Flinabe

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Goal of this investigation

To identify a non-conducting material with low melting temperature and low vapor pressure. To be able to breed is not a requirement.

Per Peterson suggested to use Flinabe to protect beam channel for IFE, due to its low vapor pressure.

Sze summarized the material properties, including the vapor pressure.

Sze suggested to use flinabe for APEX applications.

History of Flinabe

- Flinabe was proposed for molten salt reactor coolant, but rejected due to poor neutron economy.

- Flinabe was also considered for fusion breeding application, but rejected due to poor tritium breeding (~0.6).
- Recent calculation shows that flinabe can breed with additional Be.
- Since flinabe has a low melting temperature, as well as can breed, it is an excellent candidate for APEX applications.
- Na activation is a main concern.

Phase diagram

Melting temperature

Composition

Viscosity

Vapor pressure

Material compatibility

Some general conclusions

The viscosity of the salt increases with the BeF_2 concentration.

The vapor pressure of the salt also increases with the BeF_2 concentration.

Therefore, it is important to select a salt composition with low melting temperature and with low BeF_2 concentration.

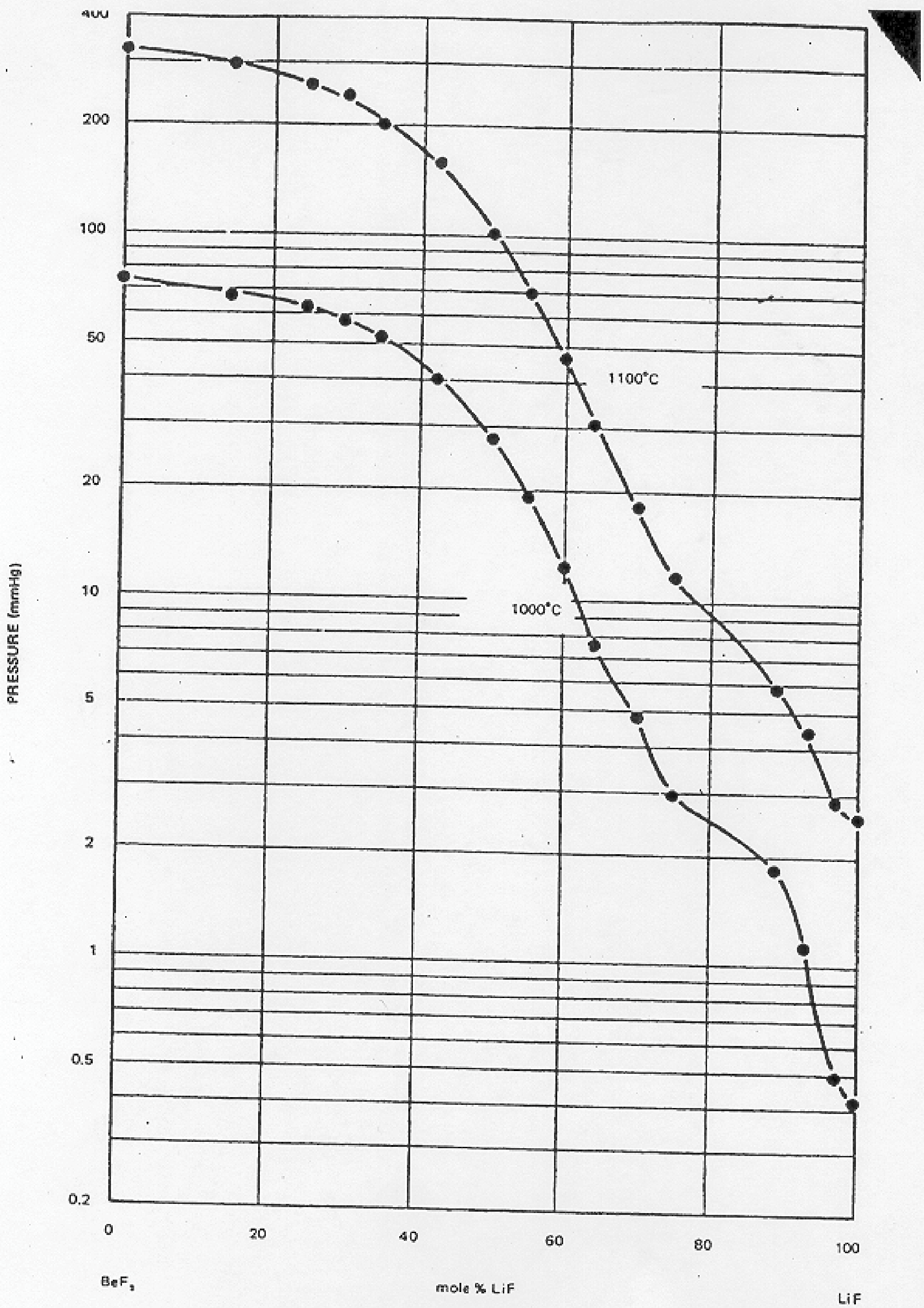


Fig. 7.1 Vapor Pressures in the $LiF-BeF_2$ System.[24]

Table 4.5 BeF_2-LiF: Viscosity, Numerical values (cp) recommended by Janz et al.[10]

[Mol percent LiF] 〔解説 Fig. 3－2（page 10）参照〕

T(K)	64.00	60.00	55.00	50.00	44.99	40.00	35.00	30.00	25.00	20.01	15.00	9.98	8.98	6.99	5.09	3.99	3.00	1.99	0.99	0
660				374																
680				273	584															
700			104	203	421															
720		49.4	81.9	153	309	762														
740	29.9	40.8	65.5	118	231	549	1470													
760	25.4	34.1	53.0	91.6	175	403	1040	3040												
780	21.8	28.7	43.3	72.2	135	300	751	2110	6880											
800	18.8	24.4	35.8	57.5	105	227	551	1490	4630											
820	16.3	20.9	29.8	46.4	82.8	174	410	1070	3180		44800		414000							
840	14.3	18.0		37.8	66.1	135	310	784	2220	7960	28900		249000		1400000					
860	12.6	15.7					237	581	1580	5440	19000		153000	358000	807000					129000000
880		13.7					184	437	1140	3780	12800	61600	95900	218000	478000	847000	1820000			58600000
900		12.1					144	333	834	2670	8720	39700	61500	135000	290000	504000	1040000			27600000
920							114	256	619	1910	6060	26100	40200	85600	180000	307000	611000	1210000		13500000
940							91.1	199	465	1390	4270	17500	26800	55300	114000	191000	367000	695000		6790000
960							73.5	157	354	1020	3060	11900	18100	36400	73200	121000	225000	410000		3530000
980							59.9			764	2220	8250	12500	24400	48000	78100	141000	247000	596000	1880000
1000										577	1630	5790	8710	16600	32100	51300	89600	152000	350000	1030000
1020											1210	4120	6170	11500	21700	34300	58100	95000	209000	581000
1040												2970	4430	8020	15000	23300	38300	60600	128000	334000
1060												2170	3220	5700	10400	16000	25700	39300	79600	197000
1080												1600	2370	4100	7390	11200	17500	25900	50400	118000
1100												1200	1760	2980	5290	7920	12000	17300	32400	72200
1120												904					8410	11800	21200	45000
1140												689					5950	8100	14100	28500
1160																	4260	5650	9480	18400
1180																	[illegible]	3990	6470	12000
1200																			4470	8010
1220																			3130	5390
1240																			2210	3680

BeF2-LiF-NaF phase diagram

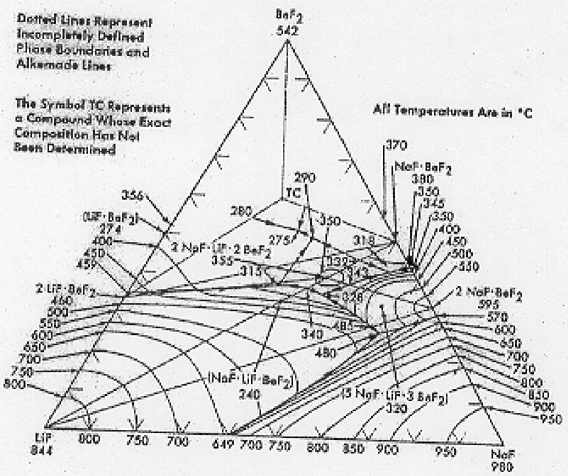


FIG. 12-5. The system LiF-NaF-BeF₂.

A suggested composition is BeF2-LiF-NaF with a melting temperature of 240C.

iF–NaF–BeF$_2$ (concl.)

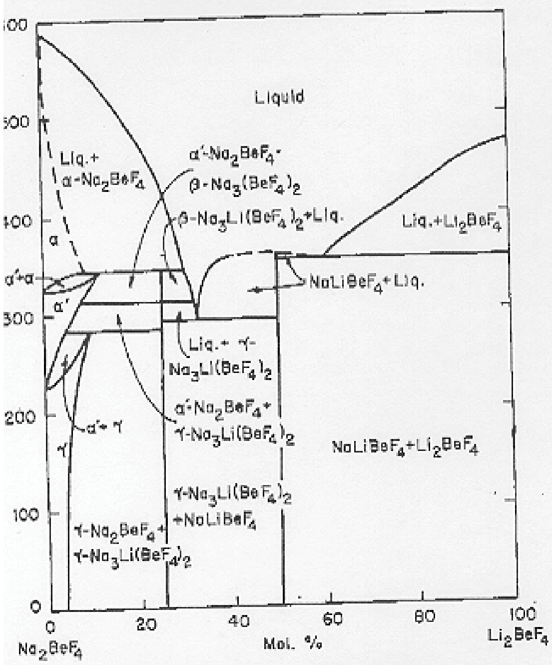


FIG. 1543.—System Li_2BeF_4–Na_2BeF_4.

N. A. Toropov and I. L. Shchetnikova, *Zhur. Neorg. Khim.*, 2, 1857 (1957).

LiF–NaF–MgF$_2$

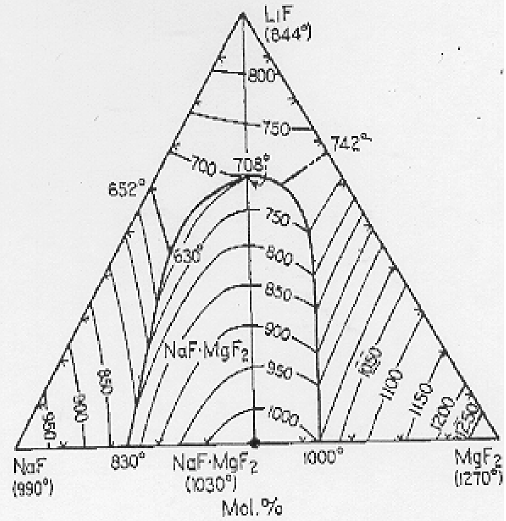


FIG. 1545.—System LiF–NaF–MgF_2.

A. G. Bergman and E. P. Dergunov, *Compt. rend. acad. sci., U.R.S.S.*, 31, 755 (1941).

LiF–NaF–CaF$_2$

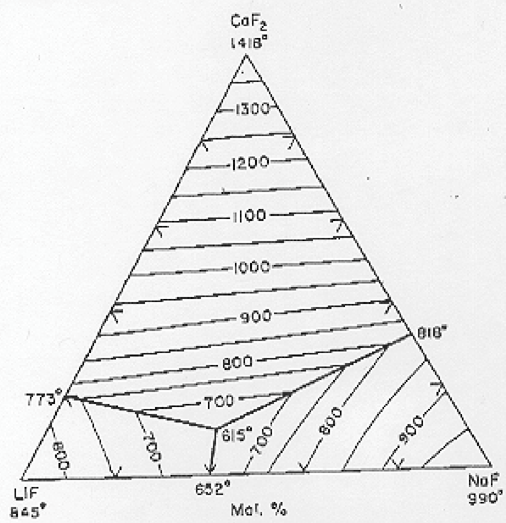


FIG. 1544.—System LiF–NaF–CaF_2.

LiF–NaF–AlF$_3$

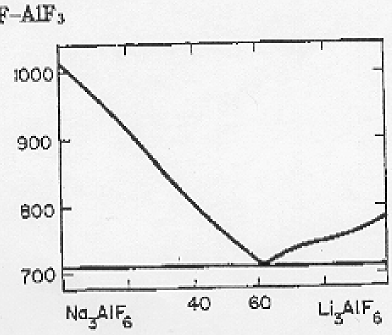


FIG. 1546.—System Li_3AlF_6–Na_3AlF_6.

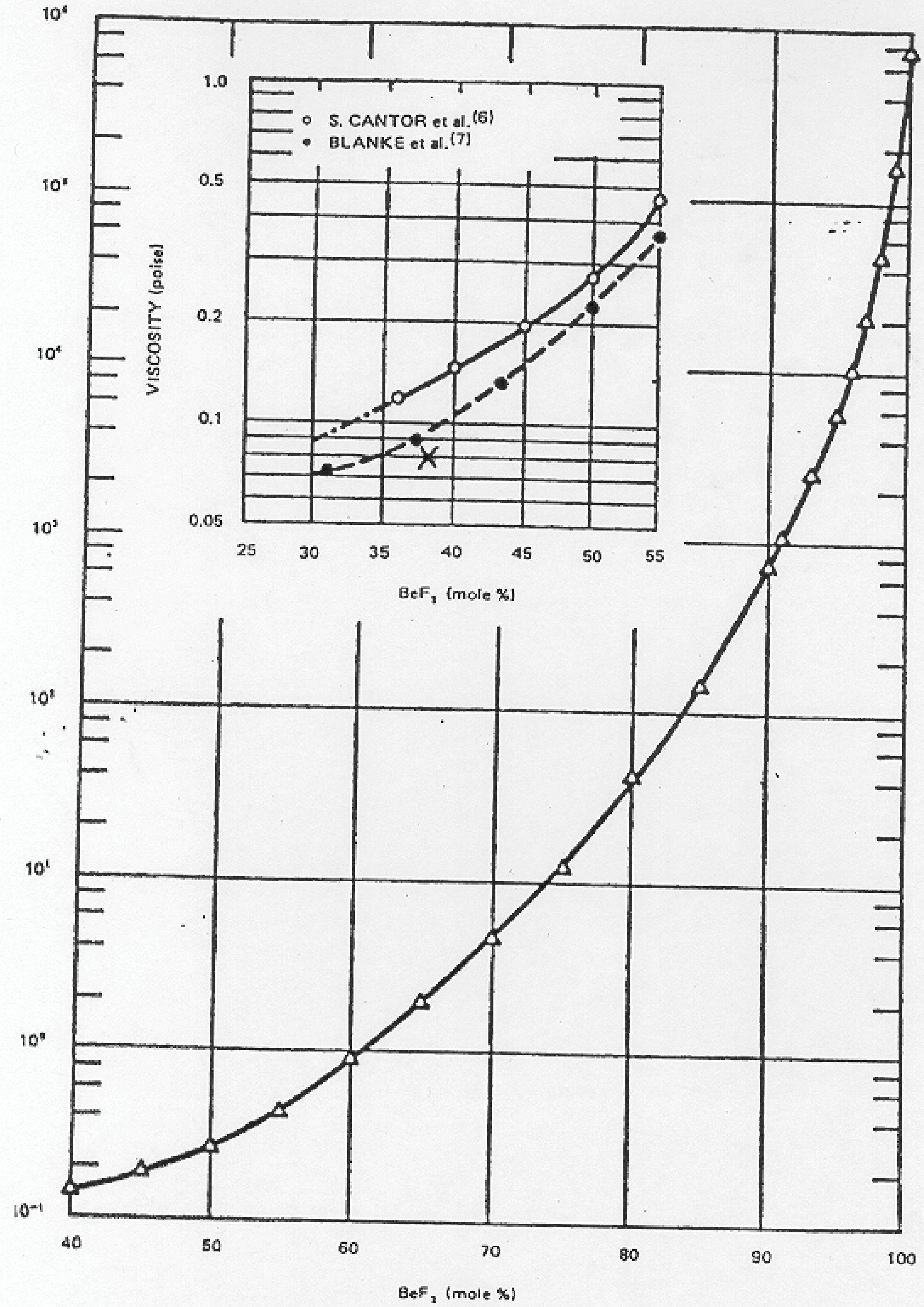
V. P. Mashovets and V. I. Petrov, *Zhur. Prikl. Khim.*, 30, 1695 (1957).

Viscosity and Heat capacity

MELTING POINTS, HEAT CAPACITIES, AND EQUATIONS FOR DENSITY AND VISCOSITY OF TYPICAL MOLTEN FLUORIDES

Composition, mole %	Melting point, °C	Liquid density, g/cc $\rho = A - BT(°C)$		Heat capacity at 700°C, cal/gram	Viscosity, centipoise		
					$\eta = Ae^{B/T(°K)}$		At 600°C
		A	B		A	B	
			$\times 10^{-5}$				
$LiF-BeF_2$ (69–31)	505	2.16	40	0.65	0.118	3624	7.5
$LiF-BeF_2$ (50–50)	350	2.46	40	0.67	0.0189	6174	22.2
$NaF-BeF_2$ (57–43)	360	2.27	37	0.52	0.0346	5164	12.8
$NaF-ZrF_4$ (50–50)	510	3.79	93	0.28	0.0709	4168	8.4
LiF–NaF–KF (46.5–11.5–42)	454	2.53	73	0.45	0.0400	4170	4.75
$LiF-NaF-BeF_2$ (35–27–38)	338	2.22	41	0.59	0.0338	4738	7.8

Both viscosity and heat capacity of flinabe are about the same as flibe at the same temperature with the same Be concentration.



'ig. 4.1 Viscosities in the BeF_2-LiF system at 600°C.[6]

X Flinabe

Vapor pressure

VAPOR PRESSURES OF NaF-BeF_2 MIXTURES*

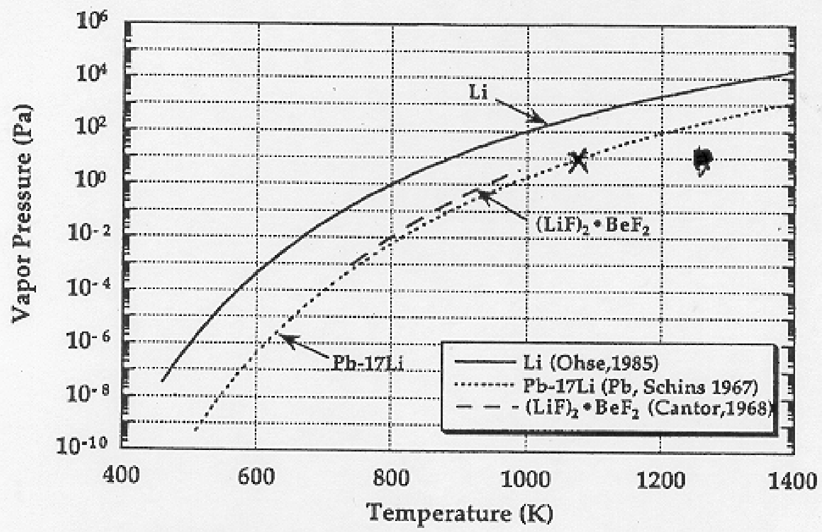
Composition, mole %		Temperature interval, °C	Vapor pressure constants†						Vapor pre at 800° mm H
			NaF		BeF_2		NaF-BeF_2		
NaF	BeF_2		*A*	*B*	*A*	*B*	*A*	*B*	
				$\times 10^4$		$\times 10^4$		$\times 10^4$	
26	74	785–977			10.43	1.096	9.77	1.206	1.69
41	59	802–988			10.06	1.085	9.79	1.187	0.94
50	50	796–996			9.52	1.071	9.82	1.187	0.41
60	40	855–1025	9.392	1.1667	9.080	1.1063			0.09
75	25	857–1035	9.237	1.2175	8.2	1.12			0.02

*Compiled from data obtained by Sense et al. [15].
†For the equation $\log P$ (mm Hg) $= A - (B/T)$, where T is in °K.

I do not have vapor pressure for flinabe. I only have vapor pressure for fnabe.

Vapor pressures comparison

COMPARISON OF THE VAPOR PRESSURE OF LIQUID COOLANTS



X 0.6NaF 0.4 BeF_2

The vapor pressure of fnabe is very similar to the vapor pressure of flibe at the same temperature with the same Be concentration.

Material compatibility

Table 13-2

Summary of Corrosion Data Obtained in Thermal-Convection and Forced-Circulation Loop Tests of Inconel and INOR-8 Exposed to Various Circulating Salt Mixtures

Constituents of base salts	UF_4 or ThF_4 content	Loop material	Maximum salt temperature, °F	Time of operation, hr	Depth of subsurface void formation at hottest part of loop, in.
$NaF-ZrF_4$	1 mole % UF_4	Inconel	1250	1000	<0.001
	1 mole % UF_4	Inconel	1270	6300	0–0.0025
	4 mole % UF_4	Inconel	1250	1000	0.002
	4 mole % UF_4	Inconel	1500	1000	0.007–0.010
	4 mole % UF_4	INOR-8	1500	1000	0.002–0.003
	0	Inconel	1500	1000	0.002–0.003
$NaF-BeF_2$	1 mole % UF_4	Inconel	1250	1000	0.001
	0	Inconel	1500	500	0.004–0.010
	3 mole % UF_4	Inconel	1500	500	0.008–0.014
	1 mole % UF_4	INOR-8	1250	6300	0.001
$LiF-BeF_2$	1 mole % UF_4	Inconel	1250	1000	0.001–0.002
	3 mole % UF_4	Inconel	1500	500	0.012–0.020
	1 mole % UF_4	INOR-8	1250	1000	0
$NaF-LiF-BeF_2$	0	Inconel	1125	1000	0.002
	0	Inconel	1500	500	0.003–0.005
	3 mole % UF_4	Inconel	1500	500	0.008–0.013
NaF-LiF-KF	0	Inconel	1125	1000	0.001
	2.5 mole % UF_4	Inconel	1500	500	0.017
	0	INOR-8	1250	1340	0
	2.5 mole % UF_4	INOR-8	1500	1000	0.001–0.003
LiF	29 mole % ThF_4	Inconel	1250	1000	0–0.0015
$NaF-BeF_2$	7 mole % ThF_4	INOR-8	1250	1000	0

The corrosion rate of flinabe to Ni-alloy is very similar to the corrosion rate of flibe. This is because the free energy of formation for NaF is about the same as LiF.

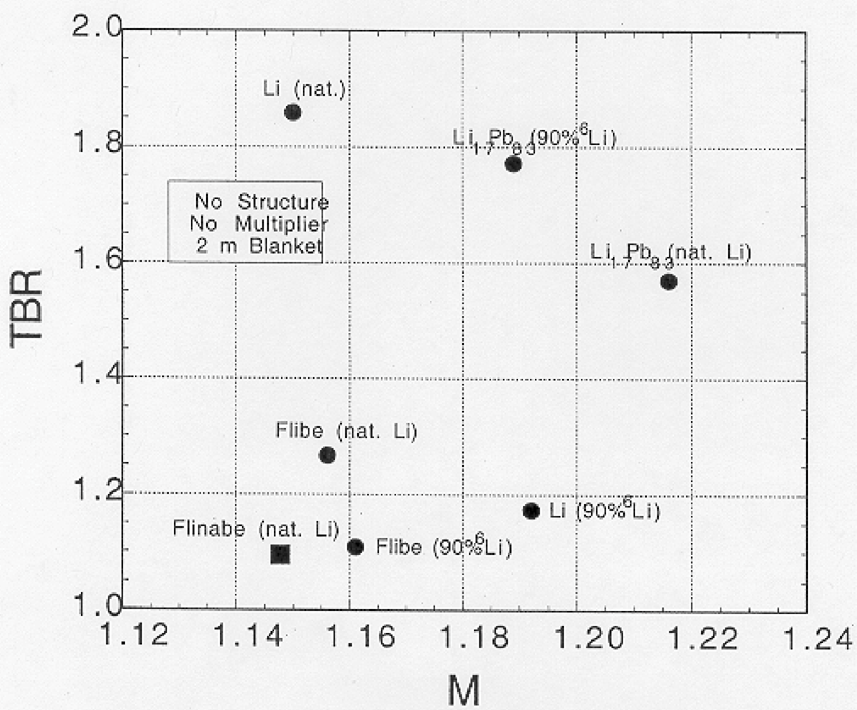
7/24/2001

Tritium Breeding Potential for Flinabe Compared to Flibe

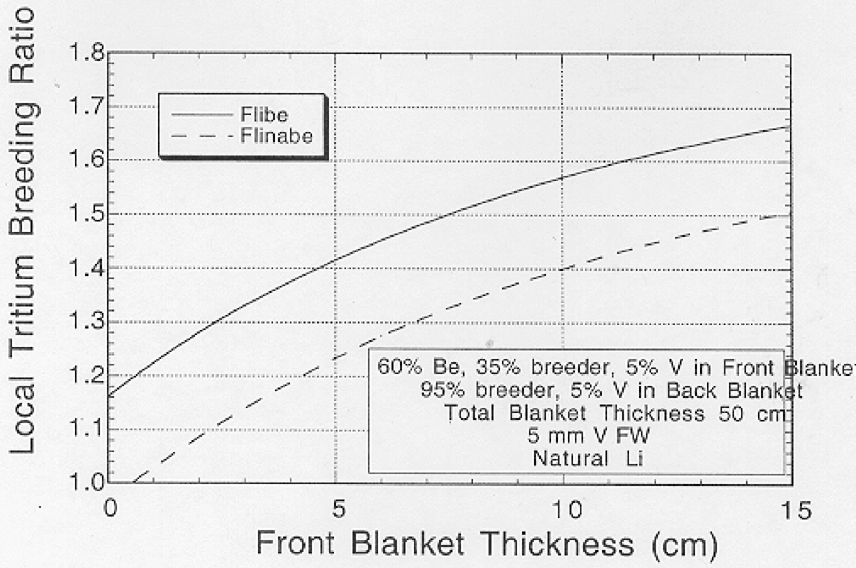
Mohamed Sawan

- The Flinabe molten salt has LiF:NaF:BeF2 ratio of 1:1:1

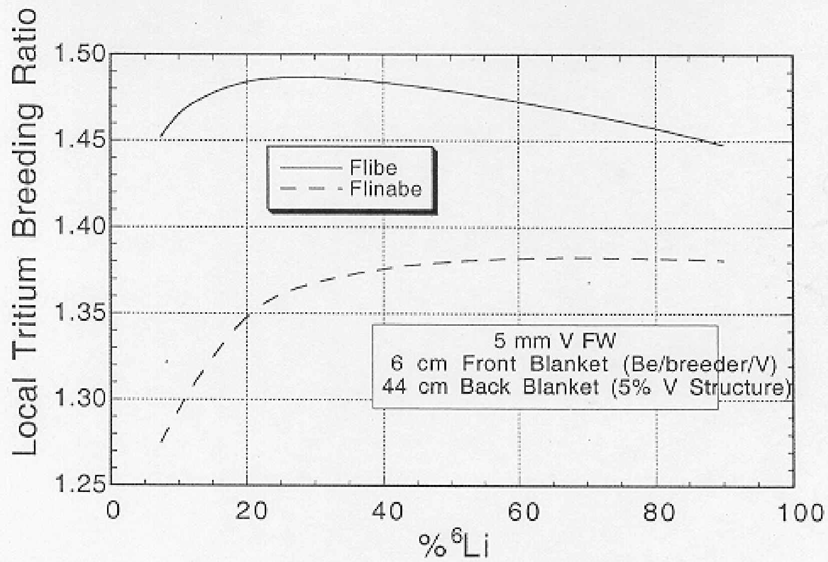
- Generic breeding calculations for Flibe presented in November 1998 APEX meeting are repeated with Flinabe



- Tritium breeding in Flinabe is less than in Flibe



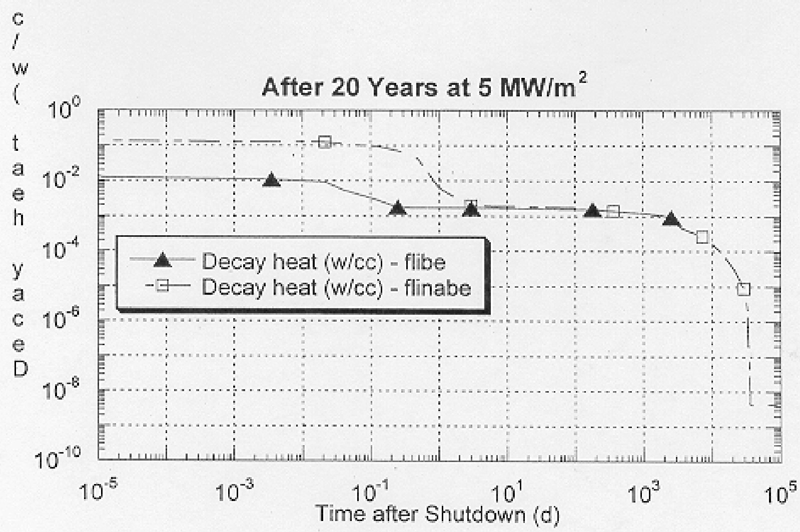
- Adding Be in front zone of blanket results in significant enhancement in TBR
- For the same Be zone thickness TBR in Flinabe is 10-17% lower than in Flibe
- A flinabe system can achieve the same local TBR as in Flibe system with about 5 cm thicker Be zone

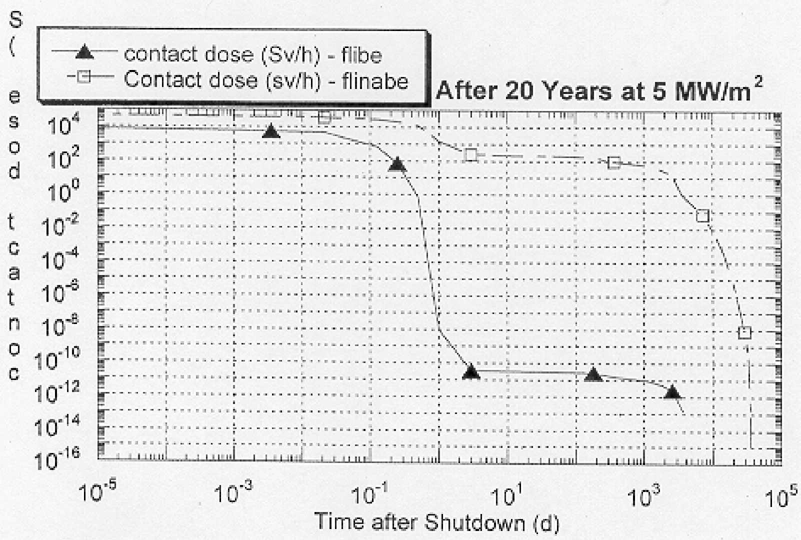


- With Be in front zone some enhancement in TBR is achieved by enriching Li in Li-6

- TBR enhancement is larger for Flinabe

- Largest TBR in Flinabe with Be and enrichment is only 7% lower than that for Flibe with Be and enrichment


After 20 Years at 5 MW/m2
Decay heat (w/cc)
Decay heat (w/cc) - flibe
Decay heat (w/cc) - flinabe
Time after Shutdown (d)


After 20 Years at 5 MW/m2
contact dose (Sv/h)
contact dose (Sv/h) - flibe
Contact dose (sv/h) - flinabe
Time after Shutdown (d)

Recommendations

- Selected the salt composition at 1-1-1 BeF_2-LiF-NaF as the reference material.
- Using 240C as the melting temperature.
- Measure the melting temperature of salt with this composition, and other compositions.
- Use material properties of BeF_2-LiF, and extrapolate to the lower temperature for best estimate.
-