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NUMERICAL ANALYSIS OF THE DIAGRAM FOR THE OPERATION OF A BIPHASIC CIRCUIT WITH PUMPING EFFECTS BY CAPILLARITY USING TWO EVAPORATORS IN PARALLEL

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Abstract. *The biphasic pumping circuits by capillarity effects (BFDPT) are passive heat transfer systems, widely used in the aerospace industry (thermal control of satellite). The main objective of this work is analyze the experimental data of a biphasic circuit with pumping done by effects of capillarity, to analyze the way that the main equipment's of the experimental bench function as much theoretically as the analysis of the experimental data. In addition, it is aimed to make a thermodynamic analysis of the operating cycle of this experimental bench in the Engineering Equation Solver (EES) software, and to make a comparison between a theoretical (ideal) analysis of the circuit with an (real) experimental analysis.*

Keywords: *diagram of operation, capillarity forces, biphasic system and heat pipe.*

1. INTRODUCTION

Currently, one of the major engineering challenges is the thermal control of industrialized products, such as general vehicle engines (motorcycles, cars, trains, etc.). A temperature controller represents a part of a larger system that may depend on feedback (closed cycles) or no feedback (open cycles). Making use of a thermal machine without knowing its limits of operation may eventually damage it. The temperature of a process must be known in order to be controlled (ZOHURI, 2016).

The heat pipe is one of the remarkable achievements of physics, thermodynamics and heat transfer engineering of the past century because it has the unique ability to transfer heat over large distances without considerable losses. The main applications of heat pipes deal with problems of environmental protection and energy saving. Heat pipes have emerged as an established and effective alternative solution to thermal problems, particularly in applications where large heat flows are required and in situations where there are many non-uniform combinations of heat transfer according (BONJOUR, 2011), (FAGHRI, 1995) and (KEW, 2006).

According to (BERTIN, 2014), there are two main types of biphasic circuits utilizing capillary pumping: Capillary pumped loop (CPL), discovered in the United States in the late 1960s and there are Loop Heat Pipe (LHP) which were discovered in the Union of Soviet Socialist Republics in the early 1970s. The basic difference between CPLs and LHPs is the position of the reservoir in the cycle, where in the CPL the reservoir is coupled to the circuit separated from the evaporator and in the LHP the reservoir is coupled to the evaporator, as can be seen in Figure 1. These thermal control circuits are one of the most competitive solutions among the new refrigeration devices currently developed. Moreover, as (BERTIN, 2011) these devices are capable of transferring large quantities of heat over long distances thanks to the circulation of the fluid by the capillary effect and because of the phase transformations of the fluid.

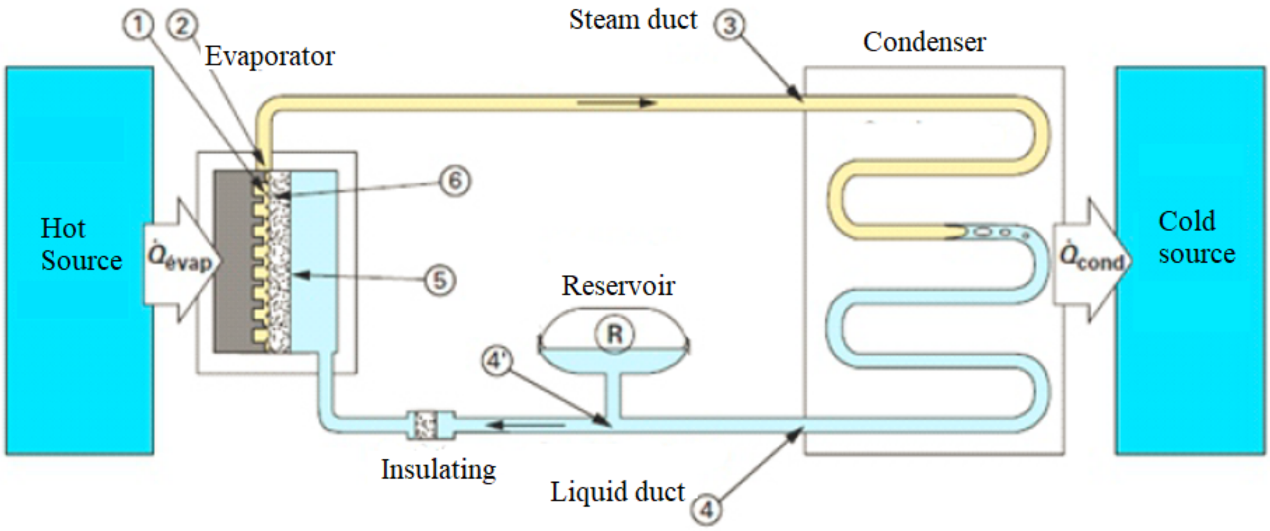

Figure 1. Schematic of the operation of a CPL.

Whatever is the concept of biphasic circuits, it can be seen that there are 3 places where the fluid can be found in the saturation state: reservoir, evaporator (transformation from liquid phase to gaseous phase) and condenser (transformation from gaseous to liquid).

2. EXPERIMENTAL AND NUMERICAL PROCEDURE

For the numerical analysis, the temperature values are given by the T-type thermocouple and pressure provided by the PT100. Figure 2 shows the positioning of the thermocouples and pressure gauges.

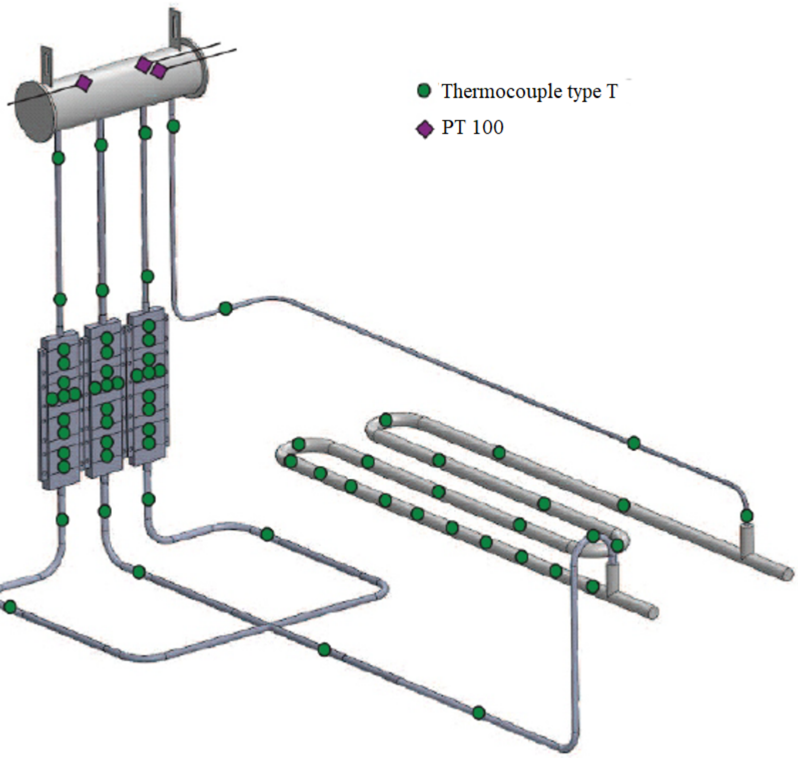

Figure 2. Equipment for data analysis.

The absolute pressure and flow meters were positioned according to Fig. 3.

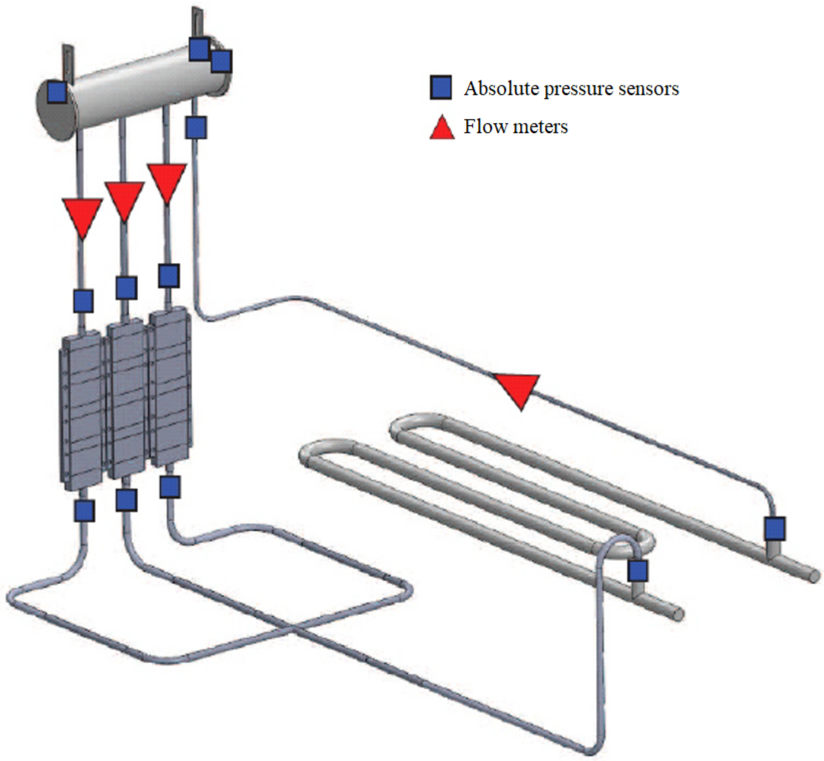

Figure 3. Equipment for data analysis.

3. THEORETICAL ANALYSIS (IDEAL CONDITION)

According to (LACHASSAGNE, 2012) to understand the key points of the system, one must follow the diagram (pressure by temperature) represented by Fig.3.

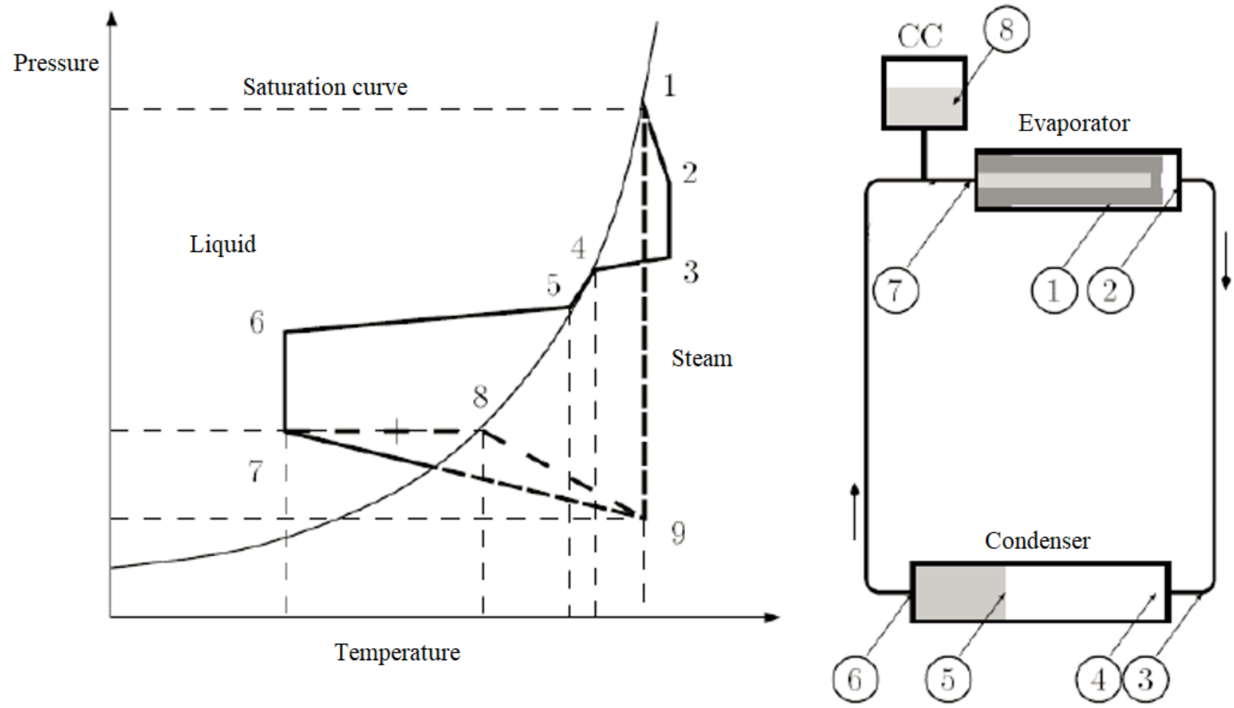

Figure 4. Operating diagram

where

- Point 1 is the temperature at the center of the evaporator (saturation region).
- Point 1 to point 2, a slight loss of pressure occurs, and a small increase in temperature, point 2 is located at the outlet of the evaporator.
- Point 2 to point 3, in the ideal condition of the steam duct being well isolated from the external environment, it is considered that the temperature remains constant in this path, but a pressure occurs, point 3 is located at the entrance of the condenser.
- Point 3 to point 4, the temperature decreases, as the fluid has entered the condenser, and at a small reduction in pressure, point 4 is located in the initial part of the condenser, where the fluid has not yet changed phase.
- Point 4 to point 5, consists of the first stage of condensation, ie, the cooling of the steam occurs to the condition of condensation. Point 5 to point 6, the rest of the condenser, the convective heat exchanges are single-phase and consists of a cooling of the fluid.
- Point 6 (outlet of the condenser) to point 7 (evaporator inlet), it is considered that in this duct the heat exchange with the external medium in the ideal condition is zero, that is, the temperature remains constant, and an increase in pressure occurs , point 8 is the evaporator inlet and point 9 is the saturation point of the reservoir.

Using Figure 4, an analysis of the main points of the circuit was made, and the experimental data were made taking into account the use of the methanol fluid.

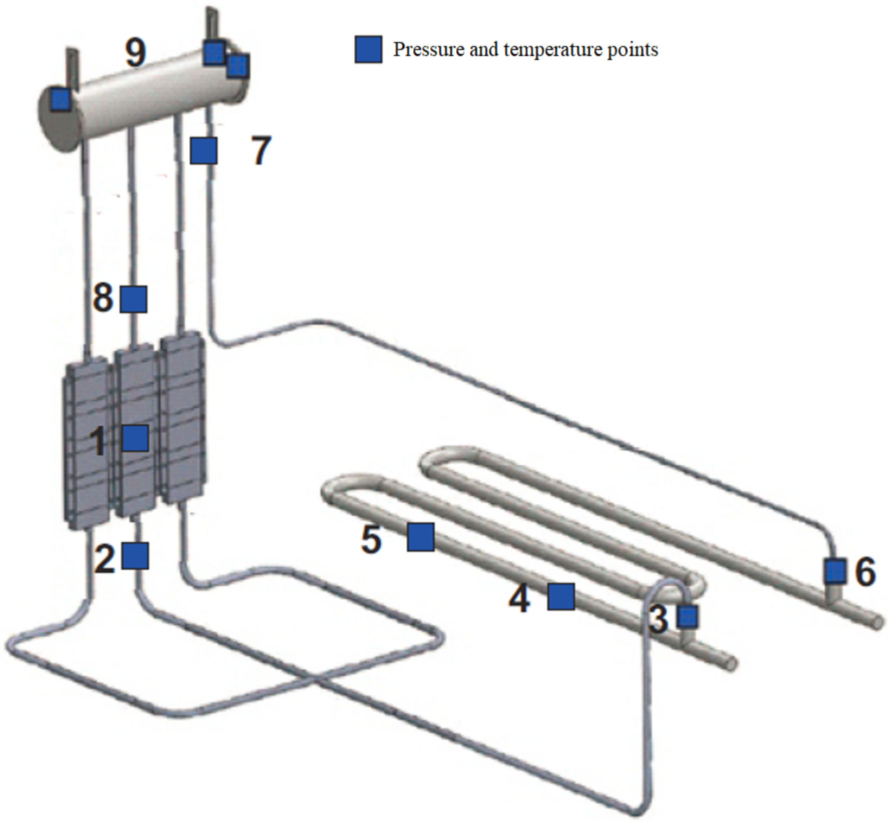

Figure 5. Pressure and temperature points

Subtitle:
Point 1 - Porous medium of the evaporator.
Point 2 - Evaporator outlet.
Point 3 - Condenser input.
Point 4 - Beginning of condensation.
Point 5 - Saturated liquid.
Point 6 - Condenser output.

Point 7 - End of the liquid duct (reservoir inlet).
Point 8 - Exit of the reservoir.
Point 9 - Reservoir.

In circuits with pumping by capillary effects, the capillary pressure jump imposed by the evaporator must be balanced with the pressure drop of the fluid in the circuit. There are different types of pressure drop that must be taken into account such as: fluid viscosity, duct geometry, presence of the biphasic zone, presence of the porous medium in the evaporator and in the condenser, gravity, liquid duct and vapor duct. Among others, basically the pressure drop in the System is given by Eq. (1).

$$\triangle P_{cap} = \triangle P_{evap} + \triangle P_{cond} + \triangle P_g + \triangle P_{dv} + \triangle P_{dl} \quad (1)$$

where
$\triangle P_{cap}$ is the capillary or total pressure drop.
$\triangle P_{evap}$ is the evaporator pressure drop.
$\triangle P_{cond}$ is the pressure drop in the condenser.
$\triangle P_g$ is the pressure drop due to gravity.
$\triangle P_g$ is the pressure drop due to gravity.
$\triangle P_{dv}$ is the pressure drop in the vapor duct.
$\triangle P_{dl}$ is the pressure drop in the liquid duct.

4. RESULTS AND DISCUSSION

The analysis of the pressure drop of the system was made taking into account the power of the source in 1,500 watts. Table 1 represents the pressure and temperature data for the analysis points according to Fig. 4. The analysis of the experimental data was made using the Engineering Equation Solver (ESS) software.

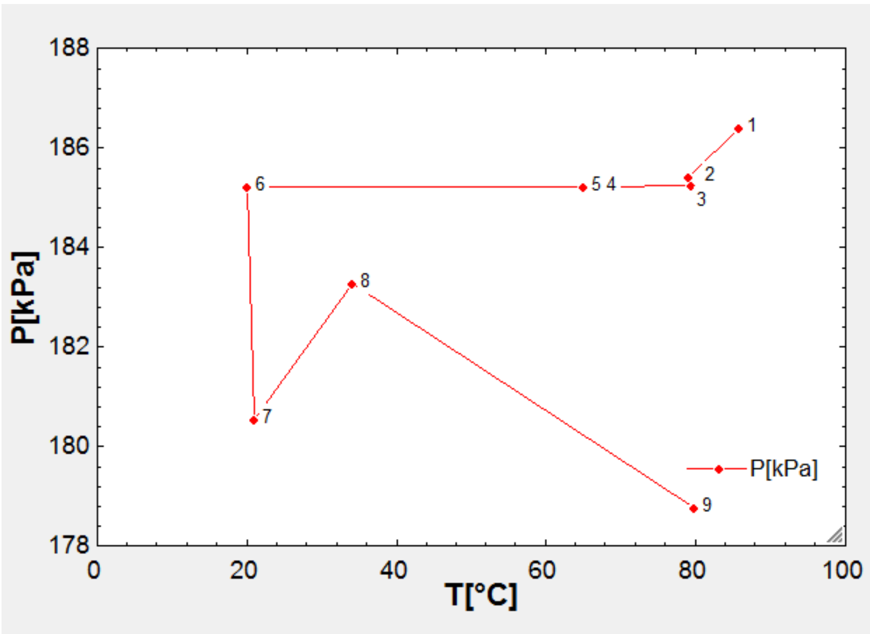

Figure 6. Pressure and temperature in different points

5. CONCLUSION

The studies of two-phase systems are important for understanding the critical points of this circuit (evaporator and its porous medium, condenser and the reservoir), because a variation of one of the parameters can significantly vary the parameters in other points of the circuit.

In addition, it is possible to realize the enormous potential that these systems have, capable of transferring heat over long distances. However, their study is limited because these heat transfer systems are very expensive in terms of equipment (evaporator with its porous medium, data acquisition systems, etc.). The advantage is the long period of time, because it is only necessary to keep the temperature constant in the reservoir, since the system is totally self-regulated.

Finally, it is known that numerous studies are necessary for the development of this type of heat transfer system to be able to explain in detail certain phenomena that occur in this biphasic circuit.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

BERTIN, Yves., ZITOUN Ratiba., POTIN-SINAPAYEN, rapport de stage d'ingenieur, Instrumentacion d'une boucle diphasique.

BERTIN, Yves., AYEL, Vincent, DORIGNAC, Eva, TSCHILL, Hugues, rapport de stage d'ingénieur, Mise em place et experimentation d'une boucle diphasique á pompage capillaire.

BERTIN, Y.; AYEL, V.; ALEXANDRE, A. Transferts de Chaleur en Diphasique- Partie II: Thermosiphons, aloducs tournants, V.C.H.P., Micro-caloducs, boucles diphasiques et caloducs oscillants – Cours A3 (Thermique), 2014.

BERTIN, Y.; ZITOUN, R.; SINAPAYEN, P. Rapport de stage d'ingenieur, Instrumentacion d'une boucle diphasique, 2011.

BERTIN, Y.; AYEL, V.; DORIGNAC, E.; Rapport de stage d'ingénieur, Mise em place et experimentation d'une boucle diphasique á pompage capillaire, 2012.

BONJOUR, Jocelyn., LEFEVRE, Frédeéric., SARTRE, Valérie., BERTIN, Yves., ROMESTANT, Cyril., AYEL, Vincent., PLATEL, Vincent., Boucles capillaires et gravitaires, Référence de l'article: B9 546.

FAGHRI, A. Heat pipe science and technology, 1995.

KEW, Peter.,REAVY, David., Heat Pipes Theory, Design and Applications, fifth edition, 2006.

LACHASSAGNE, L.; BERTIN, Y.; AYEL, V.; ROMESTANT, C.; Applied Thermal Engineering – Experimental Study of Capillary Pumped Loop for Integrated Power in Gravity Field, 2012.

VASILIEV, L.L.; KAKAÇ, S. Solid Sorption Transformations, 2013.

ZOHURI, B. Heat Pipe Design and Technology- a pratical approach, 2011.

ZOHURI, B. Heat Pipe Design and Technology,2016.

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