Void worths in subcritical cores cooled by lead-bismuth


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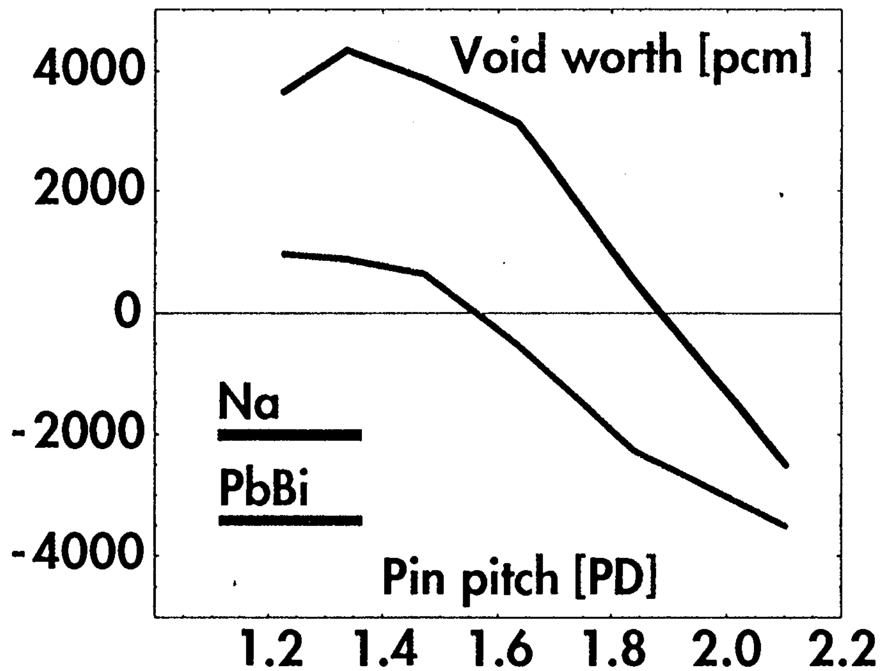
Motivation for introduction of lead-bismuth coolant in ADS

1) Good neutron economy → Higher source efficiency
2) Natural circulation possible → Decay heat removal
3) Synergy with spallation target → Simplified coolant management
4) High temperature of boiling → Larger overpower margin
5) Smaller void worths → Operation at higher k-values

Void worths in JAERI:s ADS

Design characteristics:

Fuel:	$(TRU_{0.5},Zr_{0.5})^{15}N$
Coolant:	Sodium
Core power:	800 MW
Pin pitch:	1.4 PD
k-eigenvalue:	0.95
Pu/(Pu+MA):	40%



Varying pin pitches k is kept constant by increasing Pu/(Pu+MA) ratio from 0.3 to 0.6

Problems arising due to high americium content in ADS fuel

$$\text{n} + \text{Am-241} \xrightarrow{85\%} \text{Am-242g} + \gamma \xrightarrow{16\ \text{h}} \text{Cm-242} + e^- + \nu \xrightarrow{163\ \text{d}} \text{Pu-238} + \alpha$$

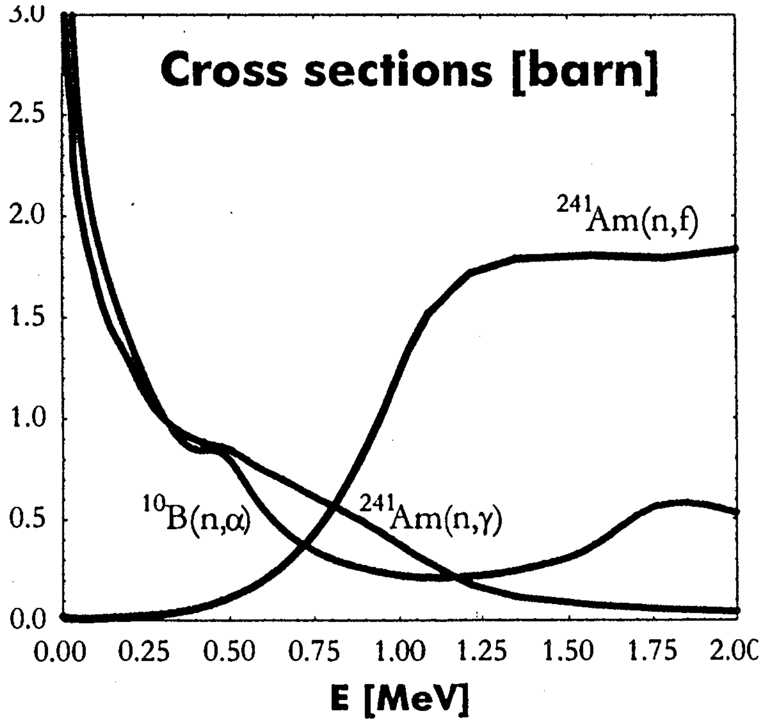
High Am-241 content leads to high α-production rate in fuel pellets

Helium migrates at lower temperature than noble fission gases

High helium gas bubble formation rates leads to fuel swelling

Release of helium (porous pellet) leads to pin pressurisation

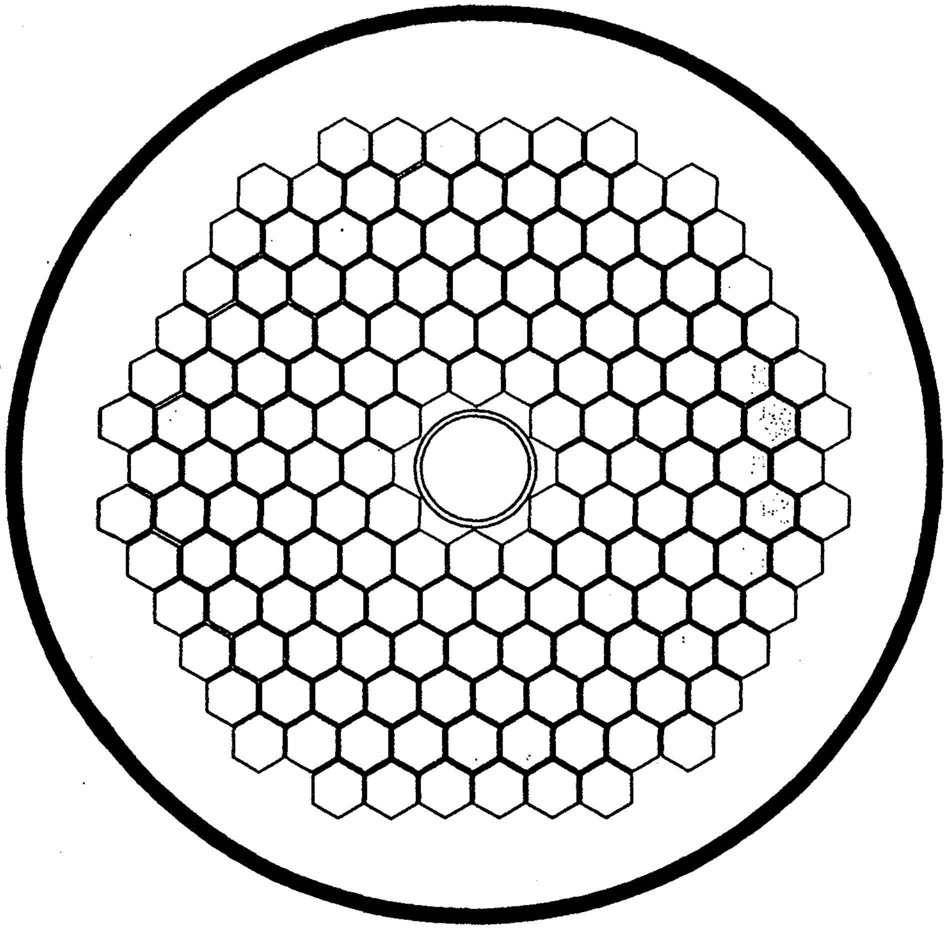
^{10}B (n,α) cross section



Enriched boron carbide can be used to supress neutron capture in ^{241}Am without deterioration of fast fission cross sections.

92% enriched B_4C is a standard material in FBR control rods.

Sing Sing Core map



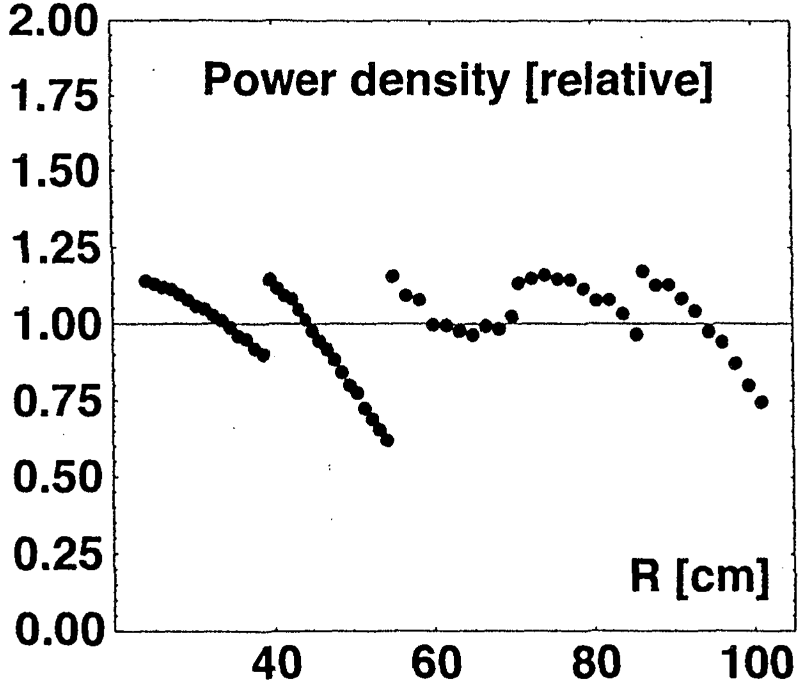
Fuel/diluent/absorber distribution

Zone	PuN	(Np,Am)N	ZrN	B_4C
1	31%	–	69%	–
2	41%	–	59%	–
3	32%	8%	–	60%
4	61%	13%	–	26%
5	70%	15%	–	15%

No Minor Actinides in zone 1 & 2 !

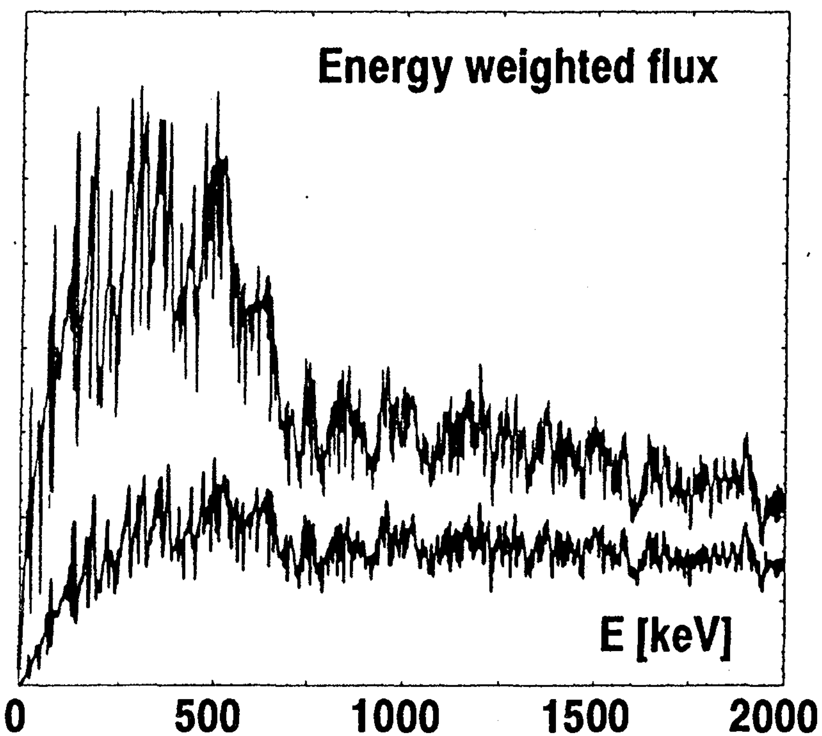
SSC power profile

Radial power peaking less than 1.2 at BOL!



k-eigenvalue:	0.967
k-source:	0.965
Source efficiency:	0.94

Sing Sing Core neutron spectrum



Red: zone 1 Blue: zone 4

Fission probability in absorption

Nuclide	zone 1	zone 4	EA	JAERI
Np-237	0.21	0.55	0.15	0.23
Pu-238	0.69	0.88	0.69	0.73
Pu-240	0.45	0.79	0.40	0.49
Pu-242	0.42	0.78	0.32	0.45
Am-241	0.19	0.43	0.12	0.16
Am-243	0.15	0.43	0.11	0.15
Cm-244	0.46	0.78	0.36	0.52

SSC void worths

Absorption dominated neutron balance

Significant fraction of nuclide fissionable by fast neutrons

Increase of void worths

Change in k-eigenvalue

Coolant	Sodium	Lead-Bismuth
Core Void	+ 4450 pcm	+ 1850 pcm
Core + Upper Plenum Void	+ 3730 pcm	+ 790 pcm