ABSTRACT

Natural circulation loops (NCLs) offer a very efficient option of heat transport from source to sink without any prime mover. Its structural simplicity and inherent reliability have resulted in diverse applications and particularly in nuclear reactor core cooling. The present dissertation focuses on theoretical modelling and experimental investigations of different aspects of NCLs.

A geometry independent unified model for single-phase NCLs is proposed through a set of generalized governing equations accompanied by the associated correlations and reference parameters. Comparison with five sets of experimental data from the literature exhibits good agreement. Non-linear stability analysis has been performed to identify the neutral condition. Rectangular loop has been found to be inherently more unstable compared to its equivalent toroidal configuration. Several options of enhancing stability margin of the rectangular loop, without greatly affecting the steady-state, has been analyzed and increase in loop height has been identified as the most beneficial option with respect to geometric parameters. Tilting the adiabatic arms by a small angle, while maintaining the rectangular shape, can be another excellent solution. The unified model was upgraded to a conjugate form as well incorporating wall conduction and ambient heat leakage. Heat loss is found to have significant adverse effect on the steady-state temperature profiles, thereby lowering the effectiveness. However, effectiveness increases with ambient temperature and approaches the ideally insulated condition at some particular ambient condition, which is a function of loop geometry and power level. Effectiveness variation with ambient temperature for different power input exhibits a crossover point.

A two-phase NCL analysis incorporating a mechanistic model for subcooled boiling has been performed to identify the influence of thermal non-equilibrium. Major effects were observed around the transition regions. A generalized working-regime map was developed to identify possible combination of fluid stream condition at boiler exit and condenser entry. Finally an extensive experimental investigation of phasic entrainment has been performed employing an appropriately scaled-down AHWR air-water loop. Droplet carryover has been observed to increase rapidly with air supply. Incorporation of a suitably porous suppressor plate has been demonstrated as an effective option leading to substantial reduction in carryover.

Keywords: Natural Circulation Loop; Unified Model; Stability Analysis; Conjugate Problem; Subcooled Boiling; Working Regime Map; Scaling Analysis; Entrainment

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