Small Nuclear Rocket Engine (SNRE) Geometry and Material Configuration

SNRE Overview

Table 1: Core Overview of the SNRE.

Core Overview	
Uranium Enrichment	93.0%
Total Number of Fuel Elements	564
Total Number of Support Elements	241
Mass of U235	59.6 kg

Geometry Data

Table 2: Geometry Data of the SNRE Fuel Element

Fuel Element Dimensions	
Flat-to-flat width	1.905 cm
Number of Coolant Channels	19
Borehole Diameter	0.256 54 cm
Borehole Pitch	0.408 94 cm
Internal Coating Thickness	100 μm
External Coating Thickness	50 μm

Table 3: Geometry Data of the SNRE Support Element

Support Element Dimensions	
Flat-to-flat width	1.894 84 cm
Central Coolant Channel Radius	0.209 55 cm
Inner Tie Tube Radius	0.260 35 cm
Inner Gap (Stagnant Hydrogen) Radius	0.266 70 cm
Moderator Radius	0.584 20 cm
Outer Coolant Channel Radius	0.678 18 cm
Outer Tie Tube Radius	0.698 50 cm
Mid Gap (Stagnant Hydrogen) Radius	0.704 85 cm
Insulator Radius	0.806 45 cm
Outer Gap (Stagnant Hydrogen) Radius	0.812 80 cm
External Coating Thickness	50.8 μm

The external core regions consist of a steel wrapper, beryllium barrel, beryllium reflector, containing 12 control drums. Positioned above the core is the control drum actuator zone, brim shield, core support plate, tie tube plenum, and shield regions. The control drums consist of a cylinder of reflective material, and control plate of absorptive material, which covers a 120 degree segment of the control drum.

Table 4: Geometry Data of the SNRE Core Exterior

Region	Inner Radius	Outer Radius	Aft Boundary	Fwd Boundary
Core	-	29.5275 cm	0.0 cm	89.0 cm
Gap	29.5275 cm	29.8450 cm	0.0 cm	89.0 cm
Stainless-Steel Wrapper	29.8450 cm	30.1625 cm	0.0 cm	89.0 cm
Gap	30.1625 cm	30.4800 cm	0.0 cm	89.0 cm
Beryllium Barrel	30.4800 cm	33.3375 cm	0.0 cm	89.0 cm
Gap	33.3375 cm	33.6550 cm	0.0 cm	89.0 cm
Beryllium Reflector	33.6550 cm	43.3870 cm	0.0 cm	89.1 cm
Gap	43.3870 cm	48.7045 cm	0.0 cm	129.640 cm
Pressure Vessel	48.7045 cm	49.2633 cm	0.0 cm	129.640 cm
Lower Tie Tube Plenum	-	33.6550 cm	89.0 cm	96.62 cm
Core Support Plate	-	33.6550 cm	96.62 cm	106.78 cm
Upper Tie Tube Plenum	-	33.6550 cm	106.78 cm	111.86 cm
Lower Internal Shield	-	33.6550 cm	111.86 cm	119.734 cm
Hydrogen Plenum	-	33.6550 cm	119.734 cm	121.766 cm
Upper Internal Shield	-	33.6550 cm	121.766 cm	129.640 cm
Control Drum Actuator Zone	33.6550 cm	43.3870 cm	89.1 cm	111.860 cm
Brim Shield	33.6550 cm	48.3870 cm	111.860 cm	119.734 cm
Hydrogen Plenum	33.6550 cm	48.3870 cm	119.734 cm	129.640 cm

Table 5: Geometry Data of the SNRE Control Drum

Control Drum Dimensions	
Control Drum Radius	6.0325 cm
Control Plate Inner Radius	5.3975 cm
Control Plate Thickness	0.635 cm

Material Data

Table 6: Material Data of the SNRE Fuel Element

Material	**Mass Density** (g/cm3) **and** w/o
	Fuel Element Coolant
Density	2.7002×10^{-3}
^{1}H	9.9977×10^{-1}
^{2}H	2.2980×10^{-4}
	Fuel
Density	3.6400
^{nat}C	3.3791×10^{-1}
^{90}Zr	2.5214×10^{-1}
^{91}Zr	5.5597×10^{-2}
^{92}Zr	8.5916×10^{-2}
^{94}Zr	8.8964×10^{-2}
^{96}Zr	1.4638×10^{-2}
^{235}U	1.5330×10^{-1}
^{238}U	1.1538×10^{-2}
	Fuel Coating
Density (100%)	6.7300
^{nat}C	1.1625×10^{-1}
^{90}Zr	4.4811×10^{-1}
^{91}Zr	9.8811×10^{-2}
^{92}Zr	1.5269×10^{-1}
^{94}Zr	1.5811×10^{-1}
^{96}Zr	2.6016×10^{-2}

Table 7: Material Data of the SNRE Support Element

Material	**Mass Density** (g/cm3) **and** w/o
	Support Element Coolant
Density	2.7002×10^{-3}
^{1}H	9.9977×10^{-1}
^{2}H	2.2980×10^{-4}
	Stagnant Hydrogen
Density	1.9127×10^{-3}
^{1}H	9.9977×10^{-1}
^{2}H	2.2980×10^{-4}
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Material	Mass Density (g/cm3) and w/o
Inconel 718	
Density	8.1900
^{10}B	9.2155×10^{-6}
^{11}B	4.0785×10^{-5}
^{nat}C	7.3000×10^{-4}
^{27}Al	5.0000×10^{-3}
^{28}Si	2.9214×10^{-3}
^{29}Si	1.5371×10^{-4}
^{30}Si	1.0494×10^{-4}
^{31}P	1.4000×10^{-4}
^{32}S	1.3260×10^{-4}
^{33}S	1.0797×10^{-6}
^{34}S	6.3031×10^{-6}
^{36}S	1.5704×10^{-8}
^{46}Ti	7.1281×10^{-4}
^{47}Ti	6.5680×10^{-4}
^{48}Ti	6.6461×10^{-3}
^{49}Ti	4.9790×10^{-4}
^{50}Ti	4.8644×10^{-4}
^{50}Cr	7.9300×10^{-3}
^{52}Cr	1.5903×10^{-1}
^{53}Cr	1.8380×10^{-2}
^{54}Cr	4.6614×10^{-3}
^{55}Mn	3.1800×10^{-3}
^{54}Fe	9.5975×10^{-3}
^{56}Fe	1.5623×10^{-1}
^{57}Fe	3.6726×10^{-3}
^{58}Fe	4.9733×10^{-4}
^{59}Co	9.1000×10^{-3}
^{58}Ni	3.5279×10^{-1}
^{60}Ni	1.4057×10^{-1}
^{61}Ni	6.2126×10^{-3}
^{62}Ni	2.0133×10^{-2}
^{64}Ni	5.2928×10^{-3}
^{63}Cu	1.8695×10^{-3}
^{65}Cu	8.6052×10^{-4}
^{93}Nb	5.1250×10^{-2}
^{92}Mo	0.030 500
^{94}Mo	0.030 500
^{95}Mo	0.030 500

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Material	Mass Density (g/cm3) and w/o
^{96}Mo	0.030 500
^{97}Mo	0.030 500
^{98}Mo	0.030 500
^{100}Mo	0.030 500
Moderator	
Density	5.6100
^{1}H	1.7582×10^{-2}
^{2}H	4.0412×10^{-6}
^{nat}Zr	9.8241×10^{-1}
Insulator	
Density (50%)	3.3650
^{nat}C	1.1625×10^{-1}
^{90}Zr	4.4811×10^{-1}
^{91}Zr	9.8811×10^{-2}
^{92}Zr	1.5269×10^{-1}
^{94}Zr	1.5811×10^{-1}
^{96}Zr	2.6016×10^{-2}
Support Element Sleeve	
Density	1.7000
^{10}B	1.8431×10^{-7}
^{11}B	8.1569×10^{-7}
^{nat}C	1.0000
Support Element Coating	
Density (100%)	6.7300
^{nat}C	1.1625×10^{-1}
^{90}Zr	4.4811×10^{-1}
^{91}Zr	9.8811×10^{-2}
^{92}Zr	1.5269×10^{-1}
^{94}Zr	1.5811×10^{-1}
^{96}Zr	2.6016×10^{-2}

Note that the insulator region is porous ZrC at 50% porosity. The support element contains regions of stagnant hydrogen.

Table 8: Material Data of the SNRE Core Exterior

Material	**Mass Density** (g/cm3) **and** w/o
Beryllium Core Periphery Filler Element	
Density	1.8480
^{9}Be	1.0000
Steel Wrapper (SS-347)	
Density	8.0000
^{nat}C	8.0000×10^{-4}
^{28}Si	9.1867×10^{-3}
^{29}Si	4.8336×10^{-4}
^{30}Si	3.2999×10^{-4}
^{31}P	4.5000×10^{-4}
^{32}S	2.8415×10^{-4}
^{33}S	2.3136×10^{-6}
^{34}S	1.3507×10^{-5}
^{36}S	3.3651×10^{-8}
^{50}Cr	7.0953×10^{-3}
^{52}Cr	1.4229×10^{-1}
^{53}Cr	1.6445×10^{-2}
^{54}Cr	4.1707×10^{-3}
^{55}Mn	2.0000×10^{-2}
^{54}Fe	3.8415×10^{-2}
^{56}Fe	6.2534×10^{-1}
^{57}Fe	1.4700×10^{-2}
^{58}Fe	1.9906×10^{-3}
^{58}Ni	1.0000×10^{-1}
^{60}Ni	2.9454×10^{-2}
^{61}Ni	1.3017×10^{-3}
^{62}Ni	4.2183×10^{-3}
^{64}Ni	1.1090×10^{-3}
^{93}Nb	4.0000×10^{-3}
^{181}Ta	3.9995×10^{-3}
Beryllium Barrel	
Density	1.8480
^{9}Be	1.0000
Reflector	
Density	1.8480
^{9}Be	1.0000
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Material	Mass Density (g/cm3) and w/o
Control Drum	
Density	1.8480
^{9}Be	1.0000
Control Plate	
Density	1.3300×10^{1}
^{174}Hf	2.0000×10^{-3}
^{176}Hf	5.2000×10^{-2}
^{177}Hf	1.8600×10^{-1}
^{178}Hf	2.7100×10^{-1}
^{179}Hf	1.3700×10^{-1}
^{180}Hf	3.5200×10^{-1}
Lower Tie Tube Plenum	
Density	3.9080×10^{-1}
^{1}H	7.4207×10^{-3}
^{2}H	1.7052×10^{-6}
^{54}Fe	5.6037×10^{-2}
^{56}Fe	9.1220×10^{-1}
^{57}Fe	2.1443×10^{-2}
^{58}Fe	2.9037×10^{-3}
Core Support Plate	
Density	1.0050
^{1}H	2.0891×10^{-3}
^{2}H	4.8017×10^{-7}
^{54}Fe	5.6338×10^{-2}
^{56}Fe	9.1709×10^{-1}
^{57}Fe	2.1559×10^{-2}
^{58}Fe	2.9193×10^{-3}
Upper Tie Tube Plenum	
Density	9.7180×10^{-1}
^{1}H	2.1604×10^{-3}
^{2}H	4.9658×10^{-7}
^{54}Fe	5.6338×10^{-2}
^{56}Fe	9.1709×10^{-1}
^{57}Fe	2.1559×10^{-2}
^{58}Fe	2.9193×10^{-3}
Lower Internal Shield	
Density	4.4519
^{1}H	2.0526×10^{-2}
^{2}H	4.7179×10^{-6}
^{10}B	9.1080×10^{-4}

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Material	**Mass Density** (g/cm3) **and** w/o
^{11}B	4.0309×10^{-3}
^{90}Zr	4.9415×10^{-1}
^{91}Zr	1.0896×10^{-1}
^{92}Zr	1.6838×10^{-1}
^{94}Zr	1.7435×10^{-1}
^{96}Zr	2.8688×10^{-2}
Hydrogen Plenum	
Density	2.7002×10^{-3}
^{1}H	9.9977×10^{-1}
^{2}H	2.2980×10^{-4}
Upper Internal Shield	
Density	4.4519
^{1}H	2.0526×10^{-2}
^{2}H	4.7179×10^{-6}
^{10}B	9.1080×10^{-4}
^{11}B	4.0309×10^{-3}
^{90}Zr	4.9415×10^{-1}
^{91}Zr	1.0896×10^{-1}
^{92}Zr	1.6838×10^{-1}
^{94}Zr	1.7435×10^{-1}
^{96}Zr	2.8688×10^{-2}
Control Drum Actuator Zone	
Density	4.2790×10^{-1}
^{1}H	5.1402×10^{-3}
^{2}H	1.1815×10^{-6}
^{54}Fe	3.6678×10^{-2}
^{56}Fe	5.9707×10^{-1}
^{57}Fe	1.4036×10^{-2}
^{58}Fe	1.9006×10^{-3}
^{63}Cu	2.3637×10^{-1}
^{65}Cu	1.0880×10^{-1}
Brim Shield	
Density	4.4519
^{1}H	2.0526×10^{-2}
^{2}H	4.7179×10^{-6}
^{10}B	9.1080×10^{-4}
^{11}B	4.0309×10^{-3}
^{90}Zr	4.9415×10^{-1}
^{91}Zr	1.0896×10^{-1}
^{92}Zr	1.6838×10^{-1}

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Material	**Mass Density** (g/cm3) **and** w/o
^{94}Zr ^{96}Zr	1.7435×10^{-1} 2.8688×10^{-2}
	Pressure Vessel
Density ^{27}Al	2.7000 1.0000

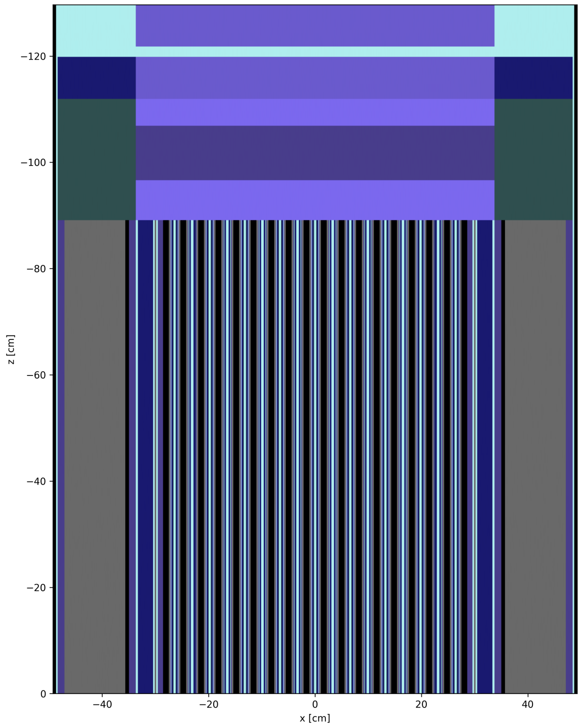

Figure 1: Model of the Core with Drums at the Critical Position (90 degrees)

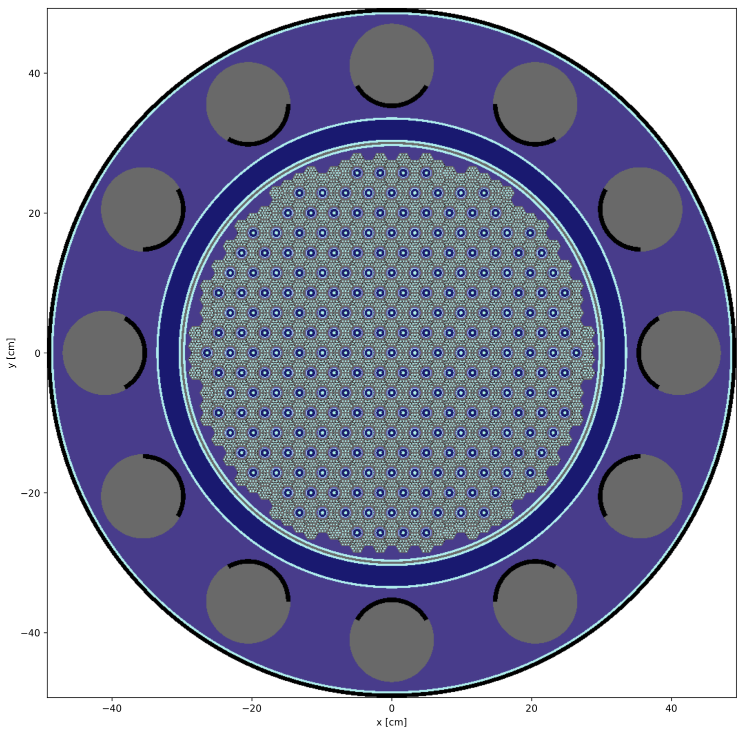

Figure 2: Model of the Core with Drums at the Critical Position (90 degrees)