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Experimental investigations on the heat transfer characteristics in a natural circulation loop for an integral type reactor☆

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ABSTRACT

The natural circulation characteristics in the primary loop of an integral type reactor were experimentally investigated during various operational conditions by using the VISTA facility. The test matrices included the natural circulation characterization tests and operational transient tests. The heat transfer characteristics in a natural circulation loop for an integral type reactor were experimentally investigated by using the VISTA facility and steady-state natural circulation tests were performed by changing the core power and feed water flow rate simultaneously. The initial core power and feed water flow rate were 25%. During a natural circulation operation both the core power and feed water flow rate were changed from 20% to 50%. The experimental data were compared with the predictions from existing correlations of Duffey et al. [1] and Vijayan et al. [2]. It was shown that Duffey et al.'s correlation [1] for a two-phase natural circulation predicted the experimental data very accurately. Also four operational transient tests were performed for the cases of feed water increase, feed water decrease, power decrease and power increase. The thermal-hydraulic parameters of core power, flow rate, pressure and fluid temperatures in the primary system, feed water flow rate, pressure and fluid temperatures in the secondary system were investigated. They showed a symmetric behavior between their increases and decreases and a quick stabilization behavior of major thermal-hydraulic parameters including the natural circulation flow rate in the primary loop.

1. Introduction

An integral type reactor, SMART [3], is an advanced integral type reactor and it contains its major reactor coolant system components within a reactor vessel to avoid the occurrence of a LBLOCA (Large Break Loss of Coolant Accident). A pilot plant of the SMART, SMART-P, is designed both for a forced convection core cooling during start-up and normal operating conditions and for a natural circulation core cooling during accidental conditions. A high temperature/high pressure thermal-hydraulic test facility, VISTA (Experimental Verification by Integral Simulation of Transients and Accidents) has been constructed to simulate the SMART-P [4]. The VISTA facility is a full-height scaled-down integral effect test facility. Its design pressure and temperature were set to simulate the steady-state and transient conditions of the SMART-P.

Natural circulation in the primary system is being used as the core heat removal mechanisms under normal operation conditions including full power operation. However, this mechanism is utilized for relatively small to medium size reactors such as SBWR [5] and CAREM [6]. As the natural circulation systems include low driving forces and have less operation flexibility, they are usually used with active systems. Since the scaling for natural circulation systems is more difficult than for active systems, the usage of experimental data obtained for a different system may not be appropriated [7]. It was the main reason why the VISTA facility was constructed to investigate the natural circulation flow characteristics in the SMART-P. Previously the characteristics of natural circulation in the PRHRS (Passive Residual Heat Removal System) loop were experimentally investigated [8] during various operational conditions by using the VISTA facility but the phenomena in the primary loop was not investigated in detail. The SMART-P used a two-phase natural circulation in the PRHRS loop to remove the heat from the steam generators to the PRHRS heat exchangers, while a single-phase natural circulation occurs in the primary loop to transfer the decay heat from the core to the steam generator. A power range of 20–25% was considered and the possibility of increasing the power level was investigated during the natural circulation operation of the SMART-P. Therefore, there are strong needs to understand the heat transfer characteristics in a natural circulation loop for the primary system of an integral type reactor experimentally and analytically. Furthermore, it was suggested from the code analysis that the reference temperature for the steam generator inlet should have been increased in order to compensate for the decreased core flow [9]. To investigate the possibility of an increase of the power and reference temperature, it is necessary to get experimental data to characterize the natural circulation phenomena in the primary loop of the SMART-P.

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