Investigation of Observed Peaking in Nuclear Parameters at Steel/Water Interfaces

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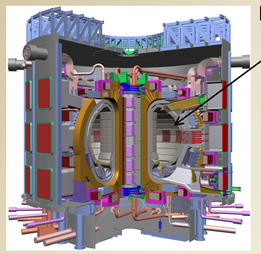
Introduction

- Detailed mapping of nuclear radiation parameters is important in designing ITER FWS modules
- Previous work revealed important heterogeneity effects when analyzing FWS Module 13 with CAD based DAG-MCNP
- Nuclear heating and He production peaked in the steel directly adjacent to water regions
- In this work, additional analysis is performed on a simplified model to understand the peaking near SS/Water interfaces
- The DANTSYS and MCNPX transport codes and ALARA activation code was used

ITER FWS Module 13 Nuclear Parameters



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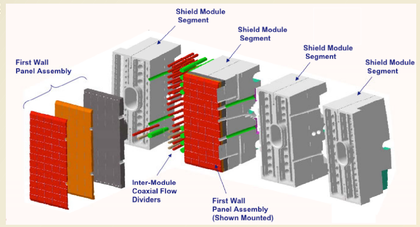
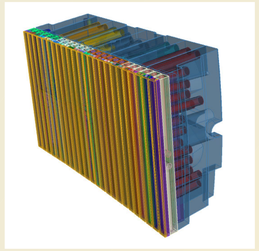
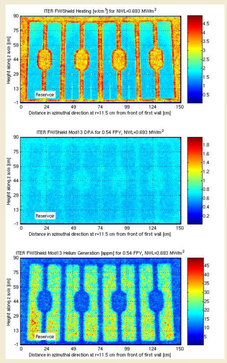


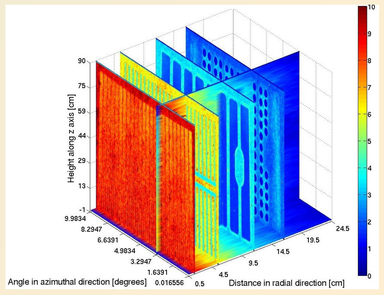
Elements of the FWS Module



Module 13 CAD model used in hybrid 1-D/3-D analysis



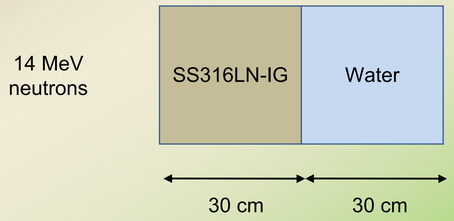
Nuclear heating, dpa, He production at 11.5 cm depth in Module 13



3-D Visualization of nuclear heating in Module 13

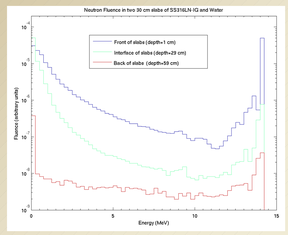
- Nuclear heating and He production peak near SS/Water Interfaces in Module 13

Simplified Model used to Examine Peaking at Steel/Water Interfaces

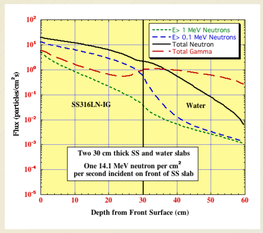


- DANTSYS and Native MCNPX used for determining nuclear parameters
- SS316LN-IG composition includes many minor elements and impurities

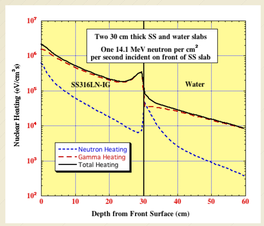
Assessment of Peaking in Nuclear Heating at Steel/Water Interfaces



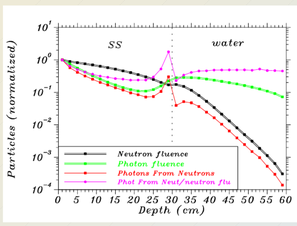
Neutron flux at 3 depths (front of SS, interface, back of water)



Neutron and photon flux versus depth from DANTSYS

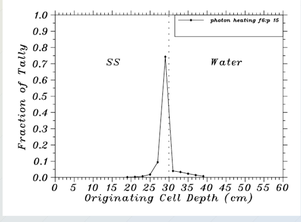


Nuclear heating versus depth from DANTSYS



Spatial variation of photon production from neutrons

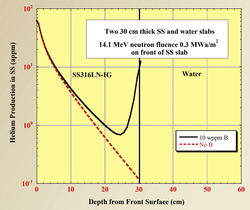
Flag and Tag "tally of interest" in MCNPX:
- The "tally of interest" is the photon heating in the last 2 cm of SS just before the water
- 90% of the scoring histories were in the water at some point (either as n or g)
- 75% of the photons that contribute to the "tally of interest" originated in the SS just before the interface



Location of origin of scoring photons for "tally of interest"

- The peak in nuclear heating in the SS near the water interface is due to the water softening the neutron spectrum which allows more photons to be produced in the SS

Assessment of Peaking in He Production at Steel/Water Interfaces

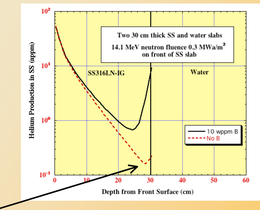


He production in SS versus depth from DANTSYS

B-10(n,α) cross section

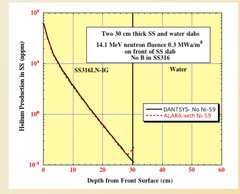
- The 10 wppm B in the SS316LN-IG combined with the softer neutron spectrum near the water causes part of the He production peaking

- Low energy neutrons also produce He through a two step neutron reaction: $^{58}Ni(n,\gamma)$-$^{59}Ni(n,\alpha)$
- ALARA activation calculations performed to investigate effect using neutron flux from DANTSYS



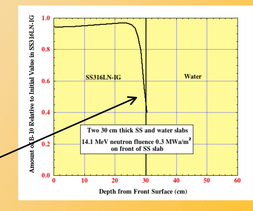
Note peaking near interface even without B in SS316

He production in SS316 versus depth from ALARA



Contribution of Ni to He production with no B in SS (DANTSYS versus ALARA)

- ALARA calculations also account for B depletion



Note half of the B is depleted at the interface by end-of-life

Spatial variation of B depletion from ALARA

- A two step reaction with Ni combined with the softer neutron spectrum causes part of the He production peaking

Conclusions

- Previous high fidelity, high resolution results for nuclear parameters in ITER FWS modules revealed peaking in heating and He production near SS/Water interfaces
- Nuclear heating peaks near the SS/Water interface due to the water softening the neutron spectrum resulting in higher photon production in the SS near the water
- He production peaks near the SS/Water interface due to the 10 wppm B present in SS316LN-IG and due to a low energy two step Ni reaction