Behavior of a W-Re Centerline Thermocouple in a (U-Pu) O_2 Fuel Pin.

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We irradiated a six-inch-long IMFBR-type (85% UO_2 +15% PuO_2) instrumented fuel pin, clad in 0.25-in OD type 316 stainless steel in the ORR for over 330 hr. The centerline temperature of the fuel was measured with a hafnia-insulated W3Re/W23Re thermocouple in a wrought W-26Re well. Indicated fuel temperatures were as high as 2300°C near the start of the test and decreased to 1830°C at the end.

The main objective of the test (ORIC-4) was to measure the decalibration of the W-Re thermocouple during its irradiation and to determine by post-irradiation examination what the mechanism of decalibration might be. Observed decreases in indicated centerline temperature were compared with expected changes in fuel temperature due to restructuring, and with results of other recent instrumented irradiation experiments.

During an initial period of about 50 hr of irradiation at 7.5×10^{13} n/cm²-sec (thermal), the W-Re thermocouple output increased slightly; then the indicated temperature dropped about 150°C per 100 hr for the remaining 300 hr of test at an estimated temperature of 2300°C. This decrease of indicated temperature compares quantitatively with a decrease of 60°C per 100 hr observed by Asamoto et al.⁽¹⁾ during irradiation of W5Re/W25Re thermocouples in (U,Pu) O_2 fuel at 2100°C in GEIR, and with a decrease of about 40°C per 100 hr observed by Heckelman and Kozar⁽²⁾ during irradiation of W3Re/W25Re thermocouples at 1800°C in the NASA Plum Brook reactor.

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To detect changes in the W-Re thermocouple, a four-wire connection was made to a 13-in. long loop at the hot junction end so that precise measurements could be made of the loop resistance using a current and potential method. Data taken periodically during the test, operated at constant cladding temperature, the W-Re thermocouple loop resistance remained constant, while the thermal emf decreased. The data also show the loop resistance to be a sensitive indicator of centerline temperature, responding to 1% changes in reactor power and to slight changes in the position of the test cartridge in the core.

The temperatures of the interface between the fuel pin cladding and the sodium heat dissipator and at the sodium - gas gap wall were measured with 0.040-in OD SS-sheathed grounded-junction type K thermocouples emplaced in 0.062-in OD wells. Cladding outer surface temperatures slightly greater than 600°C were measured during steady operation at about 18 kW/ft heat generation rate. An inner surface cladding temperature of about 700°C was calculated from these measurements.

Post-irradiation analysis of the fuel pin and centerline thermocouple included observations by neutron radiographic, metallographic and electron microprobe techniques to detect changes in structure or dimensions of components, changes in thermocouple wire diameter or alloy composition, and to identify metallic deposits in the fuel and on thermocouple insulators. Examination of the cartridge showed: a) restructuring of the fuel, indicating a maximum fuel temperature of about 2300°C.; b) significant distortion of the centerline well where it was not supported internally by the thermocouple insulator; c) no apparent change in the thermocouple wire diameter which might affect the loop resistance; d) no significant change in the rhenium content of the

W3Re thermocouple wire; and e), that metallic deposits on the surface of the insulator holes and in the fuel are tungsten. This analysis is consistent with a proposed tungsten-oxygen cycle transport mechanism used by Baxter and Kuhlman⁽³⁾ to explain W-Re thermocouple failure in out-of-pile tests and with observations by Fitts et al.⁽⁴⁾ on W-Re thermocouples irradiated in (U,Pu)O₂ fuel at 2000°C.

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