Thermal/Epithermal eXperiments (TEX) Feasibility Meeting Minutes

Sandia National Laboratories
Albuquerque, NM
July 12-13, 2011

List of Attendees

Nicolas Authier (CEA, France)
Mike Dunn (ORNL, US)
James Dyrda (AWE, UK)
Nichole Ellis (SAIC/NCSP, US)
James Felty (SAIC/NCSP, US)
Gary Harms (SNL, US)
David Heinrichs (LLNL, US)
Tatiana Ivanova (IRSN, France)
Skip Kahler (LANL, US)
Eric Létang (IRSN, France)
Dick McKnight (ANL, US)
Alison Miller (SNL, US) (Second day only)
Bill Myers (LANL, US)
Jérôme Piot (CEA, France)
Paul Raglin (SNL, US) (First day only)
Brad Rearden (ORNL, US)
Ken Riel (SNL, US)
Davis Reed (ORNL, US)
Mike Zerkle (Bettis, US)

Agenda/Schedule

Tuesday July 12, 2011

8:30 Pick up foreign guests at hotels
9:00 Badge Office with our Guests
10:00 Welcome (Gray Harms & Nichole Ellis)
10:05 NCSP Perspective (Jim Felty)
10:15 NCSP Expectations (Nichole Ellis)
10:30 Epithermal Data Needs for Criticality Safety Assessments in France (Eric Létang)
11:00 Epithermal Data Needs in UK (James Dyrda)
11:30 Lunch onsite (can see Dragon Machine speech if interested)
12:30 Epithermal Data Needs in US (Dick McKnight)
13:00 Tour of the Annular Core Research Reactor (ACRR staff)
13:30 Tour of the Sandia Pulsed Reactor Facility Critical Experiments (SPRF/CX staff)
15:00 US CEdT process (Nichole Ellis)
15:45 Open Discussion on Data Needs (All)
16:15 Prioritization of all Data Needs (All)
17:00 Adjourn

*All presentations are attached and available on the NCSP Website.

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Wednesday July 13, 2011

8:30 Pick up foreign guests at hotels
9:00 IRSN Proposal on Conceptual Design for TEX Experiments (Tatiana Ivanova)
10:30 Break
10:45 Use of TSUNAMI to Optimize Experiment Designs for Testing of Energy-Dependent Cross Sections (Davis Reed)
12:00 Lunch onsite
13:00 Open Discussion (All)
13:30 Description of a Proposed Thermal Titanium Experiment (Gary Harms)
14:00 CEF Abilities for Meeting Epithermal Data Needs (Bill Myers)
14:30 Break
14:45 Open Discussion - Moving forward with obtaining Epithermal Data Critical Experiments, do we know enough to submit a worthy CED-0? (All)
16:30 Wrap-up
17:00 Adjourn

Minutes

Gary Harms of Sandia National Laboratory (SNL), United States (US) kicked the two day meeting off by welcoming everyone and going over important safety rules and requirements for the facility. Nichole Ellis of SAIC, supporting the Department of Energy (DOE), then introduced the meeting and welcomed everyone to the meeting. She asked everyone to introduce themselves, their affiliation, and their purpose for the meeting. She also explained this meeting was intended to be interactive, so during presentations, please ask questions and make sure you understand the information or ask for clarification at that point to stimulate discussions. From here she turned it over to Jim Felty.

Jim Felty of SAIC, supporting DOE, gave his perspective on why he felt there was a huge data gap in nuclear data and experimental data in the intermediate energy range. He explained he felt this information was vital to individuals having a better understanding of many accident scenarios currently employed by the Criticality Safety Community.

Nichole Ellis started with a brief history of the data collected and evaluated in the intermediate energy range and showed a detailed spreadsheet "TEX data from DICE"* listing the International Criticality Safety Benchmark Evaluation Project (ICSBEP) evaluations that have been performed in the intermediate range, at what energy the experiments were at, and what materials have significant capture data in those energy ranges, along with other information pertinent to the discussion. Ellis then presented "Data currently available"* as a gross summary of the small amount of DICE data available as well as presenting "MCNP results overview"* to further demonstrate that not a lot of information is available to be used by the Criticality Safety Community for materials tested in the intermediate energy range. All of this lead to discussion

*All presentations are attached and available on the NCSP Website.

among the group about what data needs do we really have and what are we hoping to gain by having this meeting. Everyone agreed that data in the epithermal range was greatly needed. At this point, Ellis turned it over to the participants to specifically discuss their data needs in regards to the intermediate energy spectrum.

First, Eric Létang of IRSN, France presented "Epithermal Data Needs for Criticality Safety Assessment in IRSN"* showing specific scenarios of where data is needed by IRSN for evaluation of accident scenarios considering water density variation (mist). An example of this was where IRSN has had to evaluate PuO_2 or $UPuO_2$ power at the 450 eV energy with water reflection and interaction with steel, steam, and various fixed absorbers in different resins. Several other examples were also presented to show there is a large need for this data at IRSN for both Uranium and Plutonium. The conclusions of the presentation were:

- There are epithermal data needs for criticality safety assessment
- The experimental design must be suitable for further analysis with the uncertainty techniques available

As a result of these discussions, Létang planned to contact CEA and AREVA upon his return to see what additional data they may need. During this discussion, Ellis summarized these data needs specifics in "TEX needs summary"* and they are listed below:

- Transportation and fabrication needs mostly for normal and abnormal conditions
- Concrete reflection (15 eV, 150eV) – limited data for configurations they need in this energy range
- Steel, water interaction (15eV, 450eV)
- Water reflection (150eV, 450eV, 770eV, 20eV-770eV)
- Lead reflection (150eV)
- Fixed absorbers-resins (450eV)

Action - IRSN provide more precise data for CED-0 on specific applications (Ivanova, Létang)
Use of different structural materials for abnormal criticality safety scenarios in conditions of different water densities.

Next, James Dyrda of AWE, United Kingdom (UK) provided a summary of needs at AWE by canvassing individuals in the UK Criticality Safety Community and came up with a 'High Priority List' of needs. As a result of these discussions, Dyrda planned to contact other UK individuals upon his return to see what additional data they may need. Ellis summarized these data needs in "TEX needs summary"* and they are listed below:

- Mostly for fabrication needs
- Hf for structural materials (currently little data of quality)
- Ta for structural materials (some data available but very limited)
- W for structural materials (nothing available to use right now)

*All presentations are attached and available on the NCSP Website.

Action - UK provide more precise data for CED-0 on specific applications (Dyrda)

Last, Dick McKnight of Argonne National Laboratory (ANL), US presented a list of data needs for the US in "US Needs for Epithermal Data"*. He discussed how over the years, there were a few cross-sections that have been adjusted in the intermediate range based on low fidelity date and in some cases, the results have gotten worse without a true understanding why. Ellis summarized these data needs in "TEX needs summary"* and they are listed below:

- Mostly structural materials, some transportation needs, intermediate for abnormal conditions mostly
- Ni, Mo, Cr (Fe-Cr alloys), Mn structures for transportation
- Cu (especially for understanding Zeus), V, Ti as materials of interest
- ^{239}Pu and ^{240}Pu – don't perform well in intermediate range

From here, the meeting attendees toured the Annular Core Research Reactor and the Sandia Pulsed Reactor Facility, hosted by SNL.

Next, Ellis presented the C_EdT Process to everyone in "Critical & Subcritical Experiment Design Team of the US DOE Nuclear Criticality Safety Program"* so that they could have a clear understanding of the process used by the US to prioritize and process experiments, as well as the requirements of the US to determine the data need and how the process ensures that the need is met by any measurements and/or experiments performed by the US Nuclear Criticality Safety Program (NCSP). Much discussion followed this presentation with the group to answer all questions and make sure everyone understood the process.

From here, the floor was opened up for discussion of the data needs across the different countries and everyone agreed that the needs were basically the same. From here, materials of interest in the intermediate range were prioritized based on the day's presentations and discussions. Ellis summarized these data need priorities in "TEX needs summary"* and they are listed below:

Priority of needs:

- ^{239}Pu
- ^{240}Pu
- ^{238}U
- ^{235}U
- Temperature variations
- Water density variation
- Steel
- Lead
- Hf
- Ta
- W

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- Ni
- Mo
- Cr
- Mn
- Cu
- V
- Ti
- Concrete reflection, lack of concrete characterization (water content)

This concluded the first day of discussions.

Day two started with Harms welcoming everyone back and going over the important safety rules and requirements for the facility as a reminder and for the new participant.

From here, Tatiana Ivanova presented "IRSN Proposal on Conceptual Design for TEX Experiments"* which provided an overview of a conceptual design that could easily be used at SNL and at Valduc with Apparatus B with the ability to change materials for each experiment series with relative ease for both cases. The design allows incremental spectrum hardening from thermal to lower intermediate range. The thermal experiments are similar to those in the epithermal range to provide baseline for progressive cross-section testing. Also, sensitivity calculations of different materials of interest showed that the Sandia experiment's sensitivity to the desired test material was sufficiently significant to truly affect the conceptual experiment design demonstrating the feasibility of the concept as well as the Apparatus B sensitivities. Use of data adjustment technique for posterior uncertainty assessment demonstrates that the designed configurations have potential to contribute to the nuclear data testing in the thermal and epithermal ranges. A preliminary study on optimization of the proposed designs shows parameters important for the optimization and contributing to experimental uncertainty. The conclusions of this presentation were:

- The proposed conceptual design using of materials of interest as sleeves surrounding fissile units provides clean experimental data (none correlated with available experiments) that give high test material worth and sensitivities in the thermal range.
- The design consists of a central test region with a monolithic block of aluminum with vertical hole surrounded by an annular driver region. The aluminum block displaces water in the center of the core to (1) harden the spectrum in the central test region of core to an epithermal spectrum and (2) allows modeling criticality accidental scenarios with water density variation (mist).
- Sandia core is well suited for adjustments to ensure a hardening of the energy spectrum. A variety of epithermal spectra can be developed using aluminum blocks with different water hole designs.

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Furthermore, no additional fuel would need to be fabricated based on the current SNL inventory. Along with criticality measurements, measurements of test material reactivity on the epithermal configurations provide valuable data for cross-section testing. A design similar to this one presented in the SNL facility would allow data extraction from epithermal configurations as well as being useful to gain data that could validate and improve advanced sensitivity/uncertainly analysis methods. One issue with this design was raised. Care must be taken in annularly driven core designs of this type to ensure the central test region is large enough to have adequate sensitivity and is not dominated by the softer spectrum driver region. This issue can be dealt with by design if sufficient fuel inventory is available.

Next, Davis Reed of Oak Ridge National Laboratory (ORNL), US presented "Overview of SCALE/TSUNAMI Use for Design of Criticality Experiments"* to demonstrate the importance of using good sensitivity tools to design experiments. His conclusions were:

- Using TSUNAMI tools, experiments with high similarities to applications may be determined that require (1) much less fissile and non-fissile materials than the application and (2) a much simpler material configuration.
- For historical experiment designs, experiments for the application would have likely required a split-table apparatus for the large experiment mass.
- Use of TSUNAMI for design of similarity experiments may reduce the material or machine requirements, and allow achievement of lesser benchmark uncertainties.

Next, Reed presented "SCALE/TSUNAMI Assessment of Postulated Critical Experiments for Testing of Neutron Cross Sections for Cr, Mo, and Mn"* to show a variety of conceptual designs for epithermal cores (using the MIRTE as well as other configurations, including a sleeved concept similar to that presented by Ivanova). He used the SCALE TSUNAMI tools to determine conceptual experiment configurations of utility and determined that it is possible to employ a thermal-fission system (LEU rod lattice in water) for testing of Cr, Mo, and Mn cross sections throughout neutron energy ranges of interest. He concluded the following:

- For testing of thermal cross sections, the 1-Array Poison-Rod configuration is judged best.
- For testing of epithermal and fast cross sections, the 1-Array 2-Reflector configuration is judged best.

The issue with both of these configurations is that a new core would likely be required to be fabricated to provide adequate space to perform an entire series of experiments. The next logical design based on not needed to fabricate a new facility would be the sleeved option.

After this presentation, McKnight stressed the importance of any design concept to include a clean experiment in the thermal range similar to those to be performed in the epithermal range to ensure a baseline with good cross-section data, and then start making design adjustments so the baseline case is solid. He also stated it would be best to start with iterative experiments and then

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move to iterate on the cross sections to get new cross section data of value. He also stressed that there are angular distribution issues in the fast range and that a class of measurements on angular distribution would be required to get good results for epithermal experiments starting in the fast range and then being softened.

Harms presented "Description of a Proposed Thermal Titanium Experiment"* to meet the current need of one of the current US proposed experiment requests and demonstrated how this conceptual design could be hardened to get the same type material data for the epithermal range. Interestingly, Harms presented a sleeved concept similar to that presented by both Reed and Ivanova. He discussed the research he has already performed for the costs associated with purchasing the material of interest with the quality required and the ability and cost to form the materials as required for any experiments. His concluded the following:

- Critical experiments with titanium in the thermal spectra available in the BUCCX are feasible with the existing critical experiment hardware.
- The available quantity of BUCCX fuel is adequate to perform these experiments.
- Commercially-available titanium tubing (a.k.a. relatively low-cost) may be usable as experiment samples.
- The titanium worth in the experiments is well above the anticipated uncertainties in the experiments.
- The reaction-rate profiles across the thickness of the tubes are relatively flat indicating minimal self-shielding occurs in the tubes.

Although other materials of interest were not discussed, based on similar conclusions reached by other participants, it was generally believed this conceptual design warranted further research as a feasible approach to epithermal experiments in the low end of the epithermal range.

The last conceptual design presented was by Bill Myers of Los Alamos National Laboratory (LANL), US titled "CEF Abilities for Meeting Epithermal Energy Neutron Data Needs". This presentation focused on the ZEUS apparatus on the COMET machine located at the US Critical Experiment Facility (CEF) located in Nevada. This apparatus is a large copper reflector created to change the energy spectrum of an experiment by reflecting the neutrons back into the system at a lower energy range. Discussion also focused on the Jemima plates of HEU currently located at the CEF and the ZPPR plates currently being prepared for shipping to the CEF and how each of these could be used to take a fast system on COMET and soften it to the upper end of the intermediate range. The only issue with this conceptual design is that copper evaluation data would be needed first to clearly ensure that a well characterized and understood baseline existed for all subsequent experiments in the series to get adequate data.

After this presentation, the floor was opened to discussion of conclusion of the meeting and the answering of any specific questions that were not answered previously during presentations. Michael Zerkle of Bettis (US) and Skip Kahler of LANL (US) discussed a series of experiments performed many years ago that are documented and evaluated in HEU-MET-FAST-007 by the ICSBEP. These experiments consisted of HEU metal rectangular sheet fuel (about the same

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thickness as the Jemima plates) moderated and reflected by polyethylene of various thicknesses to achieve a large variety of neutron energy spectra that were systematically hardened from a soft thermal spectrum to a hard fast spectrum. The thermal, intermediate, and fast energy spectra achieved in this experiment bracket most neutron energy spectrum of practical interest in nuclear criticality safety. The participants then discussed that a similar series of experiments using polyethylene plates and the Jemima plates would likely be a good conceptual design to obtain material data needs in a variety of neutron energy spectra (thermal, epithermal, and fast). Dr. Zerkle noted that the clean critical experiments he has proposed (IERs 139 – 142) provided a similar capability in the intermediate/fast energy range but could be adapted to provide a generic thermal/epithermal/fast spectra material testing capability (see B-TM-1639). An adequate supply of Nb, Mo, Ta, and Re test plates has been fabricated and these test plates are currently located in the CEF warehouse. A similar set of Pu fueled experiments could be designed using the ZPPR fuel.

McKnight discussed the "diagnostic core idea" from years previous where clean cores from one energy range to another were measured to get clean core data for a good baseline. It could be used to accurately and precisely create a fissile/fertile material versus energy matrix that could be useful across the NCSP complex as well as for the other participating countries.

Dave Heinrichs of Lawrence Livermore National Laboratory (LNL), US stated there was also a viable need of data in the weapons area of Criticality Safety for reprocessing and transportation storage.

General Conclusions

- All parties present expressed the same type general need of data for many of the same materials in the epithermal energy range.

- Two complementary approaches are available to obtain data in the epithermal energy range: thermal experiments that are then hardened in steps and fast experiments that are then softened in steps. This would give data for the entire intermediate energy range.

- The sleeved material around fissile units in a light water moderated facility was determined to be a feasible conceptual experiment design to achieve the low-end epithermal material data needs.

- The Jemima plates and ZPPR material with polyethylene was determined to be a feasible conceptual experiment design to achieve the high-end epithermal material data needs. This approach also has the potential to provide a generic thermal/intermediate/fast spectrum material testing capability.

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- Multiple studies show that the water moderated facility/sleeved material design have sensitivities to materials of interest well above any uncertainty levels expected.

- More work would be required to confirm that the thermal/intermediate/fast spectrum design using the Jemima plates has adequate sensitivities to materials of interest above the expected uncertainty levels. However, material sensitivities are expected to be adequate and designable based on the similarity of this conceptual design to the design for the Prometheus Critical Experiments.

- If the NCSP Manager determines that it is feasible to pursue a series of epithermal experiments, Zerkle will be the data requester with the support of Heinrichs and both will shepherd the process for the experiments with the expectation of adhering to the CEdT Process while ensuring all interested parties' needs are met.

Any questions in regards to this meeting should be directed to Nichole Ellis at ellis_9899@msn.com.

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