Experimental and theoretical investigations of a telecommunication cabinet cooling mode with zero electrical consumption.

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Abstract—**This paper presents experimental investigations on a real Orange telecommunication cabinet cooled using a special designed cooling loop in order to increase its maximum operating power limit and reduce its electrical consumption. The proposed cooling loop is an innovative development in the telecommunication cabinets cooling field since it operates without electrical consumption. Different condenser types are tested on the loop, where their effects on the loop performance are investigated. Increasing of the working fluid fill charge enhances the evaporator performance.**

Keywords—Telecom; thermal; cooling; thermosyphon; two-phase; heat

I. INTRODUCTION

The fast development in the telecommunication field and the demand for high bit rate services are accompanied with a high increase in the generated heat inside the telecommunication cabinets, which implies an increase of the system temperature. In the telecommunication outdoor cabinets fans are used as cooling systems for which it is difficult to maintain temperature levels over prolonged periods of time. Besides, fans need electricity consumption, complex air filtration designs and high cost maintenance.

Energy consumption is a major operating cost in the telecommunication field where 33% of electricity is used for cooling. Consequently, a large variety of cooling systems have been studied to maintain applicable temperatures for telecommunication equipment. Moreover, the increase of the greenhouse gases emissions introduces new challenges especially the use of low charge of working fluids and the efficient cooling systems with zero electrical consumptions.

Active cooling systems need complex air filtration designs and high cost maintenance. They do not match the demand from the systems with a high thermal dissipation. Air cooling systems are disadvantaged by acoustic noise generation, electrical power consumption, weight addition, and periodic maintenance requirements. As stated by Chu and Simons [1], semi-active systems using air-to-air heat exchangers and thermoelectric coolers are extensively used for the telecommunications cabinets cooling. However, they consume a large amount of electric energy. Likewise, Bulut and Aktacir [2] studied free air cooling with a case study in Istanbul, Turkey. They found that the potential savings from free air cooling varied throughout the months in a year; where they found that the benefits from free air cooling from June to August are not significant due to high outdoor air temperatures. Moreover, such techniques may result in low contamination control.

Passive cooling systems arose as an innovative solution due to their ability of withstanding high heat fluxes with low working fluid charge, controlling system temperature automatically, and working with a minimum energy consumption and a less noise. They hold better thermal performances than active and semi-active systems because they use phase change processes providing higher heat transfer coefficient at low mass flow rates [3-5]. They offer various advantages such: (i) ability of dissipating heat from a heat source to a heat sink over a relatively long distance, (ii) no moving parts leading to a more reliable system operation, (iii) greater flexibility while choosing working fluids compatible with telecommunication equipment, (iv) reduction in the working fluid fill charge, and (v) and zero electrical consumption.

An analytical model for a thermosyphon loop for cooling air inside a real telecommunication cabinet is developed by Louahlia et al. [6]. 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. Results 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. The model well predicts the experimental data with a mean deviation about 6% for operating temperature.

This paper presents experimental results obtained from tests on the cooling system placed in the real telecommunication cabinet. This is a first step of a larger study dealing with cooling datacenter racks. In this present study, the outdoor cabinet represents a containment zone where thermal balance can be easier checked. The thermosyphon loop is developed and tested in the LUSAC laboratory of Caen Normandy University with the collaboration of Orange Labs.

II. EXPERIMENTAL SETUP

The tests were conducted with an Orange real outdoor telecommunication cabinet cooled by a conventional air cooling. As showed in Figure 1, the cabinet is of 1650 mm height, 1110 mm width, and 500 mm depth. 0-2KW telecommunication equipment box having 460 mm height, 500 mm width, and 180 mm depth, is located at the cabinet left side for the heat generated by telecommunication materials. It contains five heating cards. The power supply of the heating box is adjusted through a 0-220 voltage autotransformer capable of delivering 20A, and a power meter that permits data recording. Traditional cooling of the cabinet is accomplished by 4 ebm-papst fans capable of delivering 204 m^3/h air flow. These fans are located at the heating boxes inlet. is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

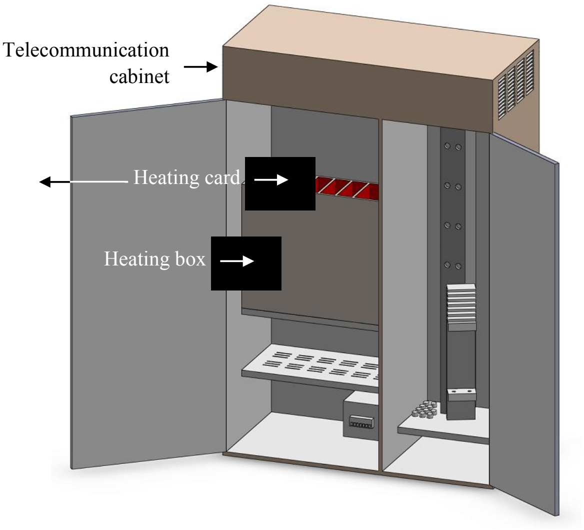

Figure 1. A schematic design of an Orange real telecommunication cabinet.

Figure 2 shows the transient thermal performance of the telecommunication cabinet for certain heat loads. Heating box inlet air temperature is considered as the cabinet operating temperature. Note that, tests are conducted depending on active cooling system associated with the fans that installed at the heating box inlet.

Figure 2 shows that air temperature inside the cabinet increases with the increase of the heat load. Besides,

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the difference between the operating and the heating box outlet temperatures increases with the increase of the imposed heat load due to the increase of the trapped heat inside the cabinet. It increases from 4 to 10°C as the heat load increases form 200 to 500 W. Also, the figure shows that the cabinet thermal performance is limited to 400 W depending on the ETSI standard [7].

Consequently, an alternative technique must be carried out in order to increase the cabinet performance under a maximum recommended environmental temperature. Figure 3 shows an Orange real outdoor telecommunication cabinet and the cooling loop thermosyphon assembly.

These devices are thus particularly suitable for cooling applications where reliability and safety are of paramount importance without energy consumption. The working fluid plays a vital part in the cooling system, since it is the medium by which cooling or heating is carried out. The ideal working fluid therefore has a number of properties; a boiling point below the objective temperature, a high vaporization point, moderate liquid density, relatively high vapor density, high critical temperature, and low operating pressure.

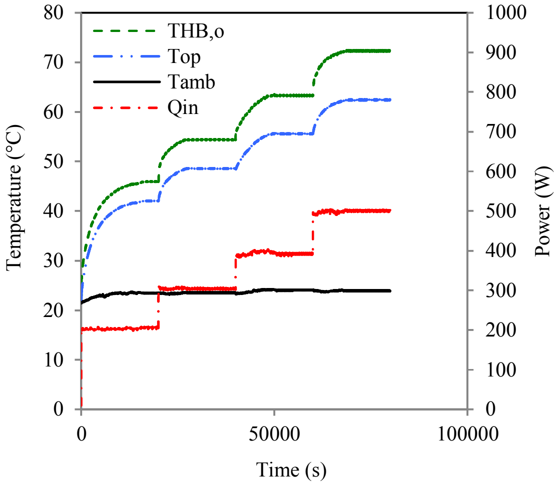

Figure 2. Thermal transient response of a real Orange telecommunication cabinet performance using traditional cooling.

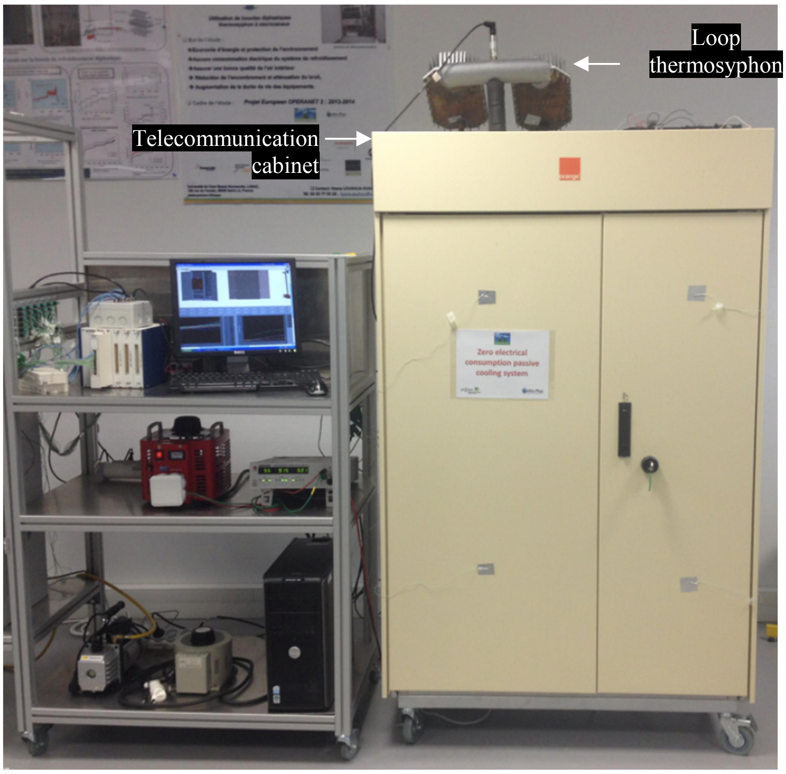

Figure 3. Photo of experimental setup; (1) voltage regulator, (2) power meter, (3) vacuum pump, (4) heating equipment, (5) outdoor cabinet, (6) thermosyphon system, (7) thermocouples, (8) NI acquisition device and (9) computer.

A passive closed loop thermosyphon is an energy-transfer device capable of transferring heat from a heat source to a separate heat sink over a relatively long distance. Additionally to the usage of small amounts of working fluids, passive loop thermosyphon operates without active control instrumentation and any mechanical moving parts.

An experimental setup is built to conduct measurements for heat transfer and cooling enhancement while using a thermosyphon loop for cooling a telecommunication cabinet. It consists of a telecommunication cabinet, a loop thermosyphon, heating equipment, a vacuum pump, a voltage transformer and a power meter, the pressure sensors and thermocouples, computer, and an acquisition data device. The telecommunication cabinet is of 1650 mm height, 1110 mm width, and 500 mm depth. Four heating cards are placed in the heating equipment that is located at the center of the telecommunication cabinet. Heat flux generated there heats the telecommunication cabinet indoor air. The loop thermosyphon is installed at the outdoor cabinet as shown by Figure 3.

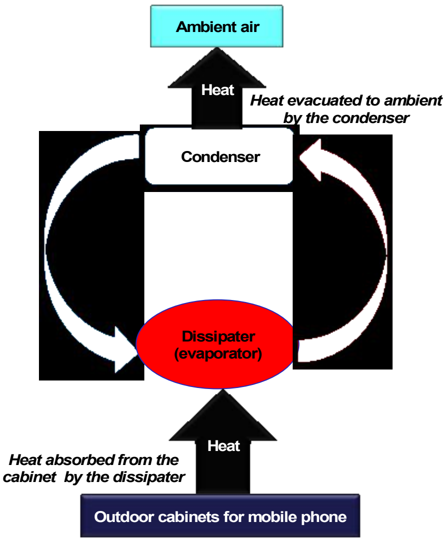

Figure 4. Closed passive cooling loop criterion.

It consists of an evaporator connected to a condenser by the means of two copper tubes. The loop's evaporator is installed inside the cabinet unlike its condenser, which is located outside. Heat transfer from telecommunication equipment could be dissipated by vaporization of the working fluid inside the evaporator, where the vapor would have the sufficient pressure to overcome the loss due to the vapor line distance to the condenser (Figure 4). The arriving vapor at the condenser changes into liquid flow due to the convection cooling. After that, condensate flow leaving the condenser moves under gravity along the liquid line. The vacuum pump is used to degas all the air and gases inside the loop before any test. The power supply is adjusted through a voltage transformer having an output voltage range from 0 to 220 V, and a power meter. Likewise, pressure sensors and 75µm diameter K type thermocouples are mounted on the entire system for the temperature and pressure measurements. Ambient air temperature is also measured during each experiment. National instruments data acquisition system is used to record all temperatures and pressures for each experimental test. Data sampling frequency is of one measure per second for all measurements. The acquisition of the data is entirely automated by using the LabView software of the National Instruments devices which facilitate measurements in real-time.

A. Experimental procedures

Before starting the tests, the vacuum pumping and liquid preheating processes were performed to remove the gases dissolved in the loop thermosyphon and eliminate the influence of non-condensable gases. The fluid fill ratio, which is defined as the ratio between the working fluid volume and the loop thermosyphon volume (eq. 1), is also conducted by several tests using several fill ratios. The fill ratio is that delivering maximum thermal performance.

$$Fill\ Ratio = V_{working\ fluid}/V_{Loop} \qquad (1)$$

During the experiments, various values of the heat loads ranging from 250 to 900 W are tested. For each test, the total power supplied to the heating equipment is set at the desired value. Heating process of the working fluid accompanied with temperature recordings begins. When all the temperature measurements at that power heat load reach steady state, the value of power supply is incremented by 50W.

III. EXPERIMENTAL RESULTS

The existence of an optimal fill charge is due to two physical phenomena that must be avoided to ensure an effective operation of the loop. The heat transfer in the evaporator is reduced due to the increase of thermal resistance of the working fluid in the liquid chamber, when the amount of fluid increases in the liquid chamber. On the other hand, drying in the liquid chamber can be triggered due to insufficient amount of liquid coolant in the liquid chamber, which also causes a decrease in heat transfer.

The optimal fill charge study is conducted using n-pentane as a working fluid. Several fill charges of n-pentane are tested in the thermosyphon loop. For each fill charge, the heating equipment power is varied from 200W to 800W by an increment of 50W after reaching the steady state. Figure 5 presents the systems thermal resistance as function of the fill charge for various heat loads. The system thermal resistance is used as an indicator for determining the cooling thermal efficiency of the cooling system under various heat loads.

$$R_{th,sys} = (T_{op} - T_{amb})/Q_{load} \qquad (2)$$

where $R_{th,sys}$ is the system thermal resistance, T_{op} and T_{amb} are the operating and ambient temperatures respectively, and Q_{load} is the heat load at the heating equipment.

Experiments are conducted using the telecommunication outdoor cabinet with and without the loop thermosyphon under 100g and 200g fill charges of n-pentane. Unlike the 100g charged loop, two compact ebm-papst fans cool each of the 3 parallel condensers when the loop is charged with 200g of n-pentane. Figure 5 shows that the fill charge increases and the cooling of the condenser effectively affect the system thermal performance.

Subsequently, 400g of n-pentane is tested in the loop. The further increase of the fill charge essentially affected the system thermal performance. Relative to 200 g fill charge, the vapor pressure attained a slight increase due to the increase of the occupied volume in the evaporator as shown in Figure 5.

The maximum heat load that the cabinet can attain (respecting the ETSI (1992) standard) using the loop charged with 400g of n-pentane is effectively increased relative to the case of cabinet without loop (from 400W to 700W).

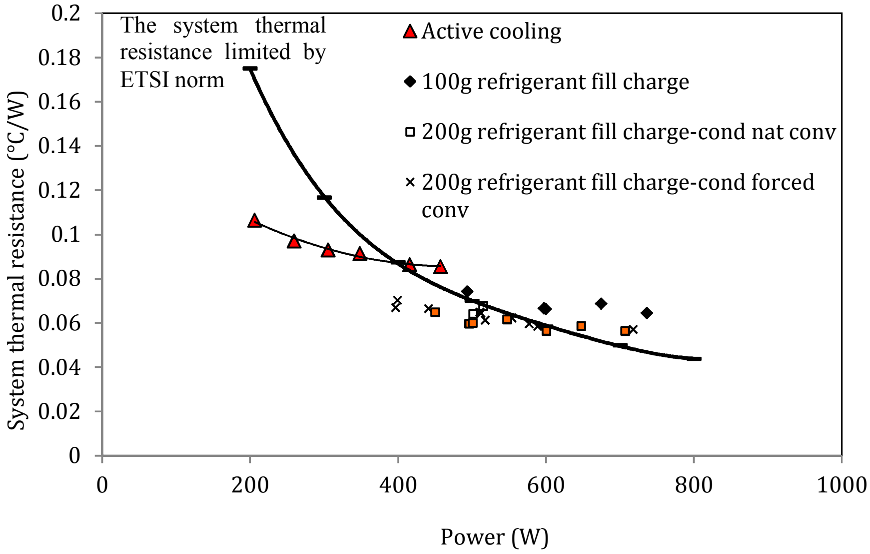

Figure 5. System thermal resistance for different charges versus heat loads.

III- CONCLUSION

This article presents experimental results of a passive cooling of outdoor telecommunication cabinets using a loop thermosyphon.

A loop thermosyphon is developed to passively cool a real Orange telecommunication cabinet in order to meet the ETSI (1992) standard. Several tests are carried out to determine the loop's performance of the thermosyphon. Among the tested experimental range, results showed that 400g fill charge gave the best performance, corresponding to minimum operating temperatures and system thermal resistances.

Relative to system cooling without the passive loop, the maximum power in the cabinet is nearly 2 times greater.

Perspectives are now to apply this kind of cooling system to larger ones like datacenter racks instead of outdoor cabinets.

ACKNOWLEDGEMENT

The authors of this article would like to thank the French Ministry of Industry and Commerce (DGCIS) for the funding of this work, which is integrated in the European project SOOGREEN labelled by Celtic-Plus.

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