Evaluation of the inherent neutron source and power density in the Intermediate Heat Exchanger of a small chloride-fueled molten salt fast reactor

*Van Rooijen, Willem[1], Terbish Jamiyansuren[2]

[1]Research Institute of Nuclear Engineering, University of Fukui, [2]Nuclear Research Center, National University of Mongolia

Abstract The multiplication factor and power production in the Intermediate Heat Exchangers (IHX) of a small chloride-fueled fast-spectrum Molten Salt Ractor is investigated. Results indicate that the IHX are deeply sub-critical ($k_{eff} \approx 0.75$), power production remains limited ($P < 520$ kW), but the neutron flux level is very high, so that IHX lifetime is limited.

Keywords: Molten Salt Reactor, Chloride fuel, Fast Reactor, Intermediate Heat Exchanger, Delayed Neutrons, Criticality

1. Introduction In a fast-spectrum Molten Salt Reactor, there is no moderator in the core region, and thus the multiplication factor is determined only by the geometry of the primary system. Since the nuclear fuel is liquid, delayed neutron precursors are transported throughout the primary system. As a result, the entire primary system outside of the core region must be treated as a sub-critical, source-driven system. In the present work the multiplication factor, power production, and neutron flux level in the Intermediate Heat Exchanger (IHX) is investigated.

2. Reactor and IHX Design Data for the primary system is given in **Table 1**. The primary system is rated at 600 MWth and it is assumed that there are four IHX. A detailed design of the primary system does not exist, hence calculations were performed assuming a total primary system volume of $V_p = 2\,V_c$ (small system) and $V_p = 5\,V_c$ (large system). The IHX is a helical coil design based on the work in [1]. More details are given in [2].

Table 1: Core and IHX design data

Core / Primary circuit	
Power	600 MWth
Fuel composition	$NaCl - CaCl_2 - UCl_3 - PuCl_3$
Core Volume	5.97 m^3
Mass flow rate	9231 kg/s
IHX (150 MWth x 4)	
Secondary coolant	$KCl - MgCl_2$
Temp. (primary)	650℃ / 550℃
Temp. (secondary)	500℃ / 575℃

3. Analysis Method Neutron transport in the IHX is calculated with the Monte Carlo code MVP. Reaction rates are tallied in the IHX volume. The source strength due to delayed neutrons is calculated with a simplified model based on the residence time of the fuel in the core, the IHX, and other parts of the primary system [2]. Reflective boundary conditions are assumed for the IHX.

4. Results See **Table 2**. The multiplication factor is sufficiently low that criticality is not an issue for the IHX. The fission power due to multiplication of delayed neutrons is low, only several hundred kW. The average flux level in the IHX is on the order of 10^{12} n/cm^2/s . This flux level is so high that material degradation due to neutron fluence in the IHX is likely to set a limit on the lifetime of the IHX components.

Table 2: Results for small and large primary system

	$V_p = 2\,V_c$	$V_p = 5\,V_c$
k_∞	0.757516 (0.008%)	0.757516 (0.008%)
Power	516 kW	150.3 kW
Flux level	9.029×10^{12}	2.6617×10^{12}

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References

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