Experimental Investigations on Single Phase and Two Phase Rectangular Natural Circulation Loop with End Heat Exchangers

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Extended Abstract

A rectangular and uniform cross section Natural Circulation Loop (NCL) with end heat exchangers is designed and fabricated. Two heat exchangers of concentric tube are placed along the horizontal top and bottom sections of the loop. The geometrical dimension of the loop are: Loop width – 700mm, Loop height – 1400mm and Loop inner diameter – 12mm and Loop outer diameter – 16mm. The heating/cooling length of concentric tube heat exchanger is 500mm, inner diameter of the shell is 78mm and outer diameter of loop pipe is 16mm. To circumvent the difficulty in inducing pressure drop and thereby changes the loop characteristics by Incorporation of any differential pressure type flow meter, a calibrated magnetic flow meter which is a non-intrusive type instrument is installed in the downcomer to measure the induced loop temporal mass flow rate. The uncertainty involved in measuring the loop flow rate with this instrument is 0.1%. Calibrated thermocouples are inserted at desired locations to measure the temporal variation of temperatures of coupling, hot and cold fluids. A Data Acquisition System (DAS) is used to interface with personal computer (PC) to record the real time data. Hot air blower is designed and fabricated to supply the hot air at desired flow rates and temperatures. This hot air used as the hot fluid (heat source) for loop and allowed to pass through the bottom horizontal heat exchanger of loop which is termed as Hot End Heat Exchanger (HEHE). Five independent electrical coils each of 1kW capacity are arranged in series with individual power supply in order to obtain wide range variation in hot fluid temperature along with the change in flow rate of air which comes from blower. The maximum capacity of blower is 0.25m^3/s. Building tap water is used as the cold fluid (heat sink) and allowed to pass through the top horizontal heat exchanger. The loop is insulated fully however, a small vertical portion in the riser i.e., the right limb of the loop is left out without insulation for visualization

of flow field development and two phase flow regime identification. Vents with caps are arranged on top of both heat exchangers and on top of top horizontal section of loop in order to ensure both heat exchangers are fully filled with hot and cold fluids and loop with coupling fluid without any void present in the loop. An expansion tank is connected on the top horizontal section of the loop to take care of any thermal expansion of loop fluid. Loop is operated at atmospheric pressure.

Initially, the loop is at room temperature. Hot fluid at desired flow rate and temperature and cold fluid at desired flow rate and at room temperature sent through their respective heat exchangers simultaneously. The responses of thermocouples and magnetic flow meter are captured with respect to time till the system reaches the steady state. The system's transient response is studied for various hot fluid flow rates and inlet temperatures keeping cold fluid rate and its inlet temperature is constant. For certain range of hot fluid flow rate and its temperature system is operated in single phase whereas it is operated in two phase for the rest of the range of operation. Loop fluid flow field establishes slowly with initial oscillations and it increases exponentially with diminished oscillations and flow rate shoots up as soon as system enters into the two phase operation. System is allowed to operate in bubbly flow as well as slug flow with the help of enhanced heat transfer area of HEHE by providing spiral fins in the hot air passage. Experiments area also conducted for dynamic study by suddenly increasing the temperature by switching on the heaters one by one after allowing the system to reach the steady state for the given hot fluid inlet temperature. A one-dimensional transient mathematical model using HEM is derived for both single phase and two phase and solved the partial differential equations and one integro-momentum equation using finite element technique. The model exhibited a good agreement with experimental results.

Keywords: Single Phase, Two Phase, Natural Circulation Loop, Transient, Dynamic, Rectangular

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