US Activities
Summary Report

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**Recent US Activities in Fusion Neutronics**

Funding is very modest (~$100K/y) – Covers few of the following activities

**Main Institutions**

Radiation Safety Information Computational Center (RSICC)

*Codes/Data Implementation on National Energy Research Super Computing (NERSC) Facility*

University of California-Los Angeles (UCLA)

*Analysis of Integral Experiments*

*Safety Factors/Design Margins Quantification*

*Nuclear Design Analyses for Innovative Concepts (APEX)*

TSI Research

*Nuclear Data Needs and Prioritization*

*Coordination of New Data Evaluations*
Main Institutions (Cont’d)

University of Wisconsin (UW)

*Code Development for Activation and Application*
*Nuclear Design Analyses for ARIES, NSO, IFE*

Argonne National Laboratory (ANL)

*Disposal Options Of Spent Nuclear Fuel And Transuranic Elements*
Radiation Safety Information Computational Center (RSICC)

Standards in Fusion Nuclear Analysis

• QA and time saving benefits of standardized neutronics tools

• RSICC involvement in promoting the use of standards

• First major implementation in 1995 for ITER Project in Garching

• Ongoing standards support for United States fusion program at NERSC facility
Present Neutronics Toolkit and Future Plans

- List of codes and data to be installed on NERSC system (mid-1999)
- Repair gas production problem with FENDL-1 carryover data in FENDL-2.0 (coordinate task with IAEA Nuclear Data Section)
- Install MCNP4C with new nuclear data (ENDF/B-VI.5 and ENDL92)
- Complete installation of activation codes
**List of Codes and Data to be Installed and Maintained at NERSC with Priorities**

**TRANSPORT CODES:**

<table>
<thead>
<tr>
<th>Code</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCNP</td>
<td>1* CCC-660/MCNP4B</td>
</tr>
<tr>
<td>DANTSYS</td>
<td>1* CCC-547/DANTSYS-3.0</td>
</tr>
<tr>
<td>TORT</td>
<td>1* CCC-650/DOORS-3.3</td>
</tr>
<tr>
<td>DORT</td>
<td>1* “</td>
</tr>
<tr>
<td>ANISN</td>
<td>1* “</td>
</tr>
</tbody>
</table>

Auxiliary codes VISA, BNDRYS, GRTUNCL, etc are included in DOORS-3.3

1

**ACTIVATION CODES:**

<table>
<thead>
<tr>
<th>Code</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>FISPACT</td>
<td>1* CCC-662/EASY-97</td>
</tr>
<tr>
<td>DKR-PULSAR</td>
<td>1* CCC-???/DKR-PULSAR</td>
</tr>
<tr>
<td>REAC</td>
<td>1* CCC-443/REAC</td>
</tr>
<tr>
<td>ALARA</td>
<td>1* from Paul Wilson (UW)</td>
</tr>
</tbody>
</table>
DATA PROCESSING CODES:

NJOY 1* PSR-480/NJOY99.0
TRANSX 1* PSR-317/TRANSX-2.15
AMPX 2* TBD

CROSS SECTION DATA:

* MATXS format multi-group data based on FENDL-2.
* ACE format continuous energy data based on FENDL-2.
* DLC-189/MCNPXS
* [ENDF/B-VI to supplement FENDL-2]
* FENDL-2 Activation and decay data
* ENDF/B-VI reference nuclear data (same priority as NJOY99)
**PLOTTING CODES:**

| ISOPLOT and XTORID   | 1 | CCC-650/DOORS-3.3 |
| ASPECT              | 1* | Will result from DOORS-3.3 |

| High priority | 1 |
| Low priority  | 2 |

- unanimous agreement (mid-1999)
Analysis of Integral Experiments, Activation, and Nuclear Analyses of Innovative High Power Density Blanket Concepts (UCLA)

Activities Completed:

• USDOE/JAERI Collaboration on Blanket Neutronics
  *Three phases of experiments on open geometry, closed geometry, heterogeneity, multiplication, and line source with penetrations*

• ITER Bulk Shielding Experiments and Analyses
  *Analysis of Large bulk shielding experiment with and without water, heterogeneity, and SCM simulation (UCLA/JAERI)*

• ITER Building Muti-Dimentional Dose mapping
  *Dose mapping of ITER building During operation and after shutdown near and away from NBI opening.*
Main Findings

- Range of uncertainties in tritium production rate (TPR) in Li2O breeder, nuclear heating and activation under various geometrical configuration and operational conditions.

- A novel methodology was developed to arrive at estimates to design safety factors that fusion blanket designers can use to ensure that the achievable tritium breeding ratio (TBR) in a blanket does not fall below unity. In doing so, a normalized distribution function (NDF) was constructed from the prediction uncertainties, $u_i$'s, and their associated deviations, $\sigma_i$'s calculated for all the experiments carried out during the program.

*Fusion Technology, 28, No. 2*
\[
\sum_{j=1}^{K} f_j = 1
\]

\[
\bar{u} = \sum_{j=1}^{K} u f_j
\]

\[
\sigma_u = \left[ \sum_{j=1}^{K} (u - \bar{u})^2 f_j \right]^{1/2}
\]
Recent Activities

• Analysis of decay heat in ~ 32 material samples irradiated with 14 MeV neutrons at JAERI and at two different operating times (5 minutes and 7 hours). ITER Task (with UW and TSI participation).

• Analysis of self-shielding effect in Tungsten placed in simulated divertor/blanket configuration. Experimental data provided by JAERI (with UW participation)

Planned Future Activities

• Participation in the analysis of the following experiments:
  (1) Activation experiment with 14 MeV neutrons for ~ 75 materials (JAERI).
  (2) Decay heat experiment on Cu and SS-316 irradiated in ITER spectrum (JAERI)

  *Experimental data will be provided next year (per F. Maekawa’s e-mail message August 4, 2000)*
Planned Future Activities (Cont'd)

• Derive design margins (uncertainties) for selected responses (e.g. decay heat, fast neutron fluence, TPR, etc.) based on the statistical methodology described above. Experimental data along with the associated experimental uncertainties will be collected from the experiments performed within the collaboration. Likewise, prediction results and the associated calculational based on various codes and data used by EU, USA, JA, and RF will also be collected and used.
Status of Fusion Nuclear Data (TSI)
1999 Symposium on Nuclear Data (November 1999 at JAERI, Japan).

- **Nuclear Data Requests List**
  - Downgraded the Priority
  - Added New Requests for Sn Isotopes

- **FENDL Library Development**
  - Continuing Data Testing and Improvement for FENDL-2
  - International Cooperation Efforts under IAEA, IEA, and ITER Activities
Status of Fusion Nuclear Data
(Continued)

• Need Review of Removal Cross Sections for Long-lived Nuclides:

  Particularly for Nb-94, Tc-99, Ag108m, Al-26, etc.

• Need Review and Evaluation of Nuclear Data for Sn Isotopes for Neutron Transport and Activation Calculations
Coupled IFE Target Neutronics and Hydraulodynamics (UW)

- In the past, target neutronics were performed using single target configuration at start of burn with uniform densities and source profile.

- Densities, configuration, and source distribution are continuously varying during burn.

- Target neutronics calculations need to be coupled with target hydrodynamics calculations to account for varying configuration during burn as well as distributed material densities and fusion neutron source.

- Neutronics transport code DANTSYS is being coupled with target hydrodynamics code BUCKY-1.
## Impact of Coupled Target Hydrodynamics/Neutronics Calculations

<table>
<thead>
<tr>
<th>Uncoupled Calculations</th>
<th>Coupled Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutron multiplication</td>
<td>1.060</td>
</tr>
<tr>
<td>Energy carried by neutrons (MeV/fusion)</td>
<td>11.75</td>
</tr>
<tr>
<td>Average energy of neutrons (MeV)</td>
<td>11.08</td>
</tr>
<tr>
<td>% of neutrons @ 14 MeV</td>
<td>61.4%</td>
</tr>
<tr>
<td>Emitted gamma per fusion</td>
<td>6.21x10^{-4}</td>
</tr>
<tr>
<td>Energy carried by gamma (MeV/fusion)</td>
<td>0.002</td>
</tr>
<tr>
<td>Average gamma energy (MeV)</td>
<td>3.17</td>
</tr>
<tr>
<td>Absorbed n energy (MeV/fusion)</td>
<td>1.960</td>
</tr>
<tr>
<td>Absorbed gamma energy (MeV/fusion)</td>
<td>1.88x10^{-6}</td>
</tr>
<tr>
<td>Endoergic losses (MeV/fusion)</td>
<td>0.388</td>
</tr>
</tbody>
</table>
ALARA Activation Code (UW)

• Newly developed code.

• Continuing development will allow it to respond to evolving needs

• Three main design principles:
  - accuracy
  - speed
  - usability

• ALARA matches the previous generation of activation codes in accuracy and is much faster.
Common Features

• Multi-point (3-D) solutions in a variety of geometries
• Accurate solution of loops in activation trees
• Exact modeling of multi-level pulsing irradiation histories
• User-defined calculation precision/accuracy
• Tracking the accumulation of light ions
• Straightforward, user-friendly input file creation
• Full, easy-to-read activation tree output
• Flexible output options including the direct calculation of waste disposal ratings and clearance indices.
Advanced Features

• Unlimited number of reaction channels
  – already proven essential for IFMIF analysis
• Exact modeling of hierarchical arbitrary irradiation schedules
• Reverse calculation mode

Future Development

• Sensitivity Analysis
• Sequential Charged Particle Reactions
• Non- Nuclear Sources/ Sinks/ Mixing
• Advanced Post- Processing
Disposal Options Of Spent Nuclear Fuel And Transuranic Elements Activity At ANL

- Assessment and R&D are underway at Argonne National Laboratory to define the best solutions to dispose of spent nuclear fuel and transuranic elements. Several options are under consideration including:
  - Accelerator Systems
  - Fission Reactors
  - Fusion Devices

- R&D activity activities have been performed to develop the essential technologies for the most promising options:
  - Liquid metal systems
  - Molten salt technology
  - Nuclear fuel development
  - Nuclear spent fuel processing

- Model development and method validation for assessing the different options under consideration have been carried out.