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Porosimetry of zirconia scales formed during oxidation of Zr-based fuel claddings in steam and air-steam mix at high temperatures

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This poster presents the main results of a study conducted to quantify the degradation state of Zr-based fuel claddings submitted to severe accident conditions in a nuclear reactor core: high temperatures and pure steam or air-steam mix. Due to the progressive thickening of a dense and protective ZrO2 layer, the oxidation kinetics of Zr-based claddings in steam, at high temperatures typical of nuclear severe accidents, is generally (sub-)parabolic. However, for some temperature domains, this oxide layer may crack, becoming porous and non-protective anymore. In these 'breakaway'conditions, the oxidation kinetics accelerate. Additionally, the temperature rise can lead core materials to melt and to relocate down to the vessel lower head, threatening its integrity. If it fails, and for specific conditions, air ingress may take place into the reactor. Hence, oxygen and nitrogen react with Zr-based claddings, successively through oxidation of Zr (forming ZrO2 layer), nitriding of Zr (forming ZrN particles) and oxidation of ZrN (forming ZrO2 and releasing nitrogen). These self-sustained reactions enhance the deterioration of Zr-based claddings and of their ZrO2 layers, increasing their open porosity. To quantify this porosity, a series of two-step experiments was conducted. First, ZirloTM cladding samples were isothermally oxidized in various conditions: in pure steam or in a 50-50mol% air-steam mix, at several temperatures, and for different durations. The main thermal effects on kinetics and the high impact of air on the cladding degradation are confirmed by experimental results. Second, pioneering porosimetry measurements by Hg intrusion were realized on such corroded cladding samples. In both atmospheres, it is pointed out that 1250 K lead to particularly porous oxide layers, especially due to strong 'breakaway'effects. Moreover, it is confirmed that the presence of air strongly enhances the oxide cracking. Finally, it is observed that in all conditions, the porous volume fraction of ZirloTM claddings continuously rises during their corrosion process.

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