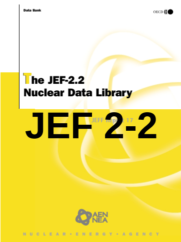

NOVEMBER 1994 JEF/Doc.498

Jezebel Benchmark Calculations performed with MCNP4A

T.T.J.M. Peeters and A. Hogenbirk

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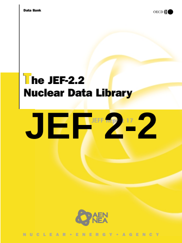

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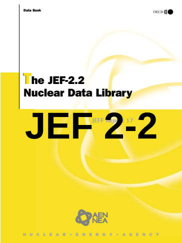

SUMMARY

In this report the results are given of the Jezebel criticality benchmark obtained by using the Monte Carlo code MCNP4A [1]. Results are given for both ENDF/B-V and JEF2.2 data. When JEF2.2 data are used, the resulting value of k_{eff} appears to be approximately 1 % lower than the result obtained by using ENDF/B-V data. This difference is due to a lower fission rate and a higher capture rate in ^{239}Pu from JEF2.2 for 67 keV < E_n < 10.0 MeV.

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1. INTRODUCTION

The Jezebel criticality benchmark [2, 3] consists of a sphere of radius 6.385 cm containing metallic plutonium fuel of the following composition: ^{239}Pu: 0.03705, ^{240}Pu: 0.001751 and ^{241}Pu: 0.000117 atoms/barn-cm. The Jezebel Criticality benchmark [4] is a fast benchmark, which can be used for testing Pu cross sections in the high energy range. In this report results are given from MCNP calculations using cross section data from the JEF2.2 and ENDF/B-V library. Extra care was given to a correct procedure to obtain k_{eff} values from an MCNP criticality calculation. A comparison is given between results from MCNP4A and the previous version MCNP4.2. A comparison with results obtained by GE [4] is given as well.

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2. USING MCNP FOR CRITICALITY CALCULATIONS

It is known [5] that Monte Carlo criticality calculations in principle suffer from a bias in the calculated value of k_{eff}. However, by using a stringent procedure, this bias can be made very small. It is essential to use a fission source distribution which is well converged.

Therefore, the following standard procedure was used (MCNP manual [1] page 2-153):

1. Starting form a point source, a fission source distribution was obtained by performing a calculation with a small batch size and a large number of cycles.
2. The fission source produced in step 1 was used in a subsequent calculation with a larger batch size and a smaller number of cycles.
3. Finally, the fission source obtained in step 2 was assumed to be converged and used in a final calculation with an even larger batch size.

Calculations were performed with the following parameters:

1. Batch size: 1000, initial guess of k_{eff}: 1, number of total cycles: 210, number of active cycles: 200, the first cycle starting from a point source in the center of the model
2. Batch size: 4000, initial guess of k_{eff}: 1, number of total cycles: 40, number of active cycles: 30, the first cycle uses a fission source produced in the last cycle of the previous MCNP run.
3. As the previous step, exept for the batch size, now being 40000.

Proceeding this way, we finally obtain:

$$k_{eff} = 1.00240, \quad \sigma = 0.00017$$

In these calculations ENDF/B-V data were used.

In order to compare the result of this procedure with a calculation of the average value of k_{eff} obtained from several MCNP runs, the following calculations were done as well:

First k_{eff} was calculated by MCNP using a point source in the center of the Jezebel model, the batch size being 1000 neutrons. Starting with an initial guess of $k_{eff} = 1$, a number of 210 cycles then were used, the first ten being settle cycles so that the last 200 active cycles were used for the calculation of k_{eff}. Then the final fission source produced by this calculation was used by a next run of MCNP using identical parameters and giving a second estimate for k_{eff}. Using the fission source of each run in a subsequent run, this procedure was repeated 21 times until a sequence of 23 values of k_{eff} finally was obtained. These values and their corresponding standard deviations are plotted in fig. 2.1.

From this sequence, mean and standard deviation are:

$$k_{eff} = 1.00242, \quad \sigma = 0.00169$$

As $k_{eff} = 1.00240 \pm 0.00017$ is well within $k_{eff} = 1.00242 \pm 0.00169$, it may be concluded that the proposed standard procedure gives a reliable result for k_{eff}.

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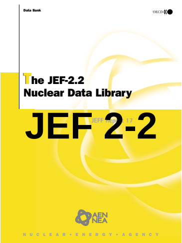

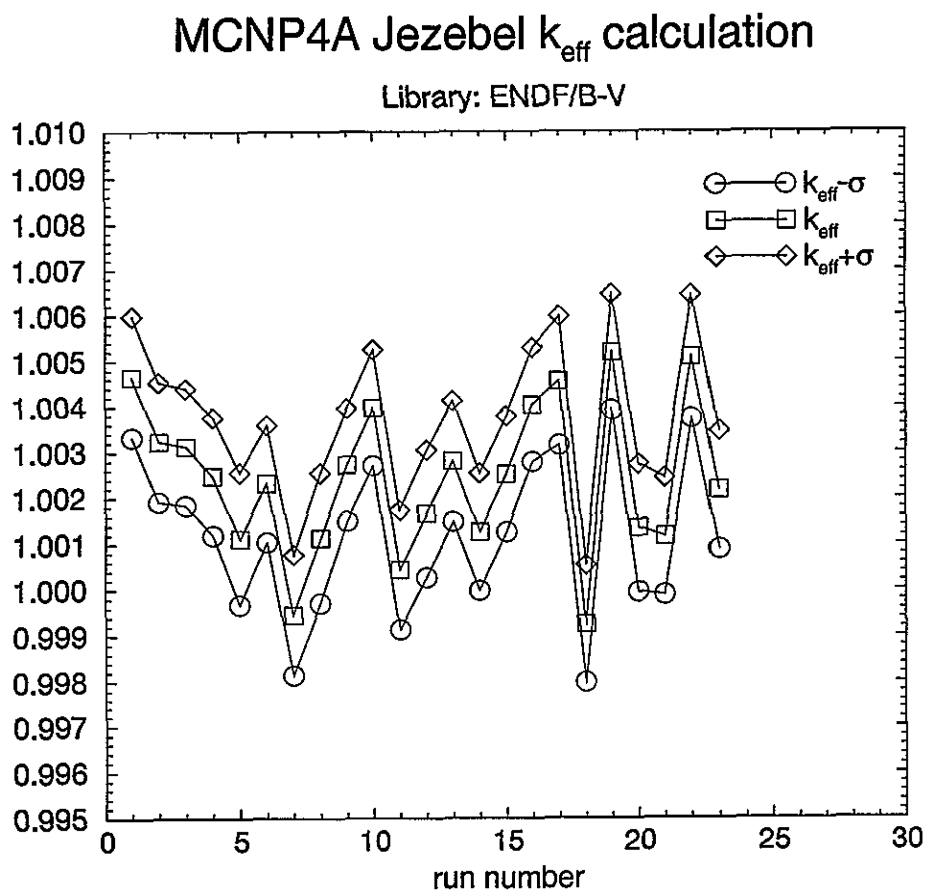

Figure 2.1 k_{eff} and corresponding error boundaries $k_{eff} \pm \sigma$ for 23 subsequent MCNP runs, σ denoting the standard deviation calculated by MCNP

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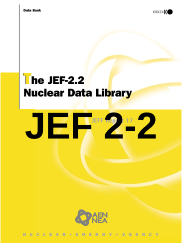

3. CALCULATIONS

3.1 Comparison MCNP4A - MCNP4.2

In the past several criticality benchmarks have been performed using MCNP4.2. A consistency check was performed in order to be able to relate these results obtained by MCNP4.2 with those obtained by MCNP4A.

3.2 Comparison ECN - GE results

In [4] the results are given of the Jezebel Benchmark as obtained by GE using MCNP4.2 and ENDF/B-V cross section data. Using the procedure mentioned in section 2, calculations were performed by us also using MCNP4.2 and ENDF/B-V data.

3.3 Comparison of JEF2.2 and ENDF/B-V data

Calculations were performed with JEF2.2 and ENDF/B-V cross section data in order to study the dependence on the cross section data used in the calculations. Calculations were again performed using the procedure mentioned in section 2.

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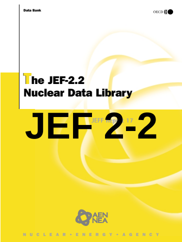

4. RESULTS

4.1 Comparison MCNP4A - MCNP4.2

Using the procedure of section 2, the following results (Table 4.1) were obtained:

Table 4.1 k_{eff} calculated by MCNP4A and MCNP4.2

	k_{eff}
MCNP4A	1.00240 ± 0.00017
MCNP4.2	1.00248 ± 0.00020

It can be concluded that there are no statistically significant differences between MCNP4.2 and MCNP4A results.

4.2 Comparison ECN - GE results

Table 4.2 shows the results of the comparison between ECN and GE:

Table 4.2 k_{eff} calculation performed by GE and ECN

	k_{eff}
GE	1.00073 ± 0.00110
ECN	1.00248 ± 0.00020

These results do not agree within the 1 σ error bar, but there is no strong disagreement. Moreover, it is not clear which procedure was used by GE to arrive at the results.

4.3 Comparison of JEF2.2 and ENDF/B-V data

It appears that there is a substantial difference between the results obtained with JEF2.2 data and those obtained with ENDF/B-V data (table 4.3). The JEF2.2 data result is 0.8 % low, whereas the ENDF/B-V result is only 0.1 % high. The Monte Carlo results obtained with JEF2-2 data are in good agreement with those obtained with deterministic calculations [6]. In the latter calculations, a value of 0.991279 is obtained for k_{eff}.

Table 4.3 k_{eff} calculated by MCNP4A using JEF2.2 and ENDF/B-V data

	k_{eff}
JEF2.2	0.99232 ± 0.00039
ENDF/B-V	1.00126 ± 0.00029

A more detailed analysis can be made by comparing reaction rates in several energy groups. The group structure for representation of the results is given in Table 4.4.

Reaction rates are given in tables 4.5 to 4.7.

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From these results it can be deduced that the main difference in k_{eff} is due to a significant difference in the fission rate and capture rate of ^{239}Pu in group 4. This difference is due to differences in ^{239}Pu cross sections in ENDF/B-V and JEF2.2. In [7], it was already concluded that the ^{239}Pu cross sections should be modified in the range 25 Kev < E_n < 20 MeV. The results presented here are not in disagreement with these conclusions. A comparison of the total fission cross section of ^{239}Pu between JEF2.2 and ENDF/B-V in the relevant energy range is given in fig. 4.1.

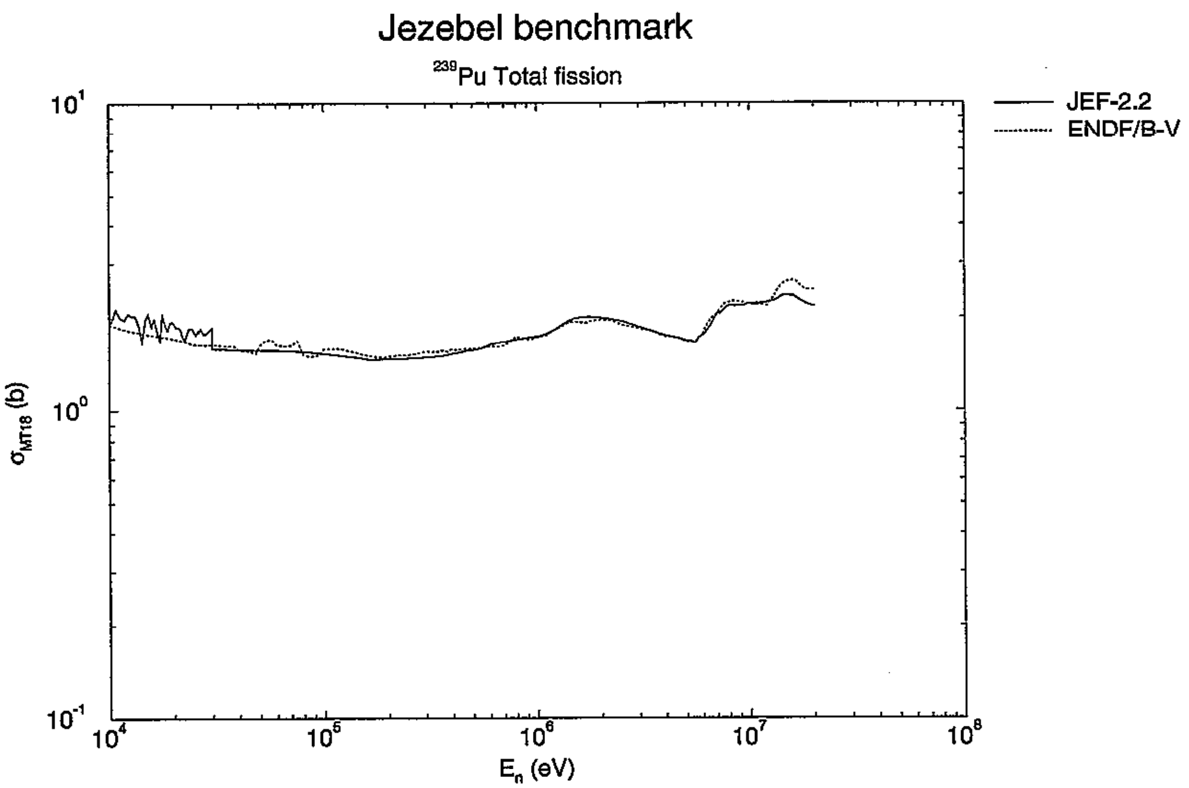

Figure 4.1 ^{239}Pu total fission cross section for JEF2.2 and ENDF/B-V

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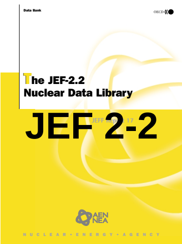

Table 4.4 Group structure for calculating the reaction rates

group	E_{low} (eV)	E_{high} (eV)
1	10^{-5}	0.625
2	0.625	3355
3	3355	$67.38\ 10^{3}$
4	$67.38\ 10^{3}$	$10.0\ 10^{6}$
5	$10.0\ 10^{6}$	$20.0\ 10^{6}$

Table 4.5 Fission rate of ^{239}Pu and ^{240}Pu

	Fission rate of ^{239}Pu		Fission rate of ^{240}Pu	
group	JEF2.2	ENDF/B-V	JEF2.2	ENDF/B-V
1	0.000E+00	0.000E+00	0.000	0.000
2	4.943E-08	1.051E-08	1.378E-09	4.128E-13
3	7.386E-06	6.957E-06	1.627E-08	1.568E-08
4	5.179E-04	5.253E-04	1.670E-05	1.715E-05
5	1.348E-06	8.850E-07	6.071E-08	4.176E-08

Table 4.6 Fission rate of ^{241}Pu and capture rate of ^{239}Pu

	Fission rate of ^{241}Pu		Capture rate of ^{239}Pu	
group	JEF2.2	ENDF/B-V	JEF2.2	ENDF/B-V
1	0.000	0.000	0.000	0.000
2	3.442E-10	1.193E-10	3.538E-08	1.659E-08
3	3.732E-08	3.418E-08	2.282E-06	2.172E-06
4	1.517E-06	1.515E-06	2.294E-05	1.591E-05
5	3.886E-09	2.512E-09	3.971E-14	9.059E-10

Table 4.7 Total flux

	Total flux	
group	JEF2.2	ENDF/B-V
1	0.000	0.000
2	3.627E-07	1.201E-07
3	1.197E-04	1.134E-04
4	7.947E-03	8.064E-03
5	1.629E-05	1.074E-05

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5. CONCLUSIONS

- In our report the results are given for the JEZEBEL criticality benchmark, performed with MCNP4A using JEF2.2 and ENDF/B-V cross section data.
- Using ENDF/B-V data, agreement is found between our results and those obtained by GE [4].
- A good agreement is found between results from MCNP4A and those from MCNP4.2
- The results obtained with JEF2.2 data agree with results from deterministic calculations [6].
- The results obtained with JEF2.2 data differ significantly from those obtained with ENDF/B-V data. This difference is due to a lower fission rate and a higher capture rate in ^{239}Pu from JEF2.2 for 67 keV < E_n < 10.0 MeV. Modifications of the ^{239}Pu JEF2.2 cross sections, as already suggested in [7], seem to be necessary.

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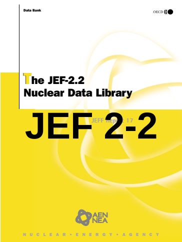

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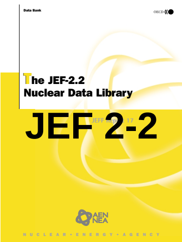

APPENDIX A. JEZEBEL MCNP BENCHMARK INPUT

```
message: ixr

jezebel fuel sphere based on endfb5 lib. (300 k)
c
c      infinite dilute 239Pu cross sections used
c
    1    1 .038918   -1
    2    1 .038918   1   -2
    3    1 .038918   2   -3
    4    0   3

    1 so   1.0
    2 so   3.0
    3 so   6.385

imp:n 1 1 1 0
kcode 40000 1.0 10 70
m1     94239.50c 0.03705 94240.50c 0.001751 94241.50c 0.000117
m2     94239.50c 1.0
m3     94240.50c 1.0
m4     94241.50c 1.0
vol    4.18879 108.9085 977.2662 0
ctme   3000
print
e0     .625e-6   3.355e-3   6.7379e-2   10.   20.0
f1:n   3
f4:n   1 2 3 t
fc4    fission reaction rates in the three Pu isotopes
       units: fissions/cm3*source neutron
       (n,gamma) in 239Pu
       units: captures/cm3*source neutron
       flux
       units: neutrons/cm2*source neutron
fm4    (0.03705 2 -6)
       (0.001751 3 -6)
       (0.000117 4 -6)
       (0.03705 2 102)
       (1)
```

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