"MOLTEN-SALT TARGET AND BLANKET CONCEPT"

[Application of the Molten-Salt Technology on the Spallation Neutron Facilities]

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SUMMARY

The applications of molten-salt target and blanket to the Molten-Salt Intense Neutron Source (MSINS) and the Accelerator Molten-Salt Breeder (AMSB) are discussed, where the molten fluorides including ThF_4 or UF_4 in high concentration are utilized as shown in Table 1.

This concept naturally has several significant benefits relating to the target fabrication, design, radiation damage, heat removal, safety, economy, etc. So far, however, it was thought to have a poor spallation neutron yield as a severe fault. According to the results of neutronic calculation carried on the molten-salt system such as $LiF-BeF_2-ThF_4$, $LiF-NaF-ThF_4$, $LiF-BeF_2-UF_4$ etc., their neutron yields have been found comparable or superior to the values for heavy metal targets such as Bi and Pb, assuring the high performance of MSINS and AMSB.(1)

The schematic figures of MSINS and AMSB are shown in Figs.1 and 4, together with the several tables and figures of their neutronic calculation models, neutron yields, predicted performances, etc.(1) Neutronic calculations have been performed with the use of NMTC/JAERI modified to include fission processes, TWOTRAN-II and other auxiliary codes. The spatial and energy distributions of neutrons are also calculated, though an effect of Be(n,2n) reaction is not included. The chemical aspect of spallation products in these facilities are examined and estimated that they are practically manageable in processing.

One of the most useful applications of MSINS may be the material irradiation facility for engineering test because of the larger irradiation volume than that in the other metal targets.

Reference

(1) K.Furukawa, K.Tsukada, and Y.Nakahara, "Single-fluid-type Accelerator Molten-Salt Breeder Concept", J. Nucl. Sci. Tech. 18 (1981). in press

Table 1 Candidate Target Salts and Their Predicted Properties

	mol %	melting point Tm (°C)	density at Tm+100°C (g/cm^3)	viscosity coeff (cpoise)	
				600°C	700°C
LiF-BeF$_2$-ThF$_4$	72-16-12	500	3.35	12	7
"	71- 9-20	540	2.97	16~18	7~9
"	67-18-15	500	2.70	13~15	6~7
"	64-18-18	540	2.7	12~14	6~7
LiF-ThF$_4$	71-29	568	3.36	20~22	12~14
LiF-NaF-ThF$_4$	54.5-13.5-32	525	3.31	19~22	11~13
NaF-KF-ThF$_4$	11-67-22	535	2.54	14~16	8~10
LiF-BeF$_2$-UF$_4$	61-21-18	550	2.87	13~15	6~7
LiF-UF$_4$	71-29	525	3.41	20~22	12~14
LiF-NaF-UF$_4$	43.5-24.3-32.2	445	3.09	20~22	12~14
LiF-RbF-UF$_4$	60-10-30	460	3.62	16~18	10~12
"	57-10-33	470	3.57	17~19	11~13
NaF-RbF-UF$_4$	45-27-28	500	2.99	15~17	9~11
NaF-KF-UF$_4$	47-20-33	550	2.89	18~20	11~13

Table 2. Comparison of Neutron Yields per 1GeV Proton for Some of Target Salts including Th and U

Case	molten salt	cascade + evaporation (≥15 MeV)	cascade + evaporation + fission (15≥MeV)	whole energy range (1000 ~0 MeV)*
1	^{7}LiF-BeF$_2$**-ThF$_4$ (72-16-12)	22.3 ± 2.3	25.1 ± 3.0	
2	" (71- 9-20)	26.1 ± 2.1	29.6 ± 2.1	
3	" (67-18-15)		28.6 ± 3.3	29.5 ± 3.4
4	" (64-18-18)			
5	^{7}LiF-ThF$_4$ (71-29)	27.3 ± 2.2	33.04 ± 1.9	
6	^{7}LiF-NaF-ThF$_4$ (54.5-13.5-32)		32.4 ± 2.1	34.0 ± 2.2
7	NaF-KF-ThF$_4$ (11-67-22)		25.9 ± 3.0	
8	^{7}LiF-BeF$_2$-UF$_4$ (61-21-18)		31.2 ± 2.4	38.4 ± 3.0
9	^{7}LiF-UF$_4$ (71-29)	28.1 ± 2.8	33.2 ± 2.6	
10	^{7}LiF-RbF-UF$_4$ (60-10-30)	27.7 ± 1.7		
11	" (57-10-33)		36.0 ± 4.0	
12	NaF-RbF-UF$_4$ (45-27-28)	28.0 ± 1.8		

(*) Including fission in the energy range both above and below 15 MeV.

(**) The effect of Be(n,2n) reaction is not enoughly included yet.

Table 3. Neutron Yield per 1GeV Proton at the Window of the Intense Neutron Source (MSINS)

molten salt	cascade + evaporation + fision (≥15 MeV)	whole energy range (1000 ~0 MeV)
^{7}LiF-BeF$_2$-UF$_4$ (61-21-18)	14.5 ± 2.2	16.9 ± 2.6

Table 4. Example of Predicted Performances of the Molten-Salt Intense Neutron Source (MSINS)

poton beam	1 GeV 10 mA
salt example	^{7}LiF-RbF-UF$_4$ (57-10-33 mol %)
melting point (Tm)	470 °C
density at Tm+100°C	3.57 g/cm^3
viscosity coefficient	17~19 cpoise (600°C)
salt temperature	inlet 520°C outlet 600°C
salt volume	3 m^3
salt weight	10.7 ton (Th 6.5 ton)
salt flow	150 L/min
heat generation	~ 50 MW th
fissile material generation	~ 5 kg/year
spallation reaction products	~ 0.7 kg/year

Table 5. Example of Predicted Performances of Single-fluid-type Accelerator Molten-Salt Breeder (AMSB)

proton beam	1 GeV, 300 mA
salt example	^{7}LiF-NaF-ThF$_4$ 54.5-13.5-32 m/o
melting point (Tm)	525 °C
density at Tm+100°C	3.31 g/cm^3
viscosity coefficient	19~22 c poise (600°C) 11~13 " (700°C)
salt temperature	inlet 560°C outlet 660°C
salt volume	100 m^3
salt weight	331 ton (Th 208 ton)
salt flow	6 m 3/sec
thermal output	~2500 MW th
elec, power generation	~1100 MWe
elec, power consumption	750 ~ 900 MWe
fissile. material production*	800~1000 kg/year 640~ 800 kg/year (80% load)
spallation products	~40 kg/year
fission products	~40 kg/year

* Except for the continuous removal, this will be increased to about twice.

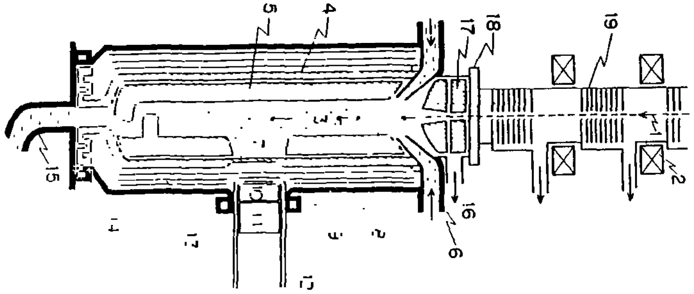

Fig. 1. Schematic Figure of MSINS (Molten-Salt Intense Neutron Source)

1 proton beam, 2 quadrupole magnet, 3 molten salt, 4 graphite vessel, 5 graphite inner cylinder, 6 inlet nozzle, 7 holes, 8 metallic container, 9 BN (decoupler), 10 polyethylene, 11 Be (BeO), 12 B_4C, 13 thermal shield, 14 freeze seal, 15 outlet, 16 vacuum line, 17 neutron shield, 18 beam shutter, 19 differential pumping system.

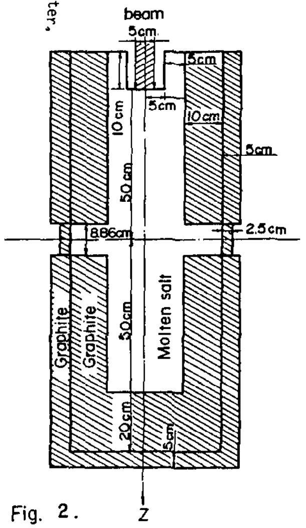

Fig. 2. Cylindrical Target Model for Neutronic Calculations of MSINS (Molten-Salt Intense Neutron Source)

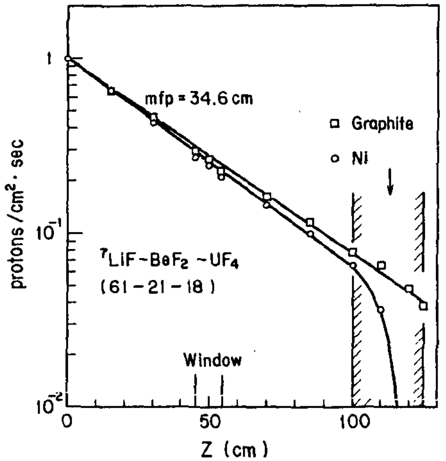

Fig.3 Axial distribution of primary protons

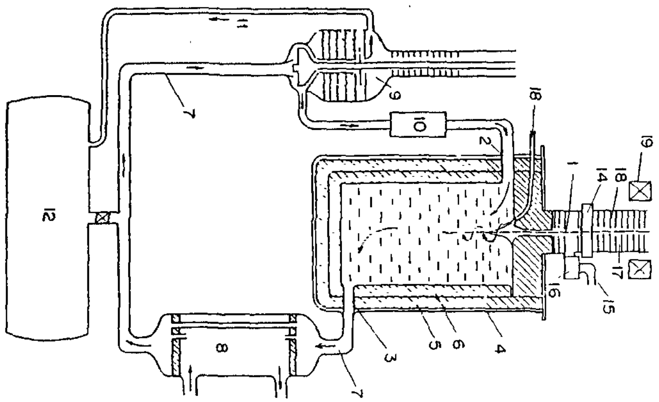

Fig. 4 Schematic Figure of Single-fluid-type Accelerator Molten-Salt Breeder

1 proton beam, 2 salt inlet, 3 salt outlet, 4 reactor vessel, 5&6 graphite, 7 primary loop, 8 heat exchanger, 9 main salt pump, 10 throttle valve, 11 overflow line, 12 storage tank, 13 high-pressure salt outlet, 14 gate valve, 15 vacuum line, 16 vapor trap, 17 duct, 18 orifice, 19 focussing magnet.

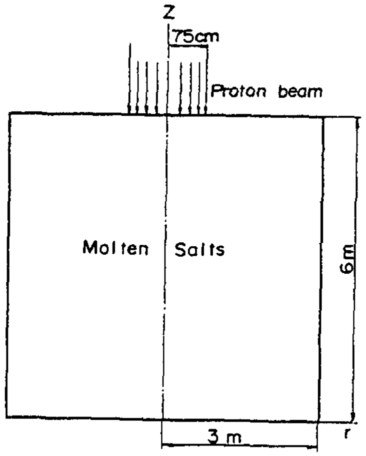

Fig. 5

Cylindrical target model for neutronic calculations of AMSB (Accelerator Molten-Salt Breeder)

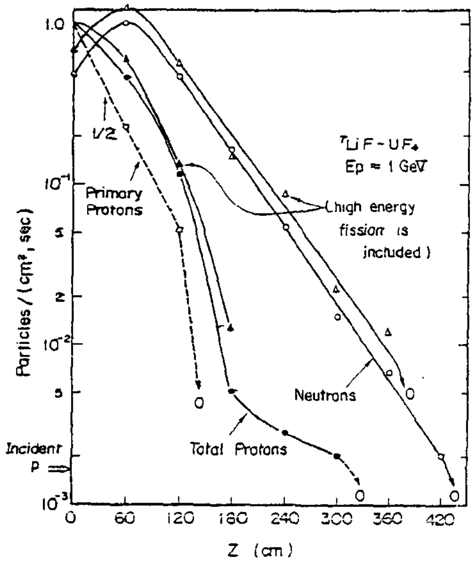

Fig. 6. Flux Distributions of Protons and Neutrons in the Direction of Incident Proton Beam. [>15MeV] (Cascade-Evaporation Only)