NEA activities in preserving, evaluating and applying data from fast reactor experiments

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Outline

• NEA – Nuclear Science Committee (NSC) – Data Bank
• Knowledge Management at the NEA and the Preservation of Essential Information
  – Integral Experiments Databases, ICSBEP and IRPhE
  – Database tools (DICE, IDAT)
  – Securing the UK Fast Reactor Archive
• Links with other NEA Activities
  – NSC Expert Group on Integral Experiments for MA Management
  – CSNI Study on availability of experimental facilities for fast reactor safety studies
• Conclusions: Progress to date & Looking Ahead
  – Supporting future developments in modelling methods and providing validation
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Russia became most recent member in January 2013.
NEA committee structure

Steering Committee for Nuclear Energy

CSNI
Committee on the Safety of Nuclear Installations

CNRA
Committee on Nuclear Regulatory Activities

RWMC
Radioactive Waste Management Committee

CRPPH
Committee on Radiation Protection and Public Health

NSC
Nuclear Science Committee

NDC
Committee for technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle

NLC
Nuclear Law Committee

As of 18 September 2012
Most of activities described here are carried out in the Programmes of Work for these standing committees.
Nuclear Science and the Data Bank Goals

Nuclear Science (from Strategic Plan 2011-2016)

• The aim of the nuclear science programme is to help member countries identify, pool, develop and disseminate basic scientific and technical knowledge required to ensure safe, reliable and economic operation of current nuclear systems and to develop next-generation technologies. The main areas covered are reactor physics, fuel cycle physics and chemistry, criticality safety and material science.

NEA Data Bank (from Strategic Plan 2011-2016)

• The Data Bank operates as an international centre of reference for its member countries with respect to basic nuclear tools, such as computer codes and nuclear data, used for the analysis and prediction of phenomena in the nuclear field. It provides a direct service to its users by acquiring, developing, improving and validating these tools and making them available as requested.
Nuclear Science – Data Bank Services: Modelling Tools and the means to test/validate them

Experiments, Nuclear Data, Computer Programs, Verification, Validation, Feedback, Applications

- Differential experiments data
- Integral experiments data
- Experimental needs
- Target accuracies
- Code bias and uncertainty for nuclear applications
- Distribution to users for modelling of nuclear applications
- Evaluated Nuclear Data
- Application Data Libraries
- Computer Programs
- Standard problems, Benchmarks, Validation
- State-of-the-art reviews, Sensitivity/Uncertainty Analysis
- Test cases
- Improved modelling needs
- User training
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NEA databases of integral experiments (1)

Nuclear Science

Working Parties

Expert Groups

WPFC
WPNS
WPNCS
WPEC
WPMM

Expert Group on Reactor Fuel Performance
Expert Group on Radiation Transport and Shielding
Expert Group on Reactor Physics and Advanced Nuclear Systems
International Technical Review Group
Expert Group on Uncertainty Analysis for Criticality Safety Assessment
Expert Group on Assay Data for Spent Nuclear Fuel
Expert Group on Criticality Excursions Analysis
Expert Group on Burnup Credit

Integral Experiments Databases

IFPE
SINBAD*
IRPhE
ICSBEP
SFCOMPO

Data Bank

* SINBAD is developed jointly with RSICC
NEA databases of integral experiments (2)

Nuclear Science

**WPFC**
- Expert Group on Reactor Fuel Performance

**WPRS** (Reactor Systems)
- Expert Group on Reactor Physics and Advanced Nuclear Systems

**WPNCS** (Critical Safety)
- Expert Group on Reactor Physics and Advanced Nuclear Systems
- ICSBEP International Technical Review Group
- Expert Group on Uncertainty Analysis for Criticality Safety Assessment
- Expert Group on Assay Data for Spent Nuclear Fuel
- Expert Group on Criticality Excursions Analysis
- Expert Group on Burnup Credit

Data Bank

**IFPE**
**SINBAD**
**IRPhE**
**ICSBEP**
**SFCOMPO**
ICSBEP & IRPhE contributors

• A combined total of twenty-four counties have contributed these projects, 20 in the ICSBEP and 19 in the IRPhEP.

• Argentina, Belgium, Brazil, Canada, China, the Czech Republic, France, Germany, Hungary, India, Israel, Italy, Japan, Kazakhstan, the Republic of Korea, Poland, the Russian Federation, the Republic of Serbia, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, and the United States.
ICSBEP & IRPhE evaluation process (1)

Evaluation process entails the following steps:

1. **Identification** of experimental reactor physics related data
2. **Verification** of data, to the extent possible, by reviewing original and subsequently revised documentation and by talking with experimenters or individuals who were associated with the experiments or the experimental facility
3. **Evaluation** of the data and quantification of overall uncertainties through various types of sensitivity/uncertainty analyses
4. **Compilation** of the data into a standardized format
5. Performance of **sample calculations** of each experiment with standard reactor physics neutronics codes
6. **Formal documentation** of the work into a single source of verified and extensively peer reviewed benchmark reactor physics data.
ICSBEP & IRPhE evaluation process (2)

• The process can be viewed as part of a broader knowledge management function, where information is gathered, evaluated, linked and made accessible to a wide range of users.

• Key is to involve experts in the field with specialist knowledge of the measurement techniques.

• Also aim to involve younger scientists/engineers in the evaluation process so that they can access the *implicit/tacit knowledge* generated during the evaluation process.
International Criticality Safety Benchmark Evaluation Project

- Est 1992/1995
- 195 Fast Critical Experiments
- 657 Fast Critical Configurations

Rocky Flats Critical Mass Laboratory
International Reactor Physics handbook Evaluation Program

- Established in 2000.
- Similar format to ICSBEP, with subsections for each measurement type.
- Primary documentation is available for experiments not yet compiled into experimental benchmarks.

**Measurement Types**

- Critical/Subcritical
- Buckling
- Spectral Characteristics
- Reactivity Effects
- Reactivity Coefficients
- Kinetics
- Reaction Rate Distribution
- Power Distributions
- Isotopic Composition
- Miscellaneous
Database Tools DICE & IDAT

Levels of data preservation
1. Archive
2. Compilation
3. Interpretation + Review → Handbook
4. Database
Extracting, comparing and trending example, C/E k-eff vs. Data Library

Limitations of Handbook
Difficult to search, opaque information content
Cannot trend across evaluations
Adding information requires new revisions

Search experiments with Plutonium Oxide Fuel
DICE Database International Criticality Experiments (est 2001)

- Search for all fast systems
New Features Include:
• Model Mesh Plots
• Automatic Similarity Assessment
• Uncertainty Information

K-eff C/E Fast Reactors

Fast Captures BFS-73
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Securing the UK Fast Reactor Archive

In 2012 NEA initiated an investigation of what could be done to make UK Fast Reactor data available to benefit designers and assessors of future fast reactor systems.

Main tasks:

• determine nature of data generated by the UK Fast Reactor Programme and its state of preservation
• preparation of plan for retrieval and preservation
• if valuable archived material is considered to be in vulnerable location, arrange to bring to ‘safe-haven’,
• prepare report on the UK Fast Reactor fuel programme including its supporting data.

Much of the work described here was undertaken by Mr C.V. Gregory, formerly Director for Fast Reactors, UKAEA.
Overview of UK Fast Reactor Programme (1)

- Original aim was design and operation of a prototype fast reactor power plant from which a series of commercial power plants would be developed.
- In reality the end point of the programme was the construction and operation (1974-1994) of the 250 MWe Prototype Fast Reactor at Dounreay.
- Technological, design and operational expertise gained provided the UK’s contribution to the design and development of the European Fast Reactor (EFR) project 1988 -1993.
- Consumed estimated 50,000 professional person-years of work.
Overview of UK Fast Reactor Programme (2)

- PFR project was underpinned by a major R&D programme
  - construction of critical facilities and research reactors providing core physics data
  - Dounreay Fast Reactor (DFR), research power reactor, first critical in 1960.
  - research information on behaviour of fuel and core materials in normal and extreme conditions
  - continued in PFR and Dounreay PIE facilities until early 1990s
  - it was in the DFR that phenomenon of neutron induced voidage in fuel and structural steels was first identified.
Overview of UK Fast Reactor Programme (3)

• UK’s fast reactors cooled by **liquid metal**
  – DFR - sodium/potassium eutectic alloy, PFR sodium
  – major research programmes undertaken to understand characteristics of these coolants
  – chemistry and metallurgy in reactor, secondary circuits and steam generators were prime topics
  – interaction of water/steam and sodium in the event of steam generator leaks.

• UK project included its own **reprocessing plant**, initially for fuel from DFR and later for PFR fuel.
  – experience of reprocessing and the underlying technology gained from the UK programme is of particular significance.
Sources of Information (1)

• **UK National Archives** located at Kew in London
  – all formal reports of various fast reactor working groups have been archived
  – Material > 30 years old is publicly available
• **British Nuclear Fuels** (BNFL)
  – manufacturer of PFR fuel assemblies
  – involved in fuel design and technology working groups
  – following the cessation of Government funding BNFL created archive of fuel data from the former UKAEA archives.
• **National Nuclear Laboratory (NNL).**
  – NNL has inherited the R&D function technical archive from BNFL.
Sources of Information (2)

• **UKAEA**
  – In the final months of the UKAEA fast reactor project a “super archive” was created. Archive was bequeathed to AEA (Technology), a successor to UKAEA, later to be privatised.
  – A few years after privatisation AEAT withdrew from nuclear work. It is understood that those elements of the archive associated with fast reactor fuel technology were taken over by BNFL.

• **North Highland College in Thurso**
  – No longer wishes to house the collection - steps being taken to catalogue and store these items.

• **Private archives**
  – A number of senior staff from the FR Programme kept their private archives when realised that no formal system to be created. Three private archives have been amalgamated as part of the present project.
Creation of framework of References and Bibliography

• Necessary to provide a framework in which to present and order the material

• Outline of each of the main technical areas is being created to provide logic and historical sequence
  – fuel development programme document ~completed

• Main effort so far has been uncovering the fast reactor material in UK National Archives at Kew.
  – yielded about 1000 relevant references

• Search of NNL archives yielded a further 1000 titles.
  – this area will be pursued in the next phase

• Intention is to share this information with fast reactor community
  – identify suitable experiments for inclusion in NEA databases
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Scope and Overview of the IEMAM Expert Group

- Arose from recognition that accuracy of **MA nuclear data needs** to be improved for:
  - Detailed design of the transmutation systems
  - Accurate prediction of the spent fuel composition

- **Integral experiments** for the MAs are scarce due to restrictions and difficulties in material handling, sample preparation, post-treatment technology, etc

- **Expert Group launched to:**
  - Identify requirement of nuclear data for MA management
  - Review existing integral data and identifying specification of missing experimental work to be required
  - Identify the bottlenecks and considering possible solutions
  - Propose action programme for international cooperation
Brief Summary of the Work Done (1/2)

- **Identified relevant activities in OECD/NEA/NSC and IAEA**
  - WPEC/subgroup 26 & 33 (uncertainty, target accuracies, integral experiments, covariance data)
  - WPFC (fuel cycle transition scenario studies)
  - WPRS (MA burning in thermal reactors)
  - IAEA CRP on Minor Actinide Nuclear Reaction Data (MANREAD)

- **Important Nuclear Data** for MA managements (both for reactor designs and for fuel cycle) identified through uncertainty analysis benchmark and scenario studies: capture/fission/decay of $^{237}$Np, $^{241}$Am, $^{242m}$Am, $^{243}$Am, $^{242}$Cm, $^{243}$Cm, $^{244}$Cm and $^{245}$Cm

- **Reviewing of Existing Integral Data**
  - basic experiments using critical facilities
  - sample irradiation experiments
  - mock-up experiments
  - accelerator-reactor experiments
Brief Summary of the Work Done (2/2)

- Identifying Bottlenecks and Finding Solutions
  - Availability of Sample & Experimental Facility summarized
  - Additional integral experiments proposed:
    - Reaction Rate Measurements in fast system
    - Small Sample Reactivity Worth Measurements
    - Irradiation Experiments
    - Mock-up Experiments
Recommendation of Programme for International Cooperation and Future Work

• Comparison of measurement techniques/data and analysis results
• Cooperation of differential nuclear data measurements complementary to integral experiments
  – Sharing of new cross section measurements and evaluations in nuclides, reactions and/or neutron energy ranges
• Cooperation of design study for specification of MA cores for integral experiments at zero power facility in support of current selected target designs for MA management

• *Publications*
  – Final Report later this year
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TAREF Objectives and Ranking Criteria

- CSNI Task on Advanced Reactor Experimental Facilities (TAREF) started in 2008
- To identify and prioritize research needs for advanced reactors, specifically Gas Cooled and Sodium Fast Reactors
  - Identify relevant safety issues
  - Identify relevant facilities for safety research on identified issues
  - Provide recommendations on strategy for facilities and international programs in support to safety assessment
Participating Countries and Facility Ranking Criteria

Participating Countries:

- Canada
- China
- Czech Republic
- Finland
- France
- Germany
- Hungary
- Italy
- India*
- Japan
- Republic of Korea
- United States

Ranking Criteria:

- Relevance to main issues, (above)
- Uniqueness
- Availability (0-3y, 4-8y, >8y)
- Readiness
- Operation/Construction cost

*India provided useful information on its experimental facilities on SFR safety research for the last meeting of the group (February 2010) and this information was considered for the conclusions of the task
For new SFR projects, the most important and top tier R&D safety needs concern the technical areas with the following priority order:

1. **Fuel Safety (B) and Severe Accidents (D)** issues are of prime interest due to the lack of knowledge on new pin design and materials,

2. **Thermo-fluids (A) and Core Physics** issues are of second priority as one can live with the current knowledge when considering some margins to cover uncertainties,

3. **Sodium Risks (E) and Structural Integrity (F)** issues may be considered with third priority as they are more design dependent

The need of fuel pin irradiation under representative SFR neutron flux is a crucial point for addressing safety issues of high priority
<table>
<thead>
<tr>
<th>Issue Country</th>
<th>Thermo-fluids</th>
<th>Fuel Safety</th>
<th>Core Physics</th>
<th>Severe Accidents</th>
<th>Sodium Risk</th>
<th>Structural Integrity</th>
<th>Other Issues</th>
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<tbody>
<tr>
<td>France</td>
<td></td>
<td></td>
<td></td>
<td>MERARG (D6)</td>
<td>DIADEMO (E6) DISCO-2 (E8)</td>
<td>DOLMEN (F1)</td>
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<tr>
<td>Germany</td>
<td>KASOLA (A1, 2, 3)</td>
<td>FBTR (B1, 4, 5)</td>
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<td>India</td>
<td>SADHANA (A3)</td>
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<td>SOWART (E6), SFTF (E1, 3, 4)</td>
<td>LCTR (F1) LEENA (F2)</td>
<td>LCTR (G2)</td>
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<td>Japan</td>
<td>TTS (A2) PLANDTL (A2)</td>
<td>MELT (D1, 4, 5)</td>
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<td>SAPFIRE (E1, 2, 4) SWAT1-3R (E6)</td>
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<td>Kazakhstan</td>
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<td>IGR (D1, 4, 5)</td>
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<tr>
<td>USA</td>
<td>CYBL (A3)</td>
<td>ACRR (B2, 3, 4, 5)</td>
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<td>ACRR (D1, 3, 4, 5, 6) MCCI (D4, 5) CAFE (D1) SURTSEY (D4)</td>
<td>TTC (E5) SURTSEY (E1, 3, 4, 6, 7, 8)</td>
<td>USV (F1) SURTSEY (F3)</td>
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## Highest ranked facilities, medium term availability

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<tr>
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<th>Thermo-fluids</th>
<th>Fuel Safety</th>
<th>Core Physics</th>
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<th>Structural Integrity</th>
<th>Other Issues</th>
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<tr>
<td>France</td>
<td>NADYNE (A1)</td>
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<td>MASURCA (C1, 2)</td>
<td>KROTOS, VULCANO (D4, 5)</td>
<td>VERDON (D6)</td>
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<td>VULCANO (G1)</td>
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<td>Italy</td>
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<td>LIFUS5 (G3)</td>
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<td>Japan</td>
<td>LSS-LC (A3)</td>
<td>JOYO (B1, 2, 3, 4, 5)</td>
<td>JOYO (D3)</td>
<td>JOYO (F1)</td>
<td>JOYO (G2)</td>
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<td>Korea</td>
<td>PDRC (A3)</td>
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<td>TREAT (B2, 3, 5)</td>
<td>TREAT (D1, 2, 3, 4, 6)</td>
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## Highest ranked facilities, long term availability

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<th>Core Physics</th>
<th>Severe Accidents</th>
<th>Sodium Risk</th>
<th>Structural Integrity</th>
<th>Other Issues</th>
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<td></td>
<td>CABRI (B2, 3, 5)</td>
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<td>CABRI (D1, D2, D3, D4, D6)</td>
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<td>ASTRID (B1, 4, 5)</td>
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<td>JHR (B1, 2, 4, 5)</td>
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<td>Italy</td>
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<td>LIFUS5 (E8)</td>
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Reports available at NEA Website:

For Sodium Cooled Fast Reactors:


For Gas Cooled Reactors:

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Conclusions: Progress to date

- Extensive programme of work to preserve and evaluate data from integral experiments has been established since the mid 1990s.
- NEA Data Bank maintains and distributes several databases of these integral experiments, notably through the ICSBEP and IRPhE projects.
- More recently programmes of work have been established to help preserve data from the UK Fast Reactor Programme and from various experiments related to minor actinide management.
- Data obtained from these programmes are made available to the nuclear science community to provide high quality benchmarks against which modelling methods can be validated.
- Involvement of younger scientists and engineers to work alongside well-established experts in the process of evaluating the information is a highly efficient means of transmitting tacit knowledge to the new generation of nuclear specialists.
Conclusions: Looking Ahead

• Further development of Databases and Database tools, e.g.
  – improved coverage of fast reactor experiments, MAs
  – improved treatment of correlations in uncertainties between experiments
  – production of sensitivities to facilitate identification of similar experiments
• Continuation securing UK archives and creating framework for information
  – Start identifying suitable integral experiments for inclusion in NEA databases
Thank you for your attention

http://www.oecd-nea.org/