International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.3 Issue No.7, pp : 899-901 1 July 2014

An Experimental Investigation of Two Phase Natural Circulation Loop (NCL) with End Heat Exchangers

Ummid I. Shaikh[1], R. R. Kulkarni[2]

[1]Mechanical Engg. Dept.,Pimpri Chinchwad College of Engineering, Nigdi, Pune, India-411044
[2]Mechanical Engg. Dept.,Vishwakarma Institute of Information Technology, Kondhwa, Pune, India-411048
[1]ummids@gmail.com , [2]ratnakarkulkarni36@gmail.com

Abstract: ***The steady state behaviour of two-phase natural circulation loop with heat exchangers at the hot and cold ends is studied experimentally. A vertical rectangular and uniform cross section Natural Circulation Loop (NCL) with end heat exchangers is designed and fabricated. Steam is used as hot fluid and tap water as cold fluid. The experimentation is carried out for various hot fluid flow rates. Four flow patterns are identified viz. Small bubbly flow, big bubbles flow, stream of small bubbles, churn flow. It is concluded that Circulation rate of the loop fluid rises with hot fluid flow rate. However heavy fluctuations in the flow rate of coupling fluid are observed the reasons of which are explored.***

Keywords: Two phase, Natural Circulation Loop, NCL, End Heat Exchangers, coupling fluid.

I. Introduction

In Natural Circulation Loop the loop fluid flow is driven by thermally generated density gradient. Owing to their simplicity, high heat transfer capability, and passive nature, the principle of natural circulation loops is employed in diverse engineering applications like thermo-syphon boilers, solar, thermal and waste heat recovery systems, nuclear reactors. NCLs involving evaporation and condensation of the working fluid, is specially lucrative due to large density difference of the vapor liquid phase.

Numerous investigations on two-phase NCL, both theoretical and experimental, are available in the literature [i to ix]. Various flow patterns were identified in two phase flow viz. Bubbly, slug, churn, wispy-annular, annular [x]. The researchers have studied both steady state and transient performance of the loop .However the review of the literature reveals that the hot and cold ends of the natural circulation loops have been idealized either by constant temperature or constant heat flux conditions. These conditions are not appropriate when the loop exchanges heat with single phase flowing fluids. Particularly, in case of a waste recovery system, energy needs to be transferred from one fluid to another. A natural circulation loop can be conveniently employed for this purpose by incorporating suitable heat exchangers with finite heat capacity fluids at the hot and cold ends.

In the present work the steady state behaviour of two-phase natural circulation loop with heat exchangers at the hot and cold ends is studied experimentally.

II. The Experimental Set up

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.

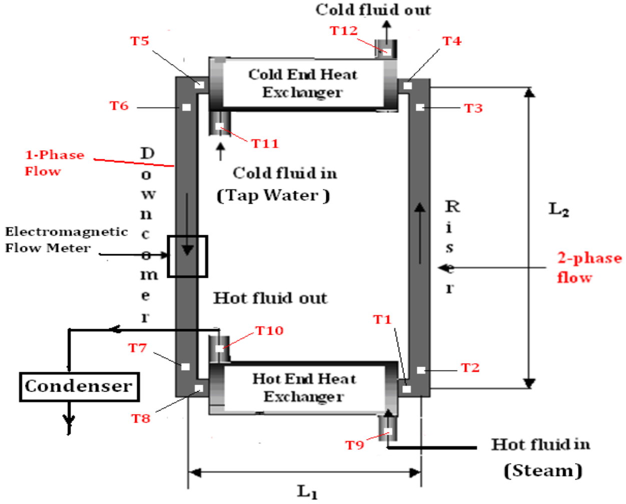

Figure.1 Experimental set up of a Two-Phase NCL with end heat exchangers erected for present study

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 in the loop characteristics by Incorporation of any differential pressure type flow meter, a calibrated magnetic flow meter (non-intrusive type) 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. Steam generated by boiler is used as hot fluid and allowed to pass through the bottom horizontal heat exchanger.

Building tap water is used as the cold fluid (heat sink) and allowed to pass through the top horizontal heat exchanger. A condenser is fitted at the outlet of HEHE to condense the steam coming out. 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 2 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.

III. The Experimentation

Loop was operated at atmospheric pressure. Initially, the loop was at room temperature. Hot fluid and cold fluid at desired flow rate were sent through their respective heat exchangers simultaneously. The responses of thermocouples and magnetic flow meter were captured with respect to time till the system reaches the steady state. The system's transient response was studied for various hot fluid flow rates keeping cold fluid rate and its inlet temperature was constant. For certain range of hot fluid flow rate and its temperature system was operated in single phase whereas it was operated in two phase for the rest of the range of operation.

IV. Results and Discussion

First hot fluid (steam) valve was adjusted such that bubbly flow was obtained as shown in fig.2 . The measured hot fluid flow rate was 0.28 lpm. The loop fluid flow rate continuously fluctuated between 0.6 to 0.4 lpm as shown in fig.3.

Figure 2. Small bubbly flow

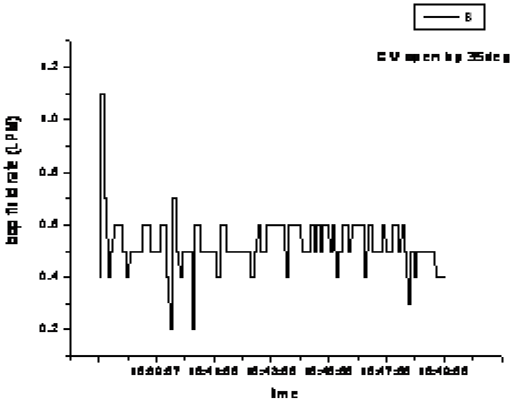

Figure 3. Graph of loop fluid flow Rate vs. Time for bubbly flow

Then steam flow rate was increased (0.31l lpm) to obtain intermittent flow of big bubbles as seen in Fig. 4. Fig. 5 reveals that the flow rate was fluctuating between 0.6 to 0.3 lpm.

Figure 4. Big bubbles flow

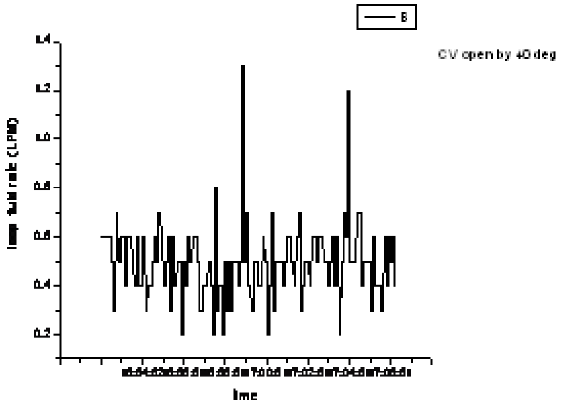

Figure 5. Graph of loop fluid flow Rate vs. Time for Big bubbles flow

Further increase in the hot fluid flow rate resulted in continuous stream of small bubbles as seen in fig.6 The flow rate fluctuated between 1.15 lpm and 1.2 lpm as shown in fig.7

Figure 6. Stream of small bubbles

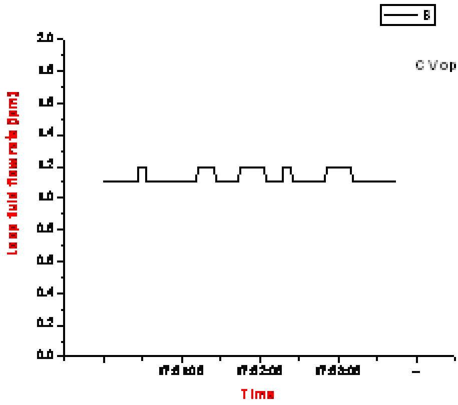

Figure 7. Graph of loop fluid flow Rate vs. Time for stream of small bubbles

Finally further increase in the hot fluid rate gave churn flow (Fig. 8) where heavy fluctuations in the flow rate (2.0 to 0.6 lpm) were seen. (Fig.9)

Figure 8. Churn flow

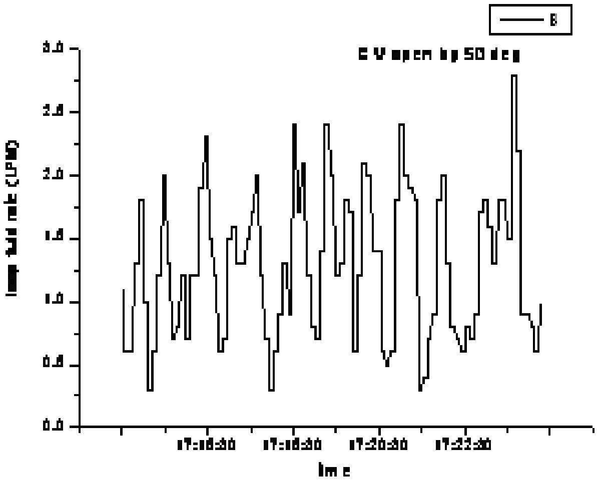

Figure 9. Graph of loop fluid flow Rate vs. Time for churn flow

From this experiment graph of mean loop fluid flow rate vs. hot fluid flow rate was plotted (Fig. 10) The Cold fluid flow was kept constant at 2.85 lpm in all trials.

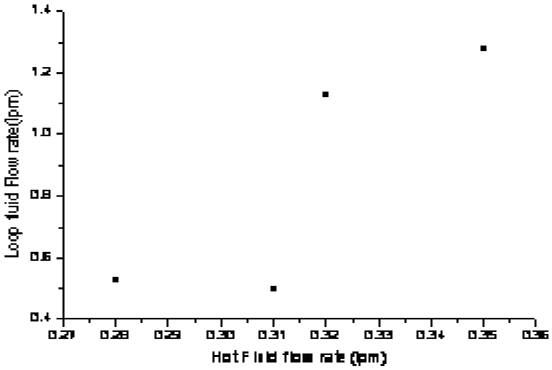

Figure10. Graph of mean loop fluid flow Rate vs. Hot fluid flow rate.

V. Conclusion

It is concluded that Circulation rate of the loop fluid rises with hot fluid flow rate however the rate of rise goes on reducing. As the hot fluid flow rate increases the flow patterns change from bubbly flow to big bubbles flow to stream of small bubbles, to churn flow. The fluctuations observed in the loop fluid flow rate were may be due to insufficient insulation of riser and the fluctuations in the hot fluid (steam) flow rate.

Acknowledgement

We take this opportunity to thank B.C.U.D. (Board of College and University Development), University of Pune, Maharashtra, India for the financial assistance for this research work.

References

i. *Chen K.S., Chang Y.R., Steady state analysis of two-phase natural circulation loop, International Journal of Heat and Mass Transfer 31 (5) 931–940,1988.*

ii. *Ishii M., Kataoka I., Scaling laws for thermal-hydraulic system under single-phase and two-phase natural circulation, Nuclear Engineering and Design 81 411–425, 1984.*

iii. *Rao N.M., Ch. Chandra Sekhar , Maiti B. , Das P.K., Steady-state performance of a two-phase natural circulation loop, International Communications in Heat and Mass Transfer 33 1042–1052, 2006.*

iv. *Lee S.Y., Ishii M., Characteristics of two-phase natural circulation in Freon-113 boiling loop, Nuclear Engineering and Design 121 69–81,1990.*

v. *Lee Sang yang and Kim Young Lyoul, A note on the two phase natural circulation in a closed rectangular loop, Two Phase Flow Modeling And Experimentation, Edizioni ETS, Pisa,1999.*

vi. *Jeng H.R., Pan Chin, Analysis of two-phase flow characteristics in a natural circulation loop using the drift-flux model taking flow pattern change and sub cooled boiling into consideration, Annals of Nuclear Energy 26 1227-1251, 1999.*

vii. *Cicchitti A. et al.,1960, Two Phase Cooling Experiments-Pressure Drop, Heat Transfer and burnout measurements, Energia Nucleare, Vol.7, No.6,pp. 407-425.*

viii. *D.D. Lisowski, O. Omotowa, M.A. Muci, A. Tokuhiro, M.H. Anderson, M.L. Corradini, Influences of boil-off on the behavior of a two-phase natural circulation loop,International Journal of Multiphase Flow, Volume 60, April 2014, Pages 135-148*

ix. *K. Kiran Kumar, M. Ram Gopal, Experimental studies on CO2 based single and two-phase natural circulation loops, Applied Thermal Engineering, Volume 31, Issue 16, November 2011,Pages 3437-3443*

x. *John G. Coolier, Convective Boiling and Condensation, 2nd Edition, McGraw Hill International Book Company.*