Oxidation Behaviour Of Dysprosium-Doped $(U,Dy)O_2$ LVRF Fuel

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ABSTRACT

When sheath defects occur under normal operating condition, coolant may enter the fuel-to-sheath gap, leading to fuel-pellet oxidation. Fuel oxidation directly affects fuel properties and performance by altering the fuel thermal properties (e.g., thermal conductivity and melting point), the fission-gas diffusion coefficient (and hence, fission-gas release behaviour) and its mechanical strength. Thus, knowledge of the fuel-oxidation behaviour is important in understanding in-reactor performance of the defective fuel.

The extent of fuel oxidation can be quantified by measuring the oxygen-to-metal (O/M) ratio of the fuel. The O/M ratio is the ratio of the number of oxygen atoms to the number of metal atoms in the fuel. When the fuel is oxidized, the O/M ratio increases, and a higher O/M value indicates a greater extent of fuel oxidation.

The CANFLEX®[2] low void reactivity fuel (LVRF) bundle contains one fuel element with dysprosium (as $(U,Dy)O_2$) as a burnable neutron poison to control the neutron activity. A concern is the relative susceptibility to oxidation of the $(U,Dy)O_2$ fuel compared to that of the UO_2 fuel. To address the concern, investigative measurements to characterize oxidation behaviour (i.e., O/M ratio) of $(U,Dy)O_2$ relative to UO_2 were conducted.

The oxidation behaviour of $(U,Dy)O_2$ fuels with Dy contents of 4.3 and 11.3 wt.% was characterized using the Coulometric Titration equipment at CRL. To facilitate comparison, the oxidation behaviour of UO_2 was also characterized. The fuel oxidation was quantified by measuring the net increase in O/M ratio (□O/M) of the fuel-powder samples, when the samples were heated in a controlled oxidizing gas mixture. The test temperatures ranged from 400°C to 1150°C. The upper and lower temperature limits approximately correspond to the surface and the centreline temperatures of the operating elements loaded with $(U,Dy)O_2$ pellets. The oxygen potentials of the gas mixture ranged from –450 kJ/mol to –81 kJ/mol. The upper limit of the oxygen potential corresponds to the pure steam condition, and the lower limit corresponds to the stoichiometic condition of UO_2. The results of the experiments demonstrate that the addition of Dy to UO_2 reduces the tendency to absorb oxygen in the material, especially in pure steam. For example, the ΔO/M values are 20% to 50% lower than that of UO_2, when the fuels are exposed to pure steam and tested at 1000°C and 1150°C. This effect is more apparent for the fuels with 11.3 wt.% Dy than that with 4.3 wt.% Dy.

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