COMPARATIVE ANALYSIS OF THE EFFICIENCY OF THE OPERATION OF VAPOUR DYNAMIC THERMOSIPHONE AND THERMOSIPHONE WITHOUT INNER CIRCULATION INSERTS

A. V. Shapovalov, A. V. Rodin, P. A. Adamenko
Department of Industrial Heat Power Engineering and Ecology
Educational Institution "Sukhoi State Technical University of Gomel", Belarus
48, Pr. Octiabria, Gomel, 246746, Republic of Belarus
Tel: (232) 40-37-42; Fax: (232) 40-16-57
E-mail: a_v_shapovalov@gstu.by

Abstract

The results of experimental study of the operation of closed loop two phase heat transfer devices i.e. thermosiphones with an extended zone of evaporation and condensation are presented. The volume of the fluid optimal for filling the devices is determined, the length distribution of the evaporator and condenser wall temperature temperatures is obtained.

KEYWORDS

Thermosiphone, vapour dynamic thermosiphone, inner circulation inserts, thermal resistance, evaporation, condensation.

INTRODUCTION

Vapour dynamic thermosiphones are invented and patented in Porous Media Laboratory of the State Scientific Institution "A.V. Luikov Heat and Mass Transfer Institute" of the National Academy of Sciences of Belarus [1]. Such devices can be used to utilize the heat of industrial plants or air conditioning systems. Another possible purpose of the devices is to stabilize the temperature at various points in the closed volume. The options for using heat exchangers on thermosyphones are presented in [2, 3].

At the Porous Media Laboratory of the State Scientific Institution "A.V. Luikov Heat and Mass Transfer Institute" of the National Academy of Sciences of Belarus and at the Department of Industrial Heat Power Engineering and Ecology of the Educational Institution "Sukhoi State Technical University of Gomel" a joint study is being conducted concerning closed loop two phase heat transfer devices – i.e. thermosiphones with an extended zone of evaporation and condensation.

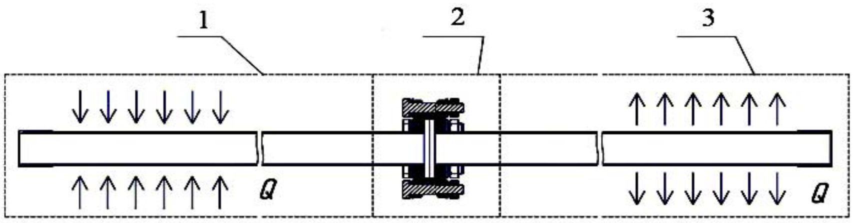
1. RESULTS OF EXPERIMENTS

A series of experimental works was carried out for the study of the performance efficiency of thermosiphones, the structure of which is shown in Fig. 1.

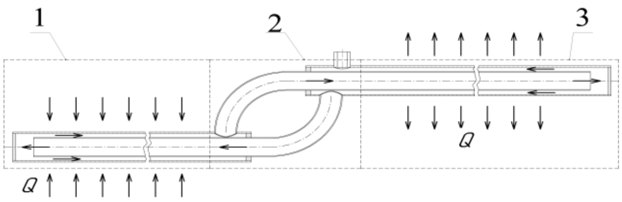
During the experiments heat flux to the thermosiphones was changing, as well as the degree of filling-up of the device with heat transfer agent and the position of the thermosiphones in space. Distilled water and ethyl alcohol were used as heat transfer agents. The volume of working fluid filled in was 250 ml (1/4 of the evaporator volume), 500 ml (1/2 of the evaporator volume), 750 ml (3/4 of the evaporator volume). Angles of inclination of the thermosiphones relative to horizontal plane were 0°, 30°, and 45°. Heat flux to the evaporator: from 148.5 to 490.5 W (from 1642 to 5423 W/m^2).

Before the main experiments, a series of qualification tests was carried out. The results obtained are in satisfactory agreement with previous studies [4], which allows us to conclude on the reliability of the chosen research methodology and the reliability of the results obtained. The maximum error in determining the thermal resistance of the device did not exceed 16%.

In Figs. 2–3 the difference in thermal resistance and average temperature values of the wall of a thermosiphone without inner circulation inserts and of a vapour dynamic thermosiphone is shown. The thermosiphone without inner circulation inserts has 25–30% higher thermal resistance and wall temperature values than those of the vapor dynamic thermosiphone.



a



b

Fig. 1. Thermosiphone without inner inserts (*a*) and vapour dynamic thermosiphone with inner cylindrical channels (*b*): *1* – evaporation zone; *2* – transport zone; *3* – condensation zone

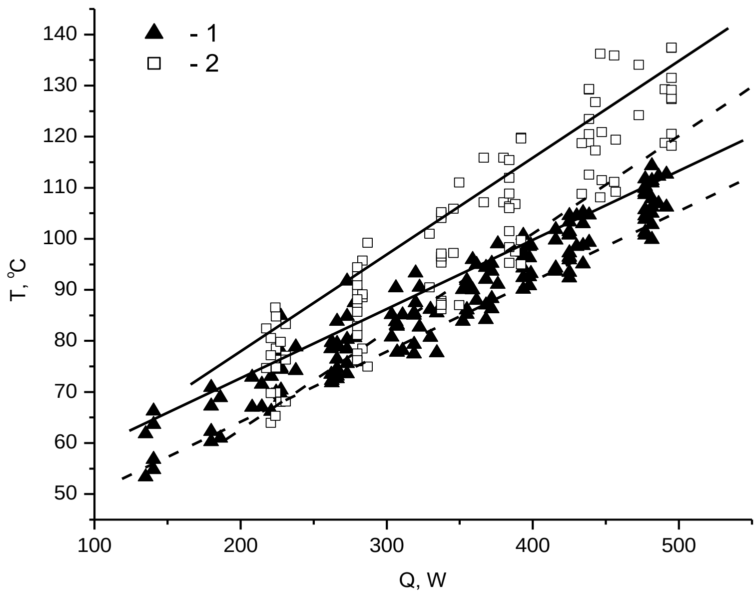


Fig. 2. Diagram of the variations of average temperatures of the evaporator and condenser vs heat flux to the classical and vapour dynamic thermosiphons (solid line – averaging line of the evaporator; dotted line – averaging line of the condenser; *1* – vapour dynamic thermosiphone; *2* – classical thermosiphone)

This is connected with the specificity of the circulation of vapour-liquid mixture inside the device. Condensate from the lower part of the vapour-dynamic thermosiphone condenser is discharged to the evaporator by lower tube of the transport zone where evaporation occurs in an annular mini-channel. Such scheme of the arrangement of movement of vapour-liquid mixture with separate movement of heated and cooled flows contributes in the improvement of the conditions of washing of the walls of condenser tubes in the region of top generatrix of the evaporator and the condenser and thus stabilizes the thremosiphone operation at small angles of inclination. Arrangement of the parallel-plate duct in the evaporator contributes in facilitating heat transfer agent boiling.

The thermosiphones filled with distilled water operate by 30% more efficiently than thermosyphones operating on ethyl alcohol. This is connected with better thermal physical water parameters of water.

The use of ethyl alcohole as a heat transfer agent enables to extend the range of the thermosiphone operation in the region of small heat loads. The temperature of the beginning of the operation of the thermosiphon operating on ethyl alcohole is 65°C while such temperature of the thermosiphone operating on distilled water is 75°C.

The design of thermosiphone presented can be used in heat exchangers for the recovery of heat exhausted from industrial emissions (smoke fumes, sewage waters, ventilation systems, heat of compressor units). External view of such heat exchangers is presented in Fig. 4.

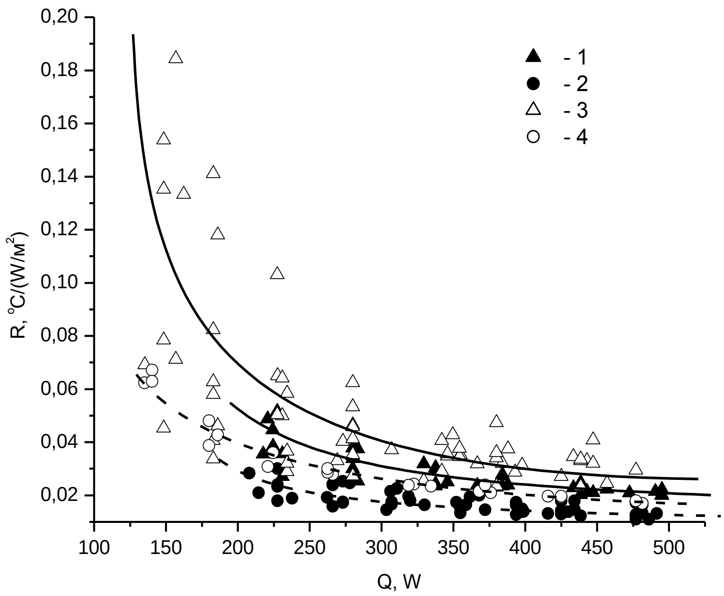


Fig. 3. Thermal resistance vs heat flux to classical and vapour dynamic thermosiphones: *1* – classical thermosiphone filed with water; *2* – vapour dynamic thermosiphone filled with water; *3* – classical thermosiphone filled with ethyl alcohole; *4* – vapour dynamic thermosiphone filled with ethyl alcohole

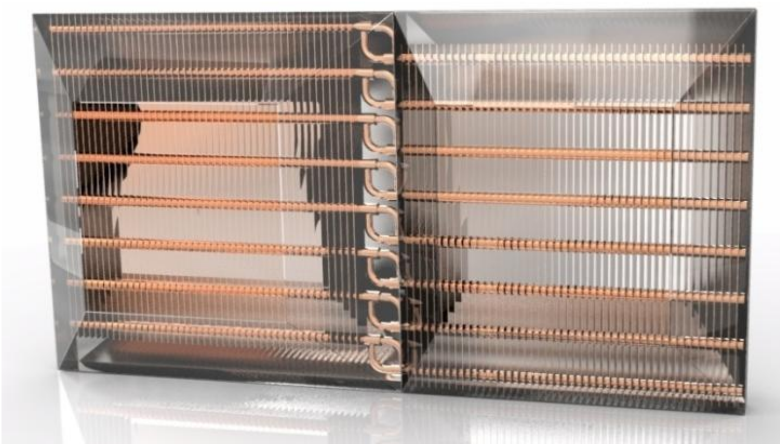


Fig. 4. Recuperator on the basis of the vapour dynamic thermosiphone

CONCLUSION

From the results of the study of heat exchange process during evaporation and condensation of model liquids (distilled water, ethyl alcohol) in classical and vapour dynamic thermosiphones conducted for the purpose of development of the efficient heat exchange apparatuses of different technological designation the following conclusions can be drawn:

1. It is established that the change of the position of the vapour dynamic thermosiphone with inner circulation inserts in space in a vertical plane in the range of the increase of the angle of inclination from 0 to 40 degrees at the volume of filling with water and ethyl alcohole equal to 1/4 and 1/2 of the evaporator volume has no considerable influence on heat exchange rate. The influence of the angle of inclination to a horizontal plane is observed in the range of low heat fluxes up to 350 W and for filling-up of the thermosiphone to 1/2 volume of the evaporator. With the increase of inclination angle a slight increase of the heat exchange rate was observed in the zone of evaporation as well as in the zone of condensation, which resulted in reducing wall temperatures approximately by 5^{o}C. Higher values of average temperatures of the walls of the evaporator and condenser of the thermosiphone without inner circulation inserts operating on water as well as on ethyl spirit are recorded in a horizontal position of the device in space.

2. Optimal volume of liquid inside the device without inner circulation inserts should be more than 1/2 of the evaporator volume and for the device with inner circulation inserts – no more than 1/2 of the volume of evaporator and no less than 1/4 of the volume of the evaporator.

3. Thermosiphones filled with distilled water operate by 30% more efficiently than thermosiphones filled with ethyl alcohol. This is connected with better thermalphysic parameters of water (thermal capacity of water is 4.181–4.287 kJ/kg·K; thermal capacity of ethyl alcohol is 2.889–3.810 kJ/kg·K in the temperature range 50–140^{o}C).

4. The use of ethyl alcohol as a heat transfer agent enables to extend operating range of the device in the region of small heat fluxes. The temperature of the beginning of the operation of thermosiphon operating on ethyl alcohol is 65^{o}C and of that operating on a distilled water is 75^{o}C.

5. It is determined that till reaching heat flux density 1500 W/m^2 (water and ethyl alcohol) in the thermosiphone without inner circulation inserts operating parameters with high rate circulation of vapour-liquid mixture are not set. Because of this an increased thermal resistance of the device is observed.

6. It is established that the operation of the thermosiphone of classical design without inner circulation inserts is characterized by thermal resistance increased by 25–30% as compared with the vapour dynamic thermosiphone.

References

1. *Pat. 4554966 US. Heat Transfer Device* / L. L. Vasiliev, V. A. Morgun, M. I. Rabetsky. 26.11.1985.
2. Zhuravlyov A. S., Vasiliev L. L., Vasiliev L. L. Jr. Horizontal vapordynamic thermosyphons, fundamentals and practical applications // *Heat Pipe Science and Technology An International Journal*. 2013. Vol. 4, No. 1–2. P. 39–52.
3. Vasiliev L., Vasiliev L. Jr., Zhuravlyov A., Shapovalov A., Rodin A. Vapordynamic thermosyphon – heat-transfer two-phase device for wide application // *Archives of Thermodynamics*. 2015. Vol. 36, No. 4. P. 65–76.
4. Vasiliev L. L., Vasiliev L. L. Jr. Horizontal vapordynamic thermosyphons, fundamentals and practical applications // *16 IHPC. Proc. of 16th Intern. Heat Pipe Conf.*, May 20–24, 2012 / CETHIL, INSA de Lyon, France Lyon, France. 2012. P. 129–134.