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HEAVY SECTION STEEL TECHNOLOGY PROGRAM
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EVALUATION BY LINEAR ELASTIC FRACTURE MECHANICS OF RADIATI N DAMAGE TO PRESSURE VESSEL STEELS*

by

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Because the microstructure and mechanical properties of the interior of the 12-inch-thick plate (1/4 and 1/2 thickness) were essentially the same and each location was isolated in a given capsule, the influence of the flux level can be evaluated. Capsule No. 5 contained specimens from the quarter thickness location of the 12-inch-thick plate and was exposed to a fluence of approximately 4×10^{19} n/cm^2 while Capsule No. 6 contained specimens from the center thickness and was exposed to a fluence of 1.3×10^{19} n/cm^2. When the 30 ft-lb transition temperature-shift and K_{Ic} values after irradiation are compared, it is evident that 1.3×10^{19} n/cm^2 does not saturate the material with regard to irradiation damage.

The final objective of the program was to assess the influence of applied tensile stress during irradiation on the fracture toughness of the various pressure vessel materials. The data for the pre-stressed fracture mechanics specimens are grouped together in Table 41. From Tables 40 and 41 it would appear that an applied tensile stress of 26,700 psi during irradiation neither enhances nor reduces the radiation embrittlement sensitivity of the pressure vessel steels studied. This is consistent with other investigators' data based on Charpy V-notch specimens subjected to an applied tensile stress during irradiation. The one exception in this investigation was the European forging grade steel. This material exhibited a K_{Ic} value much higher than expected and resulted in an invalid data point. However, if the plastic zone size during the prestressing is taken into consideration, it can be concluded that the apparent erroneous K_{Ic} value was a result of too large a plastic zone size at the crack tip during prestressing, rather than the influence of the applied stress during irradiation.

6. CONCLUSIONS

1. Weldment material of A 533, grade B, class 1 steel produced by the submerged arc process exibits a higher fracture toughness (K_{Ic}) at a given temperature then base plate material of A 533, grade B, class 1 steel when evaluated prior to irradiation.

2. European 1.2 MD07 forging grade steel, while exhibiting a somewhat lower resistance to fracture then the weldment material of A 533,

grade B, class 1 steel, exhibits a higher fracture toughness (K_{Ic}) at a given temperature than base plate material of A 533, grade B, class 1 steel when evaluated prior to irradiation.

3. Weldment material of A 533, grade B, class 1 steel produced by the submerged arc process was relatively sensitive to neutron exposure. The 12-inch-thick plate (HSST Plate No.02) of A 533, grade B, class 1 steel and the European 1.2 MD07 forging grade steel were relatively insensitive to neutron exposure. The material from the 8-inch-thick plate of A 533, grade B, class 1 steel fell in between the two extremes of sensitivity.

4. After an exposure to a fluence of $1\text{-}5 \times 10^{19}$ n/cm^2, the shift in the K_{Ic} versus temperature curve was always less than 30 ft-lb transition temperature shift.

5. The material at the top and bottom surfaces of the 12-inch-thick plate (HSST Plate No. 2) of A 533, grade B, class 1 steel was considerably tougher than the interior of the plate. It was concluded that this phenomenon is due to the quench and prolonged temper treatment that the two surfaces underwent during the quenching of the 12-inch-thick plate.

6. An applied tensile stress during irradiation neither enhanced nor reduced the radiation embrittlement sensitivity of the pressure vessel steels studied.

7. EXAMPLE PROBLEM

The criterion now used by Westinghouse for safe operation of Reactor Pressure Vessels is that described by Porse[22], which is based on ductile-brittle transition temperature concepts. The transition temperature approach to design, limits the acceptable stresses in the vessel when the vessel temperature is below the design transition temperature (DTT). The design transition temperature is defined as NDTT +60°F and is considered to be the crack arrest temperature (CAT) for a stress equal to the yield stress of the material. The allowable hoop stress is temperature-dependent, and is defined

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