Design Study of Pb-Bi- and NaK-Cooled Small Deep Sea Fast Reactors

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Abstract – ***The liquid lead-bismuth eutectic (Pb-Bi) has good compatibility with water, which is different from sodium.***

It is expected that the Pb-Bi could be used as a coolant of the deep sea fast reactor (DSFR).

Physics analysis of the Pb-Bi-cooled small reactor cores with and without inner control rods was performed. The coolant of Pb-Bi seems to be good as well as NaK for DSFR

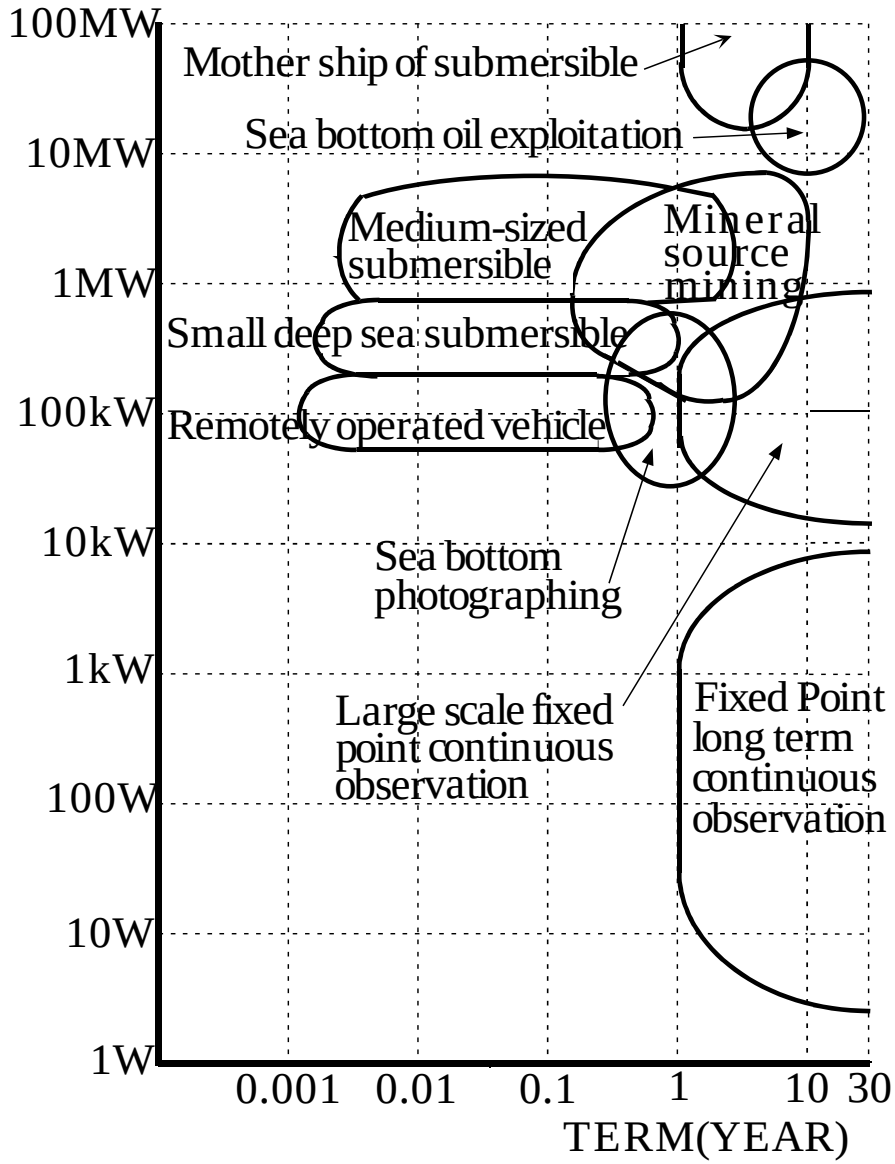


Fig. 1 Demand of electric power for activities in the sea

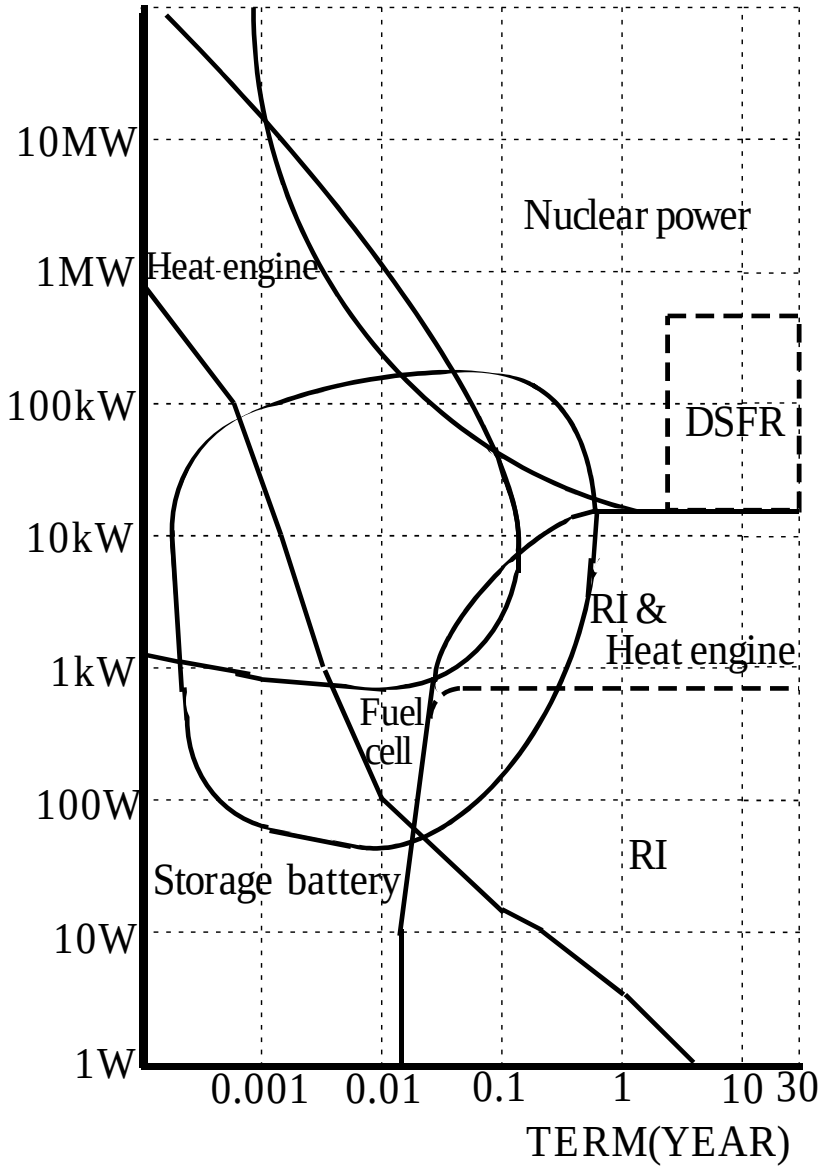


Fig. 2 Supply of electric power

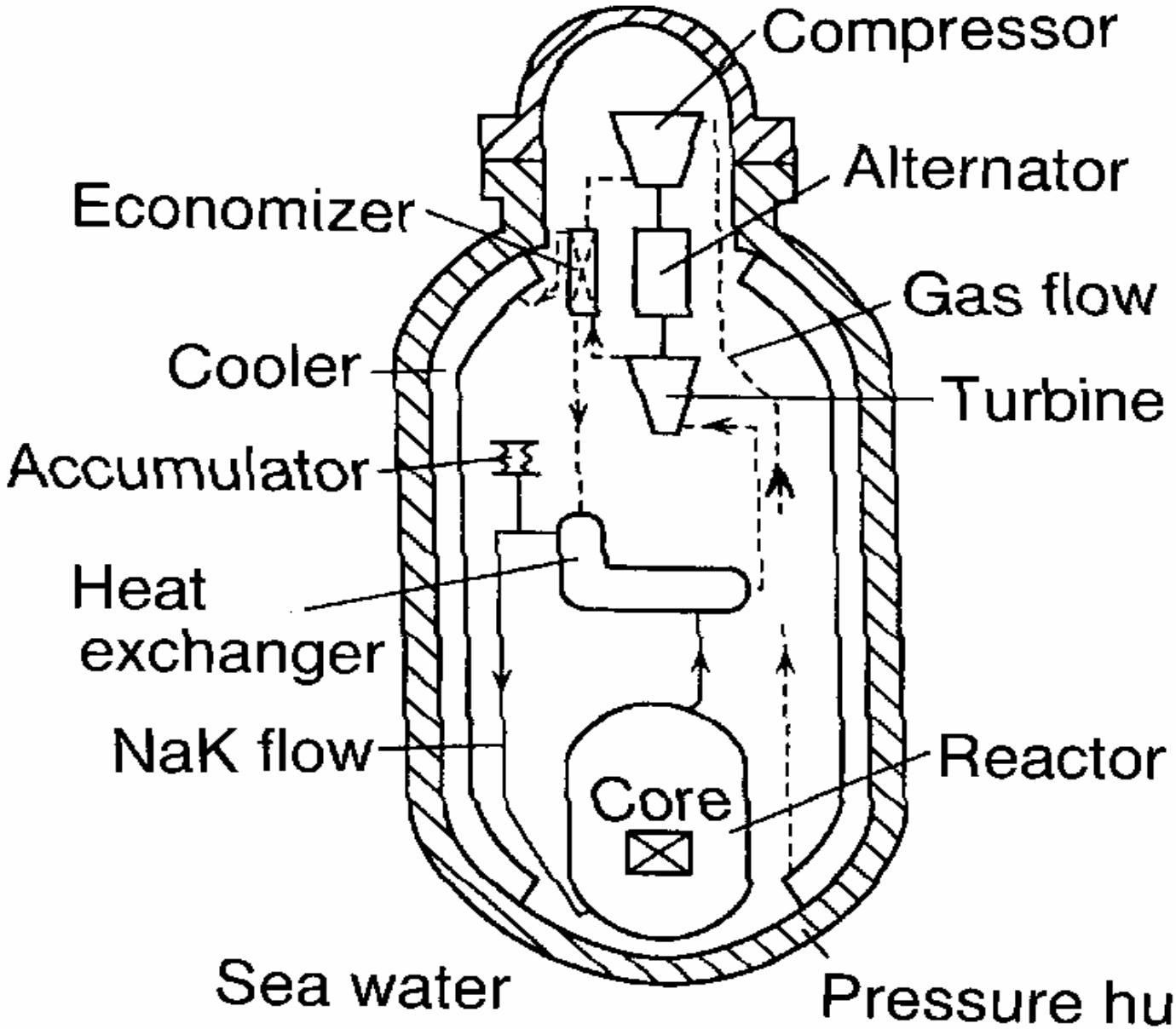


Fig. 3 Schematic of the deep sea fast reactor (DSFR)

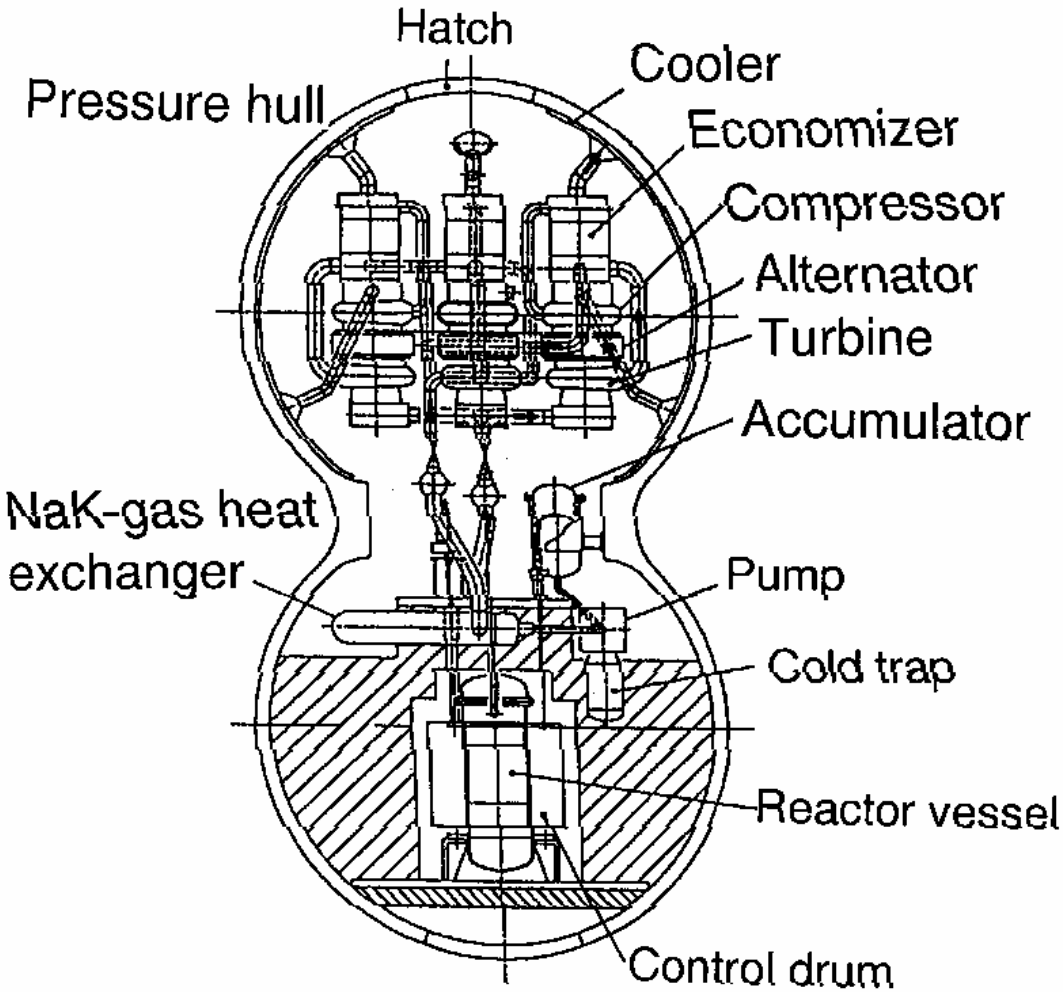


Fig.4 Structure of DSFR with power of 40kWe

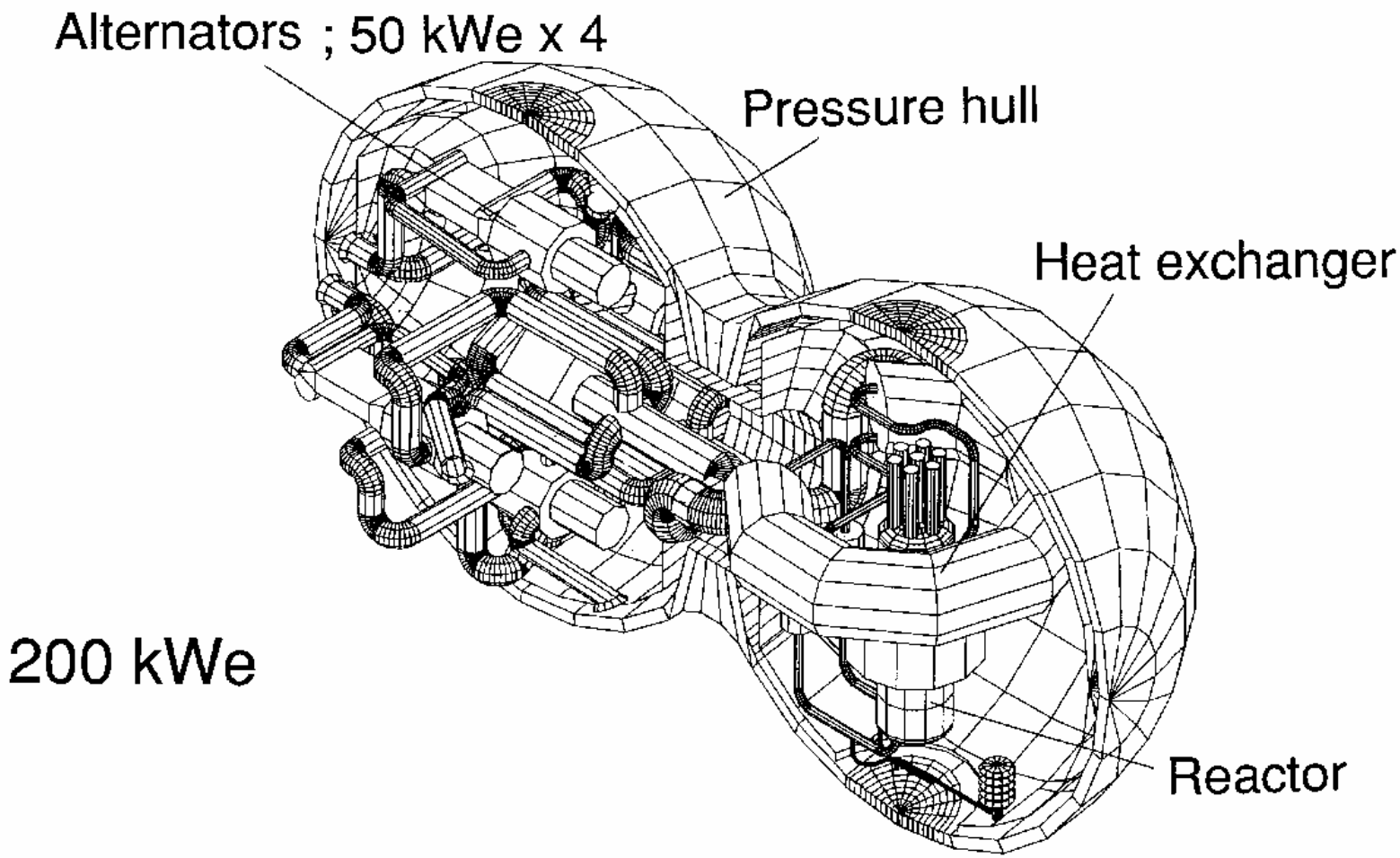


Fig. 5 DSFR with power of 200kWe

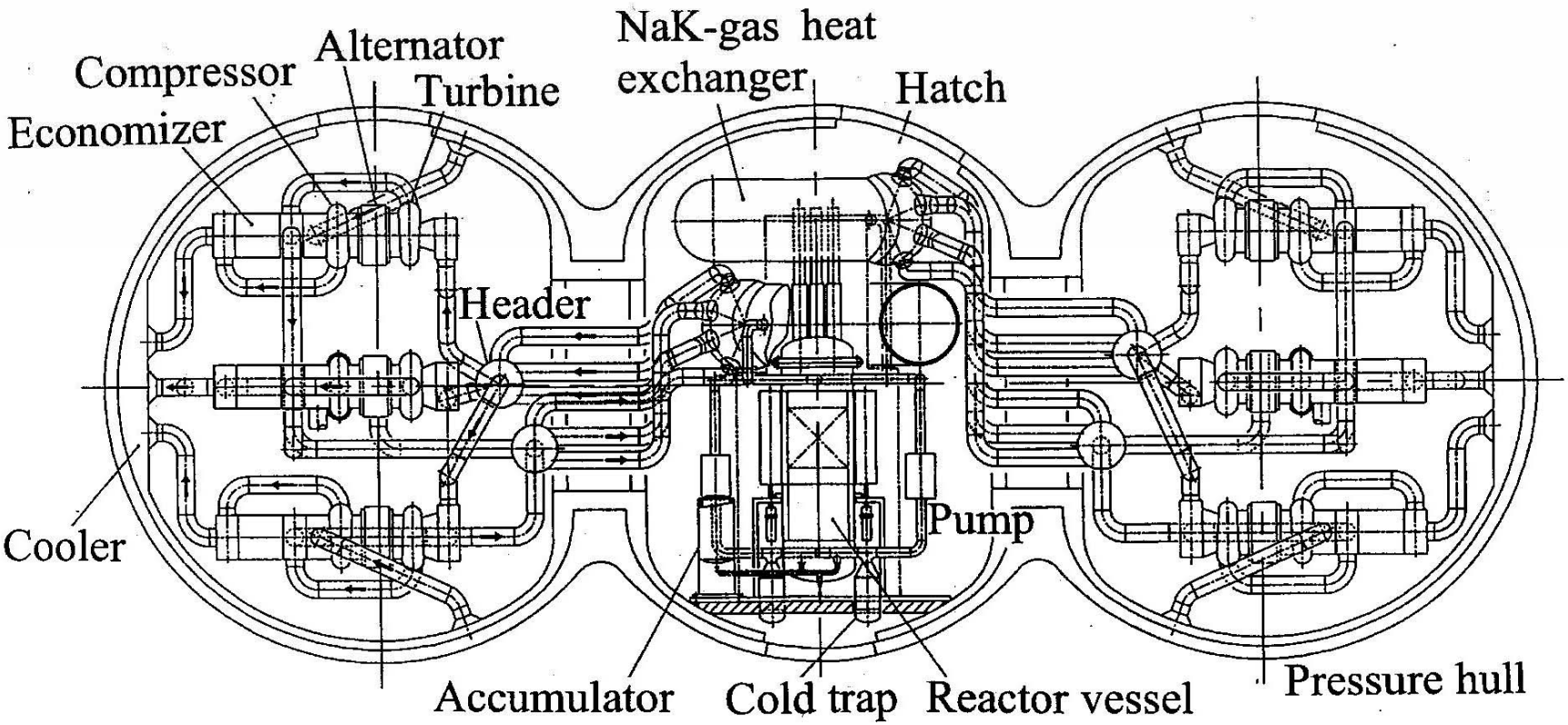


Fig. 6 500kWe System

Table 1 Comparison of NaK- & Pb-Bi-cooled 200kWe DSFRs used in the 6km-deep sea

Item	NaK	Pb-Bi
Weight	64 t	67.5 t
S.S.corrosion	Twice as high as in sodium	Higher than in NaK
Coolant & sea water reaction	Violent reaction.	No reaction (right) several hundreds kW 15th from the bottom
Core immersion accident	Re liner in cladding required	No liner required
Neutron economy	Good	Excellent
Coolant freezing at the sea lowest temp. of 2ºC	No freezing due to melting point of -12ºC	Freezing. Heating with NaK reactor required

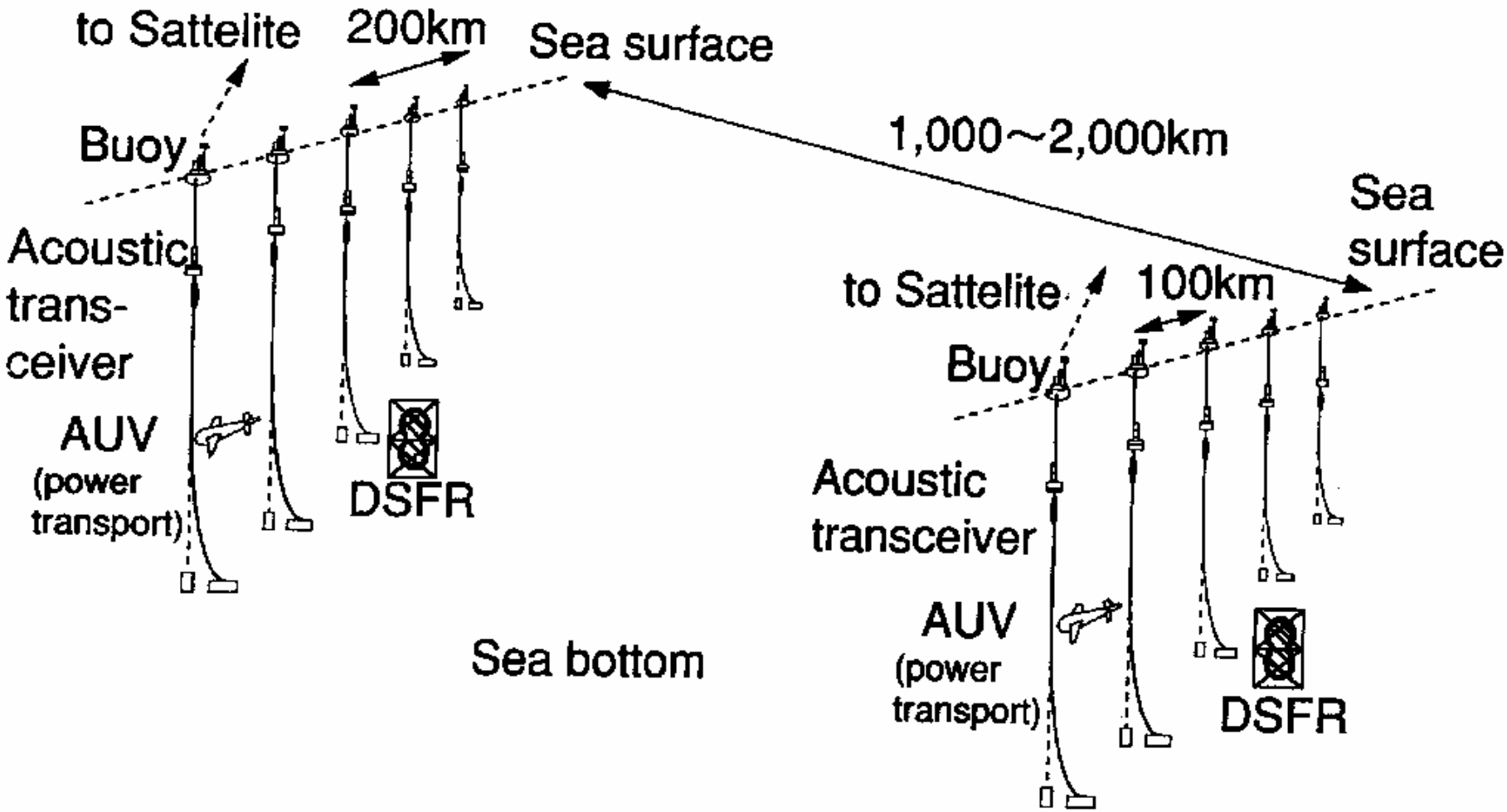
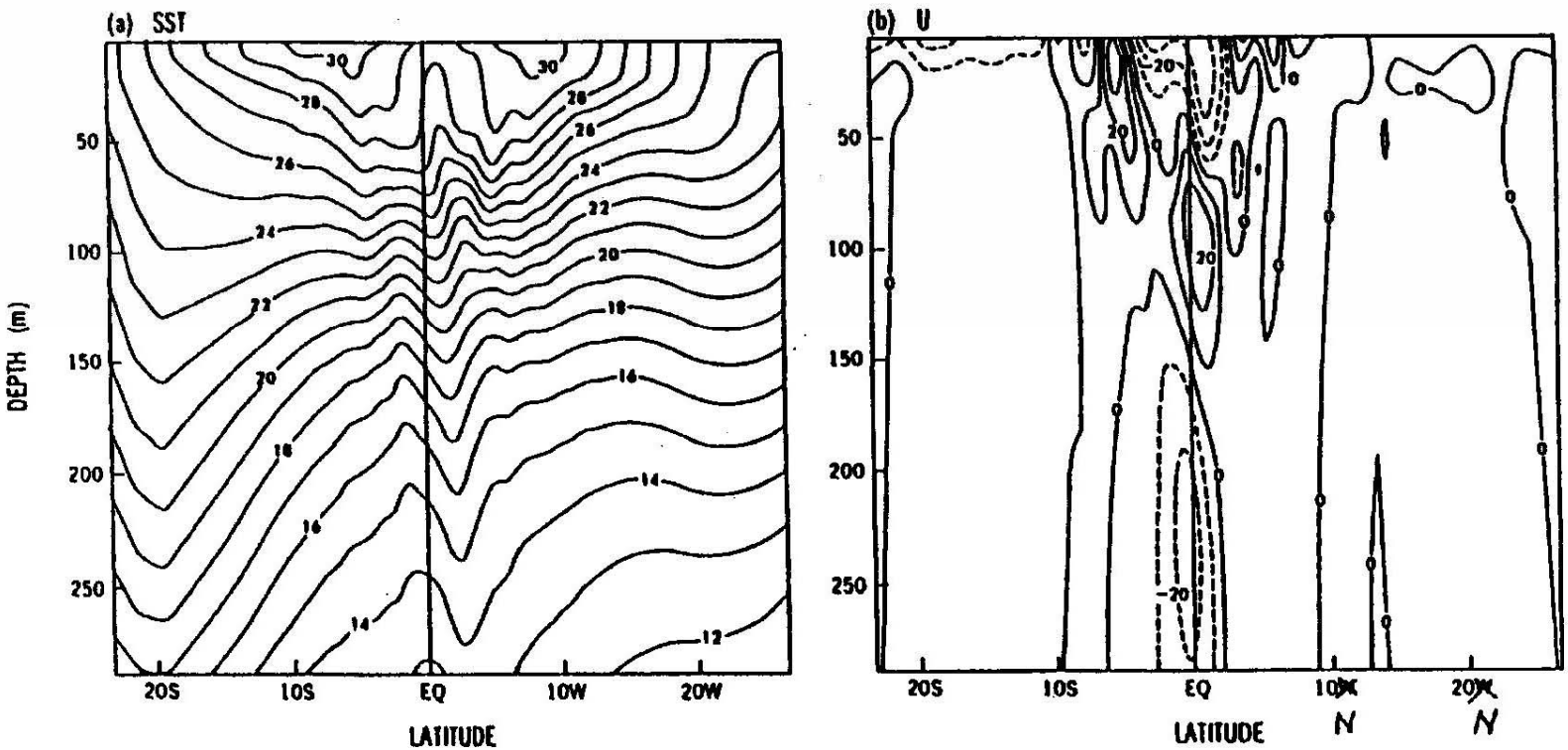


Fig. 7 Sea bottom base using acoustic tomography system



Temperature Velocity

Fig.8 Calculation results of sea water temperature and velocity

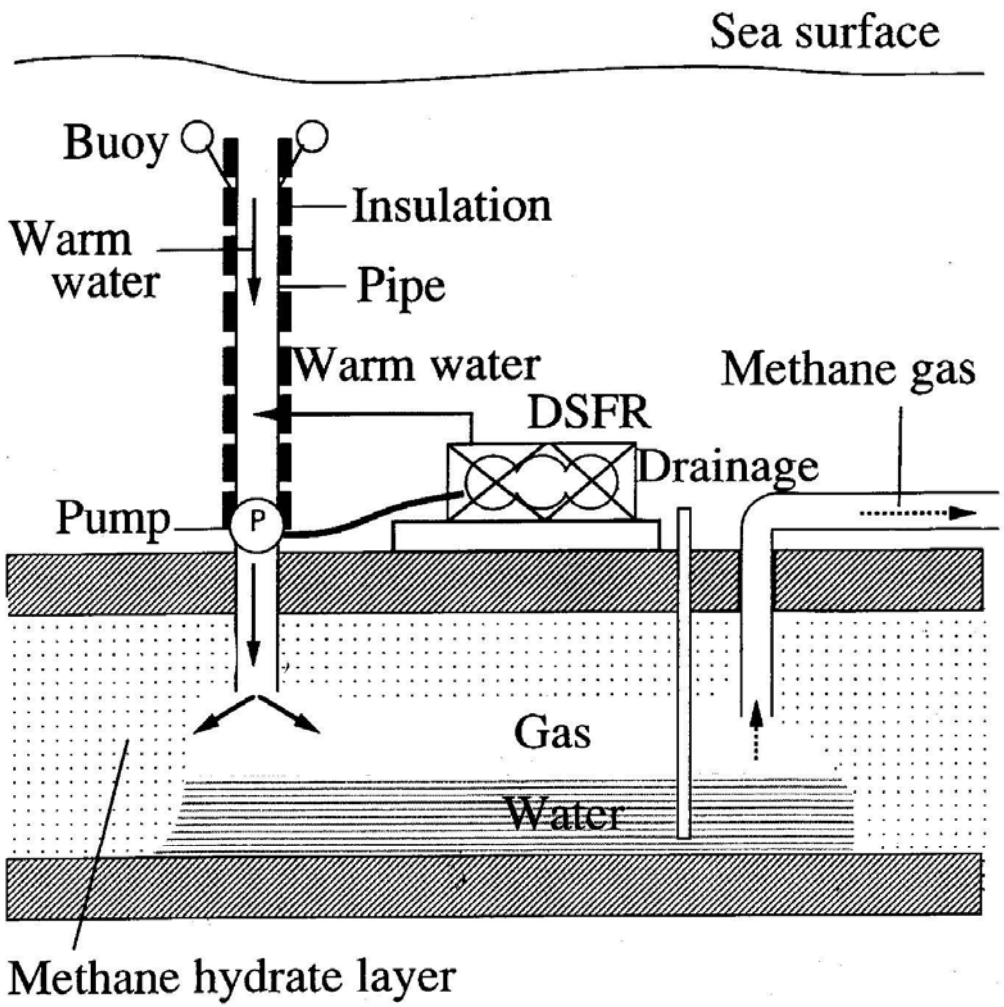


Fig. 9 Methane Gas Production System

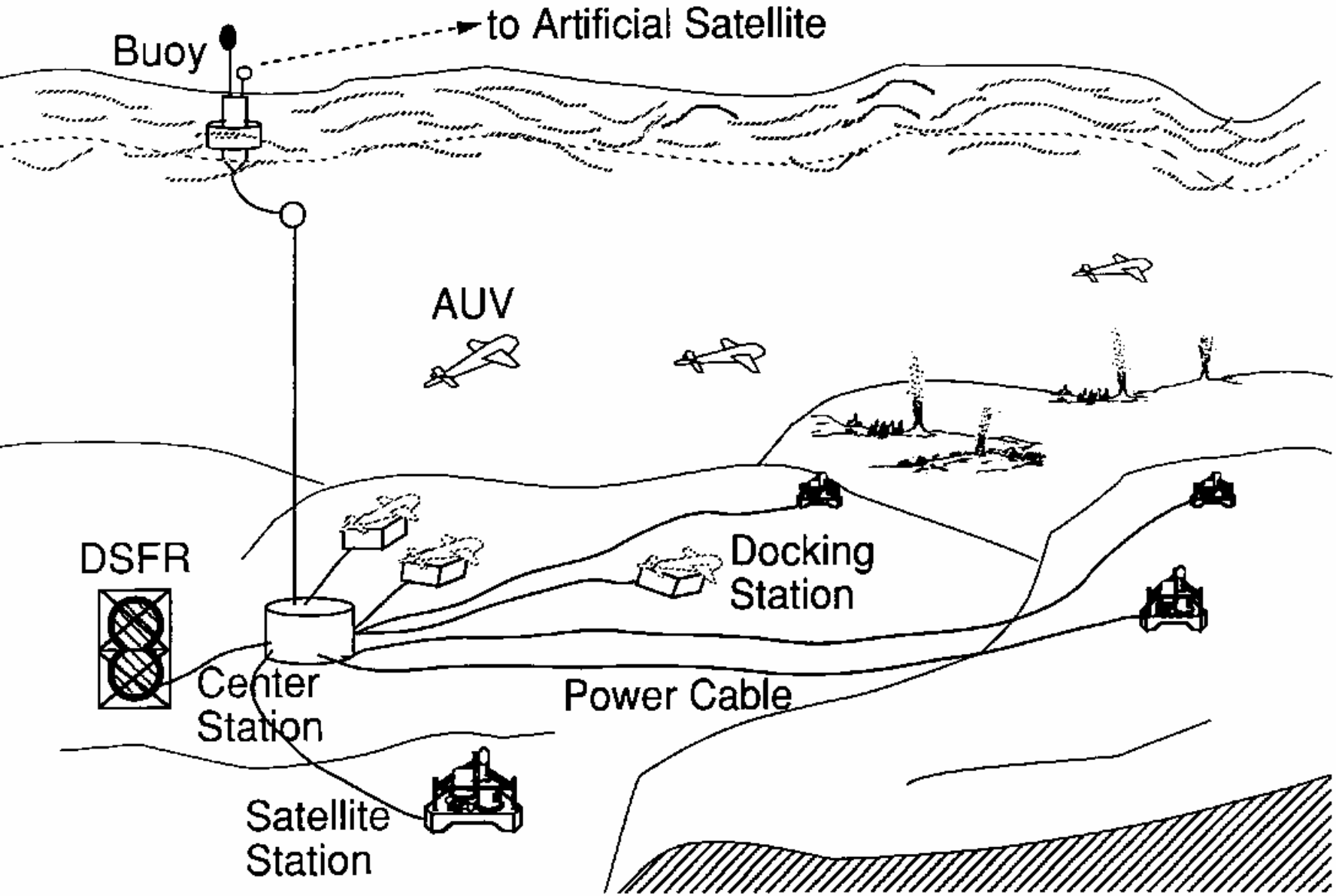
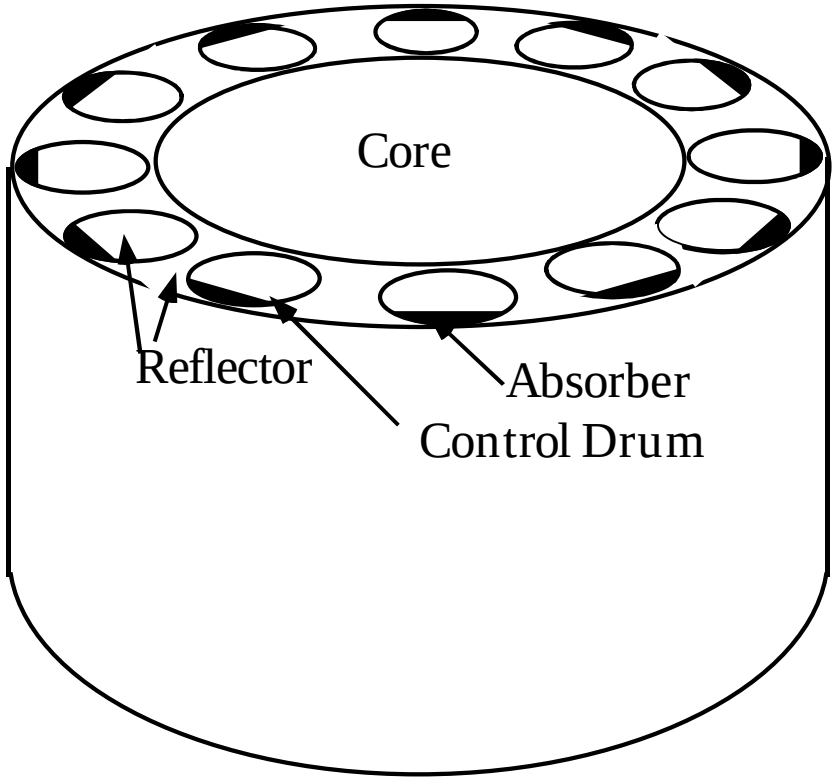
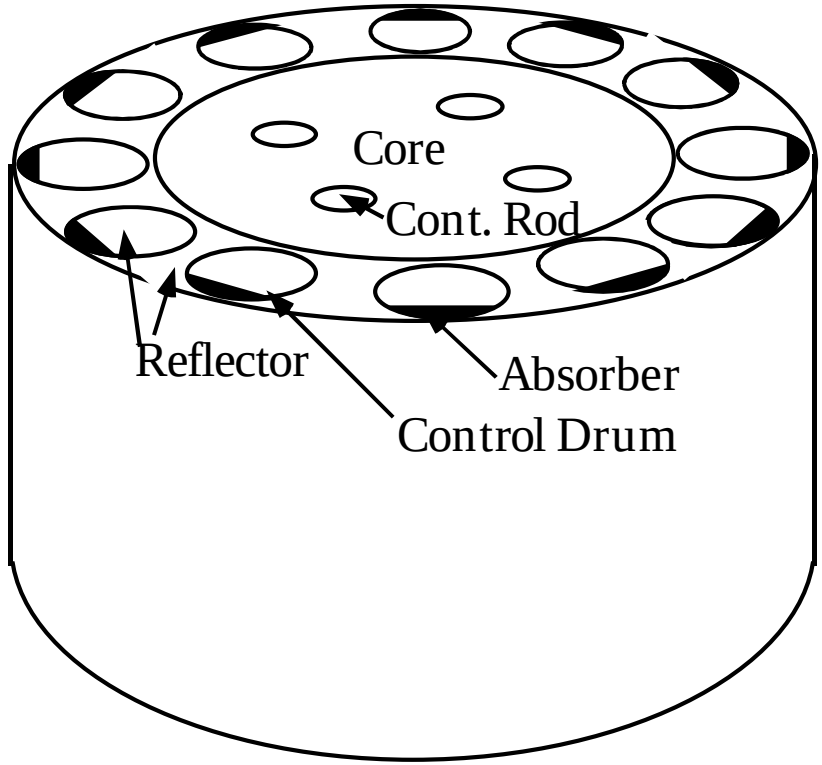


Fig. 8 Sea bottom observation base with AUVs

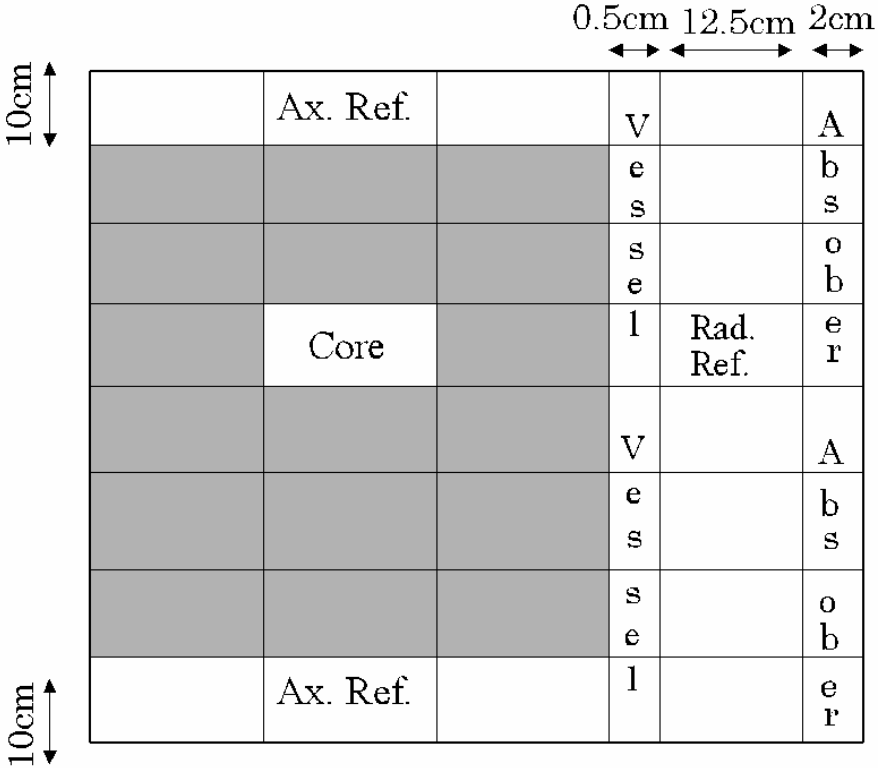


(a) Reactor without control rods inside core

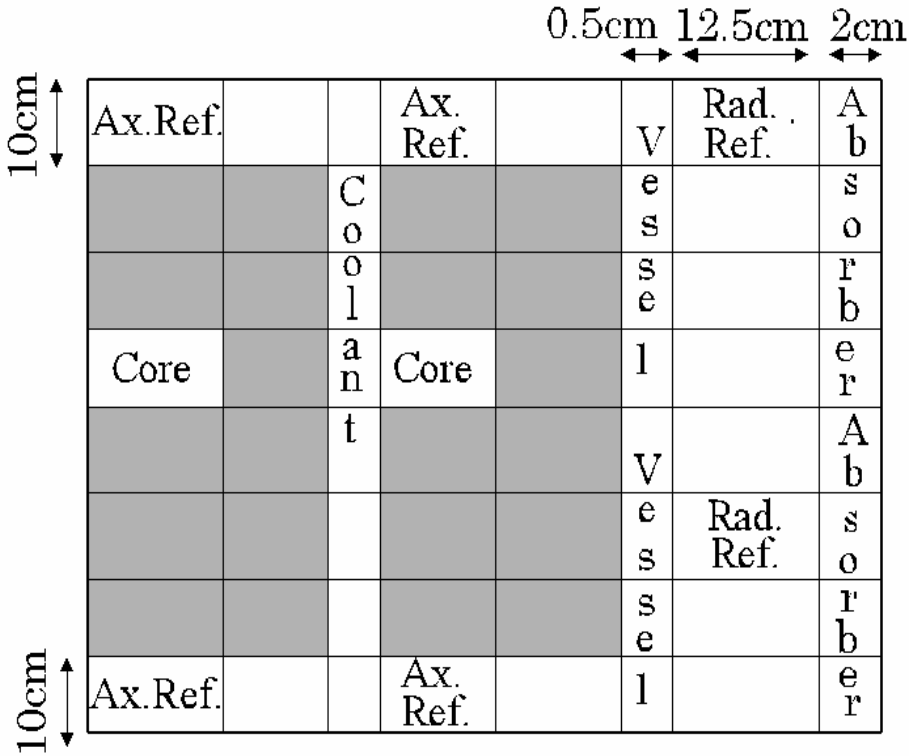


(b) Reactor with control rods inside core

Fig.10 Schematics of Pb-Bi-cooled and NaK-cooled reactors



(a) Reactor without control rods inside core



(b) Reactor with control rods inside core

Fig. 11 Analytical systems of Pb-Bi-cooled and NaK-cooled reactors

Table 2 Analytical parameters

		Without inner cont. rods	With inner cont. rods
Fuel	Nitride fuel	UN-PuN	UN
	Pu fraction	50wt.%	0wt.%
	Enrich. of U^{235}	20%	20-60%
	Enrich. of N^{15}	100%	100%
Fuel pel.	Outer diameter	5.56mm	5.56mm
	Smear density	85%	85%
Fuel pin cladding	Material	SUS316	SUS316
	Outer diameter	6.5mm	6.5mm
	Thickness	0.47mm	0.47mm
Re liner in cladding		Exist. or not	Exist. or not
Fuel pin pitch		7.3mm	6.5, 7.3mm
Axial reflector		Be, SUS316	Be, cladding, coolant
Core radius		10.5-14.5 cm	20.0cm

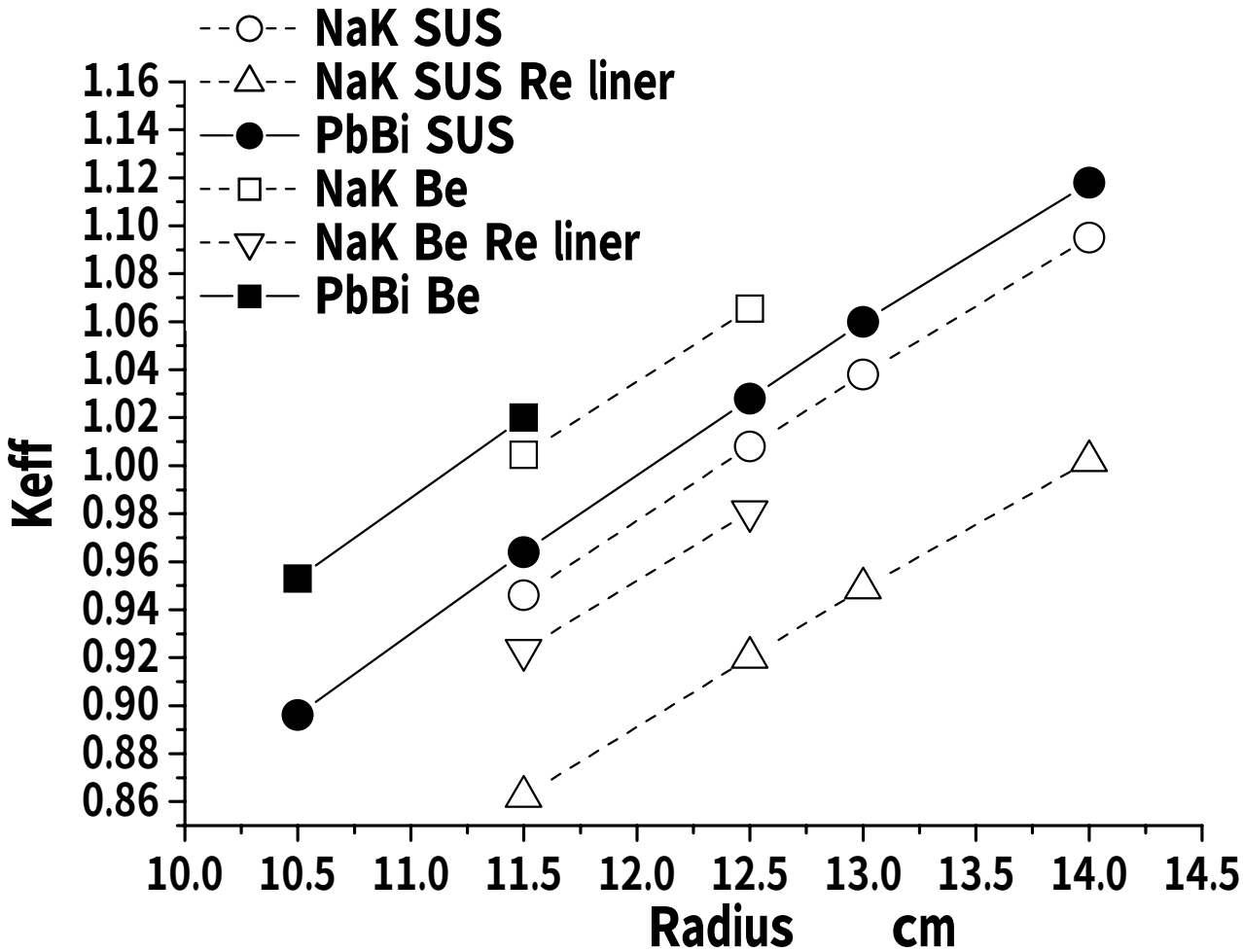


Fig. 12 Dependence of effective multiplication factor K_{eff} on core radius in the reactor without control rods inside core

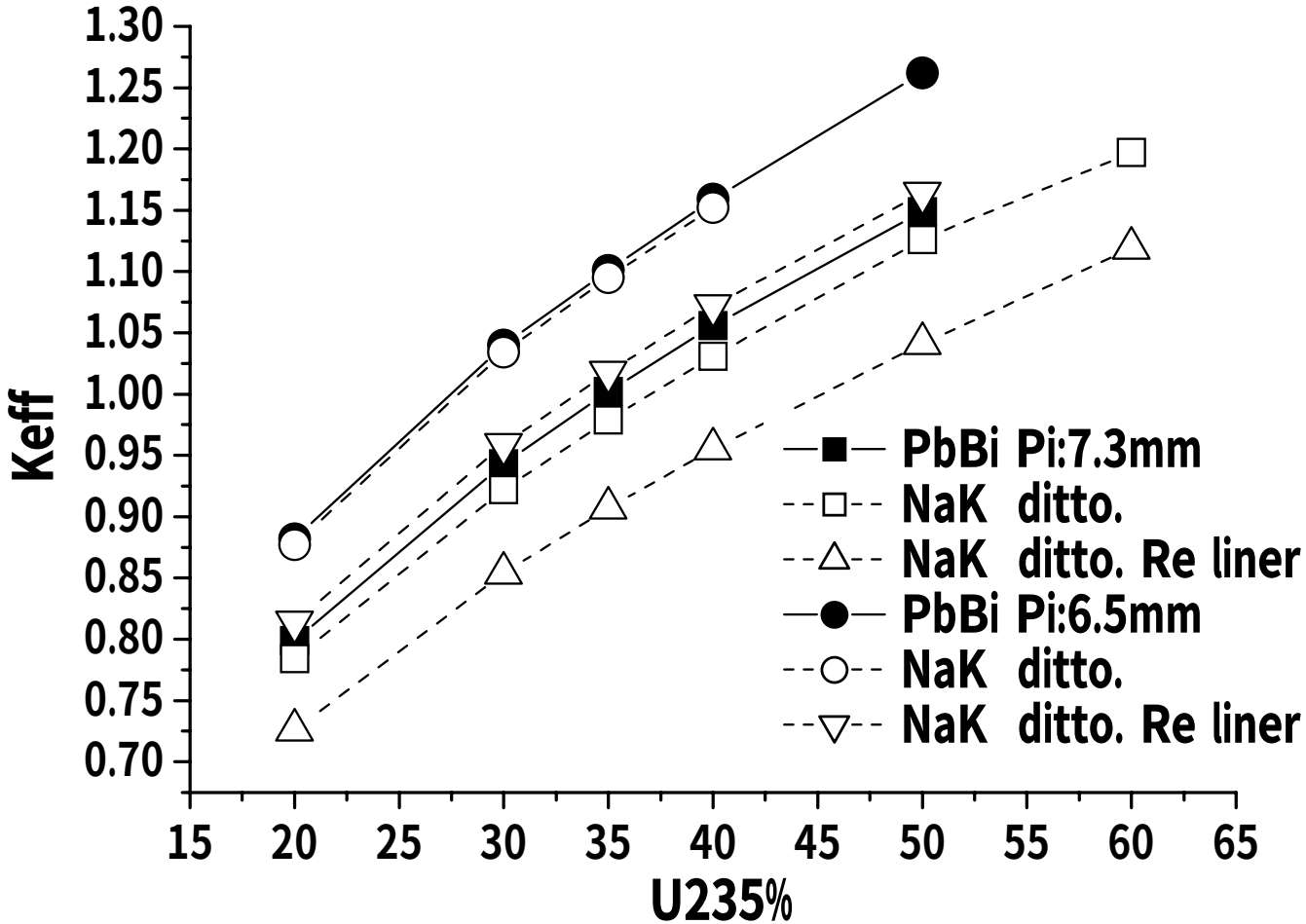


Fig. 13 Dependence of K_{eff} on enrichment of U^{235} in the reactor with control rods inside core

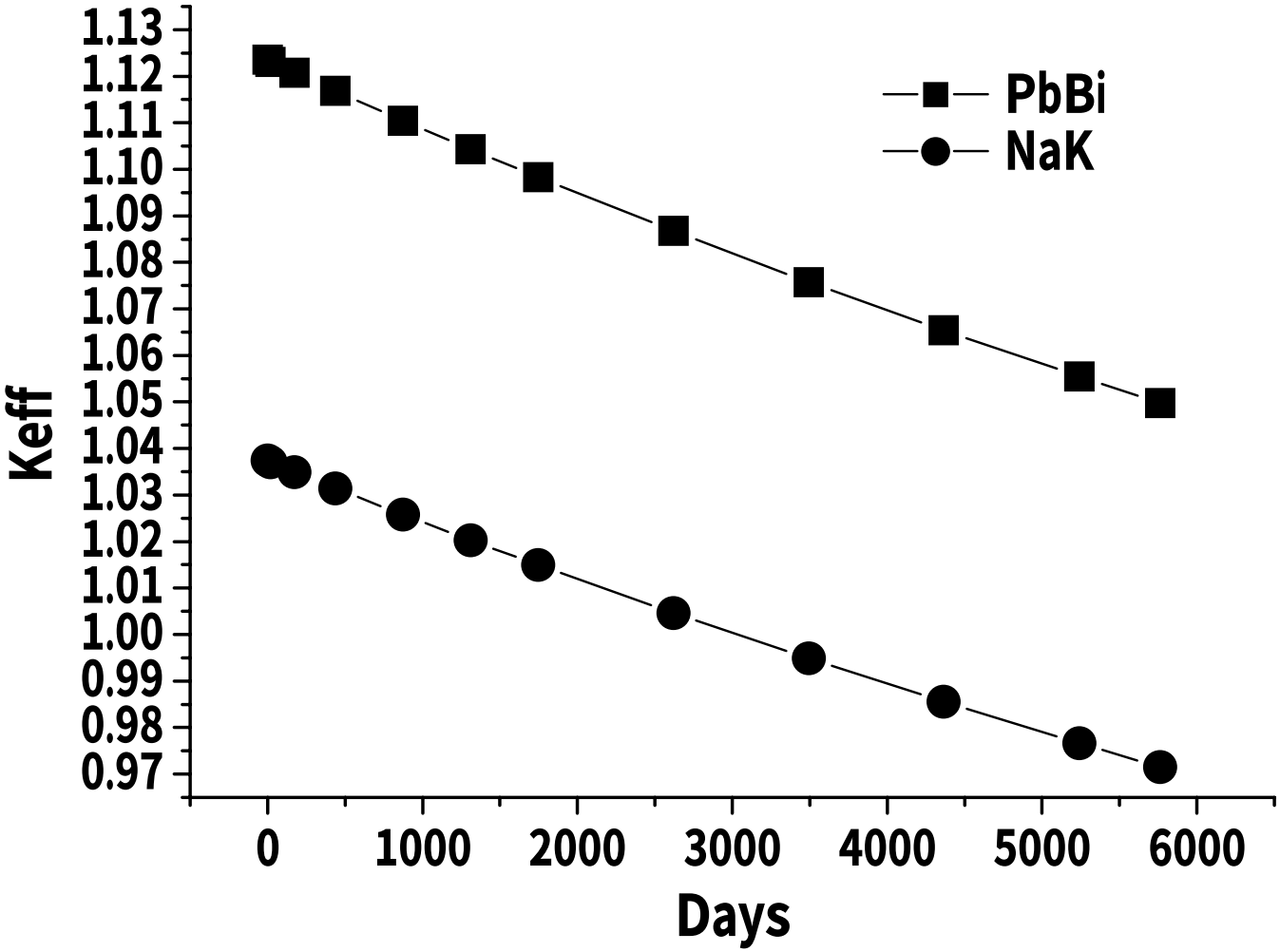


Fig. 14 Change in K_{eff} with burn-up in the rea
without control rods inside core

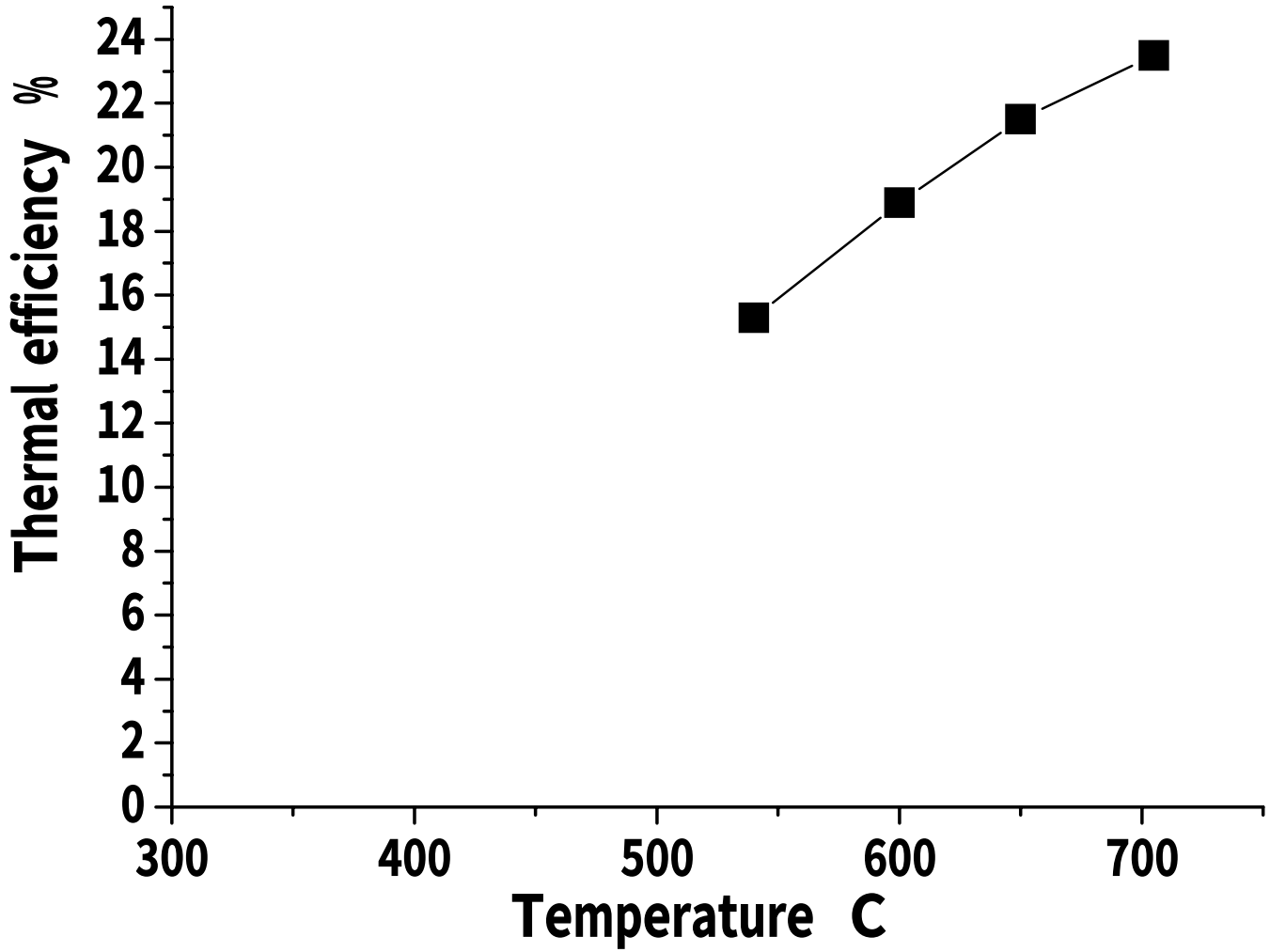


Fig. 15 Thermal efficiency and turbine inlet temperature

V. CONCLUSIONS

Development of two types of small reactors is desired. One is the NaK-cooled reactor for about 40 kWe and the other is the Pb-Bi-cooled reactor of a few hundreds kilowatts to a few megawatts to a few megawatts used as the DSFR.