natural UO_2 in each Reload G fuel bundle and 73 PuO_2-UO_2 fuel rods containing

1.03 w/o and 2.45 w/o fissile plutonium with enriched UO_2 in the NFS-DA fuel bundle. With the exception of the unpowered center rod in Reload G fuel, the four unpowered diagonal rods next to the center rod in the NFS-DA fuel bundle, and the use of plutonium recycle fuel as fissile fuel enrichment in place of U-235 in both the Reload G fuel bundles and the four NFS-DA bundles, the noted differences are relatively minor and require no further evaluation. The unpowered rods provide additional heat sinks that are calculated to reduce peak clad temperatures for fuel rods within the bundle following loss-of-coolant accidents from 2700°F to <2300°F assuming automatic depressurization and automatic activation of the emergency core spray system.

The increased quantity of plutonium in the Big Rock Point core introduces the possibility that core neutronics are affected unfavorably or that the increased toxicity of plutonium results in an unacceptable increase in radiation doses to the public during normal or post-accident conditions. We have considered reactor kinetics and the radiological consequences of reactor operation using Reload G fuel containing plutonium to replace resident fuel over the four-year period for both normal and accident conditions. We also have identified in our evaluation the unique dependence on unpowered fuel rods for Reload G and NFS-DA fuel bundles to satisfy the 2300°F temperature limit specified in the AEC Interim Acceptance Criteria for Emergency Core Cooling Systems.

Evaluation

About 32 PuO_2-UO_2 rods containing a total of 1 kg of plutonium(6) were inserted in the Big Rock Point core, two rods per bundle, in 1969. Ten of these rods have been removed and destructively examined. CPCo representatives have stated that no deviation from predicted behavior has been detected. Three EEI PuO_2-UO_2 fuel bundles(7) containing about 6 kg of plutonium per bundle were inserted in 1970. Two J-2 PuO_2-UO_2 fuel bundles(8) containing about 1.5 kg of plutonium per bundle were inserted in 1971. These bundles will be inspected during the February 1973 refueling outage and one of the EEI bundles will be removed for more detailed examination. To date none of the PuO_2-UO_2 rods irradiated in the Big Rock Point core have failed. Since the fuel rod configuration for all of the mixed oxide fuel rods irradiated in Big Rock Point to the present time has been a 9 x 9 rod array, the linear rod power generation is approximately 50% greater than will be encountered in the Reload G or NFS-DA fuel rods. The reduced fuel and clad temperatures of the new fuel bundles will reduce the possibility of fuel rod failure.

The plutonium inventory produced from U-238 in the Big Rock Point core with the equilibrium U-235 core prior to the insertion of mixed oxide fuel rods in 1969 was approximately 40 kilograms according to CPCo calculations shown in Table 2. When the equilibrium Reload G core is attained after 4 refueling outages (about 21 Reload G bundles to be substituted for depleted bundles at each outage), the plutonium inventory will increase to about 133 kilograms. CPCo has reported that with the mixed oxide fuel rods positioned in the bundle interior as in Reload G and NFS-DA bundles, core behavior characteristics will not change significantly and the effect on reactor control is negligible. We have concluded that the kinetics parameters for the core fully loaded with Reload G fuel bundles seem reasonable compared with core parameters for a U-235 enriched core. Substitution of the 11 x 11 fuel rod array with mixed oxide fuel rods in the bundle interior reduces the severity of a control rod drop accident. The amount of fuel above 265 cals/gm following an assumed 0.021 Δk rod drop accident is 139 kilograms, according to CPCo, in contrast to 232 kilograms for the U-235 enriched core with 9 x 9 fuel rod bundles. We have concluded that the change to the mixed oxide core described will provide a greater margin-to-fuel-rod failure and reactor safety is thereby enhanced.

The possibility of misplacing a highly enriched plutonium rod within a fuel bundle during fuel bundle fabrication has been investigated and, as with other evaluations of misplaced highly enriched uranium rods, fuel rod clad failure could occur during normal reactor operation if a highly enriched rod is misplaced within the bundle. Such a failure is undesirable, but we have concluded it is tolerable and will not result in continuous radioactive releases in excess of permissible operating levels. An error in placement of fuel rods in the bundle we consider to be very unlikely in view of rod identification and quality assurance procedures.

Offsite radiological effects resulting from the use of mixed oxide fuel as described by CPCo are not significantly different from those previously evaluated for the Big Rock Point facility using U-235 enriched fuel. Analysis reveals that the offsite dose rates contributed by plutonium, as determined by utilizing measured plutonium vapor pressure for 5 w/o mixed oxide fuel, are negligible compared with the dose rates from fission products alone. We have concluded that the increase in plutonium inventory for the equilibrium Reload G core (Table 2), 3.3 times greater than the Big Rock Point core without recycle plutonium, is insignificant when the relative biological importance of plutonium isotopes (10 CFR 20 limits) is considered.

TABLE 2

PLUTONIUM INVENTORY PROJECTION
BIG ROCK POINT NUCLEAR PLANT

CYCLE	BOL		EOL	
	Pu_f(kg)	Pu_{tot}(kg)	Pu_f(kg)	Pu_{tot}(kg)
Typical all UO_2 Core	21	24	33	40
Present Core, May 1972 - Feb 1973 - Includes 22 EEI-Pu rods, 3 EEI-Pu and 2 J-2 bundles	36	43	46	55
Mar 1973 - Feb 1974 - Includes 2 EEI-Pu, 2 J-2, 4 NFS, 2 G bundles and 74 UO_2 bundles	35.3	42.4	45.2	56.5
Mar 1974 - Feb 1975 - Includes 2 J-2, 4 NFS, 21 G and 57 UO_2 bundles	46.2	56.8	53.9	69.0
Mar 1975 - Feb 1976 - Includes 2 J-2, 4 NFS, 42 G and 38 UO_2 bundles	62.9	79.9	68.0	89.6
Mar 1976 - Feb 1977 - Includes 63 G and 21 UO_2 bundles	77.4	100.6	80.8	108.1
Mar 1977 - Feb 1978 - Includes 81 G bundles	96.6	128.2	96.2	133.1

The yield of the various fission products is dependent on the fissile isotope. Fission of the plutonium isotopes Pu-239 or Pu-241 results in a significant reduction of accident whole body and bone doses when compared with the doses from U-235 fission products but results in an increase in thyroid doses. Jersey Nuclear has calculated that the thyroid dose for the equilibrium Reload G fuel core is increased less than 4% and remains within 10 CFR 100 limits. We have concluded that the improvement in fuel integrity due to reduced linear rod power density and the reduction of calculated peak clad temperatures following LOCAs adequately compensates for the relatively small risk associated with the calculated 4% increase in the thyroid dose resulting from an assumed release of all iodines from the mixed oxide fuel.

The calculational models and assumptions used in the analysis of the NFS-DA fuel bundles are described in NEDO-10329 (as amended to comply with the AEC Interim Acceptance Criteria for ECCS) with modifications for (1) non-jet pump plant, (2) a 0.96 gamma smearing factor, and (3) unpowered rods[1]. Based on our evaluation of the DBA with NFS-DA fuel bundles in the core, we have concluded that the dependency on unpowered rods to limit peak fuel clad temperatures following the DBA creates uncertainties that cannot be eliminated until demonstration tests of unpowered rod wettings and heat sink effectiveness are completed early in 1973. We cannot agree that peak clad temperatures following the DBA and low pressure core spray cooling will be lower than the 2300°F limit specified in the AEC Interim ECCS Acceptance Criteria. Based on our review, however, it is evident that the new bundles will operate at lower heat generation rates and it is therefore reasonable to expect that fuel integrity has been enhanced. Because of the reduced power per rod, fuel temperatures and stored energy are reduced and there is a greater margin to clad failure or excessive clad temperatures following DBA. It is also reasonable to expect that the unpowered rods properly positioned in the bundle will provide an additional sink to which the hottest rods can radiate heat for storage (unwetted) or transport to coolant (wetted). We have concluded that unpowered rods will reduce peak fuel rod clad temperatures but cannot agree that the model and assumptions used by General Electric are conservative in this respect, i.e., peak clad temperatures may be reduced from 2700 - 2800°F, but the reduction may not be sufficient to meet the AEC Interim ECCS Policy limit of 2300°F.

With a calculational model similar to the GE model and the same DBA assumptions, Jersey Nuclear has shown that a single unpowered solid zircaloy rod in the center of the 11 x 11 Reload G fuel bundles will limit peak fuel rod clad temperatures to 2296°F. The uncertainty associated with unpowered rod wetting remains and our conclusions regarding the Reload G ECCS calculations by Jersey Nuclear are the same as our conclusions for the NFS-DA bundles.

Additional information(4)(5) provided by CPCo described the consequences of intermediate and small size breaks in the primary coolant system after plant modifications are completed in the year 1974 to provide automatic primary system depressurization and assuming feedwater pumps are restarted manually within 10 minutes of the break. Until the reliability of the proposed automatic depressurization system can be established and the dependence on offsite power to run a 1.3 MW electrically driven feedwater pump following a loss of primary coolant can be justified, and for the same reasons associated with the DBA calculational uncertainties, we cannot conclude that the AEC Interim ECCS Acceptance Criteria, i.e., the 2300°F temperature limit, will be satisfied over the range of small and intermediate size breaks. Based on the information provided to us, however, we have concluded that the integrity of the 11 x 11 fuel bundles should be superior to the 9 x 9 bundles presently in the core during normal and accident conditions and that CPCo should be authorized to insert the 2 Reload G bundles and 4 NFS-DA bundles during the February - March 1973 refueling outage. We note that the proposed change to permit automatic depressurization following loss-of-coolant accidents is only partially effective for resident fuel according to the GE calculations and assumptions(4) over the postulated range of coolant system breaks. Our evaluation of the ECCS will continue as new information is presented by CPCo in the areas we have identified.

The necessity to provide additional information related to fuel shielding and transportation has been discussed with CPCo representatives. The increased spontaneous neutron population that accompanies irradiation of recycle plutonium-bearing fuel may necessitate new restrictions on the number of assemblies that can be shipped in approved casks, additional neutron shielding may be required, or new casks may be proposed. CPCo plans to submit additional information before irradiated recycled plutonium fuel bundles (Reload G or NFS-DA) are shipped from the site.

Both solid and hollow unpowered rods have been utilized in the proposed mixed oxide fuel assemblies. Reload G fuel bundles contain one solid unpowered center rod and the NFS-DA bundles each contain four unpowered hollow rods diagonally next to the center rod. Jersey Nuclear selected the solid rod because the 3 axial spacers in each bundle are attached to the center rod and uncertainties related to collapse or rupture during rapid accident coolant blowdown are eliminated. There is no similar bundle structural dependence on the 4 unpowered rods within the NFS-DA fuel bundle, but it is nevertheless desirable to preserve the hollow tubular shape assumed in the LOCA evaluations. The mechanical effect of blowdown on the hollow center rods have been analyzed by NFS and according to the calculated results the hollow rods can withstand the blowdown forces during LOCAs without failure.

Conclusion

We have concluded that the Reload G fuel bundles with an unpowered rod in the center of each bundle and the four NFS-DA bundles with 4 unpowered rods next to the center rod in each bundle, both employing 11 x 11 rod arrays and recycle plutonium, will result in reduced fuel rod and clad temperatures during normal and accident conditions and for this reason the request to insert 2 Reload G and 4 NFS-DA fuel bundles should be granted since reactor safety will be enhanced. We cannot conclude, until new test data become available, that the unpowered rod wetting and resultant pe[illegible] clad temperatures as calculated by Jersey Nuclear and General [illegible]ic are conservative and within the limits of the AEC Interim Po[illegible] Statement.

We have considered the plutonium inventory increase and the plutonium fission product yields in relation to normal and accident releases and radiation dose consequences and we have concluded that the proposed change to a plutonium recycle core does not present significant hazards considerations not described or implicit in the Big Rock Point Safety Analysis Report, as amended, and that there is reasonable assurance that the health and safety of the public will not be endangered by operation of the reactor in the manner proposed. On this basis, Amendment 4, which increases the amount of plutonium that CPCo is authorized to receive and possess, is justified.

It should be emphasized that according to calculations by Jersey Nuclear and General Electric the AEC Interim Acceptance Criteria for the DBA large pipe-break LOCA will be satisfied by reducing the power generation per rod (11 x 11 rod arrays instead of 9 x 9 arrays) and utilizing unpowered rods at or near the center. To satisfy the AEC Interim Criteria for the entire range of primary system breaks will require additional modifications to the ECCS (an automatic depressurization system has been proposed) which must be approved by AEC before installation at the Big Rock Point plant. It appears that completion of ECCS modifications to meet the AEC Interim Acceptance Criteria will not be accomplished before July 1974.

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Enclosure:
References

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REFERENCES

1. Design Basis Accident Loss of Coolant Analysis for NFS Demonstration Fuel Assemblies - CPCo letter dated May 18, 1972.

2. Proposed Change No. 31 - Reload G containing 24 plutonium-uranium oxide fuel rods and one unpowered rod at the center . . . two lead bundles for insertion into Big Rock core during the February - March 1973 refueling outage. CPCo letter dated June 16, 1972.

3. Proposed Change No. 34 - Four NFS-DA fuel bundles with eight unpowered rods (4 hollow diagonal rods next to center rod) and 73 plutonium enriched mixed oxide rods per bundle to be inserted into Big Rock Point core during February - March 1973 refueling outage. CPCo letter dated July 24, 1972.

4. "Big Rock Point Loss-of-Coolant Analysis with Automatic Depressurization and NFS Demonstration Fuel". CPCo letter dated September 22, 1972.

5. "Small and Intermediate Break Loss of Coolant Accident Analysis for the Big Rock Reactor with an Automatic Depressurization System and Jersey Nuclear Company Reload G Fuel". CPCo letter dated November 1, 1972.

6. Amendment No. 3. April 18, 1969.

   Authority to receive, possess and use 50 kilograms of plutonium contained in PuO_2-UO_2 fuel rods in connection with operation of the Big Rock Point Nuclear Plant and operate the reactor with one or two removable fuel rods containing PuO_2-UO_2 inserted in Reload "E" or "E-G" 9 x 9 rod array fuel bundles. The 32 PuO_2-UO_2 (1.3 - 1.5 w/o Pu) rods combined contain less than 1 kg of Pu when inserted with the Big Rock Point reactor at the beginning of cycle No. 7. The plutonium inventory in the core at the beginning of the fuel cycle is increased by about 4% and less near the end of the fuel cycle.

7. Change No. 19. February 20, 1970.

8. Change No. 27. December 29, 1971.