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Experimental analysis of closed loop two phase thermosyphon: A Review of the Experimental Results.

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" I . HIGHLIGHTS "

- Heat and mass transfer performances of small size Closed Loop Two Phase Thermosyphons.
- Evaluation of the systems in connection with renewable energy systems applications.
- Analysis of the influence of heat load, operating pressure and filling ratio.
- Heat transfer analysis in evaporator and condenser.

" II. LITERATURE REVIEW"

1] M. Maiani , W. J. M. de kruijf , W. Ambosini { published on 16 july 2003 }

In this paper, an extension of previous analyses of natural circulation in a simple single-phase loop is presented. Assuming more general correlations for the friction factor and the heat transfer coefficient, an analytical model describing the system is obtained and a parametric representation of its dynamic behaviour is achieved. On this basis, stability maps can be drawn. A preliminary validation of the analytical model has been carried out by using an independent program developed for the analysis of stability in natural circulation loops. The aim of the present work is to provide a simple analytical tool devoted to the stability analysis of a reference single-phase loop. This model can be applied in a relatively wide range of conditions and regimes to provide benchmark solutions for thermal- hydraulic codes and related nodalisations.

2] Rahmatollah Khodabandeh { published online on 2 july 2004 }

In this investigation an advanced thermosyphon loop with extended evaporator and condenser surfaces has been tested at high heat fluxes. The thermosyphon investigated is designed for the cooling of three parallel high heat flux electronic components. The tested evaporators were made from small blocks of copper in which five vertical channels with a diameter of 1.5 mm and length of 14.6 mm were drilled. The riser and downcomer connected the evaporators to the condenser, which is an air-cooled roll-bond type with a total surface area of 1.5 m2 on the airside. Tests were done with Isobutane (R600a) at heat loads in the range of 10–90 W/cm2 to each of the components with forced convection condenser cooling and with natural convection with heat loads of 10–70 W.

3] S.H. Noie { Published on March 2005 }

The applications of closed two-phase thermosyphons are increasing in heat recovery systems in many industrial practices because of their high effectiveness. Various parameters affect the heat transfer performance of thermosyphons. In this paper, the effect of three parameters: input heat transfer rates (), the working fluid filling ratios (30% ⩽ FR ⩽ 90%),and the evaporator lengths (aspect ratios) were investigated experimentally. The aspect ratios for these experiments were 7.45, 9.8, and 11.8. A series of experiments were carried out to find the influence of the above parameters on steady-state heat transfer characteristics of a vertical two-phase closed thermosyphon. A smooth copper tube of total length of 980 mm with inside and outside diameters of 25 and 32 mm was employed with distilled water as working fluid. The temperature distribution along the thermosyphon was monitored; input heat to evaporator section and output heat from condenser were measured, as well. The experimental boiling heat transfer coefficients were compared with existing correlations. Conclusions have been drawn for the optimum-filling ratio at which the thermosyphon operates at its best for a certain aspect ratio.

4] Patrick T. Garrity, James F. klausner, Renweimei { published on 15 april 2008 }

The behavior of a two-phase thermosyphon, consisting of a microchannel evaporator plate and a condenser, is investigated to gain insight into the system limiting instability. A microchannel plate has been fabricated with 56 square channels that have a 1 × 1 mm cross section and a length of 115 mm. Experiments have been conducted for various condenser heights with the heat flux as the control variable. A step increase in heat flux is used to quantify the response of the system, including variations in mass flow rate, temperature, and pressure drop. Results show that small fluctuations about the steady state give rise to the instability for situations with a uniform heat load. A predictive model based on the momentum equation is introduced to estimate the onset of instability, and the threshold heat flux is predicted to within ±10% uncertainty.

5] Shanmuga Sundaram , R.V. Seeniraj , R. Velraj { published on 8 may 2010 }

Advances in information technology have made the thermal management of telecommunication equipments more challenging over the past several years. As advances are being made the electrical energy consumption of telecommunication equipments is ever increasing and thereby increasing its dissipation rate. In addition such shelters are installed in remote areas, so cooling of telecom shelters becomes a great challenge for thermal engineers. A field study revealed conventional cooling systems are not so effective in terms of energy consumption and in the absence of power grid, shelters installed in such areas require additional capital cost to provide power for cooling system. A new passive cooling system incorporating phase change material (PCM) and two-phase closed thermosyphon (TPCT) heat exchangers has been developed and experimented to provide thermal management for telecommunication equipments housed in telecom shelters. The newly developed thermal system absorbs the equipment dissipated heat during the hottest part of the day, stores it as latent heat and releases it through thermosyphons during the night to the ambient.

6] F. Devia , M. Misale { published on 19 december 2010 }

During the past years, several authors performed numerical and experimental studies on single-phase natural circulation loops (thermosiphons-NCL). However the problem of the loop stability, which is of interest in many industrial applications, cannot be considered solved. This paper is focused on the evaluation of the instantaneous mass and heat flow rates in the main loop sections. The available experimental apparatus is provided with a heat sink which can be feed with cooling fluid at controlled temperature. In this way the NCL mean temperature and heat flow rate can be varied independently. A set of CFD simulations with various heat sink temperatures, at fixed heat flow rate, has been carried out in order to improve the comprehension of the data collected during the experimental campaigns.

7] AlessandroFranco · Sauro Filippeschi { Springer Science+Business Media B.V. 2011, Published online: 7 August 2011 }

A bibliographical review on the heat and mass transfer in gravity assisted Closed Loop Two Phase Thermosyphons (CLTPT) with channels having a hydraulic diameter of the order of some millimetres and input power below 1 kW is proposed. The avail-able experimental works in the literature are critically analysed in order to highlight the main results and the correlation between mass flow rate and heat input in natural circulation loops. A comparison of different experimental apparatuses and results is made. It is observed that the results are very different among them and in many cases the experimental data disagree with the conventional theory developed for an imposed flow rate. The paper analyses the main differences among the experimental devices and try to understand these disagreements. From the present analysis it is evident that further systematic studies are required to generate a meaningful body of knowledge of the heat and mass transport mechanism in these devices for practical applications in cooling devices or energy systems.

8] S. Filippeschi { published on 1 june 2011 }

Several tests have been carried out with two miniature periodic two-phase thermosyphons (PTPTs), which have been developed for thermal control applications. A PTPT is a wickless device which can operates even against gravity. The two PTPTs have the same condenser and accumulator and different evaporators: the evaporator Type A, which can contain a large amount of liquid (20×10^{-6} m^3) and which can be tilted up to 90°, and the evaporator Type B, which has an internal volume of 5×10^{-6} m^3 and can operate just in horizontal orientation. Their unsteady and their periodic steady state performances have been studied and compared with those of several miniature loop heat pipes quoted in the references. The paper shows that the PTPT thermal resistances are similar to those of miniature LHPs, even those of PTPTs are less influenced by the arrangement of the condenser and the evaporator with respect to the gravity. The thermal resistance, as the PTPT steadily operates, is about 0.55 K/W with a heat load of 110 W. The main

experimental observation on the PTPT unsteady behaviour is that their start-ups are rather smooth in the most cases. However the start-up performances does not depend on any configuration and orientation of the loop element.

9] Hamidreza shabgard, Bin Xiao, Amir Faghri, Ramesh Gupta, walter Weissman { published on 20 july 2013 }

A two-dimensional numerical model is developed to simulate the transient operation of a thermosyphon with various working fluid filling ratios. Conservation equations for mass, momentum, and thermal energy are solved using finite volume scheme to determine the hydrodynamic and thermal behavior of the thermosyphon. The heat transfer due to the liquid pool and liquid film are accounted for. The numerical model is validated through comparison with experimental data available in the literature. The model is capable of predicting the optimal filling ratio which corresponds to a condensate film extending from the condenser end cap to the evaporator end cap at steady- state for a given heat input. Overfilled and underfilled conditions for which the working fluid inventories are respectively greater than and less than the optimal case are also investigated. Simulation results show that the evaporator temperature of the underfilled thermosyphon rises dramatically due to dryout. The optimally-filled thermosyphon has the shortest response time and the lowest thermal resistance, however, a slight increase in the input power will cause breakdown of the condensate film. The overfilled thermosyphon poses a slightly slower thermal response and greater thermal resistance compared to the optimal condition. To ensure optimal and stable steady-state operation, an optimally- filled thermosyphon is recommended with a small amount of additional working fluid to prevent breakdown of the liquid film.

10] Robert W. macGregor , Peter A. Kew , David A. Reay { published on march 2013 }

Two-phase thermosyphons are devices offering very high thermal conductance. The study reported here examined two-phase thermosyphons of length 2200 mm and external diameter 15.9 mm. Potential applications include air to air heat exchangers with operating temperature ranges of −10–50 °C for the ambient (cold) side and 60–80 °C for the hot side. The work is prompted by the fact that R134a, used in similar units, will be subject to a ban in the future as it has a high Global Warming Potential. A shortlist of potential replacement fluids was drawn up, and considering the environmental, operating and storage conditions, and cost, five were selected for tests in representative thermosyphons. The results of the experimental work showed a water–5% ethylene glycol mixture was a suitable replacement fluid, although under certain conditions its performance was less than that of R134a. The tests also showed water alone can give the highest heat transfer, although it is not suited to the target temperature range, and methanol did not perform as well as R134a for most of the experimental range. A predictive model based on the equations published by ESDU International was developed. It was found to give good results for water, workable results for water–5% ethylene glycol, be of limited use for methanol and be unsuitable for R134a.

11] Augusto J.P. Zimmermann , Claudio Melo { published on 24 december 2013 }

This work focuses on an experimental investigation of a carbon dioxide thermosyphon loop designed to fulfill the geometric and temperature requirements of a specific FPSC (Free Piston Stirling Cooler). Experiments were carried out varying the temperature difference between the heat source, i.e. air at the entrance of the evaporator and heat sink, i.e. internal surface of the condenser, refrigerant charge and evaporator airflow rate. The experimental results were explored using the thermal conductance concept applied to each heat exchanger and also to the whole loop. It was found that the loop was able to carry a maximum heat transfer rate of 514 W with a heat source-sink temperature difference of 11 °C. A first principles model was also developed and 85% of the calculations fell within ±20% of measurements. Further exploration of the model showed a good capability to capture trends and be an aid in the thermosyphon design phase.

12] Jiwon Yeo , Seiya Yamashita, Mizuki Hayashida , Shigeru Koyama { Published online on 24 october 2014 }

With rapid development of the semiconductor technology, more efficient cooling systems for electronic devices are needed. In this situation, in the present study, a loop thermosyphon type cooling system, which is composed mainly of a heating block, an evaporator and an air-cooled condenser, is investigated experimentally in order to evaluate the cooling performance. At first, it is examined that the optimum volume filling rate of this cooling system is approximately 40%. Next, four kinds of working fluids, R1234ze(E), R1234ze(Z), R134a and ethanol, are tested using a blasted heat transfer surface of the evaporator. In cases of R1234ze(E), R1234ze(Z), R134a and ethanol, the effective heat flux, at which the heating block surface temperature reaches 70˚C, is 116 W/cm^2, 106 W/cm^2, 104 W/cm^2 and 60 W/cm^2, respectively. This result indicates that R1234ze(E) is the most suitable for the present cooling system. The minimum boiling thermal resistance of R1234ze(E) is 0.05 (cm^2·K)/W around the effective heat flux of 100 W/cm^2. Finally, four kinds of heat transfer surfaces of the evaporator, smooth, blasted, copper-plated and finned

surfaces, are tested using R1234ze(E) as working fluid. The boiling thermal resistance of the blasted surface is the smallest among tested heat transfer surfaces up to 116 W/cm^2 in effective heat flux. However, it increases drastically due to the appearance of dry-patch if the effective heat flux exceeds 116 W/cm^2. On the other hand, in cases of copper- plated and finned surfaces, the dry-patch does not appear up to 150 W/cm^2 in effective heat flux, and the boiling thermal resistances of those surfaces keep 0.1 (cm^2·K)/W.

13] Gilles Desrayaud , Alberto Fichera , Manuel Marcoux { published online on 9 December 2014 }

This work aims to investigate the natural convection in a water-filled closed- loop. A numerical study of laminar, two-dimensional natural convection in an annular thermosyphon is reported, the loop being heated at a constant flux over the bottom half and cooled at a constant temperature over the top half. The annular thermosyphon configuration which is the subject of this study has never been investigated previously. It is numerically demonstrated that the complexity of the dynamic properties encountered in the experimental studies of toroidal or rectangular loops, is found here: steady flow with and without recirculating regions, periodic motion and Lorenz-like chaotic flow. The numerical work also aims to simulate the variation of mass flow rate and heat transfer behaviors where the driving parameters and correlations which are non-loop specific are also given.

14] Ali Chehade, HasnaLouahlia-Gualous, Stephane Le Masson, Eric Lepinasse { published online on 28 may 2015 }

This paper presents an analytical model for a thermosyphon loop developed for cooling air inside a telecommunication cabinet. The proposed model is based on the combination of thermal and hydraulic management of two-phase flow in the loop. Experimental tests on a closed thermosyphon loop are conducted with different working fluids that could be used for electronic cooling. Correlations for condensation and evaporation heat transfer in the thermosyphon loop are proposed. They are used in the model to calculate condenser and evaporator thermal resistances in order to predict the cabinet operating temperature, the loop's mass flow rate and pressure drops. Furthermore, various figures of merit proposed in the previous works are evaluated in order to be used for selection of the best loop's working fluid. The comparative studies show that the present model well predicts the experimental data. The mean deviation between the predictions of the theoretical model with the measurements for operating temperature is about 6%. Besides, the model is used to define an optimal liquid and vapor lines diameters and the effect of the ambient temperature on the fluid's mass flow rate and pressure drop.

" III. CONCLUSION "

The paper presents a critical evaluation of existing experimental works in the field of heat transfer of two-phase flow (boiling) in Closed Loop Two Phase Ther- mosyphons of small dimensions. The literature survey provides many works in this field. In the different ex-perimental investigations, a number of interesting but sometimes contradictory elements can be found. First of all the aims of the experimental investigation are different among them. In general it is possible to affirm that small fluctuations from the design operating condition give origin to remarkable differences in terms of the obtained mass flow rate value for the same heat input. By comparing the available experimental data onclosed loop two phase thermosyphons, it is evident that further systematic studies are required to generate a sufficient body of knowledge of the transport mechanism.

" IV. FUTURE SCOPE"

When there is heat dissipated from the source is large then thermosyphon cooling can be used. In chemical or pharmaceutical industry, control air movement as well as control temperature is required which cannot be controlled by conventional cooling systems. So thermosyphon cooling has scope in that industry. When temperature gradient is very small conventional system does not work effectively, this limitation can be overcome by thermosyphon cooling system. Thermosyphon can be used in cooling of high performance electronics modules as conventional system requires lot of electrical energy. In nuclear reactor controlled temperature is required with high security requirement so cooling by using electric component is avoided in nuclear reactor so for cooling purpose thermosyphon closed loop cooling is used in nuclear reactor.

REFERANCES

[1] M. Maiani , W. J. M. de kruijf , W. Ambosini [An analytical model for the determination of stability boundaries in a natural circulation single-phase thermosyphon loop] (2003).
[2] Rahmatollah Khodabandeh [Thermal performance of a closed advanced two- phase thermosyphon loop for cooling of radio base stations at different operating conditions] (2004).
[3] S.H. Noie [heat transfer characteristics of a two-phase closed thermosyphon] (2005).
[4] Patrick T. Garrity, James F. klausner, Renweimei [Instability phenomena in a two-phase microchannel thermosyphon](2008).

[5] Shanmuga Sundaram , R.V. Seeniraj , R. Velraj [An experimental investigation on a passive cooling system comprising phase change material and two-phase closed thermosyphon for telecom shelters in tropical and desert regions] (2010).
[6] F. Devia , M. Misale [Analysis of the effect of heat sink temperature on single-phase natural circulation loops behaviour]. Augusto J.P. Zimmermann , Claudio Melo [Two- phase loop thermosyphon using carbon dioxide applied to the cold end of the stirling cooler](2010).
[7] Alessandro Franco, SauroFilippeschi [Closed Loop Two-Phase Thermosyphon of Small Dimensions Review of the Experimental Results] (2011).
[8]S. Filippeschi [Comparison between miniature periodic two-phase thermosyphons and miniature LHP applied to electronic equipment.] (2011).
[9] Hamidreza shabgard, Bin Xiao, Amir Faghri, Ramesh Gupta, walter Weissman [Thermal characteristics of a closed thermosyphon under various filling conditions](2013).
[10] Robert W. macGregor , Peter A. Kew , David A. Reay [Investigation of low global warming potential working fluids for a closed loop two-phase thermosyphon](2013).
[11] Augusto J.P. Zimmermann , Claudio Melo [Two-phase loop thermosyphon using carbon dioxide applied to the cold end of the stirling cooler](2013).
[12] Jiwon Yeo, Seiya Yamashita, Mizuki Hayashida, Shigeru Koyama [A Loop Thermosyphon Type Cooling System for High Heat Flux] (2014).
[13] Gilles Desrayaud , Alberto Fichera , Manuel Marcoux [Numerical investigation of natural circulation in a 2D – annular closed-loop thermosyphon](2014).
[14] Ali Chehade, HasnaLouahlia-Gualous, Stephane Le Masson b Eric Lepinasse [Experimental investigations and modeling of a loop thermosyphon for cooling with zero electrical consumption] (2015).

