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Fusion Decay Power: validation of FISPACT and FENDL/A-2.0

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Abstract

Integral experiments are a rich source of information with which a wide range of validation and comparison exercises can be made in the activation data field. Materials samples have been irradiated in a wide range of simulated D-T neutron fields at three European laboratories and at JAERI FNS. The later experiment is unique because decay heat rather than activity was measured. Some results from that experiment are reported here with some details of data corrections that have been made for EAF-99.

Introduction

Comparison with experimental measurements is essential to validate the calculation method (FISPACT inventory code) and the data libraries. A program of experimental measurements is in progress at three European laboratories. Measurements made at JAERI FNS [1] have generated decay heat results, which are reported here. The results of the different validation exercises, when correlated with other sources of information, led to a set of data corrections which have been implemented on the European Activation File EAF-99 [2].

JAERI FNS

14 MeV neutrons are generated by a 2 mA, 350 keV deuteron beam impinging on a stationary tritium-bearing titanium target. The total neutron flux at the sample location, can be up to 3.0 10^{10} n/cm^{2}s^{-1}. Irradiation times of 5 min and 7 hours were used. Measurements were made on 32 materials.

The decay energy in an irradiated thin sample was measured in the Whole Energy Absorption Spectrometer (WEAS) which comprises two large bismuth-germanate BGO scintillators in a geometric arrangement that provides almost 100% detection efficiency for both β and γ-rays. Using the highly sensitive WEAS method, both β and γ-ray decay energies were measured at selected cooling times as early as one minute after the irradiation ended. The overall experimental uncertainty totals between 6 to 10%.

Calculations

The European Activation System, EASY, has been used to perform the validation exercises. Two cross section data bases have been accessed using the 97 version of the FISPACT code [3]: EAF-97 [4] and FENDL/A-2.0 [5]. The decay data libraries used with the two cross sections libraries are also different: the EAF-97 decay data and the FENDL/D-2.0 data, respectively. In order not to bias the experimental spectral data, the groupwise libraries used in the calculational scheme both correspond to a 175 Vitamin-J groups structure collapsed using a flat micro flux weighting function.

Results

Figure 1 shows the results of the measurements made on copper, compared to predictions made using the EAF-97 and FENDL/A-2.0 libraries. At cooling time > 30 min there is a small under-prediction. The pathway analysis facility in FISPACT allows the likely reaction to be pin-pointed and the $^{63}Cu(n,\alpha)^{60}Co$ [70.8 d/9.1 h] was investigated further. Figure 2 shows the change that was made to the data during the construction of EAF-99. The reaction to the ground state was increased by 15%; this change was guided both by the EXFOR database and the integral measurements.

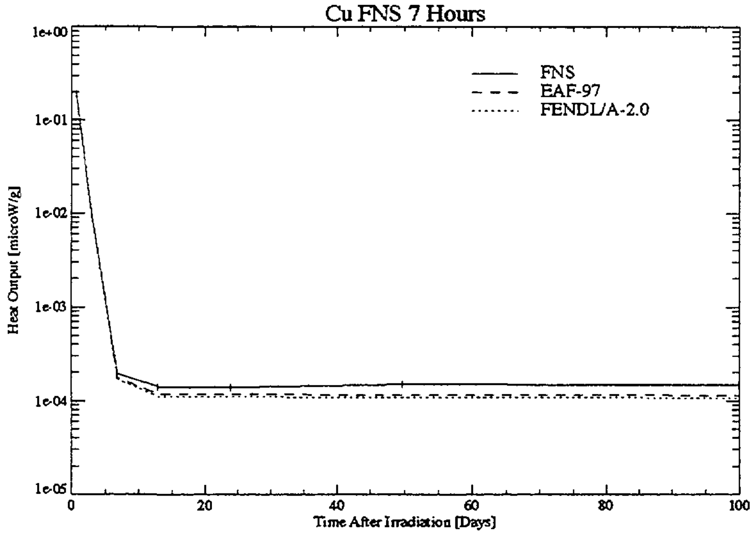

Figure 1 Decay curve for copper compared with EAF-97 and FENDL/A-2.0 predictions.

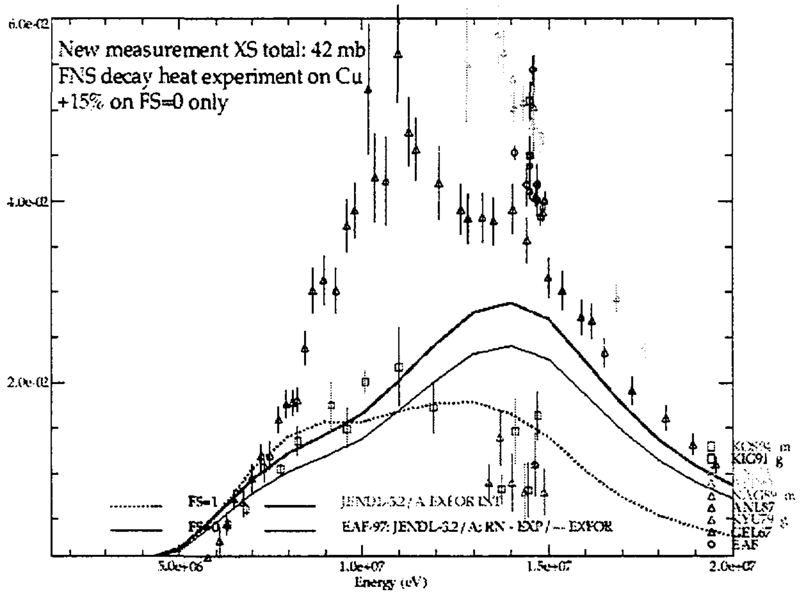

Figure 2 $^{63}Cu(n,\alpha)^{60}Co$ data from EAF-97 and –99 compared to EXFOR results

Similar comparisons for the other materials were carried out. For the FENDL library about 2/3 of the reactions show good agreement (10-20%) between the predictions and experiment over the time period of 1 min – 3 months.

The ability of FISPACT to predict uncertainties based on the cross section uncertainties meant that these uncertainties could be compared with those found experimentally. In most cases these were similar.

Although this benchmark exercise is very positive, it must be remembered that the spectrum is much harder than found in typical fusion devices. It is therefore not possible to validate the non-threshold reactions, such as capture, that have been found to be important. Thus, in the FNS spectrum ^{64}Cu is produced by: $^{63}Cu(n,\gamma)^{64}Cu$ (0.8%) and $^{65}Cu(n,2n)^{64}Cu$ (99.2%), while in an ITER spectrum it is produced by: $^{63}Cu(n,\gamma)^{64}Cu$ (83.8%) and $^{65}Cu(n,2n)^{64}Cu$ (16.2%).

Conclusions

The calculational method used in the FISPACT inventory code is good. For many materials the cross section and decay data libraries are adequate to predict decay power. The low energy reactions were not tested by this experiment.

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References

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