Survey of some Safety Issues related to some specific phenomena under Natural Circulation flow conditions

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ABSTRACT

Natural circulation (NC) flows are susceptible to several kinds of instabilities because of the inherent feedback mechanisms related to the driving forces and the pressure drops. Any disturbance in the driving force affects the flow which in turn influences the driving force. This may lead to a sustained oscillatory behaviour. Therefore, the achievement of a high safety level through the reliance on NC mechanisms requires a thorough understanding of such phenomena [1], [2].

Natural Circulation Interruption (NCI)

Under certain accidental conditions, the cooldown of the reactor is ensured by NC convection. However, under asymmetric cooldown conditions, NC in one or more cooling loops may interrupt. When depressurizing under such conditions, degenerated states could be created. For instance, a steam bubble may be formed in the top of the inverted U-tubes of the stagnant loop, and the loop temperatures may remain high. This could prevent the connection of the residual heat removal system [1]. NCI is currently being experimentally investigated within the OECD/NEA PKL and ROSA projects. In Bel V, numerical simulations of the NCI have been carried out using the CATHARE code [1], [2], [3]. The findings show that NCI can be avoided, under asymmetrical cooldown conditions, by applying a suitable cooldown strategy. When applying a linear cooldown, an appropriate low cooldown gradient will avoid NCI (see Fig.1 & 2). An adequate stepwise cooldown strategy is also suitable in such case [3].

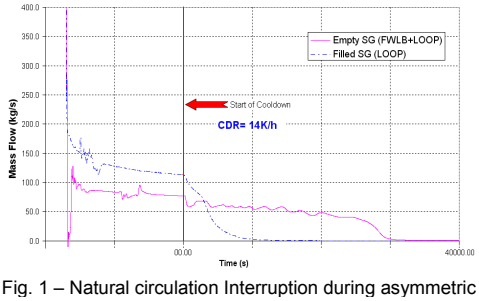

Fig. 1 – Natural circulation Interruption during asymmetric cooldown

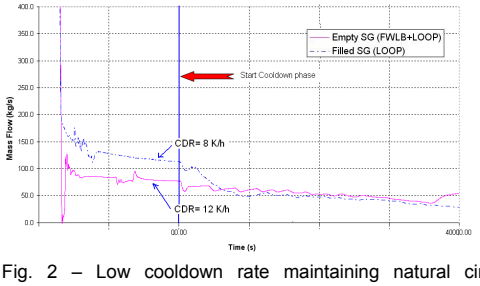

Fig. 2 – Low cooldown rate maintaining natural circulation during asymmetric cooldown.

Flow instability in the spent fuel pool

Under the spent fuel pool (SFP) operating conditions NC flow reversal in some fuel assemblies could take place. Under such conditions, nucleate boiling may initiate leading to an unstable NC flow. Indeed, under unstable NC flow, the cooling of the fuel assemblies is perturbed, and in some fuel channel the flow could be largely reduced. The situation could further degenerate leading to dry-out conditions [4].

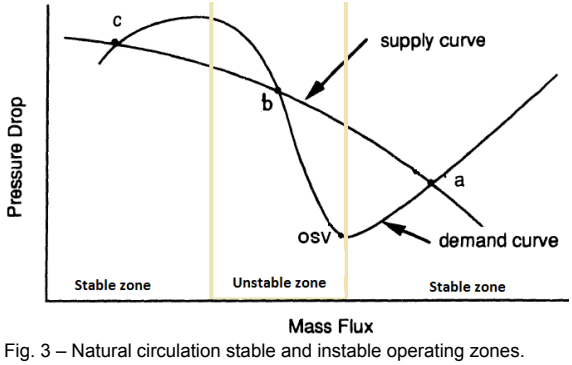

Fig. 3 – Natural circulation stable and instable operating zones.

Up to now safety analysis of SFP did not consider such phenomenon. Therefore, it is important to revisit the safety criteria related to the SFP taking into account the fuel assemblies' distribution in the SFP, the interaction between the heated channels. Bel V has recently adopted the Onset of Significant Voiding (OSV) as a safety criteria above which unstable flow under parallel channels configuration in SFP could take place.

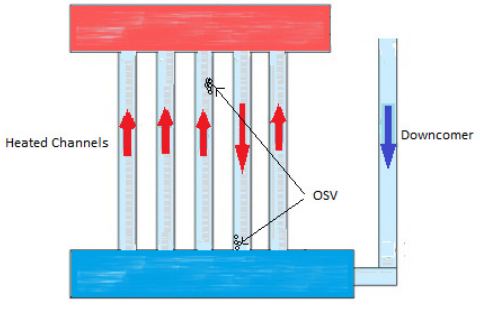

Fig. 4 – Possible NC flow under spent fuel pool storage conditions

References:

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[4] P.K. Vijayan, A.K. Nayak, Introduction to Instabilities in Natural Circulation Systems, IAEA-TECDOC-1474, Annex 7, 2005.

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