Extreme Embrittlement of Austenitic Stainless Steel Irradiated to 75-81 Dpa at 335-360°C -
S. I. Porollo, A. N. Vorobjev and Yu. V. Konobeev (Institute of Physics and Power Engineering, Obninsk, Kaluga Region, Russia) and F. A. Garner (Pacific Northwest National Laboratory, Richland, WA USA)

To be presented at the 8th International Conference on Fusion Reactor materials in Sendai, Japan, Octobr 1997.

Extended Abstract

It is generally accepted that void swelling of austenitic steels ceases below some temperature in the range 340-360°C, and exhibits relatively low swelling rates up to ~400°C. This perception may not be correct at all irradiation conditions, however, since it was largely developed from data obtained at relatively high displacement rates in fast reactors whose inlet temperatures were in the range 360-370°C.

There is an expectation, however, that the swelling regime can shift to lower temperatures at lower displacement rates via the well-known "temperature shift" phenomenon. It is also known that the swelling rates at the lower end of the swelling regime increase continuously at a sluggish rate, never approaching the terminal 1%/dpa level within the duration of previous experiments.

This paper presents the results of an experiment conducted in the BN-350 fast reactor in Kazakhstan that involved the irradiation of argon-pressurized thin-walled tubes (0-200 MPa hoop stress) constructed from Fe-16Cr-15Ni-3Mo-Nb stabilized steel in contact with the sodium coolant, which enters the reactor at ~270°C. Tubes in the annealed condition reached 75 dpa at 335°C, and another set in the 20% cold-worked condition reached 81 dpa at 360°C. Upon disassembly all tubes, except those in the stress-free condition, were found to have failed in an extremely brittle fashion. The stress-free tubes exhibited diameter changes that imply swelling levels ranging from 9 to 16%. It is expected that stress-enhancement of swelling induced even larger swelling levels in the stressed tubes.

The embrittlement is explained in terms of the sensitivity of the swelling regime to displacement rate and the large, unprecedented levels of swelling reached at 335-360°C at these high neutron fluences. The failure mechanism appears to be identical to that observed at similar swelling levels in other austenitic steels irradiated in U.S. fast reactors at 400-425°C, whereby stress-concentration between voids and nickel segregation at void surfaces predisposes the steel to an epsilon martensite transformation followed by formation of alpha martensite at crack tips. The very slow strain rate inherent in such creep tests and the relatively high helium levels may also contribute to the failure.