WESTINGHOUSE

FUEL AND LOCA

EVALUATION OF R. E. GINNA

MIXED OXIDE FUEL ASSEMBLIES

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Edited by

J. Skaritka

Approved: M. G. Arlotti

M. G. Arlotti, Manager
Fuel Licensing & Coordination
Nuclear Fuel Division

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1.0 INTRODUCTION AND SUMMARY

Rochester Gas and Electric plans to have four mixed oxide (PuO_2-UO_2) assemblies fabricated and inserted into the R.E.Ginna reactor for Cycle 10 as demonstrated assemblies. The mixed oxide fuel rods were originally fabricated by Westinghouse for Cycle 7 and have been in storage since 1974. Each 14x14 fuel assembly would contain 179 mixed oxide fuel rods.

This Westinghouse report to RGE addresses the fuel assembly design, fuel rod design and the loss-of-coolant-accident (LOCA) evaluations. This report is planned to be part of an RGE submittal to the NRC. The evaluations confirm that the standard UO_2 fuel design and LOCA safety criteria are satisfied by the mixed oxide assemblies. As part of the evaluations, the mixed oxide fuel rod design and anticipated duty are compared with the Westinghouse Region 7* standard UO_2 fuel manufactured in the same time period (1974) as the mixed oxide fuel.

The evaluations show that the mixed oxide fuel assemblies satisfy the LOCA safety criteria and also satisfy the fuel rod design bases for burnups exceeding the anticipated three cycles of irradiation (Section 2.2). There are no restrictions in core position as a result of the evaluations in this report.

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*The mechanical design of Region 7 is the same as the most recently supplied <u>W</u> fuel, Region 9

2.0 DESIGN DESCRIPTION AND EVALUATION

2.1 Fuel Assembly

The mechanical design of the mixed oxide (PuO_2-UO_2) fuel assemblies is the same as the Westinghouse supplied Region 7 standard UO_2 fuel assembly, except for the fuel isotopics and their positions in the assembly. The basic design features and design bases of the standard fuel assemblies are described in Reference 1. The mixed oxide assemblies have the same design bases as the standard UO_2 assemblies.

The fuel rods are positioned in the 14x14 array as shown in Figure 1. The mixed oxide fuel rods are installed in a standard UO_2 assembly skeleton. The 179 mixed oxide fuel rods are designed with three different nominal enrichments (3.20, 3.00 and 2.6 w/o)*, with the higher enrichments located in the center and the lower enrichments on the outside rows and in the corners. This arrangement flattens the power peaking across the fuel assembly to an estimated peak/average power of about 1.06 at the beginning-of-life. This aids the core designer in the prevention of excessive power peaking in the mixed oxide assemblies.

The mixed oxide fuel assemblies have an average reactivity equivalent U-235 enrichment of 3.1 w/o. Table 1 gives the "typical" U-Pu isotopic weights for the three enrichment fuel rods.

2.2 Fuel Rod

The mechanical design of the R.E.Ginna mixed oxide rods is nearly identical to the standard uranium dioxide rods in Region 7. The mechanical components (tubing, end plugs, and plenum spring) are identical. The pellet dimensions (length, diameter, dish geometry) are also identical. Fuel densities are equal. The mixed oxide fuel rods are pressurized with He gas.

*Mixed oxide enrichment definition: $w/o = \frac{PuO_2}{PuO_2 + UO_2} \times 100$

The mixed oxide internal rod pressures are within the range of current practice and satisfy the fuel rod design criteria for core average burnups of at least 27,000 EFPH. This is well in excess of the anticipated 21,000 EFPH accumulated during 3 cycles with the mixed oxide assemblies in the core. In particular, the rods were pressurized to assure that clad flattening will not occur, and the rod internal gas pressure remains less than the system coolant pressure (2250 psia nominal).

The material properties of PuO_2-UO_2 and UO_2 are similar for the enrichments in the R.E.Ginna fuel. A comparison of the characteristics of key properties is given in Table 2. The basis for these comparisons is described in Reference 2. As discussed in Section 3 of Reference 2, the Westinghouse fabrication specification limits the maximum PuO_2 particle size to 400μ. The average particle size is 10 to 20μ, and 99.9% of the sizes are less than 100μ. This assures that potential surface heat flux peaking due to large particles does not cause adverse effects on mixed oxide fuel performance under normal operation and accident conditions. Based on the geometric similarities and the similarity in properties, the fuel performance characteristics of the mixed-oxide fuel will be almost the same as the standard Region 7 UO_2 fuel. This is supported by the Westinghouse experience with mixed oxide fuel rods in the Saxton and San Onofre reactors, described in Reference 2.

The mixed oxide fuel rods are designed to satisfy the design criteria described in Section 3.1.2 of the FSAR(1) plus the additional criterion of no clad flattening. The fuel rod design is evaluated with an approved fuel performance code(3) to assure that the design criteria are met. The models in the fuel performance code that are applicable to uranium dioxide fuel are also applicable to mixed oxide fuel with two exceptions; the thermal conductivity and radial power depression factor of mixed-oxide fuel are slightly less than for UO_2 fuel. Appropriate expressions or methods to evaluate these parameters are given in Reference 2, and these were used in the fuel performance code for this evaluation. The FSAR design criteria limits address fuel temperatures, rod pressures, clad stress and clad strain. The design criteria limits for the mixed-oxide fuel are the same as for the Region 7 standard fuel. A reduction in the melting temperature of mixed oxide fuel was accounted for in the calculation.

Calculations were performed using the approved fuel performance code[3] with appropriate equations for mixed oxide fuel, and it was determined that all design bases were met for the R.E.Ginna mixed-oxide fuel. Calculations were also made to determine the time for clad flattening, using an approved model[4]. As previously discussed in this section, the predicted clad flattening time greater than 27,000 EFPH assures that the no flattening criterion is satisfied during the mixed oxide irradiation in the Ginna reactor.

The mixed oxide fuel rods have been in storage for approximately 5 years since they were manufactured in 1974. The rods have been stored in sealed steel containers under atmospheric (air) conditions. Effects of this storage has a negligible effect on the fuel rod materials and internal gas pressure compared to the as-fabricated rods. The Zircaloy cladding is virtually immune to corrosion in air at the peak storage temperature (less than 230°F) which is much less than the oxidation corrosion temperature of concern (well above 500°F). Table 1 gives the mixed oxide isotopics as of November 1978 for typical fuel rod enrichments.

3.0 LOCA EVALUATION

The ECCS performance of plutonium oxide fuel loaded in the R.E.Ginna Nuclear Plant core is bounded by existing analyses considering standard uranium oxide fuel. Since the fuel assembly designs are equivalent, the thermal-hydraulic transients calculated for uranium oxide fuel apply to plutonium oxide fuel as well. Fuel performance parameters [pellet temperature, fuel dimensions, gap fill pressure, core peaking] are similar for the two fuels, so the stored energy present during a LOCA will be basically the same. Due to the difference in the fission products formed by PuO_2 compared to UO_2, the decay heat of plutonium oxide in the first 200 seconds after shutdown is 8-20% lower than the corresponding uranium oxide value. Comparisons are given in the proposed ANS Standard 5.1(5). Given the thermal-hydraulic compatibility and equivalent fuel perameters, the significantly lower decay heat of plutonium oxide fuel makes it less limiting in any ECCS performance evaluation than the uranium oxide fuel which has been previously analyzed for Ginna.

4.0 REFERENCES

1. USAEC Docket Number 50-244, "Final Facility Description and Safety Analysis Report", Robert Emmet Ginna Nuclear Power Plant, Unit Number 1, January 1968.

2. Rim, C. S, et. al, "Performance Characteristics of Mixed PuO_2-UO_2 Fuels in Pressurized Water Reactors, WCAP 8349-P, February, 1975.

3. Miller, J. V., ed., "Improved Analytical Models Used in Westinghouse Fuel Rod Design Computations", WCAP 8785, October 1976

4. George, R. A., et. al., "Revised Clad Flattening Model", WCAP 8381, July 1974

5. ANS Standard 5.1, "Decay Heat Power in Light Water Reactors", October 1978. Final Approval by ANSI - August 29, 1979.

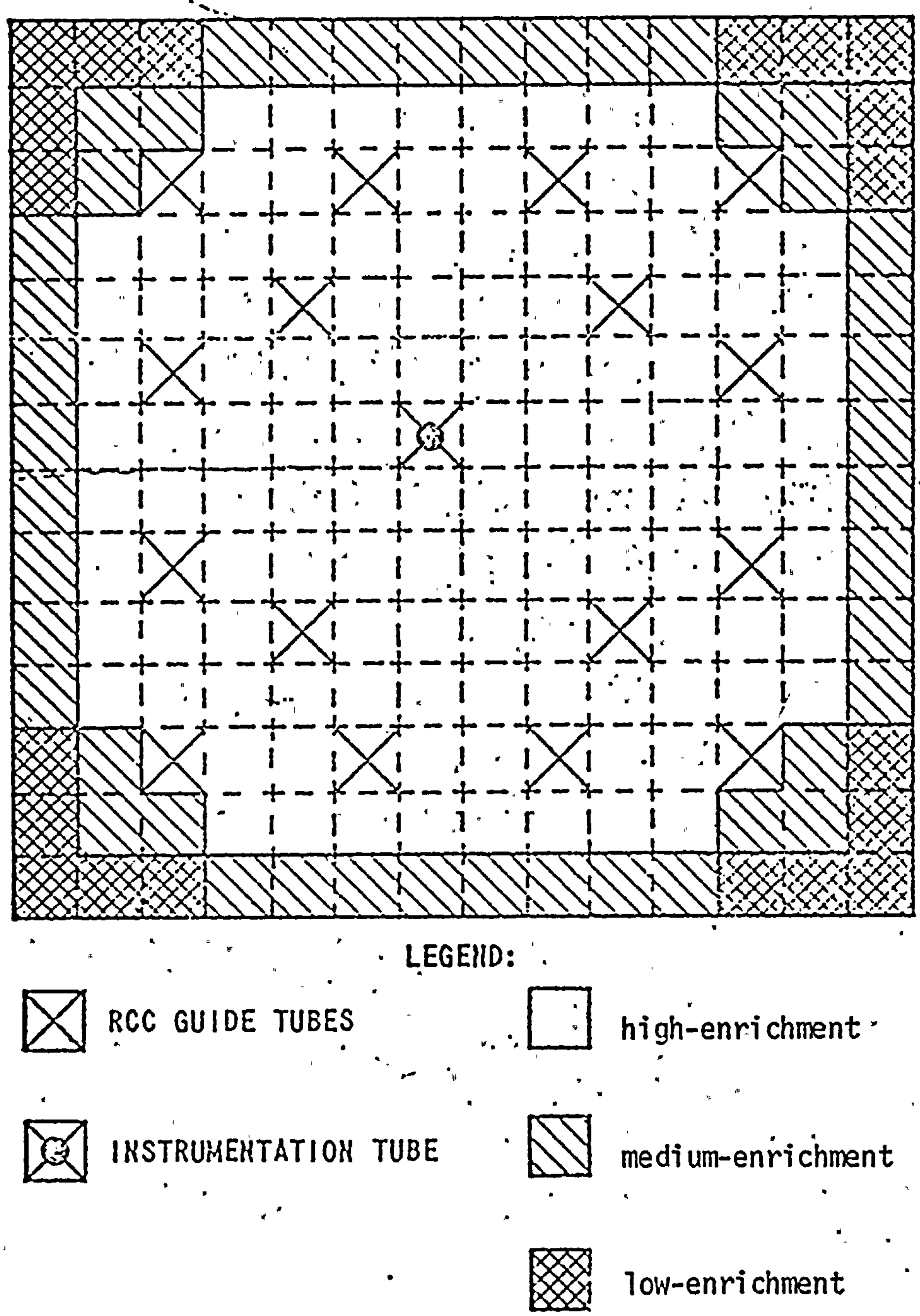

FIGURE 1

ENRICHMENT POSITION FOR PuO_2-UO_2 FUEL ASSEMBLIES

TABLE 1

R. E. Ginna
Mixed Oxide Fuel Rods
- Typical Isotopics -

- Per Fuel Rod -
Weight of Isotopic Material (Grams)

Isotopic Material	High Enrichment	Medium Enrichment	Low Enrichment
Pu^{238}	0.2	0.2	0.5
Pu^{239}	54.5	50.7	41.0
Pu^{240}	11.0	10.7	8.2
Pu^{241}	2.3	2.3	3.5
Pu^{242}	0.5	0.6	0.8
Total Pu	68.5	64.5	54
U^{235}	15.2	15.3	15.3
Total U	2143	2154	2161
Total (PuO_2-UO_2)	2510.5	2517	2515

TABLE 2

CHARACTERISTICS OF PuO_2-UO_2 COMPARED TO UO_2

Parameter	Value
PuO_2-UO_2 Melting Point	Slightly lower than UO_2
PuO_2-UO_2 Thermal Conductivity	Slightly lower than UO_2
PuO_2-UO_2 Radial Power Depression	Greater than UO_2
PuO_2-UO_2 Specific Heat	Equivalent to UO_2
PuO_2-UO_2 Thermal Expansion	Equivalent to UO_2
DNBR and Clad Failure Threshold Energy (With PuO_2 Particle Size _ 400 microns)	Equivalent to UO_2
PuO_2-UO_2 Fuel Densification	Less than or equal to UO_2
PuO_2-UO_2 Fuel Swelling	Equivalent to UO_2
PuO_2-UO_2 Fission Gas Release	Equivalent to UO_2