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VENUS-1 Two-Dimensional Benchmark on Ex-Core Dosimetry Computations

I. General Comments

In this benchmark exercise the goal is to test the current state-of-the-art two-dimensional methods of calculating neutron flux to reactor components against the measured data of the VENUS-1 critical experiment.

This is a ``blind'' test hence the measured values of the equivalent fission flux at specified Venus locations are not revealed to the participants *a priori* but will be provided when benchmark results are analysed.

The following documents are included in this distribution package:

1) ``VENUS-1: Description of Geometry and Composition of Different Materials'';
2) ``VENUS-1: Results of Experimental Determination of: Relative Power Distribution and Absolute Level of Reference Power'';
3) ``Results of Experimental Measurement of Vertical Bucklings in the Core and Outside''.

The content of these documents is briefly characterized in the following sections.

II. Document No.1: ``VENUS-1: Description of Geometry and Composition of Different Materials''

The detailed description of the VENUS-1 experiment and the VENUS-1 reactor configuration are given in the first included document. The information given fully specifies all geometry and material data required in developing the detailed computational model of the 1/8 fraction of the VENUS reactor.

All elements of the VENUS reactor specified in this document should be modelled in the calculations.

III. Document No.2: ``VENUS-1: Results of Experimental Determination of: Relative Power Distribution and Absolute Level of Reference Power''

In this second included document the measured values of pin power in the units of *fiss/s/cell* in the 1/8 of the VENUS core to be modelled in calculations are provided. The pin power distribution entries in the table are given as numbers normalized to the core average value of 1 *fiss/s/cell.*

The provided normalized pin power distributions should be used by the participants to define the fission source for neutron transport calculations.

The reference core average fission rate at 100% power is given at 2.1×10^{8} ($\pm 1.8\%$) *fiss/cm/s* and should be used in any normalizations that may be required in the calculations.

IV. Document No.3: ``Results of Experimental Measurement of Vertical Bucklings in the Core and Outside''

This document provides values of experimentally measured axial bucklings in VENUS-1 configuration of the VENUS reactor. These axial bucklings should be used as input data in the 2-D neutron transport calculations of the benchmark.

V. Results to be Provided and Their Format

The fission flux measurement points as well as the reactor zones in which they are placed in the VENUS reactor are defined in Table 1 below. The coordinates of the measurement points are given in three different ccordianate systems:

- (x,y) coordinates with respect to the reactor grid (used in the experiments),
- (x,y) coordinates with respect to the core center (for use in calculational model),
- (r,θ) coordinates with respect to the core center (for use in calculational model).

IMPORTANT!!!: The dimensioning data of the VENUS reactor are given in two different coordinate systems: partially in the (r,θ) coordinates and partially in the (x,y) coordinates. When developing the geometrical model of the VENUS reactor for the benchmark transport calculations in either coordinate system [i.e., (r,θ) or (x,y)] a need will arise to transform the VENUS geometrical data from one coordinate system to another. For example, in the (r,θ) model of the VENUS reactor a transformation of dimensioning data from (x,y) coordinate system to (r,θ) coordinate system will be necessary when modelling neutron sources and some material zones. **Extreme care** is advised in performing the coordinate system transformation. In addition, **when reporting** your results, **please describe** your coordinate system **transformation procedure** and **criteria/principles applied** as these **can affect** the results.

For the measurement points in Table 1 the ``equivalent fission flux'' and neutron fluxes at threshold energies $E_{th}$>1.0 MeV and $E_{th}$>0.1 MeV should be calculated and reported in Tables 2 and 3 defined below. The ``equivalent fission flux'' is defined as a ratio of calculated reaction rate [five different reactions to be considered are defined in Tables 2 and 3] and the average dosimeter cross section.

In the calculations, the participants are kindly requested to use the **IRDF-90 *version 2*** dosimeter cross section data in order to assure comparability between different results.

The following information should be included when reporting the results of the benchmark:

- Description of the calculations procedure (all important information about modelling assumptions and codes/methods used); if S_N method is used then the quadrature set order should be reported (a symmetric or not quadrature is used?), etc.;
- Grid/mesh structure of the model;
- The name and version of the point library neutron transport cross section data and the energy group structure;
- Method/model used in cross section collapsing;

- The name and version of the dosimeter cross sections data

- Any other infortmation not listed above but judged by the participant as important in interpreting this benchmark should be included.

VI. Optional Calculations

Three additional but **optional** calculations are suggested:

1) The participants who wish are kindly invited to calculate the DPA using pre-calculated neutron spectra. Those DPAs should be reported in columns marked ``**Optional**: **DPA**'' in Tables 2 and 3.

2) Those participants who wish to test their pin power calculations techniques may compute the pin power distribution map as given in the Document No. 2 ``VENUS-1: Results of Experimental Determination of: Relative Power Distribution and Absolute Level of Reference Power''. In such a case the results should be reported using an identical format as Figure 2 of this document.

3) The participants who wish to perform the uncertainty analysis of their benchmark calculations are encouraged to do so as an additional option.

Table 1: Coordinates of VENUS-1 measurement positions

No.	Measurement point zone	(x,y) coordinates with respect to reactor grid	(r,θ) in (cm,°) coordinates with respect to core center	(x,y) in (cm,cm) coordinates with respect to core center.
	Central hole			
1		(+2.5, +2.5)		(0., 0.)
	Interior baffle			
2		(-1, +2)	(-, 8.1°)	(-4.41, -0.63)
3		(-1, -1)	(-, 45.0°)	(-4.41, -4.41)
	Exterior baffle			
4		(-29, +2)	(-, 0.9°)	(-39.69, -0.69)
5		(-29, -2)	(-, 8,1°)	(-39.69, -5.67)
6		(-29, -7)	(-, 16.8°)	(-39.69, -11.97)
7		(-29, -12)	(-, 24.7°)	(-39.69, -18.27)
8		(-27, -14)	(-, 29.2°)	(-37.17, -20.79)
9		(-22, -14)	(-, 34.0°)	(-30.87, -20.79)
10		(-17, -14)	(-, 40.2°)	(-24.57, -20.79)
	Barrel			
11		(-37, +2)	(-, 0.7°)	(-49.77, -0.63)
12		(-37, -5)	(-, 10.8°)	(-49.77, -9.45)
13		(-35, -12)	(-, 21.1°)	(-47.25, -18.27)
14		(-34, -15)	(-, 25.6°)	(-45.99, -22.05)
15		(-33, -17)	(-, 28.8°)	(-44.73, -24.57)
16		(-31, -20)	(-, 33.9°)	(-42.21, -28.35)
17		(-28, -24)	(-, 41.0°)	(-38.43, -33.39)
18		(-26, -26)	(-, 45.0°)	(-35.91, -35.91)
	Water between barrel and neutron pad (WATER GAP II)			
19		(-, -)	(55.2, 10.8°)	(-54.36, -9.59)
20		(-, -)	(55.2, 16.6°)	(-52.89, -15.80)
21		(-, -)	(55.2, 21.1°)	(-51.53, -19.78)
22		(-, -)	(55.2, 25.6°)	(-50.03, -23.33)
23		(-, -)	(55.2, 28.8°)	(-48.74, -25.91)
24		(-, -)	(55.2, 33.9°)	(-46.29, -30.06)
25		(-, -)	(55.2, 37.4°)	(-44.08, -33.22)
26		(-, -)	(55.2, 41.0°)	(-42.29, -35.48)
27		(-, -)	(55.2, 45.0°)	(-39.03, -39.03)
	Thermal shield (Neutron Pad)			
28		(-, -)	(62.7, 21.1°)	(-58.54, -22.47)
29		(-, -)	(62.7, 42.0°)	(-46.60, -41.95)
	Reflector (WATER GAP I)			
30		(-16, -16)	(-, 45°)	(-23.31, -23.31)
31		(-18, -18)	(-, 45°)	(-25.83, -25.83)
32		(-20, -20)	(-, 45°)	(-28.35, -28.35)
33		(-22, -22)	(-, 45°)	(-30.87, -30.87)
34		(-24, -24)	(-, 45°)	(-33.39, -33.39)

Table 2 Ex-vessel equivalent fission flux in stainless steel zones - VENUS 1

Measure position	$Ni^{58}(n,p)$	$In^{115}(n,n')$	$Rh^{103}(n,n')$	$U^{238}(n,f)$	$Np^{237}(n,f)$	Flux at E>0.1 MeV	Flux at E>1.0 MeV	**Optional DPA**
Int. baffle								
(-1, +2)								
(-1, -1)								
Ext. baffle								
(-29, +2)								
(-29, -2)								
(-29, -7)								
(-29, -12)								
(-27, -14)								
(-22, -14)								
(-17, -14)								
Barrel								
(-37, +2)								
(-37, -5)								
(-35, -12)								
(-34, -15)								
(-33, -17)								
(-31, -20)								
(-28, -24)								
(-26, -26)								
Neutron Pad								
21°								
42°								

Table 3 Ex-vessel equivalent fission flux in water zones - VENUS 1

Measure position	$Ni^{58}(n,p)$	$In^{115}(n,n')$	$Rh^{103}(n,n')$	$U^{238}(n,f)$	$Np^{237}(n,f)$	Flux at E>0.1 MeV	Flux at E>1.0 MeV	**Optional DPA**
Central hole: (+2.5, +2.5) Water I: (-16, -16) (-18, -18) (-20, -20) (-22, -22) (-24, -24) Water II (R=55.26): 10.75 16.63° 21.14° 25.62° 28.78° 33.89° 37.44° 40.99° 45.00°								