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Thermal Performance of Annular-Coated And Sphere-Pac LWR Fuel Rod Designs

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THERMAL PERFORMANCE OF ANNULAR-COATED
AND SPHERE-PAC LWR FUEL ROD DESIGNS

Two FCI-resistant U_2 fuel rod designs are being compared to a reference design in irradiation tests in the Halden Boiling Water Reactor (HBWR) as part of the DOE-sponsored Fuel Performance Improvement Program (FPIP). The FPIP is a joint effort of Consumers Power Company, Exxon Nuclear Company, Inc., and Battelle's Pacific Northwest Laboratory. The primary fuel design (annular-coated-pressurized) incorporates annular pellets, a graphite coating on the inner surface of the Zircaloy cladding, and pressurized helium fill gas. Also being investigated is an 87% smear density sphere-pac design with pressurized helium fill gas. The solid pellet (reference) and annular-coated designs described herein had helium fill gas at ~ 100 kPa⁽¹⁾ and the sphere-pac rods were pressurized at ~ 455 kPa.⁽²⁾

Thermal performance of the fuel rods was measured by fuel centerline W/Re thermocouples. The measured temperatures have not been corrected for thermocouple decalibration; however, this will not affect the comparison of thermal performance. Although the average linear heat generation rates (LHGRs) of the rods irradiated in the IFA-517 test rig [reference (R1) and sphere-pac (S41 and S42) rods] were about 25% higher than for those irradiated in the IFA 518 rig [reference (R2) and annular-coated (AC9) rods], the peak LHGRs at the thermocouples were comparable.

Central fuel temperatures for the five rods as a function of burnup at an LHGR of 36 kW/m are shown in Figure 1. The fuel temperatures in the reference rods increased with burnup, particularly at burnup levels above 500 GJ/kgM. The difference in thermal responses of the two reference rods (R1, R2) is attributed to a larger fission gas release in rod R1 as a result of higher average LHGR and fuel temperature. The annular-coated rod showed no significant change in fuel temperature over a slightly larger burnup range. These observations are illustrated more graphically in Figure 2, where the fuel temperatures are shown for three reactor power ascensions at different burnups.

The fuel temperatures of the reference (R1) and sphere-pac (S41 and S42) rods from IFA-517 increased with burnup, particularly at burnup levels above 300 GJ/kgM (Figure 1). A comparison of fuel temperatures for these two fuel designs during reactor power ascensions at two burnup levels is made in Figure 3.

CONCLUSIONS

Because of lower operating temperatures, the annular-coated rod apparently released less fission gas than the reference rods. As a result, no significant degradation of the fuel-cladding gap conductivity and no significant increase in fuel temperature with burnup occurred. The lower fuel temperatures and associated lower fission gas (product) release of the annular-coated design are expected to contribute to enhanced FCI resistance.

The sphere-pac rods operated at lower fuel temperatures than the reference rods at comparable LHGRs. However, the increase in peak fuel temperature as a function of burnup was similar in the sibling reference and sphere-pac rods. This similarity indicates that the effects of fission gas release and the resultant degradation of effective thermal conductivity of the fuel and/or gap conductance in both designs are comparable.

References

1. S. R. Wagoner, J.O. Barner, and R.K. Welty, "Description and Characterization of HBWR Series H-1 Test Rods," COO-4066-11, PNL-2906 (1979).
2. R.J. Guenther, J.O. Barner, and R.K. Welty, "Description and Characterization of HBWR Series H-2, H-3 and H-4 Test Rods," DOE/ET/34215-14, PNL-3371 (1980).

Figure Captions

Figure 1. Measured fuel temperatures as a function of burnup at constant LHGR.

Figure 2. Measured fuel temperatures as a function of LHGR in IFA-518 reference and annular-coated rods.

Figure 3. Measured fuel temperatures as a function of LHGR in IFA-517 reference and sphere-pac (average of two) rods.





