OVERVIEW OF JAERI/US
Collaboration on
Fusion Neutronics

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OVERVIEW OF JAERI/US COLLABORATION ON FUSION NEUTRONICS

Introductory Remarks

- The collaboration started formally in 1983
- The collaboration has been extremely successful
  - Excellent technical accomplishments
  - Ideal professional interactions among scientists
  - Presented by USDOE to the State Department as excellent example of mutually beneficial cooperation
  - Marked the first time the US came to Japan to use a Japanese facility
- Technical Accomplishments
  - Much needed development in measurement techniques
  - Great advances in techniques for integral neutronics experiments
  - New methodologies for analysis and interpretation of experiments
  - Uncovered many areas of data deficiencies and methods shortcomings
  - Comprehensive: tritium breeding, nuclear heating, radioactivity, decay heat, neutron transport

Highlights of research findings from the USDOE/JAERI Collaborative Program

Background

(1984-1989)

- Intense 14 MeV point source driven experiments on local tritium production rate measured by various techniques.

- Li_2O used as the basic breeding material.

- Test assembly progressed from a single material zone (Li_2O) to a more prototypical assembly that includes the engineering features of a blanket;

e.g. S.S. first wall
coolant channels
neutron multiplier (Be) in various configurations

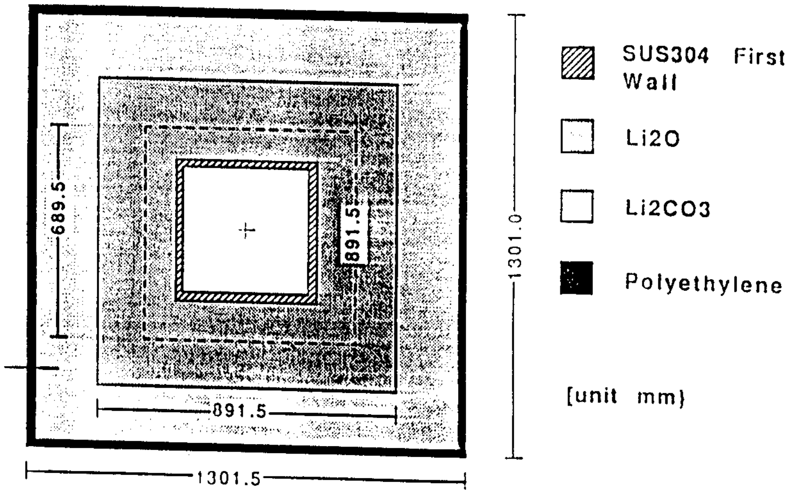
- Fifteen (15) experiments were performed through Phase I to Phase II in open and closed geometry, respectively.

(1989-1992):

Major shift in focus and great (historic) achievements:

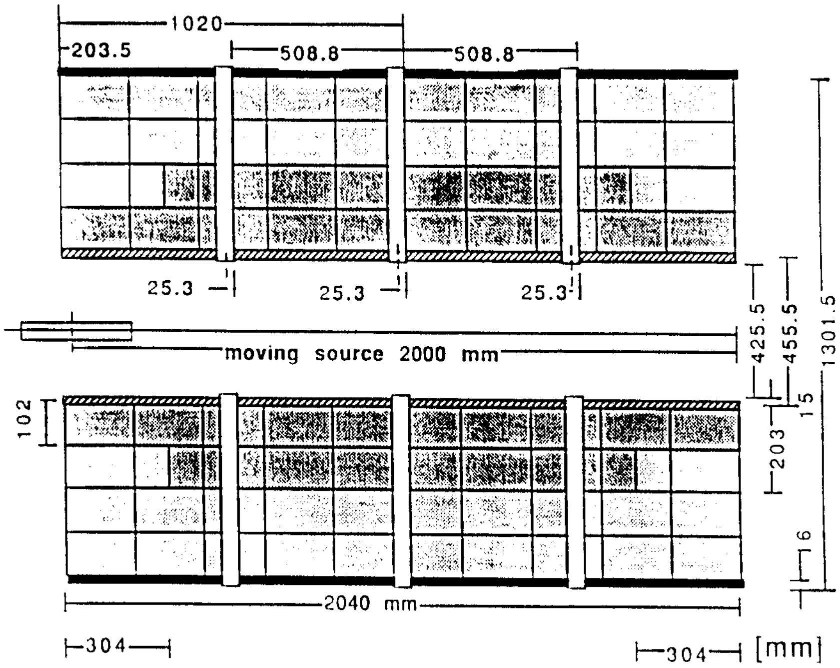
1. Simulated line Source driven experiments on tritium production Rate.

   - The line source has close similarity to the plasmas in Tokamaks. (e.g. better simulation to the angular



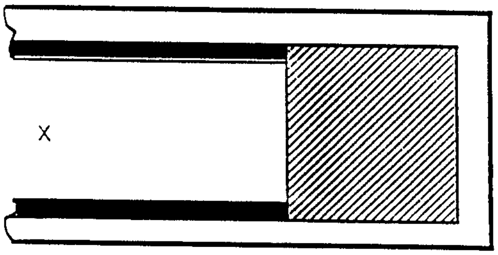
Geometrical Arrangement for Phase IIIA Experiments

(Cross-Sectional View)

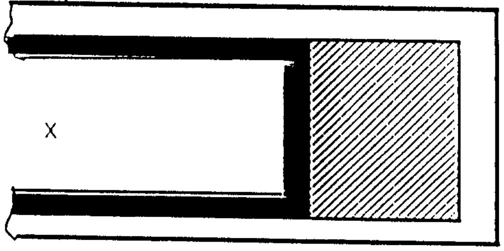


Geometrical Arrangement for Phase IIIA Experiments

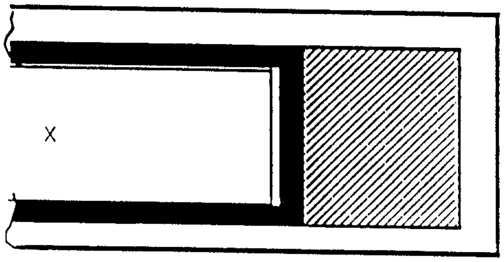
(elevation View)



Reference Experiment (REF)



Be Front Experiment (BEF)



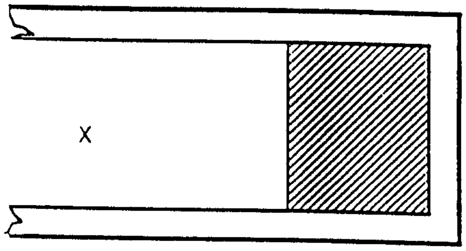
Be Front Exp. With First Wall (BEFWF)

Phase IIB Exp.

■ Beryllium

□ Li2CO3

▨ Li2O



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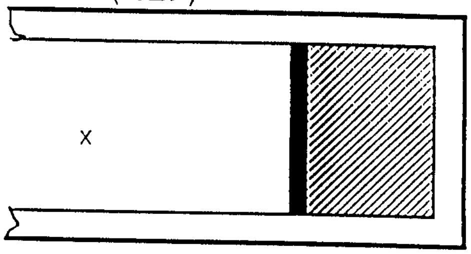
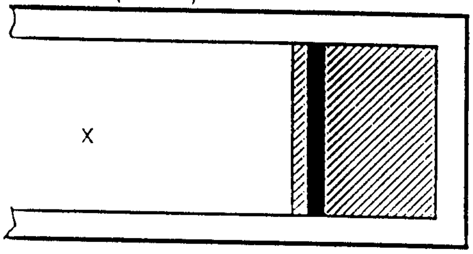


Be Front Experiment (BEF)



Be Sandwiched Experiment (BES)

Phase IIA Exp.

SUMMARY OF FINDINGS ON TRITIUM BREEDING

- Various experimental techniques to measure tritium production rates exhibit significant differences among themselves in measured values

  ~ 8% for ^6Li

  ~ 22% for ^7Li

- The low energy component (< 100 KeV) of the neutron spectrum shows, in general, larger uncertainty and is one of the major contributors to the overall uncertainty.

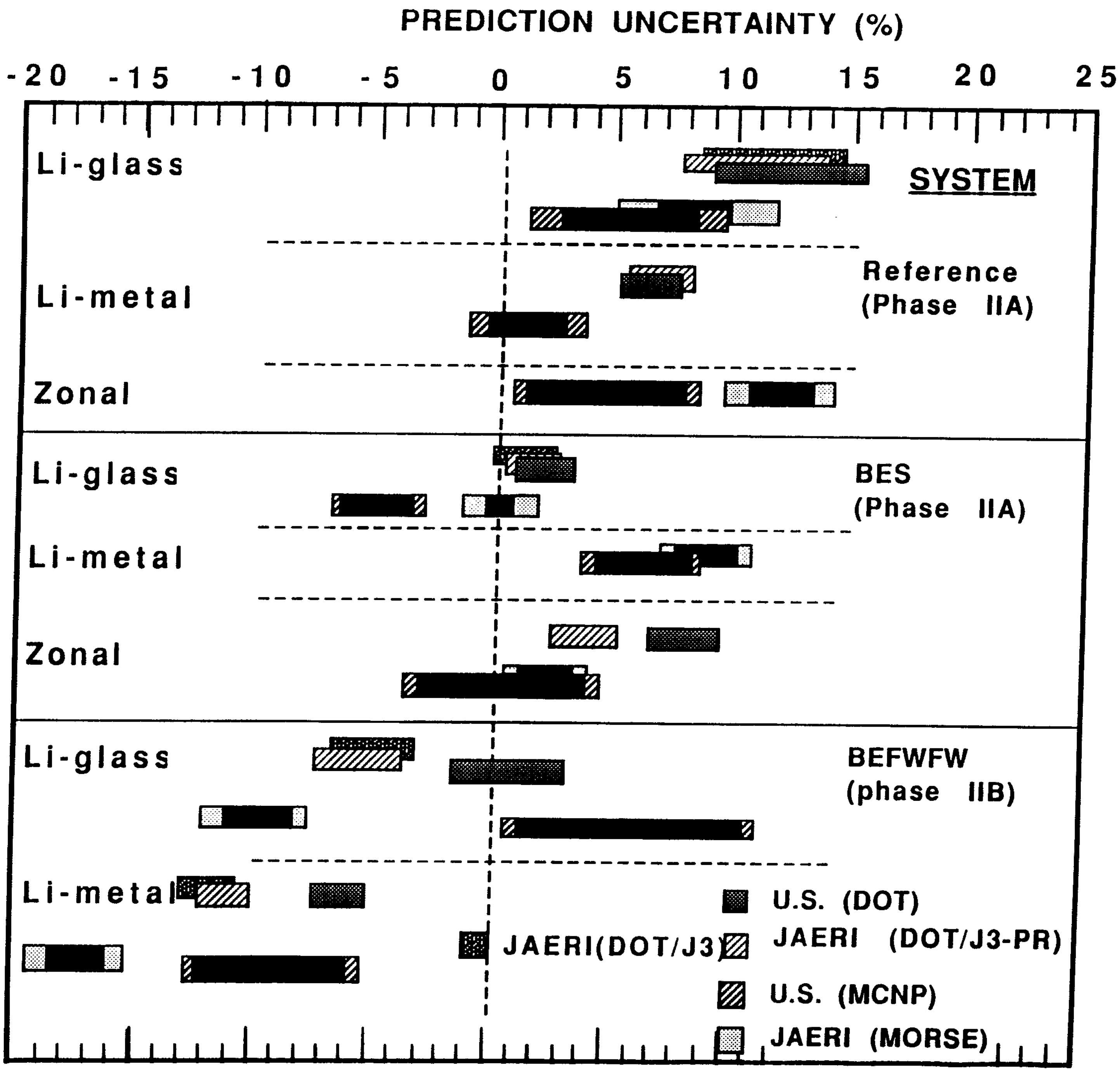
- For a given measurement technique, prediction from calculations are different from those from measurements. For the simple configuration experiments, the following <u>uncertainties</u> are obtained:

  <u>MCNP</u>

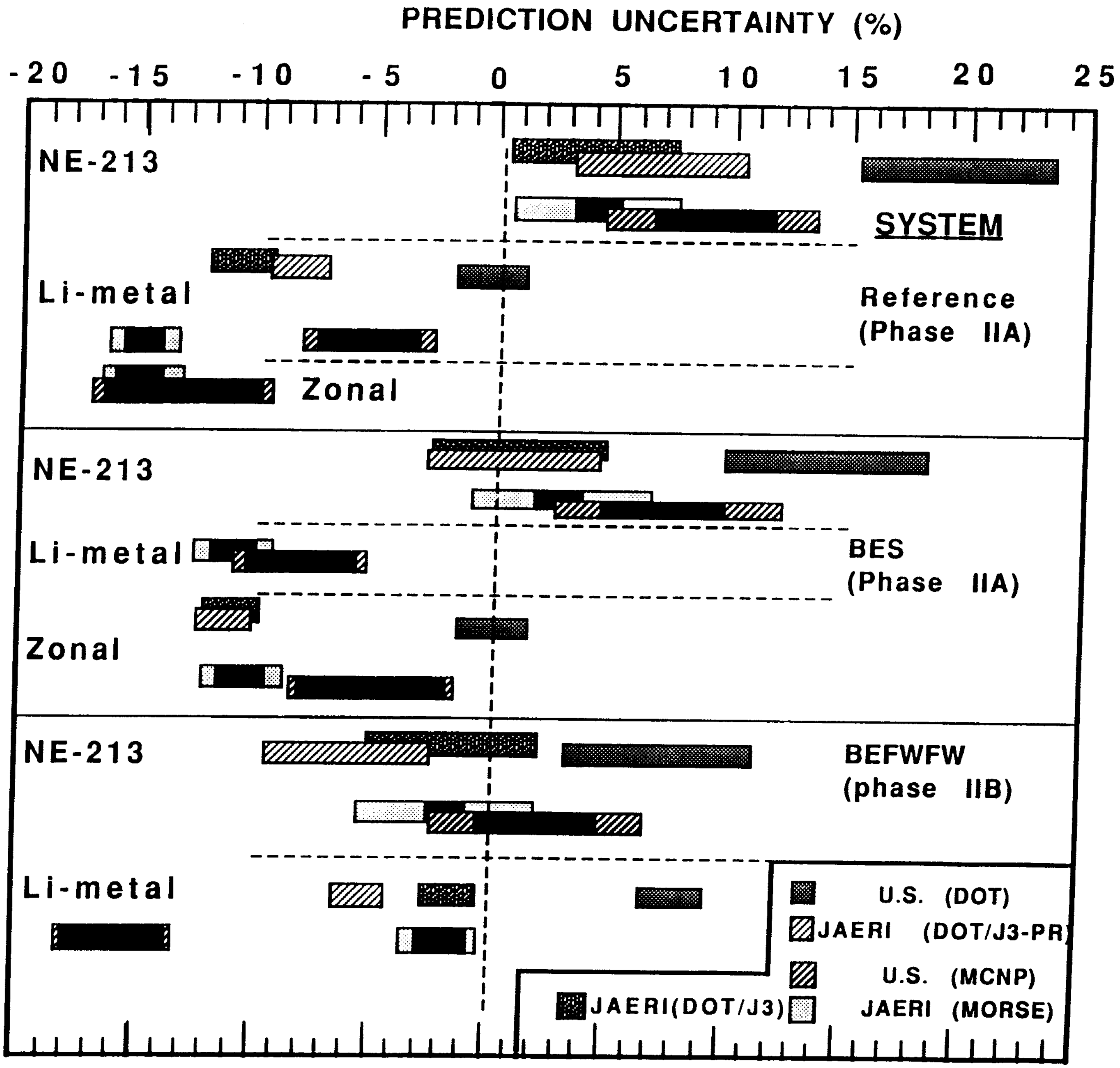
  T_6 : - 10% to 18%
  T_7 : - 8% to 18%

  <u>DOT</u>

  T_6 : - 5% to 24%
  T_7 : - 15% to 25%



LINE-INTEGRATED TRITIUM PRODUCTION RATE FROM Li-6 (T-6)



LINE-INTEGRATED TRITIUM PRODUCTION RATE FROM Li-7 (T-7)

OVERALL CONCLUSIONS AND RECOMMENDATIONS ON TRITIUM BREEDING

- The overall uncertainty in predicting tritium breeding in simple configurations is on the order of 5 to 10%.
- Future effort in the integral experiments area should focus on:
  - Improving and selecting an accurate measurement technique for tritium production
  - Future integral experiments should aim at
    - complex geometries with coolant channel and structural heterogeneities, interfaces among breeder/coolant/structure/multiplier
    - avoid sources of experimental uncertainties: e.g. room return
    - focus on <u>smaller number</u> of experiments with greater emphasis on improving measurements and analysis
- Tritium self sufficiency in fusion systems can not be assured. Early verification is necessary. Recommend efforts on:
  - comprehensive modelling of the complete fuel cycle
  - direct measurements of tritium production in sectors in fusion facilities (e.g. in ITER)
  - emphasize R&D goals for self sufficiency e.g. high tritium fractional burnup in plasma (divertor performance and recycling in tokamaks)

RADIOACTIVITY
INTEGRAL MEASUREMENTS

- Approach:

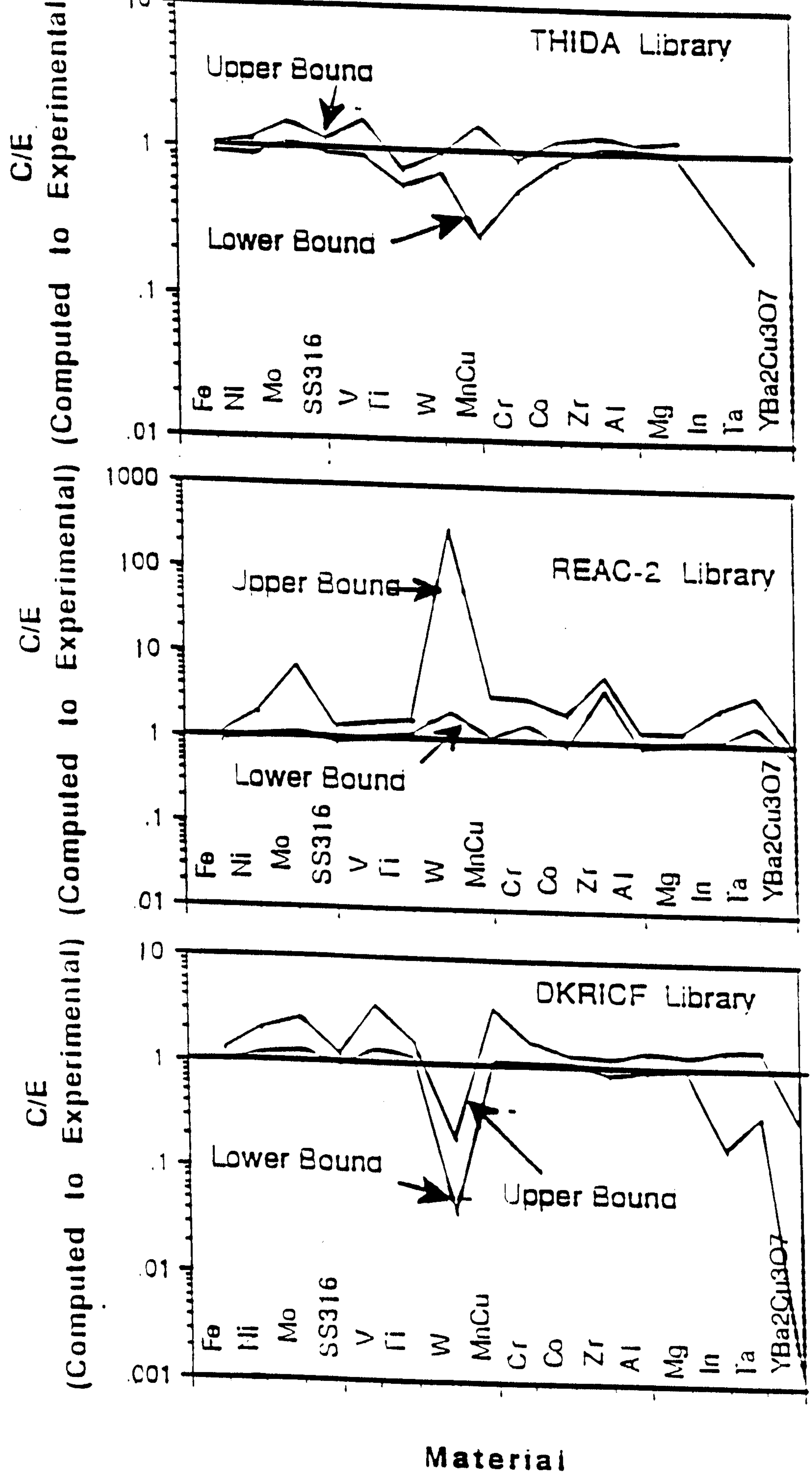
  1) Irradiate small samples of several materials at key locations of the first wall/blanket prototype planned for other integral experiments, e.g. tritium breeding or shielding.
  2) The γ-spectroscopy of the irradiated samples obtained at variable cooling times shows contributions from radioactive products with half-lives ranging from a few minutes to a few years.

- Advantages:

  - Direct experimental verification of integral parameters (radioactivity) expected in fusion environment.

    - Measure of adequacy of prediction capability of decay data, reaction cross section, and calculations.

  - Cost effective since it is performed concurrently with other integral experiments.



Measured and DKRICF computed decay γ integrated decay rate: comparison.

Accomplishments (Radioactivity)

- Measurements were conducted on samples of Fe, Ni, Cr, Mn-Cu alloy, Ti, Mo, Zr, Ta, W, Si, Mg, Al, V, Nb, SS316, Sn, Ag, Pb, Zn, In, and Au. Half-lives covered range from 2.24m (^{28}Al) to 5.3y (^{60}Co). The samples were irradiated at selected locations in fusion blanket assemblies.
- γ-spectroscopy of each sample was done at varying cooling times.
- Measurements were compared to calculations. Sources of discrepancies were identified.

Issues/Future Effort

- Need more integral measurements for short half-life, and new techniques (and higher source intensity, longer irradiation) for long-term activation products.
- Provide "request list" of a small number of differential cross section measurements.
- Automate/computerize incorporation of decay data in radioactivity library (e.g. from nuclear data sheets).

NUCLEAR HEATING

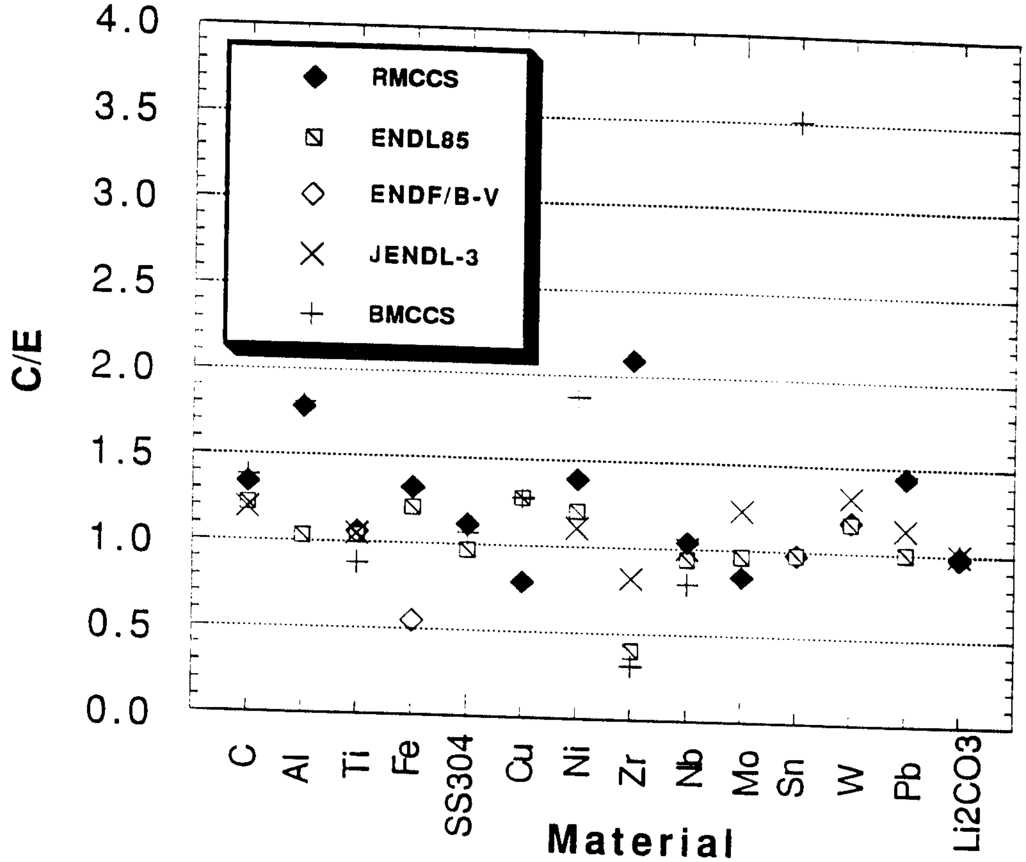
Need for Measurements

- Calculational methods for nuclear heating (kerma factors) for fusion application were developed about 20 years ago. Experimental verification of calculated nuclear heating rates, particularly using the most recent libraries, is required to provide uncertainty estimates for temperature and temperature-dependent parameters, e.g., tritium diffusion, structural material response, etc.

Measuring Technique

- A microcalorimetric technique has been developed to measure total nuclear heating in small material samples kept very close (3 to 5 cm) to intense neutron source (RNT). Very sensitive thermal sensors and automated electronic instrumentation have been employed in the experimental set-up.

Nuclear Heating Experiments - C/E Spreads



Accomplishments (Nuclear Heating)

- The experimental technique has demonstrated its large potential by helping obtain nuclear heating rates in samples of Graphite, Al, Ti, Fe, SS304, Cu, Ni, Zn, Zr, Nb, Mo, Sn, W, Pb, and Li_2CO_3. It is remarkable to note that the lowest measured heating rates have been as low as 40 μW/g.

- The calculations have been performed using both US and Japanese codes and data-libraries. Large discrepancies have been found between calculations and measurements. However, for all the above materials, almost all the C/E values lie in a band extending from 0.5 to 2.0.

Issues/Future

- Need to focus on separating uncertainties in neutron/gamma transport from those due to kerma factor (e.g. simultaneous measurements of neutron spectra, key reaction rates; predictable assemblies).

- Need further development in measurement techniques for in-situ measurements and higher sensitivity.

- Need to develop techniques to separate neutron heating from gamma heating.

- Higher intensity neutron source will help tremendously.

FUTURE COLLABORATIVE EFFORT

- The US/JAERI collaborative effort in its present format will be completed this year.

- Collaboration between US and JAERI will proceed in the future in new format and other arrangements most compatible with new international activities (e.g. ITER, IEA, others).

- UCLA and JAERI have developed an excellent working relationship and effective communication channels among scientists from both organizations. This should greatly contribute to the success of future collaborative efforts.

RECOGNITION AND APPRECIATION

I would like to express my great appreciation to the many scientists, program managers and government officials who have contributed to making the US/JAERI Collaborative Effort on Fusion Neutronics a great success.

In particular, special thanks to:

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