Reassessment of void swelling rates in austenitic pressure vessel internals and structural components of other lower operating temperature devices

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Void swelling is a problem in high-flux fast reactors (e.g. EBR-II, FFTF, BN-350, BN-600) and various test reactors (e.g. HFIR, ORR), and is anticipated as a problem in lower-flux pressurized water reactors (PWRs), although to date all observed swelling in PWRS is <1% at the highest doses examined. The current AISI 304 swelling equation was derived from data collected in the EBR-II reflector and is based on the expectation that at all PWR-relevant displacement rates and temperatures the eventual post-transient swelling rate will be ~1%/dpa. It now appears that this expectation is not valid for most of the temperature (280-390°C) range and dose rate regime of PWRs.

It is now known that there is a transition between a low swelling-rate regime (~0.06-0.07%/dpa) and the high swelling rate regime that lies at ~370 ±10°C, the exact value depending on dpa rate. Since the inlet temperature of EBR-II was 370°C and FFTF was 365°C, it was impossible to observe this lower rate unless one looked very carefully at lower-flux and lower-temperature regions outside of reactor cores. If data are derived from first-generation fast reactors with lower inlet temperatures (e.g. DFR, 270°C and BOR-60, 320-330°C) then the transition between the two swelling-rate regimes can be easily observed.

This activity involved reanalysis of data sets involving 304 stainless steel components, many not previously published. Data from Russian and British variants of 300-series steels irradiated in fast reactors at lower PWR-relevant temperatures were also used to assess the generality of conclusions concerning low-temperature swelling behavior of 304 and other austenitic steels.

Although the post-transient ~1%/dpa swelling rate, sometimes referred to as a "crystal constant", eventually develops over a wide range of temperatures in 300-series austenitic steels, there appears to be another previously unrecognized, much lower swelling rate of ~0.06 to 0.07%/dpa that precedes the 1%/dpa regime. This second crystal constant rate often persists to very high doses, especially at lower irradiation temperatures characteristic of PWR internals. It therefore appears that the 1%/dpa swelling rate mandated in the current swelling correlation is not destiny and may not apply to most of the steel in PWR internals.