Irradiation of Fusion Materials for ORNL (US)

Background
A representative selection of high chromium steels of fusion relevance has been irradiated in the BR2 reactor, in the framework of a collaborative project between ORNL (Oak Ridge National Laboratory, US) and SCK•CEN.

Objectives
The experiment, denominated FRISCO-F (Fusion and Reactor Materials Irradiation SCK•CEN/ORNL – Fusion materials), included tensile and miniature C(T) fracture toughness specimens of the following materials: EUROFER97, F82H, CLAM (Chinese Low Activation Material) and four ORNL developmental alloys (9Cr, 5Cr, 3Cr, 3Cr+Ta); in addition, we also irradiated samples of the well-known ferritic/martensitic steel T91, which is not relevant for fusion (its chemical composition cannot be considered reduced-activation) but is regarded as one of the reference materials for applications such as accelerated-driven systems (ADS) and future high temperature nuclear energy systems (Gen IV).

Principal results
The irradiation campaign took place during five cycles of BR2 in the period June 2005/March 2006; the nominal irradiation temperature was 300 °C.
On the basis of analytical calculations which have been verified by actual dosimetry measurements, the average fast neutron fluence (E>1 MeV) for all irradiated specimens is 8.02×10^{20} n/cm², corresponding to 1.20 dpa.

Future work
Post Irradiation Examination of the irradiated specimens, which will be shared between ORNL and SCK•CEN, is currently under negotiation.

Main reference
E. Lucon, *Irradiation of Fusion Materials in the BR2 Reactor: the FRISCO-F Experiment*, External Report ER-12, May 2006; also published in the Semi-Annual DOE Newsletter, July 2006.

Irradiation of RPV Steels for ORNL (US)

Background
The primary goal of the Heavy-Section Steel Irradiation (HSSI) Program is to provide a thorough, quantitative assessment of the effects of neutron irradiation on the material behaviour, and in particular the fracture toughness properties, of typical pressure vessel steels as they relate to light-water RPV integrity. The program includes studies of the effects of irradiation on the degradation of mechanical and fracture properties of vessel materials augmented by enhanced examinations and modelling of the accompanying microstructural changes. Effects of: specimen size; material chemistry; product form and microstructure; irradiation fluence, flux, temperature, and spectrum; and post-irradiation mitigation are being examined on a wide range of fracture properties. Results from the HSSI studies are incorporated into codes and standards directly applicable to resolving major regulatory issues that involve RPV irradiation embrittlement such as pressurized-thermal shock, operating pressure-temperature limits, low-temperature over pressurization, and the specialized problems associated with low upper-shelf welds.

Objectives
The HSSI Program, funded by the U.S. Nuclear Regulatory Commission (USNRC) at Oak Ridge National Laboratory (ORNL), has contracted with SCK•CEN on a project aimed at investigating the effects of relatively high, fast neutron flux on RPV steels.

Principal results
The irradiation campaign, denominated FRISCO-R (Fusion and Reactor Materials Irradiation SCK•CEN/ORNL – RPV steels), was performed during the last three BR2 cycles of 2005 in the period July/December.
All specimens, with the exception mentioned below, have been irradiated in the in-pile section 3 (IPS-3) of BR2 during cycles 04/2005 and 05/2005, at an equivalent fission flux of approximately 2×10^{13} n/(cm²·s), E>1 MeV. Samples from Palisades Weld were also irradiated in the in-pile section 2 (IPS-2) of BR2 during cycle 03/2005, at an equivalent fission flux of approximately 5×10^{13} n/(cm²·s), E>1 MeV.

Future work
The irradiated specimens are presently kept in storage at SCK•CEN for future investigations, both mechanical (tensile and fracture toughness) and microstructural (small-angle neutron scattering and atom probe analysis). Negotiations are in progress with both ORNL and US-NRC (Nuclear Regulatory Committee).

Main reference
E. Lucon, *Irradiation of Heavy-Section Steel Irradiation (HSSI) Program Specimens in the BR2 Reactor: the FRISCO-R Experiment*, Restricted SCK•CEN Report R-4325, Ap

Irradiation of RPV Steels for CRIEPI (Japan)

Background
Neutron irradiation embrittlement of RPV steels at high fluences is a common concern worldwide for the light water reactors, especially in countries where long term operation of such reactors is planned. Irradiation in test reactors is an important tool to study embrittlement at high fluences, although full understanding and consensus has not yet been reached on the effect of the difference in neutron flux (dose rate) between commercial and test reactors.

Objectives
The objective of the collaborative project between CRIEPI and SCK•CEN denominated IRPEC (Irradiation of RPV StEels for CRIEPI) is the irradiation in BR2 of a low Cu reactor pressure vessel (RPV) steel up to high fluences.

Principal results
Within the IRPEC project, a commercial Japanese RPV material with low copper concentration has been irradiated in the BR2 test reactor up to two values of fast neutron fluence; data from the lower fluence will be compared with available commercial reactor surveillance data of the same material, while data from the higher fluence will be used to investigate the embrittlement at the end-of-life conditions for the material.
The samples have been irradiated at 288 ± 5 °C in the in-pile section 3 (IPS-3) of BR2 during two cycles (03/2006 and 04/2006) up to the following target values of fast neutron fluence: 1×10^{20} n/cm² and 6.0×10^{19} n/cm².
All the specimens have been provided by CRIEPI. Most of the irradiated samples (12 tensile and 24 Charpy specimens) are made of a Japanese RPV steel of the SA533B Cl.1 type denominated SD1; 8 additional Charpy specimens from four RPV steels denominated EP1, EP2, EP3 and EF1 have also been irradiated.

Future work
As part of the IRPEC project, mechanical tests (tensile and Charpy impact) on the SD1 material have already been performed, both in the unirradiated and irradiated conditions. Further fracture toughness tests on reconstituted precracked Charpy (PCCv) specimens are planned for 2007, and are currently under negotiation.

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Main references
E. Lucon and M. Scibetta, *Project IRPEC: Neutron Irradiation Embrittlement of a Low Cu Reactor Pressure Vessel Material at High Fluences; Part 1 – Irradiation in BR2 and characterization of the reference condition*, Restricted SCK•CEN Report R-4383, October 2006.
E. Lucon and M. Scibetta, *Project IRPEC: Neutron Irradiation Embrittlement of a Low Cu Reactor Pressure Vessel Material at High Fluences; Part 2 – Dosimetry results and characterization of the irradiated conditions*, Restricted SCK•CEN Report R-4416, January 2007.