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FENDL NEUTRONICS BENCHMARK:

SPECIFICATIONS FOR THE CALCULATIONAL NEUTRONICS AND SHIELDING BENCHMARK

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with an introduction by
Srinivasan Ganesan
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Vienna, Austria

December 1994

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Abstract

During the IAEA Advisory Group Meeting on "Improved Evaluations and Integral Data Testing for FENDL" held in Garching near Munich, Germany in the period 12-16 September 1994, the Working Group II on "Experimental and Calculational Benchmarks on Fusion Neutronics for ITER" recommended that a calculational benchmark representative of the ITER design should be developed. This report describes the neutronics and shielding calculational benchmark available for scientists interested in performing analysis for this benchmark.

December 1994

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December 1994

Introduction

(written by S. Ganesan, IAEA Nuclear Data Section, Vienna, Austria)

The IAEA Nuclear Data Section has implemented a computerized collection of data from those integral neutronic experiments that are suitable to test libraries of evaluated fusion relevant nuclear data ("benchmark experiments"). In particular, the Fusion Evaluated Nuclear Data Library (FENDL), the reference library for the International Thermonuclear Experimental Reactor (ITER) project, should be validated using these experimental data. An IAEA Consultant's Meeting on "Preparation of Fusion Benchmarks in Electronic Format for Nuclear Data Validation Studies has given detailed recommendations for submissions of experimental data and parameters for this collection (see summary report INDC(NDS)-298, March 1994). It was pointed out that, in addition to numerical data, explanatory hard-copy material in the form of text and figures is indispensable to enable calculations to be made.

An extract reproduced below from the recommendations of the IAEA Advisory Group Meeting on "Improved Evaluations and Integral Data Testing for FENDL", organized by the International Atomic Energy Agency in co-operation with the Max-Planck-Institut für Plasmaphysik and held at the Max-Planck-Institut für Plasmaphysik, Garching near Munich, Germany, 12 to 16 September 1994 (Ref. summary report: INDC(NDS)-312, November 1994) in the Working Group (II) on Experimental and Calculational Benchmarks on Fusion Neutronics for FENDL Validation (Y. Oyama (JAERI) Chairman, R. Roussin (ORNL-RSIC) Secretary of the Working Group) follows:

"G. Calculational Benchmarks

M. Sawan (U. Wisconsin) will provide to the IAEA Nuclear Data Section, by 31 October 1994, a detailed description for a representative of ITER calculational benchmark as well as of the responses to be calculated. He will collect and summarize contributions from participants and report results at the next FENDL meeting. The calculational benchmark will be added to the Nuclear Data Section on-line system."

Following this recommendation, the neutronics and shielding calculational benchmark has been compiled and placed into the Nuclear Data Section online system. This document complements the online information available by ftp command from the IAEA:

```
ftp     161.5.2.2
user    FENDL
cd      FENDL/BENCHMARKS/WISCONSIN
```

The file 'ITERDESIGNCALC.TXT' in this directory corresponds to this document.

SPECIFICATIONS FOR THE CALCULATIONAL NEUTRONICS AND SHIELDING BENCHMARK

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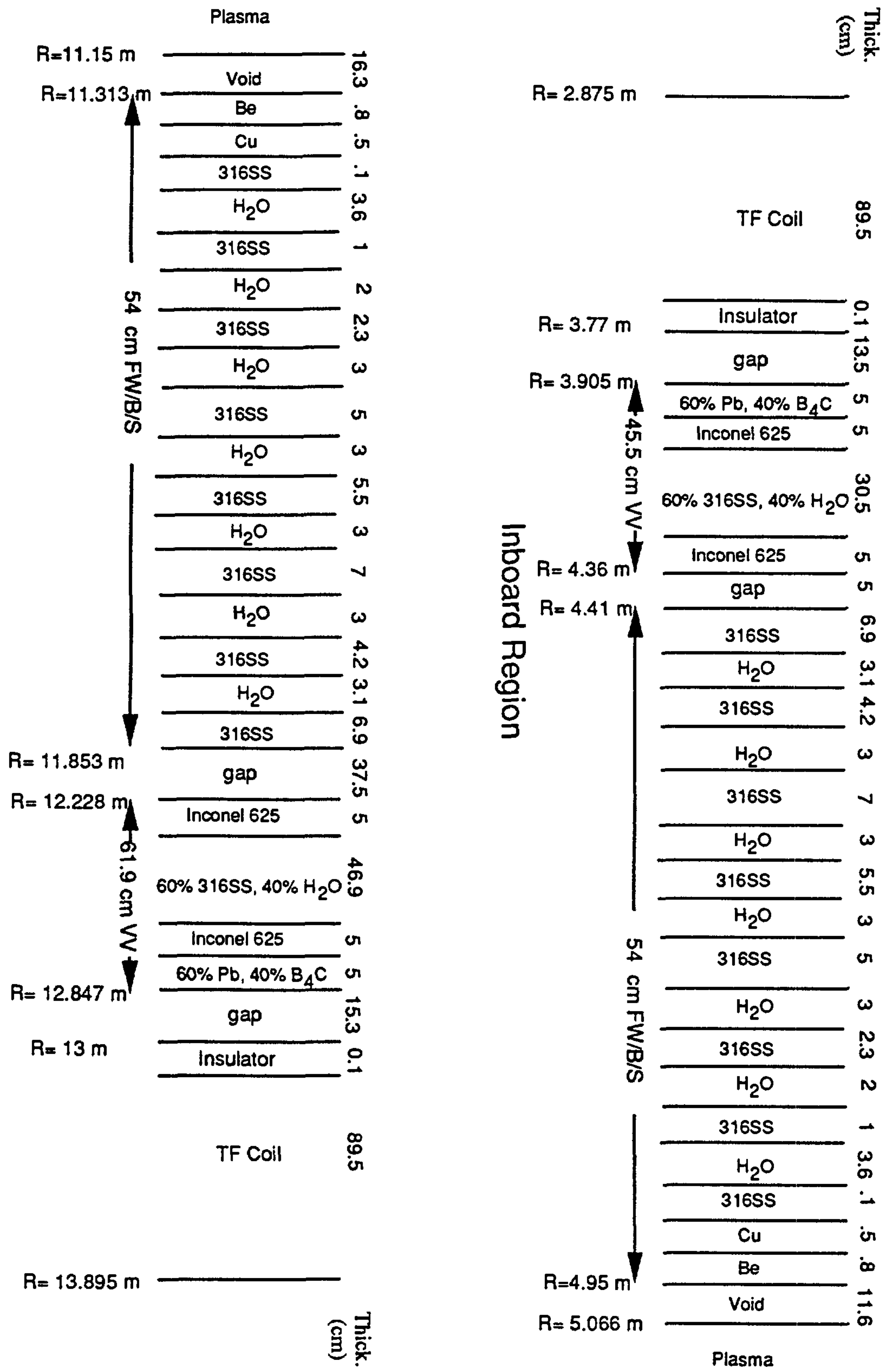
6 October 1994

Calculational Neutronics and Shielding Benchmark Description

- The benchmark represents the reference steel/water shielding blanket design in the ITER outline design.
- The first wall is 14 mm thick consisting of 8 mm thick Be coating and 5 mm Cu attached to 1 mm thick SS.
- The shielding blanket is 526 mm thick with alternating layers of 316 SS and water.
- A double wall Inconel 625 vacuum vessel is used with single size water cooled 316 SS balls. The VV walls are 50 mm thick. A 50 mm thick back shield zone made of lead and boron carbide is used at the back of the VV. The total VV thickness is 455 mm in inboard region and 619 mm in outboard region.
- 1-D toroidal cylindrical model with inboard and outboard regions modeled simultaneously is used.
- The model includes 54 zones divided into 573 intervals.
- A maximum fine mesh interval width of 1 cm is used in the model except in plasma and void zones.
- A uniform 14.1 MeV isotropic neutron source in the plasma zone.
- The source in the plasma zone is normalized to 6.1E17 n/cm.s yielding inboard and outboard neutron wall loadings of 1 and 1.5 MW/m^2, respectively.
- The end-of-life results are based on a total ITER lifetime of 3 FPY (9.45E8 s).



RADIAL BUILD FOR THE CALCULATIONAL NEUTRONICS AND SHIELDING BENCHMARK

Zone Specifications

Zone Number	Material	Thickness (cm)	Number of Intervals
Central Zone			
1	void	287.5	29
Inboard Magnet			
2	47% 316SS 12% Cu 17.2% Liq. He 13.3% R-glass epoxy 3% Nb_3Sn 7.5% bronze	89.4	90
3	R-glass epoxy	0.1	1
Gap			
4	void	13.5	14
Inboard VV			
5	60% Pb 40% B_4C	5	5
6	Inconel 625	5	5
7	60% 316SS 40% H_2O	30.5	31
8	Inconel 625	5	5
Gap			
9	void	5	5
Inboard Blanket			
10	316SS	6.9	7
11	H_2O	3.1	4
12	316SS	4.2	5
13	H_2O	3	3
14	316SS	7	7
15	H_2O	3	3
16	316SS	5.5	6
17	H_2O	3	3

18	316SS	5	5
19	H_2O	3	3
20	316SS	2.3	3
21	H_2O	2	2
22	316SS	1	1
23	H_2O	3.6	4
Inboard FW			
24	316SS	0.1	1
25	Cu-Be-Ni	0.5	1
26	Be	0.8	1
Inboard Scrapeoff			
27	void	11.6	2
Plasma			
28	void	608.4	61
Outboard Scrapeoff			
29	void	16.3	2
Outboard FW			
30	Be	0.8	1
31	Cu-Be-Ni	0.5	1
32	316SS	0.1	1
Outboard Blanket			
33	H_2O	3.6	4
34	316SS	1	1
35	H_2O	2	2
36	316SS	2.3	3
37	H_2O	3	3
38	316SS	5	5
39	H_2O	3	3
40	316SS	5.5	6
41	H_2O	3	3
42	316SS	7	7
43	H_2O	3	3
44	316SS	4.2	5
45	H_2O	3.1	4
46	316SS	6.9	7

Gap			
47	void	37.5	38
Outboard VV			
48	Inconel 625	5	5
49	60% 316SS 40% H_2O	46.9	47
50	Inconel 625	5	5
51	60% Pb 40% B_4C	5	5
Gap			
52	void	15.3	14
Outboard Magnet			
53	R-glass epoxy	0.1	1
54	47% 316SS 12% Cu 17.2% Liq. He 13.3% R-glass epoxy 3% Nb_3Sn 7.5% bronze	89.4	90

Material Composition

Material	Constituent Element	Nuclide Density (nuclei/b.cm)
R-glass epoxy	H	2.16300E-02
	C	1.89200E-02
	N	2.06000E-03
	O	2.70600E-02
	Mg	1.19000E-03
	Al	3.93000E-03
	Si	8.00000E-03
	S	5.10000E-04
	Cu	9.10000E-04
Cu	Cu	8.29204E-02
Nb_3Sn	Nb	4.09117E-02
	Sn	1.36372E-02
Liq. He	He	1.83643E-02
Pb	Pb	3.29558E-02
B_4C	B10	2.17280E-02
	B11	8.81205E-02
	C	2.74621E-02
H_2O	H	6.68560E-02
	O	3.34280E-02
Cu-Be-Ni	Be	2.97000E-03
	Ni	1.82000E-03
	Cu	8.20000E-02
Be	Be	1.23619E-01
Bronze	Cu	7.67230E-02
	Sn	3.57200E-03

SS316	B10	8.70716E-07
	B11	3.50474E-06
	C	7.08895E-05
	N	2.36402E-04
	O	5.89895E-06
	Al	5.25950E-04
	Si	7.74757E-04
	P	3.97072E-05
	S	1.47526E-05
	K	6.04926E-07
	Ti	3.95194E-05
	V	3.71431E-06
	Cr	1.55566E-02
	Mn	1.46375E-03
	Fe	5.45732E-02
	Co	2.40797E-05
	Ni	1.06384E-02
	Cu	7.44397E-05
	Zr	1.03708E-06
	Nb	1.01830E-06
	Mo	1.23274E-03
	Sn	7.96952E-07
	Ta	1.30709E-07
	W	2.56984E-07
	Pb	1.82623E-07
	Bi	1.81082E-07
Inconel 625	Ni	5.27000E-02
	Cr	2.09000E-02
	Fe	2.27000E-03
	Mo	4.75000E-03
	Si	4.50000E-04
	Mn	2.30000E-04
	Al	3.75000E-04
	Ti	2.12000E-04
	S	1.27000E-05
	C	2.11000E-04
	Nb	1.90700E-03

Information Requested

Codes and Data:

1- Transport code used.
2- Angular quadrature order.
3- Legendre order of scattering.
4- Nuclear data evaluation used.
5- Nuclear data processing codes.
6- Energy group structure.
7- Weight function used to generate multi-group data.

Calculation Results:

1- Neutron and gamma fluxes in the first wall layers (Be, Cu, SS).
(Intervals # 244, 243, 242 inboard and 310, 311, 312 outboard)
2- Peak neutron and gamma fluxes in vacuum vessel and magnet.
(Intervals # 180, 120 inboard and 407, 483 outboard)
3- Nuclear heating (W/cm) in each of the non-void zones.
4- Power density (W/cm^3) in the first wall layers (Be, Cu, SS).
(Intervals # 244, 243, 242 inboard and 310, 311, 312 outboard)
5- Peak power density (W/cm^3) in vacuum vessel and magnet.
(Intervals # 180, 119 inboard and 407, 484 outboard)
6- End-of-life dpa in Cu and SS layers of first wall.
(Intervals # 243, 242 inboard and 311, 312 outboard)
7- Peak end-of-life dpa in Inconel vacuum vessel.
(Intervals # 180 inboard and 407 outboard)
8- End-of-life appm gas production (tritium, hydrogen, helium) in FW layers.
(Intervals # 244, 243, 242 inboard and 310, 311, 312 outboard)
9- Peak end-of-life appm gas production in Inconel VV.
(Intervals # 180 inboard and 407 outboard)
10- Peak end-of-life fast neutron fluence (E>0.1 MeV) in magnet.
(Intervals # 119 inboard and 484 outboard)
11- Peak end-of-life Cu dpa in magnet.
(Intervals # 119 inboard and 484 outboard)
12- Peak end-of-life magnet insulator absorbed dose (eV/cm^3).
(Intervals # 120 inboard and 483 outboard)

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