



Materials Research at the Halden Reactor Project – Selected Results and Plans –

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1

Materials Research at HRP: - Selected results and plans -

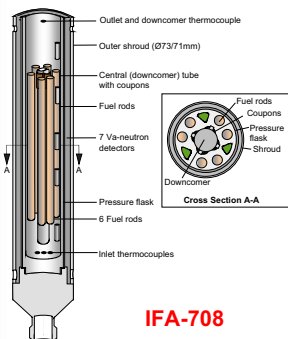
- LWR fuel cladding corrosion and hydriding testing
- Fuel assembly / structural materials creep & stress relaxation testing
- Irradiation Stress Corrosion Cracking (IASCC) testing

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2



Clad corrosion: technical approach



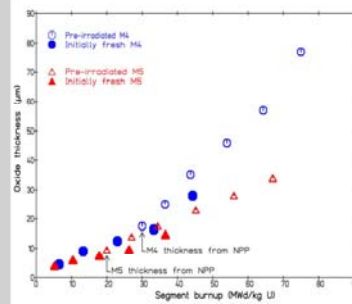
- 3 full length reference clad fuel rods
 - M5
 - Opt. ZIRLO
 - M-MDA
 - *Similar materials used in concurrent clad creep test*
- 3 segmented fuel rods each with 4 alloy variants
- Loop system used simulating “aggressive” PWR conditions
- Assessing margin for further increases in duty and Li-content for future PWR operation

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3



Clad corrosion: selected results



Clad corrosion thickness derived from eddy current measurements show that the Halden test could represent commercial PWR corrosion conditions (data from predecessor clad corrosion test IFA-638)

- 1257 full power days
- Rod average burnup 46 MWD/kg UO₂
- 6 inspections were performed
 - eddy current oxide thickness measurement
 - weight gains on coupons
 - some fuelled clad segments showed oxide layer spalling
- On-going PIE:
 - Metallography at IFE hot lab to confirm oxide thickness and measure hydrogen pick-up
 - TEM analyses by PSI to investigate microstructure at metal-oxide interface on selected test rods

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4

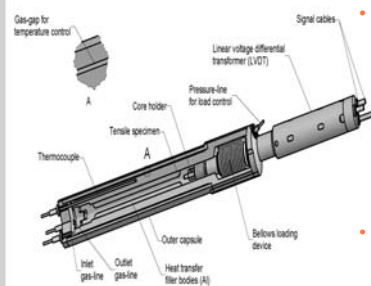


Clad corrosion: results and plans

- Operating conditions of IFA-708
 - Rod average linear heat rates 26 - 29 kW/m
 - Coolant temperature 312 - 330°C
 - Mass evaporation rate 1300 - 3000 kg/m²/h
 - Water chemistry 2.6 ppm H₂; 9.0 ppm Li; 1804 ppm B; pH₃₀₀ = 7.3
- In second year of operation. Irradiation will continue with annual interim inspections (eddy current for oxide thickness) for approx. 5 years
- Future corrosion testing - development of an in-pile corrosion detector based on Electrochemical Impedance Spectroscopy (EIS)



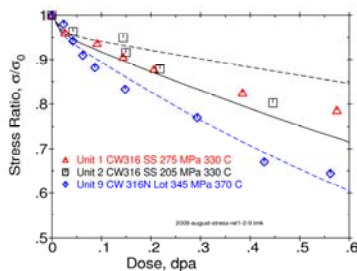
Stress relaxation: technical approach



- 30 encapsulated tensile specimens
 - 92 - 345 MPa applied with bellows (constant stress or constant displacement)
 - 290, 330, 370°C under inert gas conditions
 - LVDTs monitor sample elongation on-line
- Materials are:
 - Alloy 718
 - Stainless steels: CW 316, CW 316LN, CW 316N Lot, SA 304



Stress relaxation: selected results



- Stress relaxation data for CW 316 & CW 316N
- Results consistent with other in-pile data

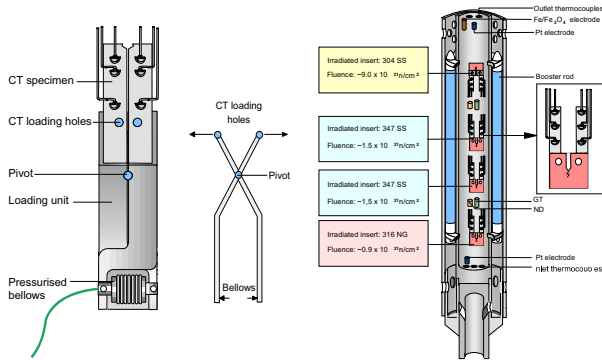


Stress relaxation: results and plans

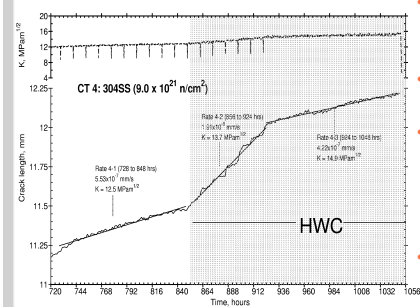
- Irradiation creep and stress relaxation data are consistent for CW 316 specimens tested under the two different modes (creep and stress relaxation)
- CW 316LN more resistant to stress relaxation than CW 316 SS
 - First ever irradiation stress relaxation test of 316LN
 - Results confirm the predicted decrease in creep rate for 316LN
 - 316LN has potential application as reactor internals structure bolts because they should retain their initial preload longer than standard CW 316
- Irradiation test at Halden is continuing and further data evaluation is in progress



IASCC: technical approach



IASCC: selected results



- 304 SS CT specimen of medium fast fluence ($9 \times 10^{21} \text{ n/cm}^2$)
- Tested in BWR loop with NWC then HWC
- Assessing addition of hydrogen as an ameliorating measure against structural material cracking rates
- Shown to be successful for this material at this fluence



IASCC: results and plans

- Generating long-term crack growth rate data from BWR & PWR structural materials
 - BWR loop tests (280-290°C, O₂ and H₂)
 - PWR loop tests (320-340°C, Li, B, H₂)
 - Materials (SS 347, 304, 316) retrieved from commercial reactors
 - Range of fluence levels (7×10^{19} to $2.5 \times 10^{22} \text{ n/cm}^2$)
- Studying effects of fluence (microstructure and mechanical properties) as well as flux on crack growth rates
- New BWR and PWR tests planned for 2009-2011

