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Numerical Simulation of a Sodium Thermosyphon

M. Manzoni[1], T.W. Uhlmann[2], M.B.H. Mantelli[3], P. Eskilon[4] and M. Marengo[5]

[1] *Università degli Studi di Bergamo, Dept. of Eng. and App. Science, Viale Marconi 5, 24044 Dalmine (BG), Italy; University of Brighton, School of Computing, Eng. and Maths, Lewes Road, BN2 4GJ, Brighton, UK, miriam.manzoni@unibg.it*
[2] *Federal University of Santa Catarina, Mech. Eng. Dept., Bairro Trindade 88040-970 Florianópolis (SC), Brazil, tiago@labtucal.ufsc.br*
[3] *Federal University of Santa Catarina, Mech. Eng. Dept., Bairro Trindade 88040-970 Florianópolis (SC), Brazil, marcia.mantelli@ufsc.br*
[4] *Cleanergy, Theres Svenssons gata 15, 417 55 Göteborg, Sweden, per.eskilson@cleanergy.com*
[5] *Università degli Studi di Bergamo, Dept. of Eng. and App. Science, Viale Marconi 5, 24044 Dalmine (BG), Italy; University of Brighton, School of Computing, Eng. and Maths, Lewes Road, BN2 4GJ, Brighton, UK, m.marengo@brighton.ac.uk*

Extended Abstract

Thermosyphons are closed, wickless, two-phase heat transfer devices. They can transport heat at high rates over appreciable distances, virtually isothermally, without any requirement for external pumping devices, by making use of evaporation and condensation.

A gravity assisted conventional thermosyphon consists of an evacuated sealed tube containing a small pool of liquid on the bottom. Heat is applied on the bottom region (hot section), evaporating part of the pool liquid. Local pressure increases, pushing upward the vapor toward the cold section, where condensation occurs and heat is rejected to the external environment. The flow circuit is completed by the condensed liquid, forced back to the pool by gravity in the form of a thin film on the tube wall. High temperature thermosyphons, working above 800K, are already successfully implemented as thermal transport devices, for example, in nuclear or solar plants. Liquid metals with high boiling point, like sodium, lithium or potassium, are usually chosen as working fluids, for these kinds of applications.

However, most of the empirical correlations for the prediction of the thermosyphons internal coefficients of heat transfer, working limits and thermal performances were developed for water and might not be applicable to other fluids, such as alkaline metals. Therefore, a simple mathematical model able to simulate the behaviour of a thermosyphon independently of the employed working fluid is a powerful tool to help engineers to design and optimize thermosyphon assisted equipment. In this paper, a novel one-dimensional lumped parameters numerical code, for the thermo-hydraulic simulation of thermosyphons, is proposed. Solid components and fluidic domains are subdivided into a limited number of control nodes characterized by a particular thermodynamic status and connected by electrically analogical elements, as in Fig 1. The generated set of non-linear ordinary differential equations is then solved numerically. This model has been applied to prototype and optimized an industrial thermal management system for a Stirling Engine Unit powered by a hybrid heating source (i.e. combustion and solar energy). The results of the work will be presented in this paper. The final designed thermosyphons are able to transfer up to 40kW of power with a very high efficiency (the equivalent thermal conductivity computed is over 3000W/mK), at different inclination angles, from quasi horizontal to vertical position.

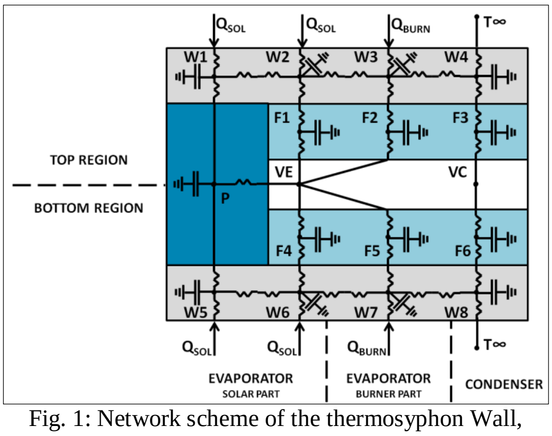

Fig. 1: Network scheme of the thermosyphon Wall, liquid Film and Pool. Vapor nodes are also indicated (VE and VC).