PRELIMINARY ASSESSMENT OF THE FREEZE-PLUG MELTING BEHAVIOR IN THE MOLTEN SALT FAST REACTOR

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1. INTRODUCTION

The Molten Salt Fast Reactor (MSFR) is one of the six Generation IV nuclear reactors that must excel in safety, reliability, and sustainability, to help meeting the world’s rising energy needs, while accommodating the concerns about waste storage, proliferation, and accidents grown in a large part of the public and political parties, especially following the Fukushima Daichi accident.

This paper focuses on a key safety component of the MSFR: the freeze-plug. It is a valve made of frozen fuel salt, designed to melt in case of an event requiring the core drainage, when the decay heat released by fission products, in the absence of a proper heat sink, threatens the reactor structural integrity.

The freeze-plug valve was first developed and used at Oak Ridge National Lab (ORNL) during the Molten Salt Reactor Experiment [1]. Formed by first pumping the salt into the core by pressure difference and then applying a cooling gas flow to the outside of the draining pipe, the plug was designed to melt when the cooling supply was turned off, by either exploiting the residual heat in the pipe or turning on external heaters. The reference MSFR configuration includes a vertical freeze-plug at the base of each of the sixteen sectors of the primary circuit (Figure 1a); the plugs are based on the ORNL design, but must melt passively.

This work aims at preliminarily investigating the freeze-plug melting behavior, assessing the influence of various design parameters, like the plug position along the draining pipe and its sub-cooling. Melting simulations were run adopting an apparent heat-capacity method within the Finite Element tool COMSOL Multiphysics. Since only few design parameters are currently set for the freeze-plug, the conclusions drawn here could guide the future development of the component.

2. DESCRIPTION OF THE WORK

Figure 1b shows the freeze-plug designs considered in this work: a single plug, occupying the full width of the draining pipe, along with a design consisting of 7 smaller plugs in a copper plate. They rely only on the transfer of decay heat from the core cavity to the plug, mainly through the draining pipe walls, to melt. The plug has to melt before the fuel salt reaches the critical temperature of 1200°C, to avoid structural damages [2]; however, there is no definitive estimate for how long this will take: between 480s [2] and 1600s [3]. For this reason, an average melting time threshold of 1000s was assumed.