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FP7 project LONGLIFE: Treatment of long-term irradiation embrittlement effects in RPV safety assessment

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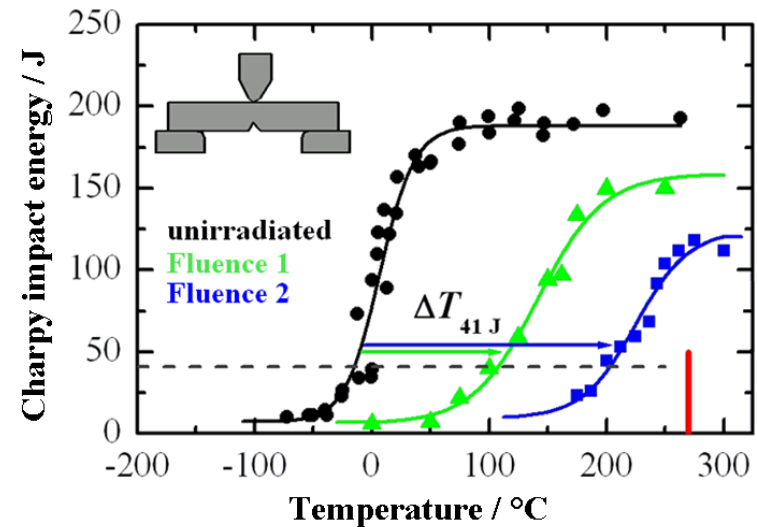
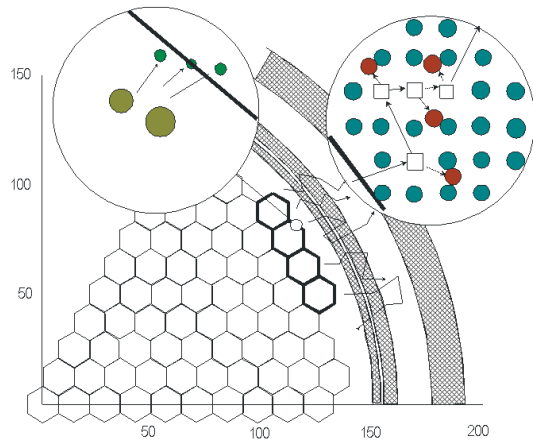
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Project general information

- **LONGLIFE: Treatment of Long Term Irradiation Embrittlement Effects in RPV Safety Assessment**
- **Collaborative Project: EC grant ~2.6 M€, Project number 249360**
- **NULIFE umbrella project**
- **Project was launched on 01. Feb 2010 (duration: 48 months)**



- Increasing age of European fleet and envisaged lifetime extensions up to 80 a require an efficient and reliable ageing management
- Accurate prediction and surveillance of RPV neutron irradiation embrittlement is a key issue
- LONGLIFE has been launched in February 2010 (EURATOM FP7, EC grant 2.6 M€)

- **Improved knowledge on LTO specific irradiation phenomena in RPV steels relevant for European reactors**
- **Assessment and proposed improvements of prediction tools, codes and standards**
- **Elaboration of best practice guidelines on irradiation embrittlement surveillance under LTO conditions**

(LTO = long term operation)

Addressed issues relevant for LTO

- **High fluence behaviour (saturation?)**
- **Flux effect**
- **Late blooming effect (LBE) in low Cu materials**
- **Effect of Ni and Mn in medium or high Cu materials**
- **P-Segregation / intergranular fracture / NHE**

16 partners from 9 countries

- **HZDR (Coordination)**
- **AREVA (WP7-Leader)**
- **SERCO (WP5-Leader)**
- **MTA EK (AEKI) (WP2-Leader)**
- **NRI (WP4-Leader, WP8-Leader)**
- **CIEMAT (WP3-Leader)**
- **TECNATOM (WP6-Leader)**
- **SCK-CEN**
- **CEA**
- **EdF**
- **CNRS – Uni Rouen**
- **VTT**
- **Ringhals**
- **Rolls-Royce**
- **Uni Oxford**
- **JRC Petten**

Associated Russian partner: PROMETHEY
CooA signed

Workpackages

- **WP1: Management**
- **WP2: LTO RPV conditions and available data for LWRs**
- **WP3: Microstructure**
- **WP4: Mechanical properties and testing**
- **WP5: Materials assessment and applications**
- **WP6: Training and dissemination of results**
- **WP7: Surveillance guidelines**
- **WP8: Cooperation with Russia**

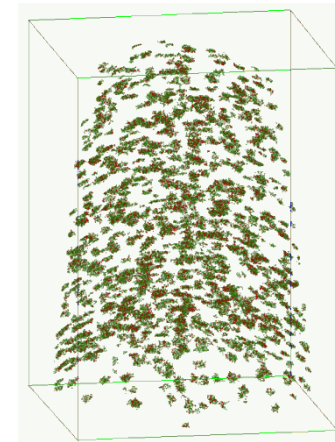
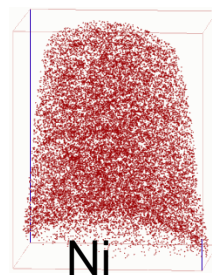
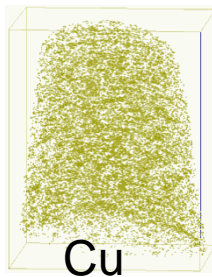
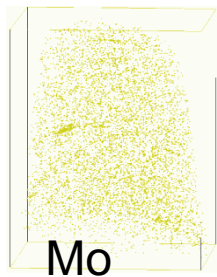
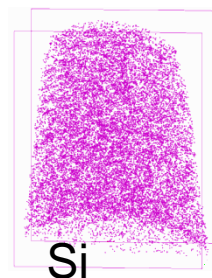
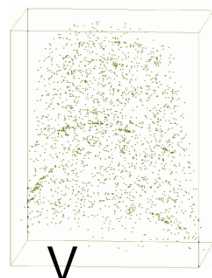
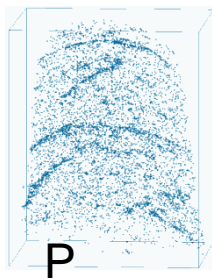
WP2: LTO RPV conditions and available data for LWRs

- **WP-Leader: MTA EK (AEKI)**
- **Objectives**
 - Determine LTO irradiation conditions of the different types LWR reactors
 - Collecting existing irradiation embrittlement data relevant for LTO
 - Identification of missing data for LTO

- WP-Leader: CIEMAT

- Objectives

- Generation of microstructural data of highly irradiated RPV materials
- Effect of Cu, P, Ni and Mn on the evolution of microstructure under irradiation
- Flux effect on the evolution of microstructure
- Correlation of microstructure and mechanical properties



100x100x140 nm³

Mn/Ni/Si/Cu clusters in
1.7%-Ni-Weld ANP-6
irradiated to 5.22×10^{19} cm⁻²

WP4: Mechanical properties and testing

- **WP-Leader: NRI (with assistance of ANP for Western LWRs)**
- **Objectives**
 - Generation of a database for LTO relevant fluences in terms of hardness, tensile curves, DBTT shift and FT (T_0)
 - Perform additional tests where necessary
 - Flux and saturation effects on mechanical properties
 - Effect of Cu, P, Ni and Mn on the mechanical properties under irradiation

WP5: Materials assessment and applications

- **WP-Leader: SERCO (with assistance of HAS CER (AEKI) for WWERs)**
- **Objectives**
 - Critical evaluation of internationally-accepted procedures for predicting the effects of irradiation embrittlement on RPV steels (trend curves)
 - Contribute to the materials knowledge base needed to ensure the safe LTO of existing European LWRs and Generation-III reactors under construction
 - Support efforts towards harmonisation of European procedures for RPV safety assessment and plant lifetime extension

WP6: Training and dissemination of results

- **WP-Leader: TECNATOM**

- **Objectives**

- Transmission and preserving the knowledge by educating and training professionals and young researchers
- Establish a sustainable exchange of information on LTO within NUGENIA
- Producing relevant information for RPV licensing activities by dissemination of the project results
- Develop and maintain the project website

WP7: Surveillance guidelines

- **WP-Leader: ANP-G (with assistance of NRI for WWERs)**
- **Objectives:**
 - Review of surveillance standards
 - Transferability of results from irradiation in high flux MTRs to LWR conditions
 - Possibilities to extend standard RPV surveillance programs towards LTO
 - Benefits of mitigation measures (flux reduction, annealing)
 - Surveillance guidelines for LTO (End product of LONGLIFE)

- **WP-Leader: NRI**

- **Objectives**

- Comparison of Russian and European approaches for the treatment of LTO embrittlement effects in RPV safety assessment
- Comparison of the Master curve concept and the Unified curve concept for highly irradiated RPV steels
- To enlarge the knowledge base on LTO irradiation effects by a synergistic use of Russian and European data and procedures

Microstructure

- TEM
- TEM deformed
- APFIM
- SANS
- SEM
- AES
- PAS

Mechanics

- Re-evaluation of data
- FT tests
- Tensile
- Charpy impact
- Hardness

Samples

- Preparation
- (Further irradiation)
- Materials procurement
- Transports

Selected materials – Experimental matrix

ANP-2 P60	WM S3NiMo1	MTR	AP, SANS, TEM FT	Representative Western LWR
ANP-6 / RAB1	WM S3NiMo	MTR	AP, SANS, TEM, PAS	
ANP-5	WM NiCrMo1	MTR (evidence for flux effect)	SANS, PAS	
ANP-4 P60	BM 22NiMoCr3-7	MTR	SANS, TEM	
SCK-6	BM 22NiMoCr3-7	MTR	SANS, TEM, IF, PAS Tensile	
SCK-EDF-1	BM 16MND5	Surveillance + decomm. (Chooz A)	AP, SANS, TEM	
EDF-2 P60	BM 16MND5	Surveillance	AP, SANS, TEM	
EDF-3 P60	WM 16MND5	Surveillance	AP, TEM	
FZD-1a	BM A533B high P (JPB)	MTR (evidence for LBE at $T_{irr}=255^{\circ}C$)	AP, SANS, TEM, AES Tensile	Western LWR Special Effects
FZD-1b	BM A533B low P (JPC)	MTR (evidence for LBE at $T_{irr}=255^{\circ}C$)	AP, SANS, TEM, AES Tensile	
FZD-2	WM 10KhMFT	Decomm. (Greifswald 4)	SANS, AES FT, SPT, Tensile, HV	VVER-440/230
VTT-1	WM 10KhMFT	Surveillance	SANS, TEM FT	
AEK-1	BM 15Kh2MFA	MTR Decomm. (Greifswald 8, unirradiated)	AP, SANS, TEM FT, HV	VVER-440/213
NRI-6	BM+WM 15Kh2MFA	Surveillance	TEM	
NRI-1	WM 5Kh2NMFAA	MTR	AP, TEM Impact, Tensile, HV	VVER-1000

Range of chemical compositions

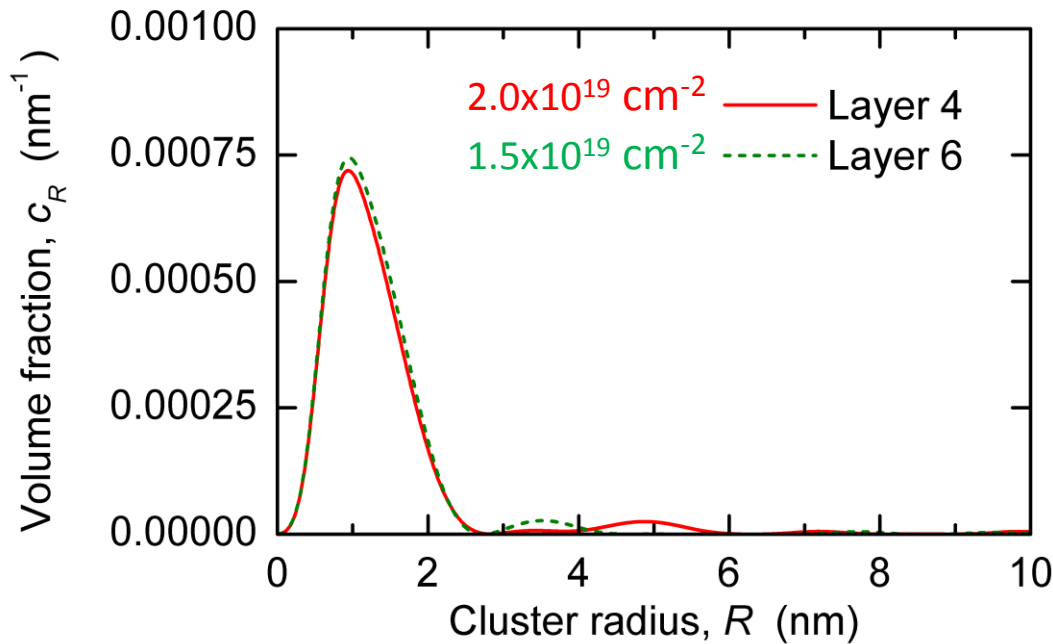
	Cu	Ni	Mn	Si	P
Min	0.01 (FZD-1a,b)	0.04 (AEK-1)	0.44 (AEK-1)	0.14 (AEK-1)	0.006 (SCK-6)
Max	0.22 (ANP-5)	1.70 (ANP-6)	1.45 (FZD-1b)	0.35 (EDF-3)	0.038 (VTT-1)

WP2: LTO Boundary Conditions

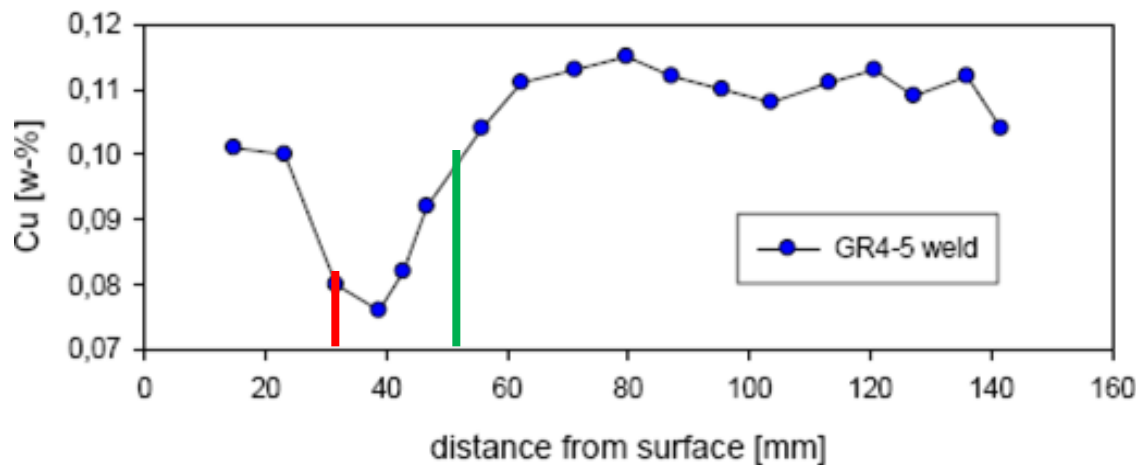
	WWER-440 V-213	KONVOI	BWR
Flux [n/cm ² s] E > 1MeV	2.1 · 10 ¹¹	2 · 10 ⁹	1.2 · 10 ⁹
Fluence [n/cm ²] E > 1MeV 80 a operation	5.2 · 10 ²⁰	5 · 10 ¹⁸	< 3 · 10 ¹⁸
T _k / RT _{NDT} [°C] 80 a operation	< 140 (T _k)	< 40 (RT _{NDT})	< 40 (RT _{NDT})

Source: Gillemot et al. D2.1

WP3: SANS results on VVER-440 weld (Greifswald 4)



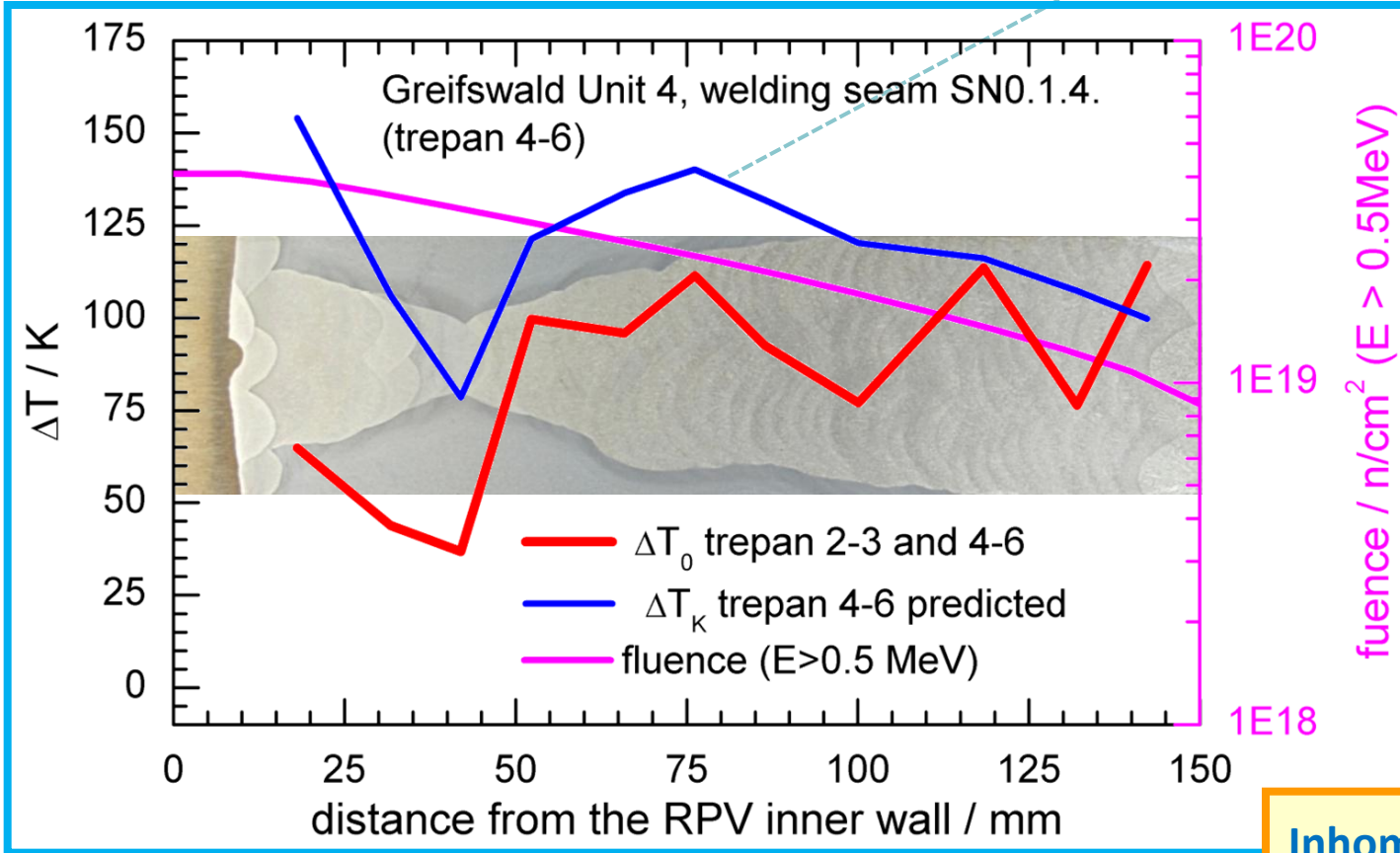
Ulbricht A et al., J. Nucl. Mater. 416 (2011)



Viehrig HW et al., Int. J. Pres. Vessel Piping 89 (2012) 129-136

WP4: FT measurements on material FZD-2 completed

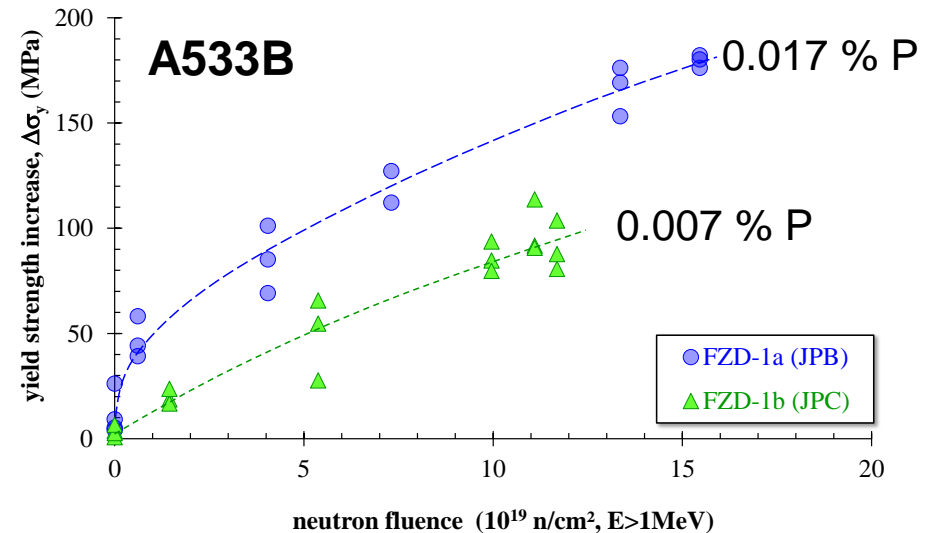
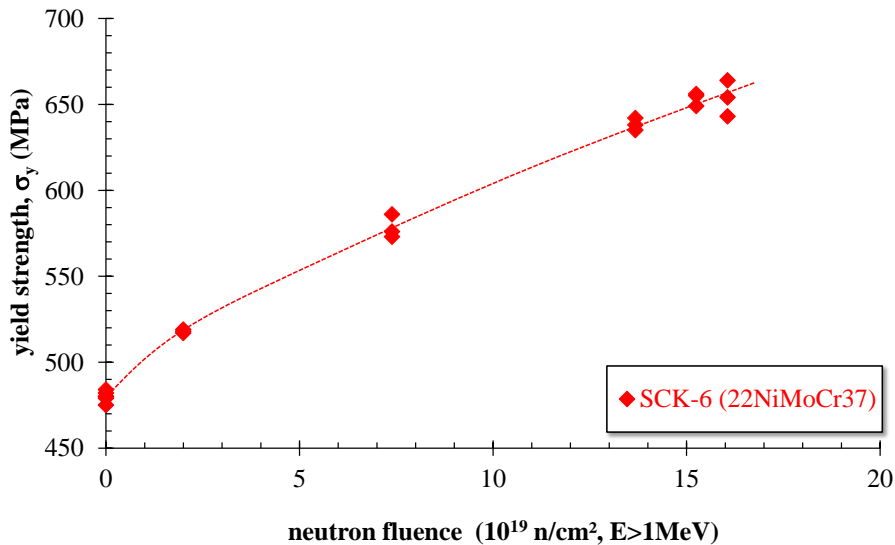
$$\Delta T_k = 800 \cdot (P + 0.07 \text{ Cu}) \cdot \sqrt[3]{F_n}$$



Inhomogeneities in the multi-layer weld dominate over irradiation effects

Viehrig HW et al., *Int. J. Pres. Vessel Piping* 89 (2012) 129-136

WP4: Mechanical testing of highly irradiated materials

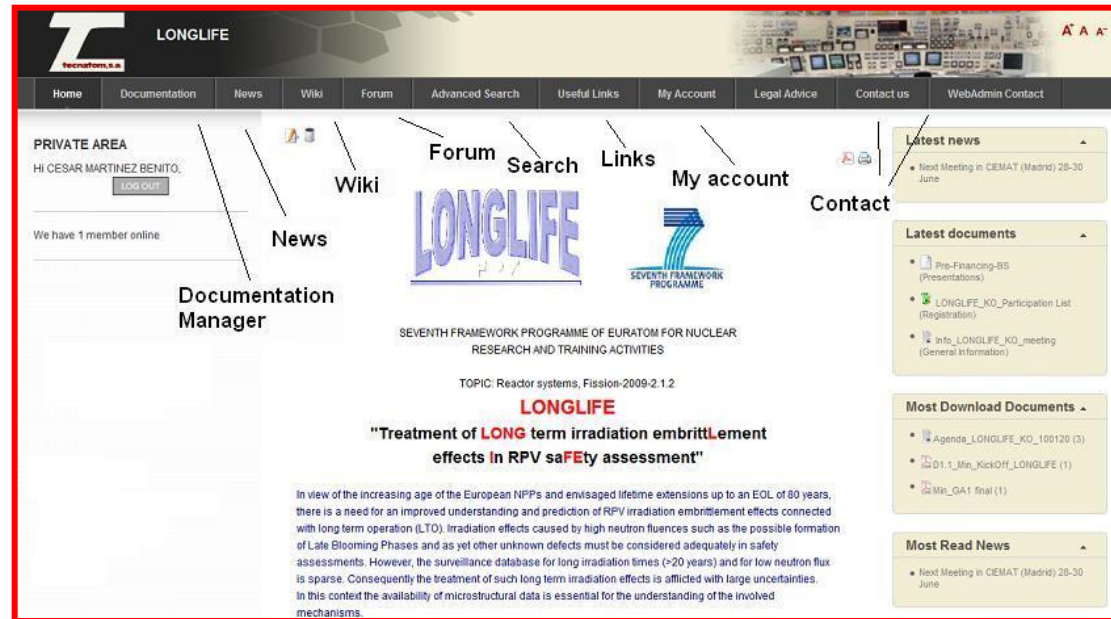


- Here: no Late Blooming Effects at LTO fluences (290 °C irradiation)
- For lower irradiation temperature (255 °C) and neutron flux, LBE has been reported for FZD-1a and FZD-1b
- Difference between JPB and JPC indicates P-Effect

- **Training**

- CAPTURE tutorial / IAEA technical meeting in Znojmo Oct 2010 (2 LONGLIFE grants)
- Oct 2011: APT school Rouen (LONGLIFE support of young scientists); special nuclear session dedicated to LTO phenomena in RPV steels

- **Website operates well**



The screenshot shows the LONGLIFE website interface. At the top, there is a navigation menu with links: Home, Documentation, News, Wiki, Forum, Advanced Search, Useful Links, My Account, Legal Advice, Contact us, and WebAdmin Contact. Below the menu, the main content area features a large 'LONGLIFE' logo and a title: 'SEVENTH FRAMEWORK PROGRAMME OF EURATOM FOR NUCLEAR RESEARCH AND TRAINING ACTIVITIES'. The topic is 'Reactor systems, Fission-2009-2.1.2'. The main heading is '"Treatment of LONG term irradiation embrittlement effects in RPV safety assessment"'. Below this, there is a paragraph of text starting with 'In view of the increasing age of the European NPPs...'. On the right side, there are three sidebar sections: 'Latest news' (with a link to 'Next Meeting in CEMAT (Madrid) 28-30 June'), 'Latest documents' (with links to 'Pre-Financing-BS (Presentations)', 'LONGLIFE_KO_Participation List (Registration)', and 'Info_LONGLIFE_KO_meeting (General Information)'), and 'Most Download Documents' (with links to 'Agenda_LONGLIFE_KO_100120 (3)', 'D1_1_Min_KickOff_LONGLIFE (1)', and 'MI_GA1 final (1)'). At the bottom right, there is a 'Most Read News' section with a link to 'Next Meeting in CEMAT (Madrid) 28-30 June'. Annotations with arrows point to various elements: 'Forum', 'Search', 'Links', 'My account', 'Contact', 'Wiki', 'News', and 'Documentation Manager'.

Soteria

Soteria was the Greek goddess of Safety

1st
announcement

Training Symposium on
Irradiation Effects in
Structural Materials for
Nuclear Reactors

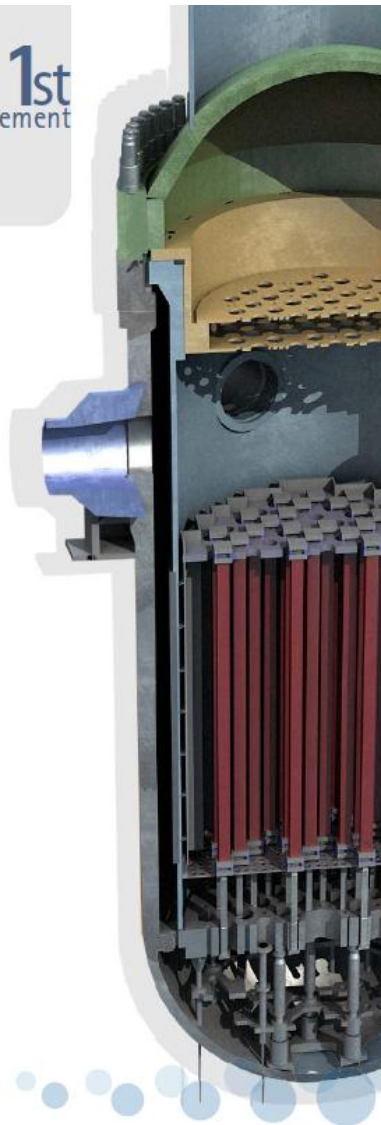
Addressed to young scientists
and engineers

September 17-21, 2012

Seville

University of Seville
School of Architecture

50
1960-2011
ETS
SEVILLA



- **Main Topics**

- Overview of NPP technologies
- Long term operation
- Effects of irradiation on reactor materials

- **Registration Deadline:
June 15, 2012**

