IAEA TECHNICAL MEETING ON DEGRADATION OF PRIMARY SYSTEM COMPONENTS OF WATER COOLED NUCLEAR POWER PLANTS: CURRENT ISSUES AND FUTURE CHALLENGES

Thermal Annealing of Reactor Pressure Vessels Is a Needed Mitigation Option

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Thermal annealing of commercial nuclear reactor pressure vessels has been performed on a routine basis for Russian-design VVER-440s. However, this mitigative approach to restore fracture toughness properties back close to their original starting state has not been performed outside of these Russian-design VVER-440s. Back in the 1990s, the Palisades nuclear power plant reactor pressure vessel was about to reach a perceived embrittlement limit related to pressurized thermal shock (PTS) and was scheduled to be thermally annealed. Preparatory studies by the US Department of Energy (DOE) and the utility industry led to a feasibility demonstration at the cancelled, mostly fabricated Marble Hill plant in Kentucky which proved to be highly successful. Additionally, the US Nuclear Regulatory Commission (NRC) developed a thermal anneal rule in the Code of federal Regulations, 10 CFR 50.66, as well as Regulatory Guide 1.161 to better define what the NRC expected to see if the Palisades utility moved forward with the thermal anneal. Additionally, the ASME Section XI Code body developed Code Case N-557 to define a maximum temperature limit for a thermal anneal which effectively limited the stresses and strains in the shell courses and nozzle regions of the vessel during a thermal anneal. ASTM already had a guide on thermal annealing (ASTM E 509) which also was updated to provide further guidance on the need for a supplemental surveillance program following a thermal anneal to measure the re-embrittlement behavior of the critical vessel materials. The Palisades vessel thermal anneal was never undertaken due to revised evaluations, but after all of these preparatory steps, the planned thermal anneal was expected to be a success and would be approved by the US NRC. Since that time a handful of nuclear reactor vessel have been judged to be close to PTS limits, but generally other evaluations or measures have made which allow the plants to safely continue to operate. However, as 80 or more years of operation are being considered, the thermal anneal option needs to be clearly available. Even when there is not a strong technical reason for thermal annealing for these longer terms of operation, the political situation within a country may make it prudent to seriously consider thermal annealing since it can produce a huge recovery of the fracture toughness properties of the highly irradiated reactor pressure vessel materials of concern. This paper reviews the past history and the general technology for thermal annealing and presents the argument that thermal annealing is a needed mitigative measure that should be seriously considered for extended operating life of non-Russian design reactor pressure vessels throughout the world.