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EVALUATION OF ADVANCED LIQUID METAL REACTOR PASSIVE AIR COOLING SYSTEMS

P. G. Kroeger and G. J. Van Tuyle

Department of Nuclear Energy
BROOKHAVEN NATIONAL LABORATORY
Upton, New York 11973

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Both advanced liquid metal reactor concepts (PRISM[1] and SAFR[2]) currently being proposed by DOE include a passive air cooling system for final decay heat removal under accident conditions. To be completely passive, these cooling systems are operative at all times, causing a minor parasitic energy loss during normal operation.

In these designs, as schematically shown in Figure 1, air is supplied to the bottom of the guard vessel, flowing upward along the guard vessel due to natural convection and being discharged through a stack, providing sufficient draft to remove the decay heat under accident conditions.

In either concept, the heat rejection from the reactor vessel to the air cooling system is by radiation and convection across a gas gap between the reactor vessel and the guard vessel, and by radiation from the guard vessel to the opposite air cooling system surface (collector surface), and ultimately by convection from both surfaces to the rising air. Additionally, the SAFR concept[2] includes fins on the collector surface. For this concept the simultaneous effects of radiation and conduction on the collector surface are considered.

The evaluation of the passive air cooling system was performed with the PASCOL code, which was originally developed for analyzing a similar passive air cooling system in the modular high temperature gas cooled reactor program. This code can either be applied as a free standing program, given a spatial reactor vessel temperature distribution, or coupled to the relevant code for accident analysis. It solves simultaneously the quasi-steady momentum and energy equations for the air, coupled with simultaneous radiation, conduction and convection from the reactor vessel via the guard vessel and the other air cooling system surfaces to the coolant.

The performance evaluation reported here considers the operation under accident conditions. For the PRISM reactor[1] the heat transfer surfaces were not finned. As the vendor specififed data did not include sufficient details to compute the inlet and exit ducting pressure drops, the system was evaluated parametrically with inlet and exit loss coefficients being varied between 1 and 10. The results, shown in Figure 2, indicate that the vendor's claimed performance can readily be obtained, if ducting is such that inlet and exit losses each amount to about four velocity heads. The vendor assumed solid surface emmissivities of only 0.7, while values of 0.85 are readily achievable. Our evaluations showed that an increase in the heat removal rate of 16% is possible with such an increase in emmissivity.

For the SAFR air cooling system an evaluation of the simultaneous conduction and radiation in the collector surface had to be made. Defining a performance factor

$$\phi = \frac{\text{total convective heat transfer to air}}{\text{convective heat transfer to air from guard vessel}}$$

It was found that a value of $\phi \approx 1.8$ to 2.5 can be expected under accident conditions. The vendor's claimed performance can be reached down to a value of $\phi = 1.5$. Increasing the emmissivity from the vendor's value of 0.65 to 0.85 resulted in 18% higher performance.

A comparison of our results and the vendors claimed performance for both concepts is shown in Table 1. As can be seen, both systems can readily achieve the required decay heat removal rate. Further increases in performance could readily be achieved. However, such performance increases may not be desirable, since they would raise the parasitic heat losses under normal operating conditions.

References

1. E. L. Gluekler, N. W. Brown, C. L. Cowan, A. Hunsbedt, and R. A. Meyer, "Safety Characteristics of a Small Modular Reactor," Proceedings of the Int. Topical Meeting on Fast Reactor Safety, 1, pp. 69-74, 1985.

2. R. T. Lancet and J. F. Marchaterre, "Inherent Safety of the SAFR Plant," Proceedings of the Int. Topical Meeting on Fast Reactor Safety, 1, pp. 43-50, 1985.

Figure Titles

Figure 1	Schematic of Passive Air Cooling System for Advanced Liquid Metal Reactors
Figure 2	PRISM Passive Air Cooling System Performance During Decay Heat Removal as Function Inlet and Outlet Ducting Flow Resistances

TABLE 1

Advanced Liquid Metal Reactor Passive Air Cooling System Performance During Decay Heat Removal

	PRISM-GE	PRISM-BNL	SAFR-RI	SAFR-BNL
Emissivity	0.7	0.7	0.65	0.65
Surface Effectiveness		≈1.7		1.5*
$K_{air_{in}} + K_{airex}$		8.0	10	10
W_{air}	25.9	26.0	39	37.2
Q (MW)	2.42	2.45	3.90	3.96
$\Delta\theta$ (C)	92.2	91.7	99.4	102.5

* Surface effectiveness is likely mugh higher than 1.5. At best estimate value of 2.2, Q is estimated to be 4.85 MW

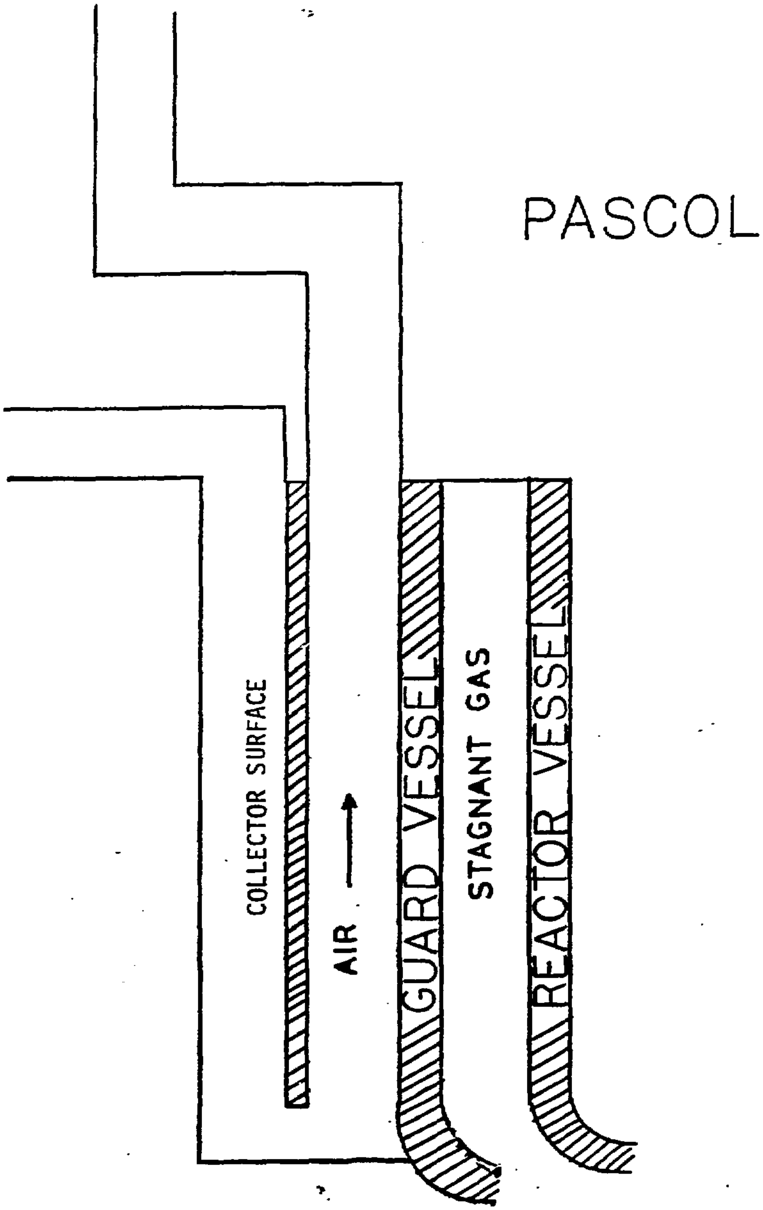

FIGURE 1: Schematic of Passive Air Cooling System for Advanced Liquid Metal Reactors

IGURE 2: PRISM Passive Air Cooling System Performance During Decay Heat Removal as Function Inlet and Outlet Ducting Flow Resistances