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Specification of fuel cells composition and power histories relevant to applications in WP1 and WP3

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1. Introduction

This document contains the specification of fuel cell compositions and power histories relevant to cell burnup benchmark calculations. The specification is made according to the Pu cell benchmark performed in HTR-N1. As fuel low enriched (8 % U-235) UO2 was used, however. The specification of the fuel kernels were according to the kernels for the HTR MODUL and PBMR (see Fig. 1). As for the case of the Pu-cell benchmark the realistic environment of the analysed cell (fuel elements with average burn-up) was not taken into account with the consequence of strongly varying multiplication factors. The target burn-up was chosen to 100 MWd/kg U. The U content of the fuel cells varied from 6 to 10 g U/ fuel element.

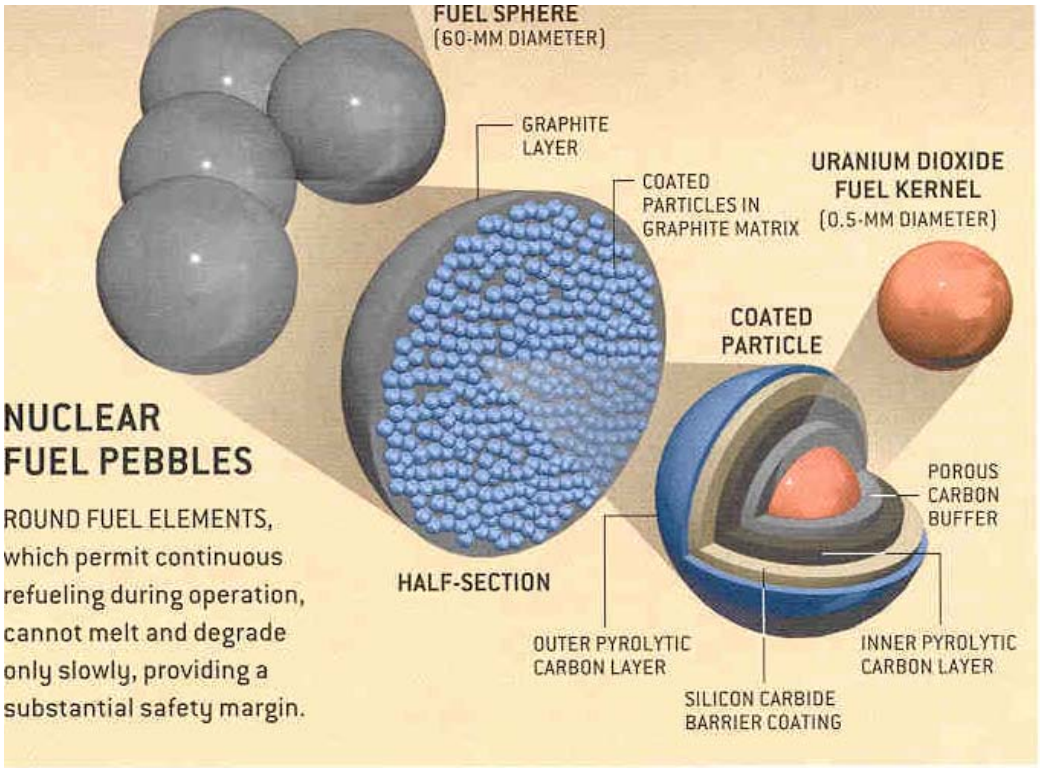

Fig. 1. Fuel element composition

2. Fuel cell definition

For simplicity the benchmark concerns only a spherical ("pebble") fuel element containing coated fuel particles. The neutronic boundary condition is assumed to be "white", i.e. isotropic reflection from the outer boundary of the pebble. Although this is not entirely representative for a full scale pebble bed HTR it is expected to serve the purpose as a basis for intercomparison of codes and data for the reactor physics analysis of an HTR fuel at moderate burnup. More specifically k_∞ will drop below 1 at high values of the irradiation. This is not considered to be a problem, as in a real pebble bed HTR such a pebble at high burnup will be surrounded by "driver" fuel at lower burnup so that the criticality of the reactor can be maintained. The fuel element parameters and isotopic compositions correspond to those of the UO_2 coated particles defined in the "Definition of reference coated particles of the German MODUL reactor [1].

2.1 Fuel element parameters

The main parameters of the fuel elements employed in this benchmark are the following:

Diameter of fuel element (FE)	6.0 cm
Diameter of central fuel zone of FE	5.0 cm
Graphite density	1.75 g/cm^3
Amount of U	6.0 g U per FE (*8% U-235*)
	7.0 g U per FE (8% U-235)
	8.0 g U per FE (*8% U-235*)
	9.0 g U per FE (8% U-235)
	10.0 g U per FE (8% U-235)

2.2 Coated particle parameters

The coated fuel particles consist of a fuel kernel containing the UO_2 fuel surrounded by coatings. These coated particles are embedded in a graphite matrix (density: 1.75 g/cm^3) in the central fuel zone of the FE. The main parameters of the coated fuel particles are the following:

UO_2-density in the kernel	10.4 g/cm^3
Kernel diameter	0.25 mm
Coating layer materials (inner to outer)	C / C / SiC / C
Coating thickness (inner to outer)	95 / 40 / 35 / 40 µm
Coating density (inner to outer)	1.05 / 1.90 / 3.18 /1.90 g/cm^3

2.3 General parameters

Power per FE (constant during burnup)	1.0 kW

Average temperature of 5 cm central fuel zone (i.e. kernel, coatings and matrix)	800 degr. C
Average temperature of 0.5 cm graphite outer zone	750 degr. C
Final burnup	100 MWd/kgHM
Irradiation time	100 * x full power days (x g U per FE)

2.4 Items to be calculated

The burnup history of the fuel at the defined constant power should be calculated for the selected Pu composition, not using any neutron poison, or any other means, for reactivity control. For a burnup of **0, 20, 40, 60, 80 and 100 MWd/kgHM** the following items should be reported:

- Neutron multiplication of FE (k_∞) **[-]**
- Isotopic (heavy metal and fission products) composition of the fuel kernel (see next table for list of nuclides) **[10^{24}/cm^3]**
- Neutron flux (collapsed to 1 group) **[$s^{-1}cm^{-2}$]**
- 1-group microscopic absorption cross sections for each of the considered isotopes **[barn]**
- 1-group microscopic fission cross sections for each of the considered isotopes **[barn]**
- Total fission rate **[s^{-1}]**

The nuclides to be considered in the isotopic compositions (and the 1-group microscopic cross sections) are the listed below. It is understood that some of the nuclides mentioned may not explicitly calculated by some of the code systems.

Heavy metal	**Fission products**	
U-235, U-236		
U-238		
Pu-238	Am-241	Se-79	Sn-126
Pu-239	Am-242m	Rb-87	I-129
Pu-240	Am-243	Sr-90	Cs-135
Pu-241	Cm-242	Zr-93	Cs-137
Pu-242	Cm-243	Mo-93	Sm-147
Pu-243	Cm-244	Nb-94	Sm-151
Pu-244	Cm-245	Tc-99	Eu-154
		Pd-107	

References

[1] Reutler, H.; Lohnert, G.: Der modulare HTR – Ein neues Konzept für den Kugelhaufenreaktor. Atomwirtschaft 27 (1982).