EMBRITTLEMENT OF REDUCED-ACTIVATION FERRITIC/MARTENSITIC STEELS IRRADIATED IN HFIR AT 300 AND 400°C—R. L. Klueh, M. A. Sokolov (Oak Ridge National Laboratory), K. Shiba, and Y. Miwa (Japan Atomic Research Institute)

Extended Abstract*

Miniature Charpy and tensile specimens of the following reduced-activation ferritic/martensitic steels and one modified (nickel-doped) steel were irradiated in the High Flux Isotope Reactor (HFIR) to a maximum dose of ≈11 dpa: a 5-ton heat of standard F82H (F82H-Std), nominally Fe-7.5Cr-2W-0.2V-0.04Ta-0.0034B-0.1C (compositions in wt. %); a 5-ton heat of the IEA modified F82H (F82H-Mod), nominally Fe-7.5Cr-2W-0.15V-0.02Ta-0.1C; an experimental 400-g heat of ORNL 9Cr-2WVTa, nominally 9Cr-2W-0.25V-0.07Ta-0.1C; and an experimental 400-g heat of the 9Cr-2WVTa modified by the addition of 2% Ni (9Cr-2WVTa-2Ni). The two F82H steels were irradiated at 300 and 400°C, and the 9Cr-2WVTa and 9Cr-2WVTa-2Ni steels were irradiated at 400°C.

An objective of these tests was to determine if there is a helium effect on impact behavior over and above that due to irradiation hardening. Nickel was added to the 9Cr-2WVTa to produce helium from (n,α) reactions of ^{58}Ni with thermal neutrons in the HFIR spectrum. For the maximum dose of ≈11 dpa, ≈115 appm He formed in the 9Cr-2WVTa-2Ni. The F82H-Std contained ≈40 appm He after ≈11 dpa. For this steel, helium was produced from (n,α) reactions of thermal neutrons with the 34 wppm B in this steel. The F82H-Mod and the 9Cr-2WVTa steels contained ≈5 appm He after irradiation to 11 dpa.

All of the steels hardened during irradiation at 300 and 400°C, as determined by the increase in strength. The F82H-Mod showed a slightly larger increase than the F82H-Std, although the F82H-Std was somewhat stronger than the F82H-Mod at 300°C before irradiation. Before irradiation, the strength at 400°C of the 9Cr-2WVTa and 9Cr-2WVTa-2Ni were similar. Irradiation caused a similar increase in the yield stress of 9Cr-2WVTa-2Ni and 9Cr-2WVTa steels. Ductilities of the two steels before and after irradiation were also similar.

Irradiation embrittlement was observed for all of the steels as a shift in ductile-brittle transition temperature (DBTT) and a decrease in upper shelf energy (USE) in the Charpy tests. The largest shift in DBTT (ΔDBTT) occurred for the two F82H steels irradiated at 300°C, but there was little difference in ΔDBTT of the two steels. At 400°C where all four steels were irradiated, the 9Cr-2WVTa had the smallest shift (79°C), and the F82H-Mod had the largest shift (146°C), with intermediate values for the F82H-Std (117°C) and the 9Cr-2WVTa-2Ni (133°C).

Whether helium affects the Charpy behavior of the F82H-Std relative to the F82H-Mod is unclear. If helium concentration was the only difference between the two steels, then the results indicated no helium effect. However, there are differences in composition and in grain sizes of the two steels, so the effect of helium, if any, was not discernable. The 9Cr-2WVTa-2Ni steel was irradiated to determine if there was an effect of ≈115 appm He produced from the ^{58}Ni in the steel. The ΔDBTT of the 9Cr-2WVTa-2Ni (133°C) was 68% greater than for 9Cr-2WVTa (79°C). Irradiation hardening of the steels was similar. The results were tentatively taken to be a helium effect. However, in previous work on nickel-doped modified 9Cr-1Mo and Sandvik HT9, there were indications of possible intergranular fracture on specimens tested on the lower shelf, and this led to the proposal that helium affected the fracture behavior of the steels by causing a change in fracture mode. No indication of intergranular fracture was observed on the 9Cr-2WVTa-2Ni steel.

* Extended abstract of paper submitted for publication in the *Journal of Nuclear Materials* (Proceedings of the Ninth International Conference on Fusion Reactor Materials).