



## **FBNR Letter 15 December 1, 2005**

*The estimated dimensions and volume fractions of the materials in the FBNR module. This is a revised version of FBNR Letter 08.*

### **Fuel Element Description**

The 15 mm diameter spherical fuel elements are made of compacted coated particles in a graphite matrix. The coated particles are similar to TRISO fuel with outer diameters about 2mm. They consist of 1.58 mm diameter uranium dioxide spheres coated with 3 layers. The inner layer is of 0.09 mm thick porous pyrolytic carbide (PYC) with density of 1 g/cm<sup>3</sup> called buffer layer, providing space for gaseous fission products. The second layer is of 0.02 mm thick dense PYC (density of 1.8 g/cm<sup>3</sup>) and the outer layer is 0.1 mm thick corrosion resistant silicon carbide (SiC, density of 3.17 g/cm<sup>3</sup>). The fuel element is cladded by 1mm thick SiC. *Fuel enrichment 5%.*

**Table 1. Fuel particle (2 mm diameter)**

<b>Material</b>	<b>density (g/cm<sup>3</sup>)</b>	<b>d. inside (cm)</b>	<b>d.outside (cm)</b>	<b>volume (cm<sup>3</sup>)</b>	<b>mass (gr)</b>
<b>UO<sub>2</sub></b>	10.5	0	0.158	0.002065237	0.021684988
<b>PYC (porous)</b>	1	0.158	0.176	0.000789306	0.000789306
<b>PYC (dense)</b>	1.8	0.176	0.18	0.000199085	0.000358353
<b>SiC</b>	3.17	0.18	0.2	0.001135162	0.003598464
<b>Average for microsphere</b>	<b>6.3099629</b>		<b>0.2</b>	<b>0.00418879</b>	<b>0.026431111</b>

**Table 2. Fuel Element (15 mm diameter)**

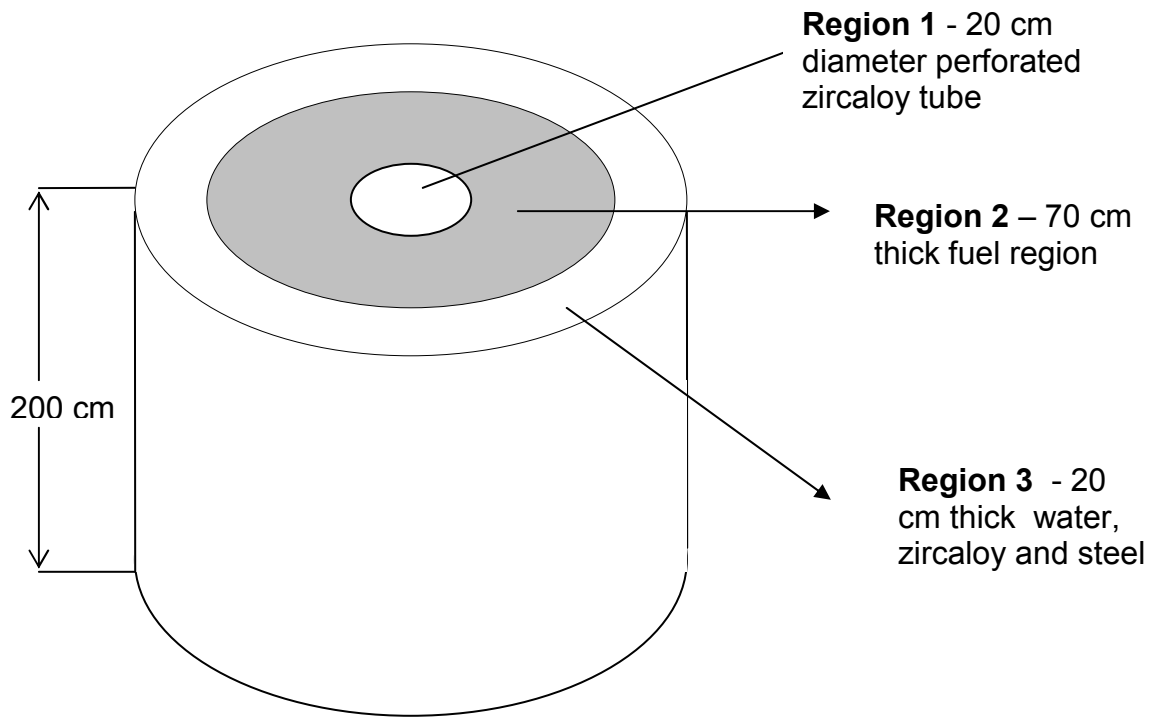
Material	Mass (gr)	Volume (cm <sup>3</sup> )	Density (g/cm <sup>3</sup> )	Mass fraction	Volume fraction	Thermal conductivity (W/m.°C)	Specific heat (kJ/kg.°C)
UO <sub>2</sub>	3.578	0.341	10.5	0.501	0.193	5.2	
PYC porous (amorfo) 600K	0.130	0.130	1	0.0182	0.0737	2.19	1406
PYC dense (amorfo) 600K	0.887	0.493	1.8	0.124	0.279	2.19	1406
SiC	2.549	0.804	3.17	0.357	0,455	77.5	1300
<b>fuel element</b>	<b>7.145</b>	<b>1.768</b>	<b>4.041</b>	<b>1</b>	<b>1</b>	<b>30.566</b>	<b>1400</b>

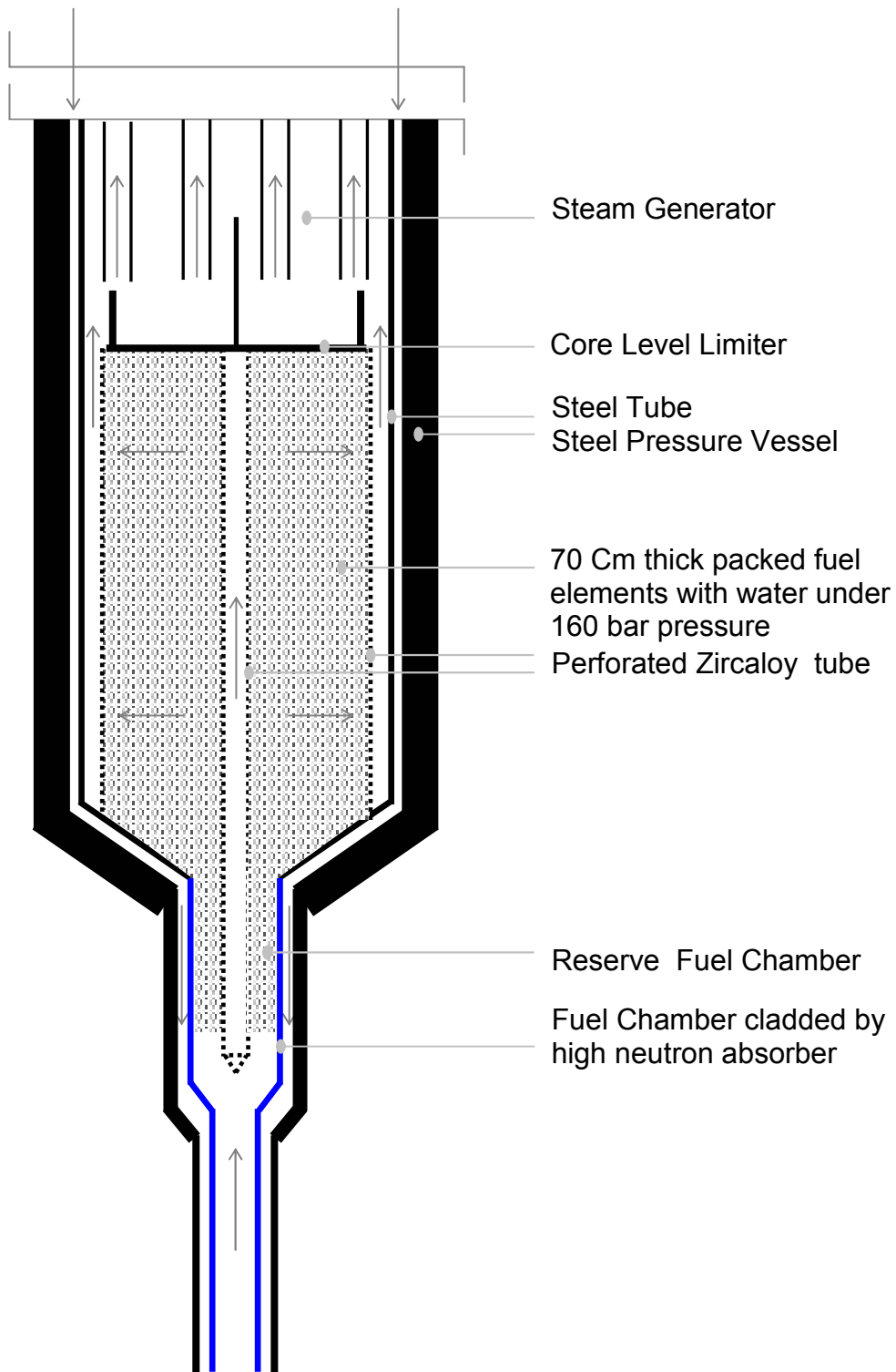
( 60% fuel particles and 40% dense graphite matrix clad by 1 mm thick SiC)

**Table 3. Volume fraction (%) of the materials in a FBNR module.**

	UO <sub>2</sub>	H <sub>2</sub> O	C	Steel	Zircaloy	SiC	Fuel	Total
<b>Region 1</b>	0	95	0	0	5	0	0	100%
<b>Region 2</b>	11.58	40	21.12	0	0	27.3	60	100%
<b>Region 3</b>	0	95	0	5	1	0	0	100%

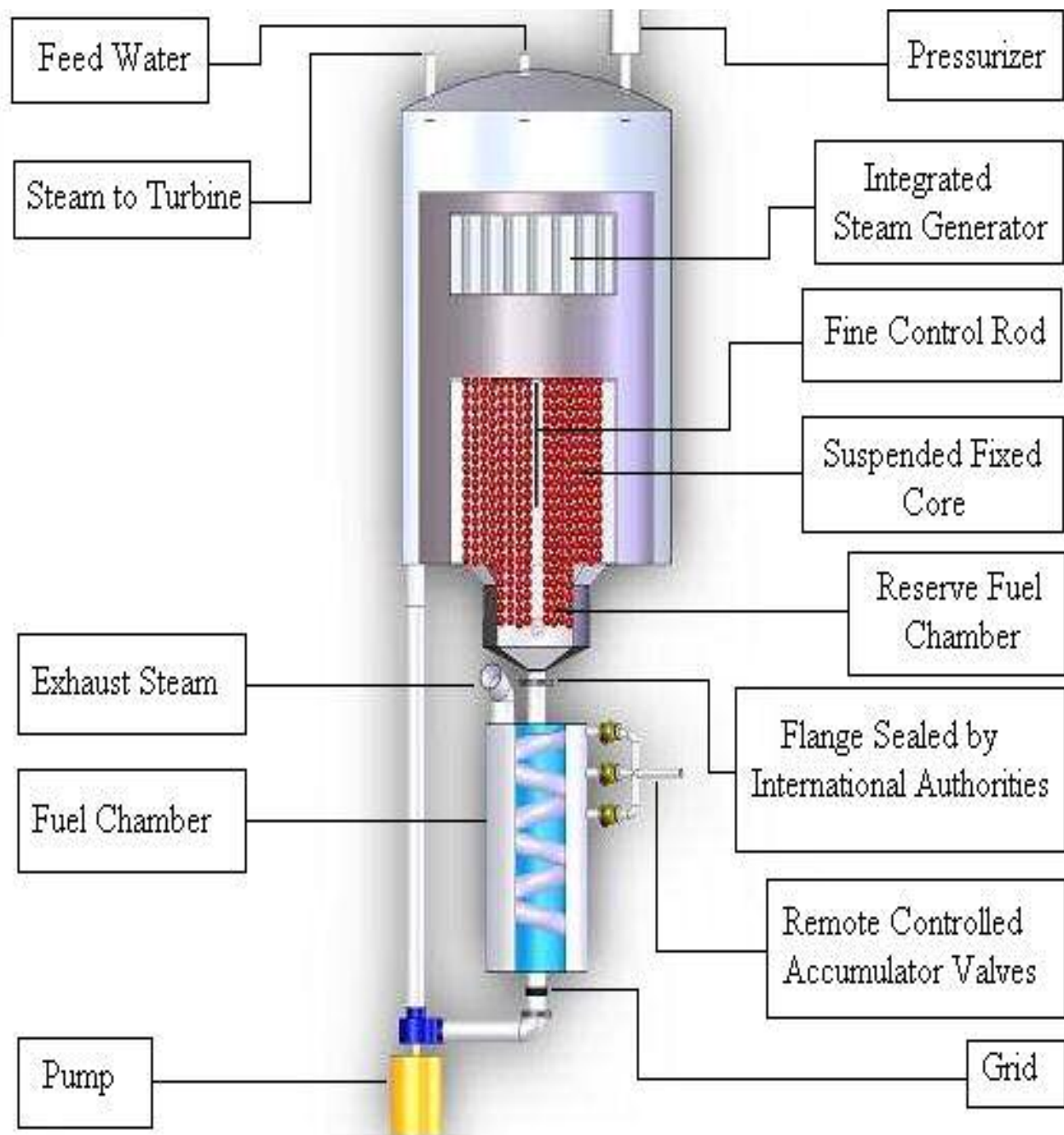
- Stainless steel with a density of 7.758 g/cm<sup>3</sup> is composed of 67.84% Fe, 10.86% Ni, 19.22% Cr, 1.88% Mn, and 0.20% Si.
- Zircaloy with a density of 5.874 g/cm<sup>3</sup> is composed of 99.69% Zr, 0.21% Fe, and 0.10% Cr.
- Region 3 does not include pressure vessel.





**Table 4. Characteristics of the FBNR reactor**

<b>Parameter</b>	<b>Value</b>
<i>Power:</i>	
Net power generation (MWe)	40
Power generation (MWt)	134
Core power density (KWt/lit)	33.7
Pump power (MWe)	3.4
<i>Hydraulics:</i>	
Coolant volume (m <sup>3</sup> )	12
Coolant mass flow (kg/sec)	668.53
Coolant pressure (bar)	160
Pressure loss in the loop (bar)	100
Pressure loss in the bed (bar)	9.52
Terminal velocity (m/sec)	1.64
<i>Thermal:</i>	
Coolant inlet temperature (°C)	290
Coolant outlet temperature (°C)	326
Coolant inlet enthalpy (kJ/kg)	1284
Coolant inlet density (kg/m <sup>3</sup> )	747
Enthalpy rise in the core (kJ/kg)	1490
Film boiling convective heat transfer coefficient at 300 °C ( W/m <sup>2</sup> °C )	453.7
Fuel element average thermal conductivity (W/m.°C)	30.58
Fuel element average specific heat (J/kg.°C)	802.5
Fuel element average density (gr/cm <sup>3</sup> )	4.041
Maximum fuel temperature after a LOCA (°C)	< 357
Coolant temperature rise after a LOFA after 10 days (°C)	0.035
Water needed to cool during 10 days after LOCA (m <sup>3</sup> )	0.45
<i>Module dimensions:</i>	
Core height (cm)	200
Core inner diameter (cm)	20
Core outer diameter (cm)	160
Core volume (m <sup>3</sup> )	3.96
Fuel in the core (Ton)	9.60
UO <sub>2</sub> in the core (Ton)	4.81
<i>Fuel element</i>	
Fuel element diameter (cm)	1.5
SiC clad thickness (cm)	0.1
Number of microspheres in a fuel element.	165
Number of fuel elements in the core.	1.34x10 <sup>6</sup>
UO <sub>2</sub> in each fuel element (% vol)	19.3
Dense graphite in each fuel element (% vol)	27.8
Porous graphite in each fuel element (% vol)	7.4
SiC in each fuel element (% vol)	45.5
UO <sub>2</sub> density (gr/cm <sup>3</sup> )	10.5
PYC porous density (gr/cm <sup>3</sup> )	1.0
PYC dense density (gr/cm <sup>3</sup> )	1.8
SiC density (gr/cm <sup>3</sup> )	3.17



**Schematic Design of FBNR**