Conference and Workshop on the Research Needs of Boiling Water Reactors, Bangor University, 25th-27th October 2016

Summary of Breakout Session on "Research Needs Discussions for BWR High Performance Core and Fuel"

A Conference and Workshop on the research needs of BWRs was recently held at Bangor University (October 2016), attended by Hitachi, representatives of the UK nuclear industry and UK academia. On 26th October two parallel "Breakout Sessions" took place in order to begin to establish areas of research of mutual benefit to Hitachi and the UK.

This memo summarises the proceedings of the "BWR Core and Fuel" session (the other session was concerned with "BWR Thermal Hydraulics" and will be reported separately). The breakout session comprised discussing and then compiling a list of potential research areas, followed by an attempt to identify the areas of greatest interest to both Hitachi and UK industry and academia.

List of potential research areas of mutual benefit

Each item was placed into one or more of the following categories:

> *M – Methods/computer code development, including core design, fuel performance and neutronics/thermal-hydraulic coupling (M)*
> *C – Fuel cladding research (C)*
> *E – Environmental research, including crud investigations, coolant activation , material degradation and environmentally-assisted cracking(E)*

- Fuel performance analysis methods for higher burnup fuel (e.g., extending the validation database to higher burnups) (M)
- Development and validation of modelling techniques to be used to represent the harder neutron spectrum (cf. a thermal reactor) when operating a Reduced moderation Boiling Water Reactor (RBWR) (M)
- Collaboration on advance numerical modelling methods, such as reduced order modelling, predictive modelling and uncertainty propagation (M)
- Development and use of UK neutronic and T&H BWR methods (e.g., WIMS/PANTHER could be coupled with a T&H/system code such as RELAP) enabling comparisons with Hitachi calculations (M)
- Corrosion of Zr alloy claddings – mechanistic understanding of oxidation under single and two-phase environments, prediction of oxidation rates, development of more resistant alloys (C)
- Post Irradiation Examination (PIE) of active samples, e.g., cladding (C)
- Novel clad coatings, e.g., graphene and surface treatments(C)
- Possible internship(s) at Hitachi, focussing on core/fuel modelling of existing technology using Hitachi techniques and methodology (with a view to using these techniques back in the UK using UK methods) (M)
- Further development of RBWR analyses, adding to work already carried out in the UK (M)
- Investigation into failed fuel rod identification techniques using robotics and laser ultra-sonic testing (C)

- Comparison between UK (ENIGMA) and Hitachi (PRIME) fuel performance codes, including importing of BWR specific models and development of ENIGMA for BWR operating conditions (already licensed in the UK for Advanced Gas Reactor and PWR purposes) (M)
- Atomistic modelling of fuel, e.g., fission gas release, Pellet Clad Interaction, rim effects (M)+ (C)
- Chemical release rates of stellite alternatives (E)
- Research into radiation damage of steels (E)
- Research into stress-corrosion cracking (including irradiation-assisted SCC of austenitic stainless steel components, SCC during start-up and cool-down, effectiveness of different water chemistries, hydrogen embrittlement) (E)
- Further investigation into BWR crud deposition in appropriate water chemistries and flow conditions (UK work carried out currently on behalf of EPRI) (E)
- Research into corrosion fatigue including applicability of design curves (E)
- Further workshop on development of reactor core design and safety analysis methods and techniques (M)

List of Initial Priorities

- Core design and core analysis methods development, e.g., modelling MOX in ABWR and possibly RBWR (M)
- Possible coupling of balance-of-plant code (e.g., RELAP) with core neutronics code (e.g., PANTHER) perhaps incorporating novel 'reduced order' numerical methods (M)
- Possible import of further BWR models into UK's ENIGMA fuel performance code, followed by UK(ENIGMA) vs. Hitachi(PRIME: Developed and owned by Global Nuclear Fuel)) code comparison (M)
- UK groups currently working on cladding materials -> would be beneficial to map this work onto BWR conditions, including microstructural investigations of BWR alloys irradiated in a reactor (as opposed to ion beam irradiation) (C)

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