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Controlling RPV Embrittlement through Wet Annealing in Support of Life Extension

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Abstract : As a main barrier against radioactivity outlet reactor pressure vessel (RPV) is a key component in terms of NPP safety. Therefore, present-day demands in RPV reliability enhance have to be met by all possible actions for RPV in-service embrittlement mitigation. Annealing treatment is known to be the effective measure to restore the RPV metal properties deteriorated by neutron irradiation. There are two approaches to annealing. The first one is so-called ‘dry’ high temperature (~475°C) annealing. It allows obtaining practically complete recovery, but requires the removal of the reactor core and internals. External heat source (furnace) is required to carry out RPV heat treatment. The alternative approach is to anneal RPV at a maximum coolant temperature which can be obtained using the reactor core or primary circuit pumps while operating within the RPV design limits. This low temperature «wet» annealing, although it cannot be expected to produce complete recovery, is more attractive from the practical point of view especially in cases when the removal of the internals is impossible. The first RPV «wet» annealing was done using nuclear heat (US Army SM-1A reactor). The second one was done by means of primary pumps heat (Belgian BR-3 reactor). As a rule, there is no recovery effect up to annealing and irradiation temperature difference of 70°C. It is known, however, that along with radiation embrittlement neutron irradiation may mitigate the radiation damage in metals. Therefore, we have tried to test the possibility to use the effect of radiation-induced ductilization in ‘wet’ annealing technology by means of nuclear heat utilization as heat and neutron irradiation sources at once. In support of the above-mentioned conception the 3-year duration reactor experiment on 15Cr3NiMoV type steel with preliminary irradiation at operating PWR at 270°C and following extra irradiation (87 h at 330°C) at IR-8 test reactor was fulfilled. In fact, embrittlement was partly suppressed up to value equivalent to 1,5 fold neutron fluence decrease. The degree of recovery in case of radiation enhanced annealing is equal to 27% whereas furnace annealing results in zero effect under existing conditions. Mechanism of the radiation-induced damage mitigation is proposed. It is hoped that «wet » annealing technology will help provide a better management of the RPV degradation as a factor affecting the lifetime of nuclear power plants which, together with associated management methods, will help facilitate safe and economic long-term operation of PWRs.

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