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IMPROVED STRUCTURAL MATERIAL CROSS SECTIONS FOR STEEL REFLECTED FAST REACTOR CALCULATIONS

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INTRODUCTION

The conversion of fast breeder reactors into plutonium burning reactors needs the removal of breeder blankets and their replacement by steel reflectors. This modification creates specific problems in the prediction of core characteristics due to nuclear data and computational methods.

The CIRANO experimental program has been realised at the MASURCA facility in order to provide an experimental basis for the development of a calculational scheme for these steel reflected configurations. The preliminary analysis of this program with the JEF2/ECCO/ERANOS nuclear data and calculation system code has shown discrepancies between calculation and experimental results for two integral parameters of interest: the reactivity and the fission rate traverses in the reflector [1].

The removal of these discrepancies was one of the objective of a thesis dedicated to the development and the validation of JEF2/ECCO/ERANOS nuclear data and calculation system code for steel reflected fast reactors [2]:

First, a reference calculation scheme was defined and validated with a comparison with TRIPOLI Monte-Carlo code results. Then, the role of nuclear data in the residual discrepancies was investigated. An adjustment of structural material cross sections was made in order to quantify the possible changes on cross sections and especially on structural material cross sections.

The conclusions of the part of this work devoted to nuclear data are summarized in this paper.

EXPERIMENTS

The three configurations of the CIRANO experimental program, realised in order to study the replacement of breeder blankets by steel reflectors are:

- ZONA2A configuration with both axial and radial fertile blankets,
- ZONA2A3 configuration with the radial fertile blanket replaced by steel reflector,
- ZONA2B configuration with both axial and radial steel reflectors.

All three configurations are fuelled with the ZONA2 core fuel cell containing ~25% enriched plutonium oxide fuel. In the ZONA2A3 and ZONA2B configurations the fertile blanket is replced by sodium/steel reflectors containing 25% sodium/ 75% stainless steel.

CALCULATIONAL SCHEME

Reference ECCO cell calculations use a macrocell modelisation for cross section preparation of the reflector media. This method provides an accurate transport calculation and a precise coupling of core and reflector media with a fine group treatment (1968 groups).

These cross sections are then used in spatial calculations with the ERANOS code scheme with 175 energy groups, in order to explicitly treat large scattering resonances of structural material isotopes. It has been shown that reducing the number of groups increases the discrepancies. This is mainly due to the bad treatment of the slowing down process in the spatial calculations.

The chosen method has been validated with the TRIPOLI Monte-Carlo code. Differences obtained between ERANOS and TRIPOLI for reactivity and fission rate traverses were very small.

The discrepancies between calculated and experimental values obtained are, for the two studied integral parameters of interest:

(E-C)/C=0.00324, (E-C)/C=0.00127 and (E-C)/C=-0.00261 for the reactivity of CIRANO ZONA2A, ZONA2A3 et ZONA2B configurations respectively.

(E-C)/C=-0.076 for the ratio of the maximum of the U235 fission rate in the reflector to the U235 fission rate at the core centre of ZONA2B configuration.

NUCLEAR DATA STUDY

The residual discrepancies were then due to nuclear data.

Sensitivity calculations of these integral parameters to cross sections were made and the isotopes of interest for the study of reflectors were determined. The more important one is Fe56. Then the two other structural materials Cr52 and Ni58 are coming.

Impact of different Fe56 evaluations on integral parameters:

The use of different Fe56 evaluations does not lead to a significant reduction of the C/E discrepancy for the U235 fission rate distribution.

For instance, the use of the EFF3.0 evaluation, candidate for the JEFF3 starting file, only gives a small difference for the calculation of U235 fission traverse compared to the JEF2.2 calculated one. The changes between JEF2.2 and EFF3.0 evaluations, are located above 850keV, while the U235 fission traverse is essentialy sensitive to cross sections in a lower energy range.

However, the use of EFF3.0 Fe56 evaluation gives a discrepancy between the k-effective values obtained with the reference method and the experimental results of ZONA2B configuration equal to (E-C)/C=-0.00056 and so leads to a decrease of the C/E discrepancy.

The C/E discrepancy for fission rate traverse in the steel reflector cannot be reduced with the existing Fe56 evaluations.

Adjustment of JEF2 data library:

The first adjustment of JEF2 nuclear data, made in order to reduce C/E discrepancies of the integral parameters of fast breeder reactors and to validate nuclear data, was described in Reference [3]. This lead to the realization of ERALIB1 adjusted library. In this library, only predominant structural material isotopes (Fe56, Ni58 and Cr52) were adjusted. About 350 integral parameters were used among whom are the three critical masses of previously described CIRANO configurations. But the ratio of U235 fission rate in the reflector to the U235 fission rate at the core centre was not included in the data base.

The discrepancies between the ERALIB1 calculated values of critical masses and the experimental ones are of small magnitude. But the discrepancies between ERALIB1 calculated values and experimental results for U235 fission rate ratio, in different points of the reflector to the core centre, are quite similar with those obtained using JEF2 data. This was related to the fact that the adjustment of structural material cross sections was not sufficient.

In order to improve the adjustment results, ratios of U235 fission rates and Pu239 fission rates were introduced in the integral parameter data base, together with new integral parameters of experiments sensitive to structural materials in particular (reactivity worth and k-infinity of Kobra experiments, for instance). Then, a new adjustment was made.

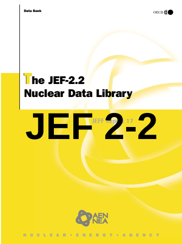
The discrepancies between experimental and calculated fission rate ratios are after this second ajustment eliminated. This is essentialy due to a more precise adjustment of Fe56 and Cr52 cross sections and comes from the introduction of the CIRANO integral parameters in the adjustment.

The more significant cross section variations obtained with this new adjustment are given on the following figures. The most important changes are:

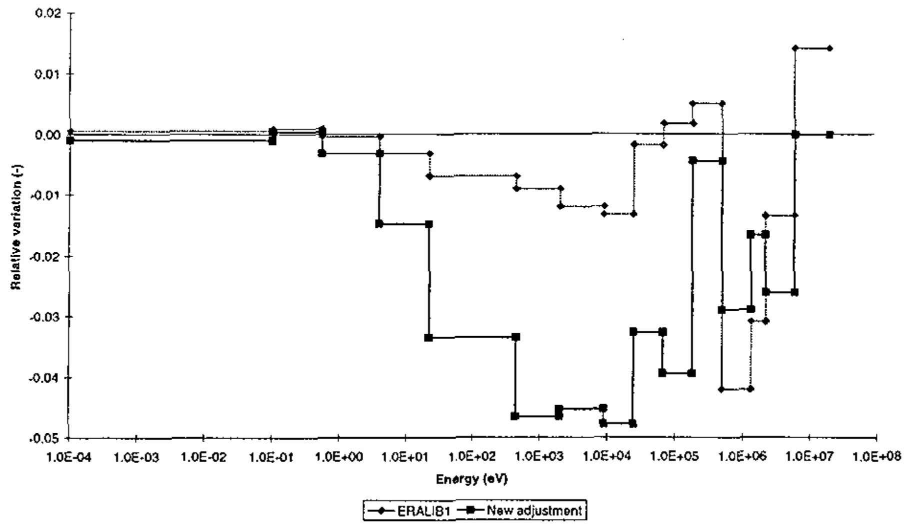
- for the Fe56 elastic scattering cross section, a decrease of about 5% between 0.5keV and 500keV,

- for the Fe56 capture cross section, an increase of about 15-20% between 5eV and 5keV,

- for the Cr52 elastic scattering cross section, a decrease of about 30% between 50keV and 500keV.



Variations of the ERALIB1 and new adjustments for the Fe56 elastic scattering cross section



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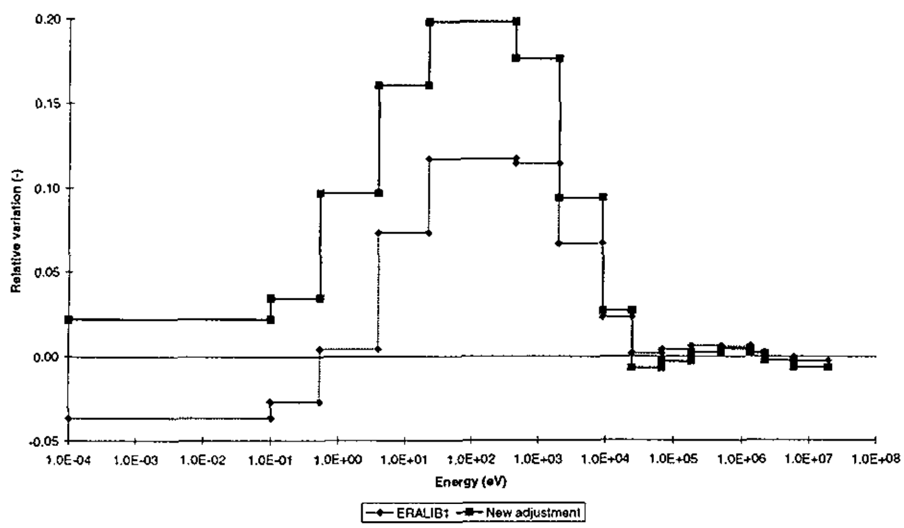
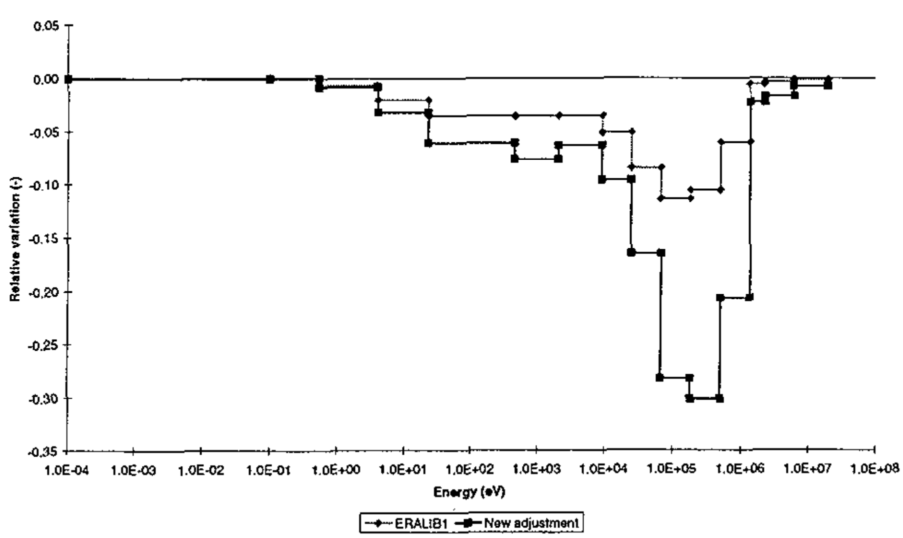


Variations of the ERALIB1 and new adjustments for the Cr52 elastic scattering cross section



In the recent A. Luthi's thesis [4] concerning gamma-heating calculations for Pu-burning fast reactors, C/E discrepancies for TLD responses in the steel reflectors of the ZONA2B configuration are eliminated with these cross section changes. would be quite reduced with this adjustment. This quite independant aspect of the conclusion brings more confidence in the results.

CONCLUSION

This study indicates the need to work towards better evaluations for structural materials in the 5eV-500keV energy range. Changes in the EFF3.0 data within their uncertainties might be possible in order to satisfy our need for accurate cross sections but differential measurements in this energy range, provided they are accurate enough, will bring a valuable cross check of these findings.

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