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Computational modelling of inter-wrapper flow and primary system temperature evolution in FBTR under extended Station Blackout

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To handle a station black-out (SBO) event, sodium cooled fast reactors are equipped with passive systems to remove decay heat, which do not require external power source. The duration of SBO can extend up to a week. Decay heat removal in FBTR, depends on natural convection, driving flow through the core subassemblies and inter-wrapper spaces. The relatively low decay heat and the extended duration of SBO presents a risk of coolant freezing in the primary circuit inlet pipes. This impacts coolability of core, as flow through subassemblies would be impeded and major heat removal path would become ineffective. It becomes essential to understand heat transfer to reactor vault, temperature distribution in the primary sodium pool and evolution of inter-wrapper flow and clad temperature.

The present study aims to develop mathematical models for this scenario and investigates thermal hydraulics of the reactor. The study assumes that internal flow through subassemblies is impeded and only inter wrapper space is available for heat removal from core. Heat sink is provided by primary vessel sodium plenum and surrounding structural components. Ultimate heat sink is atmosphere. A two dimensional axisymmetric Computational Fluid Dynamics model of primary plenum is developed. Influence of reactor subassemblies on inter-wrapper flow, which act as primary heat removal path is modeled with the aid of appropriate momentum and heat sinks. Decay heat generation in core is obtained from available reactor physics calculations. Thermal effects of structures surrounding the reactor vessel (thermal capacity and resistance) are modeled using a one dimensional lumped parameter model, which supplies boundary conditions to the reactor vessel model.

Flow in primary reactor plenum is seen to be controlled by natural convection in the inter-wrapper space, carrying heat from reactor core to main plenum (above core region), which dissipates heat to the surrounding structures through reactor vessel. Flow and temperature in reactor plenum during duration of the transient is predicted and compared against available safety limits. These predicted temperatures are extended using a two dimensional model, to predict fuel and clad temperatures inside fuel subassemblies. Results reveal that fuel clad temperatures reach design safety limit(s) after two days. It is concluded that adequate time is available for deploying Emergency Diesel Generator(s) and initiation of double envelope cooling. Full paper would present the sequentially coupled thermal hydraulic model, evolution of inter-wrapper flow and finally clad temperature as a function of time.

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