EFFECT OF HIGH FLUENCES ON THE EMBRITTLEMENT OF LOW COPPER VVER 440 SURVEILLANCE SAMPLES

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An atom probe tomography microstructural characterization has been performed on low (0.06 at. %) copper surveillance samples from a VVER 440 reactor that were exposed to high fluences in order to evaluate the susceptibility of these pressure vessel steels to embrittlement. The 15Kh2MFAA base and 10KhMFT weld specimens were each examined in three conditions: unirradiated, thermally aged (10 and 5 years, respectively at 295 °C) and neutron irradiated at 275°C to fluences of 1 x 10^{25} m^{-2} and 5 x 10^{24} m^{-2}, E > 0.5 MeV, respectively. The results from Charpy V-notch tests, and the measured ultimate and yield strengths were similar for both unirradiated and thermally aged materials. However after neutron irradiation, significant shifts (>100°C) in the ductile-to-brittle transition temperatures and increases in the yield and ultimate tensile strengths were found in both the base and weld materials. Three-dimensional atom probe compositional measurements revealed enrichments of manganese, silicon, phosphorus, copper and carbon at dislocations in neutron irradiated materials. Some spherical features were also observed which could arise from solute segregation to small dislocation loops or other small defects, such as vacancy clusters or nanovoids or through the clustering or precipitation of copper atoms and these embryos then attract or act as a sink for the other solutes or vacancies.

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