Report on TopFuel 2012 (I)

Top Fuel 2012, an annual conference organised by ENS, the American Nuclear Society and the Atomic Energy Society of Japan, took place from 2-6 September 2012 at the Renaissance Hotel, in Manchester, UK. This conference, a flagship ENS event, provides a platform for bringing together nuclear fuel specialists from around the world to discuss advances in nuclear fuel management technology, and to apply the findings of cutting-edge research for the development and manufacture of the high performance nuclear fuels of today and tomorrow. The technical scope of ***Top Fuel 2012*** included a wide range of applications relating to nuclear fuel technology, from fuel rod to core design and manufacturing; from performance in commercial and research reactors to current and future developments and trends.

Approximately 300 delegates attended the conference, which kicked off on the evening of 2 September with a welcome drink.

Day 1

The opening session on Day 1 of the conference, on 3 September, featured a welcome speech from Mark Basset, Deputy Chief Inspector at the UK's Office of Nuclear Regulation (ONR). After thanking the organisers and sponsors of the conference for their support, he outlined not only his own work at the ONR, but also the Office's mission to ensure that at all times the safety of British citizens is paramount. The main subject of his speech was the issue of safety. He explained how in addition to the risks associated with nuclear energy, society should be made more aware of its benefits. By comparing the

Fukushima accident with the deep water horizon accident, Mark Basset highlighted the differences that exist between “typical industries” and the nuclear industry. For example, the whole nuclear industry is held collectively responsible when a disaster occurs – not any one company – and yet when an accident like the deep water horizon one occurs the operating company is held directly responsible (in this case it was BP). The nuclear industry is a hostage to its collective responsibility.

Mr Basset then addressed the subject of responsibility for enhancing standards. This lies primarily with the IAEA, but ENS also has a responsibility to contribute to the process. He stressed once again that it is necessary to communicate clearly and transparently with the public, and that communication should be done jointly by all nuclear partners.

The keynote speaker during the opening session was Victor Inozemtsev, from the IAEA. He presented the IAEA’s activities in the area of fuel engineering. He gave a short status update onthe nuclear power plants currently in operation and mentioned how Fukushima has slowed down the building and planning of new reactors. He then gave an overview of the Agency’s Nuclear Safety Action Plan, which is composed of 12 areas of action, or “sub-programmes.” Fuel engineering is one of these sub-programmes. Finally, Mr. Inozemtsev explained the multiple possibilities offered by the research that the IAEA is carrying out into the improvement of nuclear fuel safety.

The first plenary session was chaired by John Jones, one of TopFuel’s co-organisers, and ENS President, Marco Streit. The first of three presentations was made by Andrew Lingenfelter, Vice President of Fuel Engineering at Global Nuclear Fuel. He spoke about GE Hitachi’s improvements and developments in the nuclear fuel sector, which cover all aspects from the front end, via plant performance and safety & innovation to the back end. A big problem in the US is the licensing process for new power plant sites. Without licences no new for R&D in the fuel management field is possible. Over the last few years much effort has been made and considerable improvement achieved when it comes to plant performance. Due to new technologies there are almost no fuel failures in the US anymore. One major challenge was the channel bow; this could be reduced by 80% due to new materials. A topic that Mr. Lingen felter touched upon in this talk, and which recurred often during the conference, was the power enhancement of NPPs, which leads to R&D needs to keep the safety at the highest possible level. In his conclusion Mr. Lingenfelter admitted that the US had lost its leadership role in the back end research to Europe.

The second speaker was Jeffery Bradfute, who gave a presentation entitled: *Next generation fuel designs – a Westinghouse perspective.* After making an announcement about next year’s Top Fuel Conference in Charlotte, US, he began by focusing on some historical issues and on the challenges facing new generation fuels. He then spoke about light water reactor (LWR) fuel cladding corrosion, which is decreasing thanks to new developments. The main focus of his presentation, however, was the development of accident tolerant fuel and of new materials that should ensure that fission products are safely enclosed, that no melting can occur and that explosive gases are retained. One material that he highlighted is SiC, a ceramic matrix composite with low n-absorption.

The final speaker during the first plenary session was Alain Frichet from AREVA. The title of his talk was *Investment in competences and innovation for the highest safety standards and performance*. He pointed out that human resources are also an important part of the safety equation, and that best practises in this area should be shared. He presented the best practise training programmes offered at all major AREVA centres. Many safety issues, Mr Frichet pointed out, are identified thanks to R&D programmes, so these programmes should definitely be maintained. Finally, he stressed that safety must be the first priority and emphasised the importance of fuel development when it comes to creating safer designs.

During the coffee break delegates had a possibility to look at the poster exhibition. Then they were offered a choice between two parallel sessions: *Operation and Experience or Transient Fuel Behavior*. I chose the latter one, which was chaired by Nicolas Wacekel and Toyoshi Fuketa. There were six presentations in this session. The first one was given by Mr. Garat, who talked about a new cladding material – the M5® cladding, which has a lower H content than Zircaloy and has been tested under accident conditions. The results show that the margins with the M5® cladding are acceptable, in RIA and LOCA. The second presentation was given by Mr. Cazalis, who addressed the behaviour of MOX fuel under reactivity initiated accidents. The third presentation was given by Mr. Clifford. He introduced the US regulatory strategy for revising the RIA's acceptance criteria. Several tests and experiments have been performed to show the feasibility of this new approach. Separate criteria for cladding failures related to pressurized water reactors (PWR) and boiling water reactors (BWR) were introduced and core "coolability" criteria was revised.

The next presentation was given by Dr. H. Yueh, who focused on new techniques for the testing of cladding material under RIA conditions. He explained the need for new test procedures in order to obtain more data on cladding performance. Temperature performance was another issue taken into consideration for these tests, as well as for modified burst tests.

In my opinion, the most interesting presentation in this session was the one given by Mr. Schrire, who spoke about *Transient dry-out in Forsmark 2 during a fast pump runback – verification of peak cladding temperature*. He gave an overview about the event that occurred in June 2008, where the core was loaded with an operating limit for the minimum critical power ratio that was based on the assumption that only a controlled ramp-down of the pumps could occur. After the event it was calculated that about `4 fuel assemblies briefly violated the safety limit minimum critical power ratio and 18 of these ,ienced a very short transient dry-out. The main interest of their research was analysis of the peak

cladding temperature that could have occurred. They used the Westinghouse BISON module to calculate this parameter. The other field of research was the hardness of the cladding and how it changes during the temperature increase. During reactor operation the cladding hardens quickly, and it was thought that with a temperature increase there might be a recovering effect for weaker cladding. However, the experiments showed that this was not the case.

The final presentation in this parallel session was by Mr. Smith, who focused on the CHF testing of VVER-1000 fuels in the Westinghouse ODEN loop.

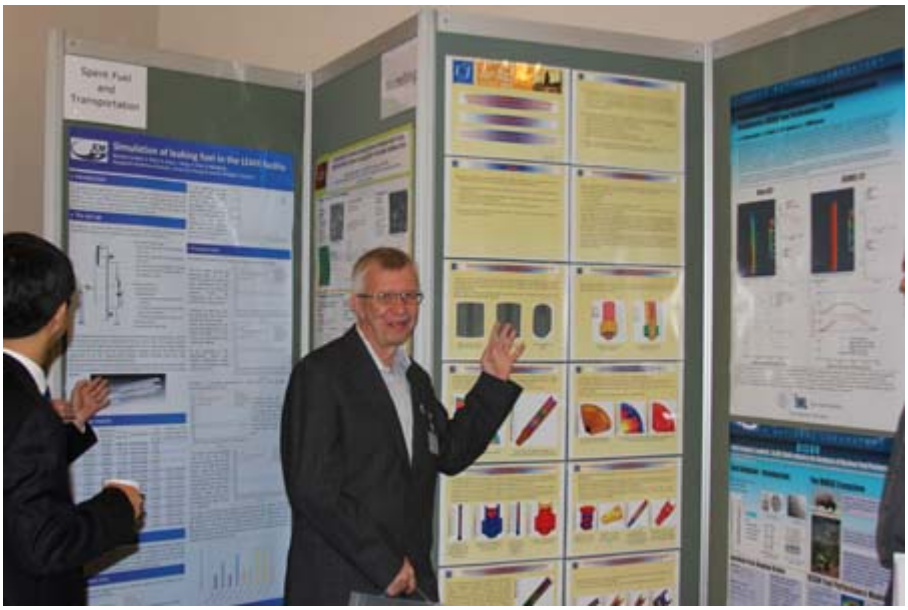
After the lunch break the delegates could once again choose to attend one of two parallel sessions. I attended the *Operation and Experience II session*, which was chaired by José Aycart and Lars Hallstadius. It began with a presentation by Mr. Kim entitled: *Atomic diffusivity measurement of Xenon Gas in various types of fuels with low burn-up by post-irradiation annealing test*. Research in this field focused on the Xe-diffusion in ceramic fuels, which was tested under various conditions and using different fuel types. The method they used was irradiation in the HANARO research reactor for a short time period of time (16min), and subsequent annealing at several temperatures. To analyse the results, gamma detectors were used, including a filtration system.

The second presentation, given by Mr. Arana, was entitled: *Post–irradiation examination of high burn-up fuel rods in Vandellos II*. Many European NPPs are performing power increases at the moment, and this leads to a higher fuel burn-up. Therefore, it's necessary to study any possible safety concerns regarding this change in fuel use. Mr. Arana described a post-irradiation examination of 8 rods, with a burn-up of up to 75MWd/kg U. Their fission gas release was examined, as well as the fuel swelling. They had different Gd contents in the fuel as they thought this might have an impact on the outcome of the experiment, but no difference was observed. One result noted was that fission gas release is enhanced with higher burn-up.

The third presentation, entitled: *Successful high burn-up irradiation campaign of the GE14 LUAS at TVO's OL1 Reactor: Inspection results and assessments*, was given by Mr. Dunavant. He highlighted the burn-up increase from 45MWd/kg U up to 50-55MWd/kg U and the experiments related to this project. The investigating team wanted to see the GE14s performance at higher burn-up levels, so they outlined the history of the project, the Kr-85 experiments and the cladding oxidation data they had gathered.

The fourth presentation gave an overview of the PIE examinations on the AGR fuel pins that were carried out by Studsvik. It was the first PIE examination of AGR fuel pins, which were performed with in-pool inspections to observe the graphite sleeve. The two remaining presentations during this session were given by Mr. Cantonwine, who talked about the *Performance of an updated cell friction methodology* and by Mr. Druenne, who gave delegates an insight into *In-Core fuel management with mixed fuel assemblies for Belgian nuclear power plants*.

The next two parallel sessions focused on *Design and Materials – Hydriding and oxidation, and Transient fuel behaviour*, respectively. The first session consisted of five presentations and the second one of six. The main focus of the first one was to show the different material properties of Zirconium in alloys.



Day 2

On Day 2 the conference started with a plenary session co-chaired by John Jones and John Roberts. The first presentation was given by Mr. Lalieux. He gave some insight into *Back end requirements that need to be taken into account in the fuel design phase*. He stressed that, as the risk in waste storage is present for hundreds of thousands of years, radiation must be contained by the choice of the storage. In his opinion, the most promising solution would be geological disposal, which has 3 safety functions: containment, retardation and isolation. Another point that he emphasised was the fact that there should not only be man-made barriers (engineered barrier system – EBS) but also natural barriers. The Belgium EBS is driven by two key factors: the thermal component and the radiotoxicitiy and radiation component. The first factor can only be assured over a certain period of time, and after the failure of this barrier there will be a release into the rock. Therefore, either the containment has to be improved, or the front end manufacturing needs to take this risk into account and include small changes. In his closing remarks Mr. Lalieux said is that more R&D is needed on the front end side to ensure the safe and secure storage of spent fuel.

The second presentation in this plenary session was dedicated to the subject of *Molecular Dynamics* and was given by Mr. R. Grimes. Mr. Grimes showed delegates a simulation on an atomic scale, which will help to better understand fuel dynamics.

The last presentation was given by Mr. L. Hallstadius, who spoke about the evolution of fuel materials. He gave a broad overview of the development of Zircaloy, explaining why the material was chosen in the first place, and which new concepts are being developed. He then explained the H problem, and also the corrosion troubles that have been experienced with Zircaloy.

Next on the agenda were three more parallel sessions entitled respectively: *Design and Materials – hydriding and Oxidation, Fuel Rod Thermal Mechanics and Operation and Experience*. I attended the last one, which was chaired by Marco Streit. The first presentation during this parallel session was given by Mr. D.Lutz, who focused on BWR fuel failures. In the US they have experienced fuel failures in the 2 nd usage cycle. Mr. Lutz's presentation illustrated the steps that were taken to investigate the reasons for these failures. The conclusion that he drew was that it was most probably a mixture of responsibility, materials and water chemistry.

The second presentation was given by K.Yueh. The focus of his talk was the *Revised industry guidance on LWR fuel surveillance and inspection*, which has resulted in the production of a new guidance document. The third presentation was given by Martina Mala, who gave an introduction on the *Fuel Inspection and Root Cause study* at the Temelin NPP. She explained how the fuel inspections have mainly been done in western countries, and how the IAEA has launched an initiative aimed at determining the root causes of fuel failure, as 25% of the causes usually remain unidentifed. The fourth presentation was given by M. Aullo. He focused on the *Reduction of fuel assembly bow with RFA fuel*. J.Bradfrute then outlined Westinghouse's fuel design and performance, highlighting the techniques they use in fuel R&D, and underlining Westinghouse's goal of achieving a 100% reliable fuel and peak -free performance by 2015. The final presentation during this parallel session was given by E.I. Grishanin, who enlightened delegates about New Cores on Based Coated Particles for Power Water Reactors (PWR-CP).

During and after the lunch break posters were presented and delegates had an opportunity to talk to their designers.

The first parallel afternoon session offered a choice between the three following topics: *Design and Materials – Advanced Materials, Fuel Rod – Thermal Mechanics and Spent Fuel and Transportation*. Mr. G. Demazy chaired the last of the 3 sessions, which started with Mr. D. Papaioannou, from the ITU in Karlsruhe, talking about *Oxidation Studies on Irradiated UO_2 fuels*. Almost no research had previously been carried out on this topic, in spite of the great concern that remains about the handling and storage of spent fuel. Therefore, long-term research had to be performed over a period of months and years – even though almost no sophisticated test equipment was available. The result of his study was that oxidation occurs as the U_3O_8 builds up.

The afternoon's second presentation was given by Mr. Quecedo, who concentrated delegates' attention on the *Results of Thermal Creep Tests on Irradiated Zry-2.* The third presentation, given by H.Issard, focused on *Dry storage reliability solutions for the management of spent nuclear fuel in the long term*. His presentation provided an overview of different spent fuel storage facilities and reprocessing systems. Mr. Farkas then gave a presentation about the modeling with MCNP that has been carried out at Bratislava, highlighting the results of criticality safety analyses carried out on fresh and spent fuel storage and the managing of VVERs using code MNCP 5. The final talk was given by G. Grandi, who outlined Studsvik's CMS capability for spent nuclear fuel research. This research has revealed a new use of the CMS code for the modeling of nuclear fuel.

The last parallel sessions on Day 2 were *Design and Material New Concepts, Spent fuel and Transportation and Fabrication and Seismic Simulation* respectively. That evening the conference gala dinner that took place at Manchester Town Hall gave us a great opportunity to make new contacts, have a dance and generally have fun.

Day 3

The final day of ***TopFuel 2012*** started with a plenary session chaired by John Jones, who began by thanking the conference sponsors. He then gave a presentation entitled: *Pre-licensing assessment of fuel designs for new commercial nuclear reactors within the UK.* As there hasn't been any new licensing for new fuel designs in the UK for decades, new regulations and licenses need to be established. Therefore, all the risks must be evaluated and the "as low as reasonable practicable" principle should be applied. The licensing will take into account all possible accidents that might occur. His conclusions were as follows: The aim is to provide a robust demonstration that the plant can meet the challenges presented by anticipated faults and that all reasonable practical measures have been taken to reduce the risk to a broadly acceptable level.

The second talk in this last plenary session was given by N.Waeckel. The focus of his talk was *R&D in Support of Safety Analyses and Design*. Mr. Waeckel stated that the safety analysis design limits should be upgraded as problems with fuel occur. The in-pile testing will be part of this enhancement process. The new French research reactor will be a big help for the carrying out of these new tasks. Part of his presentation was dedicated to accident tolerant fuels, where the right concepts must be found, the manufacturing concerns must be resolved and the behaviour under normal operation and accidental situations must be addressed. More testing and modeling should be done to keep the fuel safe.

The last plenary session presentation was about *Lessons learned from running OECD-NEA fuel projects*. Mr. Vitanza, of the OECD/NEA, introduced the Halden research reactor project, which was used for carrying out fuel and material studies. As the research reactor is very flexible, it can operate in ways that an NPP would never be capable of. He listed all the testing possibilities and the lessons learned.

The subsequent parallel sessions were divided into two parts: *Design and Materials, Methods and Testing and Modeling Thermal Hydraulics and Coupling*. The first session was chaired by John Roberts and the first presentation was given by Mr. Burukin. Mr. Burukin talked about the *Research Reactor MIR: the Russian National base for testing water cooled reactor fuel rods under transient and accident conditions.* He explained the potential offered by the research reactor and highlighted the characterisation of the loop facilities. The techniques for fuel testing were also demonstrated, as well as the possibility of testing full size VVER rods. The MIR can also do power ramping, cycling, RIA and LOCA tests to determine fuel rod behaviour.

The 2nd presentation, given by Mr. Mozzani, focused on: *Iodine-induced stress corrosion cracking (I-ISCC) of Ziracloy 4: Effect of mechanical loading history, iodine concentration and irradiation on crack initiation.* The pellet-cladding interaction is the main cause of multiple fuel failures in NPPs, which reduces power.

Mr. Granfors gave the next presentation. The topic this time was *Radial profiling and isotopic inventory analyses of irradiated nuclear fuel using laser ablation ICP-MS.* The fuel pellets were handled in hot cells and laser ablation was done with the help of a floating 213nm laser. The material was moved to ICP (6000 K) ionized, and analysed with a mass spectrometer. The calibration of the MS is difficult, so the only comparisons made were with solutions of acid fuel. The overall result of this study was that these techniques can be used instead of traditional dissolution analyses, as they represent a time saving and cost reduction method that achieves comparable results to traditional analyses.

The CEA then presented to delegates their GRIZZLY experiments. The final presentation was given by D.V. Markov, who talked about the “FEDS” Database and its application for carrying out the tasks of reactor material science.

The final parallel sessions kicked off after lunch. The topics presented to the conference participants were *Design and Material and Multi-physics*.

The conference ended with a farewell cocktail.

In my opinion, ***TopFuel 2012*** offered a great opportunity to gain a broad overview of the current status of research and development with regards to fuel, fuel designs, cladding and materials, as well as a status updatetus in many countries from a regulations perspective. There is undoubtedly great interest in making fuel safe and current trends point towards the development of “accident safe fuel” and the enhancement of cladding resistance to accidents. There will always be more conservative views regarding cladding materials, but new concepts and techniques have been investigated and will be tested in future.

I would like to thank the ENS for the opportunity given to me to participate in this conference.

Eileen Radde
YGN Austria

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