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EVALUATION OF THE INFLUENCE OF AMBIENT TEMPERATURE ON THE PERFORMANCE COEFFICIENT OF A REFRIGERATION CYCLE BY SINGLE PRESSURE ABSORPTION

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Abstract. *The reuse of exhaust energy from internal combustion engines (ICE) in absorption refrigeration cycles has been the focus of several studies, it is estimated that for water cooled engines about 35% of the energy for ICE is lost through of exhaust gases. This makes the reuse of the energy emitted by these gases become a viable alternative for the non-use cycle of absorption of the engine cooling system. Previous studies have shown that mass flow control is derived from the exhaust gas for the absorption cycle is a good way to improve the Coefficient of Performance (COP) of this type of refrigeration cycle. This article experimentally evaluates an influence of the ambient temperature on the coefficient of performance of a refrigerator operating in a single pressure absorption refrigeration cycle and evaluates as limitations imposed by the ambient temperature.*
Keywords: *Internal Combustion Engines, Absorption Refrigeration Cycle, Exhaust Gas, Coefficient of Performance, Ambient temperature.*

1. INTRODUCTION

Cooling systems have been marketed for more than a century for applications in air conditioning and refrigeration systems, and in the last three decades, their use has increased significantly, mainly due to global climate change. In this scenario, refrigeration systems that use alternative sources of energy, such as absorption refrigeration systems (Gantz, 2015) have once again played a prominent role in thermodynamic studies involving cogeneration, especially when analyzed from the point of view recovery of energy lost in the form of heat in the various existing industrial processes.

The latest research has focused on new refrigerants, in systems that involve the use of clean energy, such as solar energy, primarily through collectors (Fan et al, 2007), and the reuse of heat lost, as in exhaust gases of internal combustion engines and industrial processes.

Fossil fuels are considered the main source of world energy generation (Siddiqui et al, 2015). Various industries using fossil fuels to generate the heat needed for their production process, but much of this heat is rejected in the form of exhaust gases. According to (Singh and Said, 2016), 25.5% of the energy produced by the Diesel engine of a submarine is dissipated in the form of heat through the exhaust gases. This energy rejected in exhaust can be reused using a refrigeration system operating by heat, as in the case of absorption refrigeration systems (Srikhirin et al., 2001). According to Manzela et al. (2010) for the ideal functioning of a Diffusion Absorption Refrigeration Cycle (DARC) with ammonia water (refrigerant absorbent, respectively) and hydrogen (as inert gas) the ideal temperature at the inlet of the generator is about 200 ° C (Manzela et al, 2010). From this, Rêgo et al. (2013) developed a methodology for controlling the heat supplied by exhaust gases from an internal combustion engine of the Otto cycle to maintain the temperature of the generator inlet at 200 ° C (Rêgo et al, 2013). However, the authors' research did not take into account the effects of ambient temperature on the COP. Therefore, this work intends to evaluate changes in the COP of a DARC caused by the variation of the ambient temperature in a test room of a motor generator group.

2. EXPERIMENTAL PROCEDURE

The refrigerator used in the experimental tests (Fig. 1) operates through a single pressure absorption refrigeration cycle and was manufactured by Norcold, model N305-3R with a capacity of 76.46 liters. It allows its use under three sources of heat in the generator: alternating current thermistor (127 V), direct current thermoresistor (12 V) and LPG combustion. Its working power is 180 W, when operated with alternating current, which will be used in this work, and it has a total pressure of 5.52 MPa. This refrigerator uses the mixture of ammonia, water and hydrogen as a refrigerant.

The Diesel engine used (Fig.2) is of the 2298/4 series manufactured by MWM International Motors with 4 stroke, direct injection, displacement of 3.92 liters and 17: 1 compression ratio.

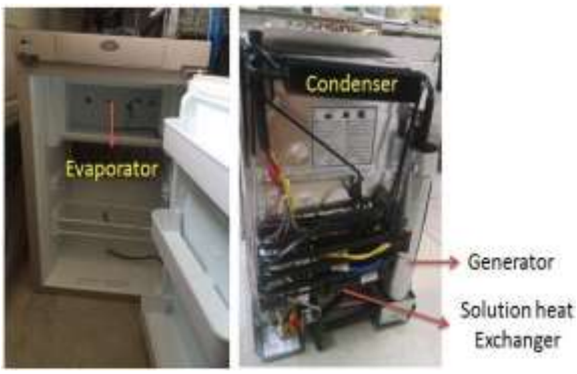


Figure 1. Refrigerator Norcold N305-3R

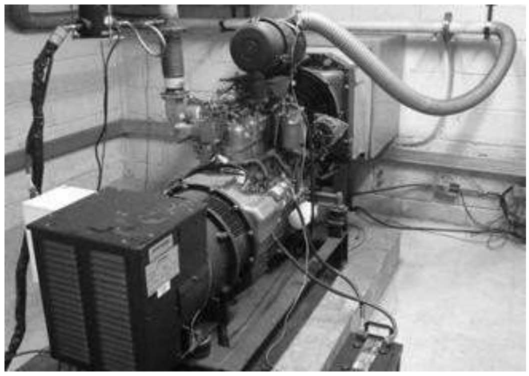


Figure 2. Generator group – Diesel engine

The test is to maintain a control group and in both the source of heat to the generator of the refrigerator during the tests will come from a thermosistor that works with alternating current. These tests shall be carried out in accordance with ISO 15502 for refrigeration. The tests that will be performed with the generator set will use the engine standard of the ABNT NBR 6396: 1976. The temperature measuring points in the refrigerator shall follow those standards and shall contemplate the points that can be seen in Table 1.

Table 1. Thermocouple implementation points

Location of thermocouples and *DS18B20*	*Quantity*
Generator input and output	2
Evaporator input and output	2
Internal and external side walls	4
Internal and external upper walls	2
Total	10

The law of conservation of mass can be applied by the equation (1):

$$\frac{dm_{cv}}{dt} = \sum \dot{m}_i - \sum \dot{m}_o \tag{1}$$

Where:
$\frac{dm_{cv}}{dt}$ – mass flow rate rate [kg/s];
$\dot{m}_i$ and $\dot{m}_o$ – mass flow rate in and out, respectively [kg/s];

First law of thermodynamics can be applied by de equation (2):

$$\frac{dE_{cv}}{dt} = \dot{Q}_{cv} + \dot{W}_{cv} + \sum \dot{m}_i \left(h_i + \frac{1}{2}V_i^2 + gz_i\right) - \sum \dot{m}_o \left(h_o + \frac{1}{2}V_o^2 + gz_o\right) \tag{2}$$

Where:

$\frac{dE_{cv}}{dt}$ energy variation rate [kW];

$\dot{Q}_{cv}$ – Heat transfer to inside cycle [kW];

$\dot{W}_{cv}$ – Power transfer to environment [kW];

h_i and h_o – Enthalpy in and out, respectively [kJ/kg];

V_i^2 and V_o^2 – Kinetic energy in and out, respectively [m²/s²];

gz_i and gz_o – Potential energy in and out, respectively [m²/s²].

The Coeficient of Performance (COP) can be calculated by the equation (3):

$$COP = \frac{T_r(T_s - T_a)}{T_s(T_a - T_r)} \quad (3)$$

Where:

T_r is the temperature of the refrigerant in evaporator [K];

T_s is the temperature of the solution in generator [K];

T_a is the temperature of the solution in absorber [K].

3. RESULTS AND DISCUSSION

Figure 3 shows the measured temperature chart, with K-type thermocouples and DS18B20 sensors, for the internal and external walls of the refrigerator to the center, the sides of the refrigerator and the top of the refrigerator. Figure 4 shows the COP was considered that the refrigerator entered in permanent regime after 3 hours and 36 minutes, with little significant changes in the temperatures, caused mainly by small changes of the ambient temperature, after entering a permanent regime, was evaluated at 0.31.

The calculation of the COP was based on equation 3 involving only the temperatures of the fluid in the evaporator, the fluid in the absorber and the fluid in the generator, based on these data the COP of the refrigerator were calculated in different ambient temperatures, as can be seen in figures 3, 4 the temperature directly influences the COP, and the increase in ambient temperature reduces the COP because it reduces the capacity of the condenser to reject heat into the environment which directly reduces the evaporator's ability to absorb heat while increasing the temperature environment does not produce significant reduction in the amount of heat inserted in the generator to heat the fluid to the working temperature, the ambient temperature was collected with two type K thermocouples positioned on the top and side of the refrigerator. The data used in the graphs represented by Figures 3, 4 and 5 are of the refrigerator in permanent regime.

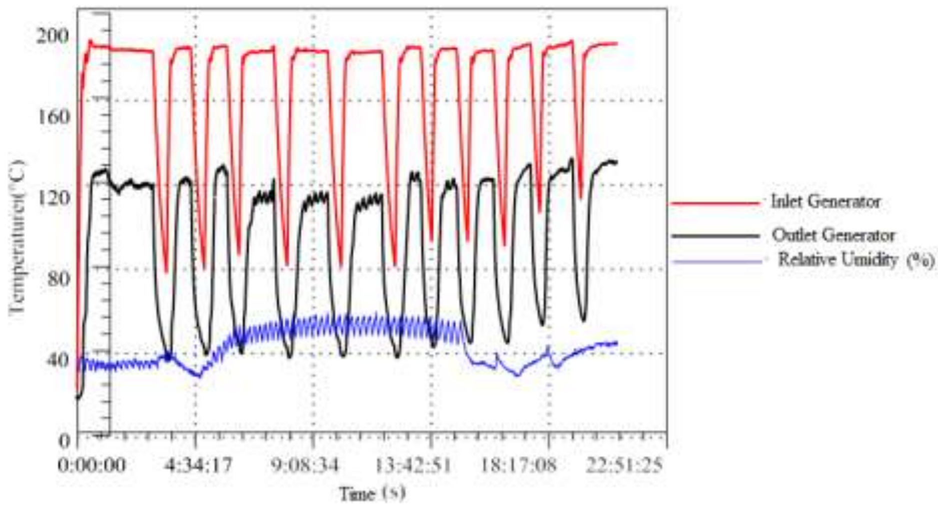
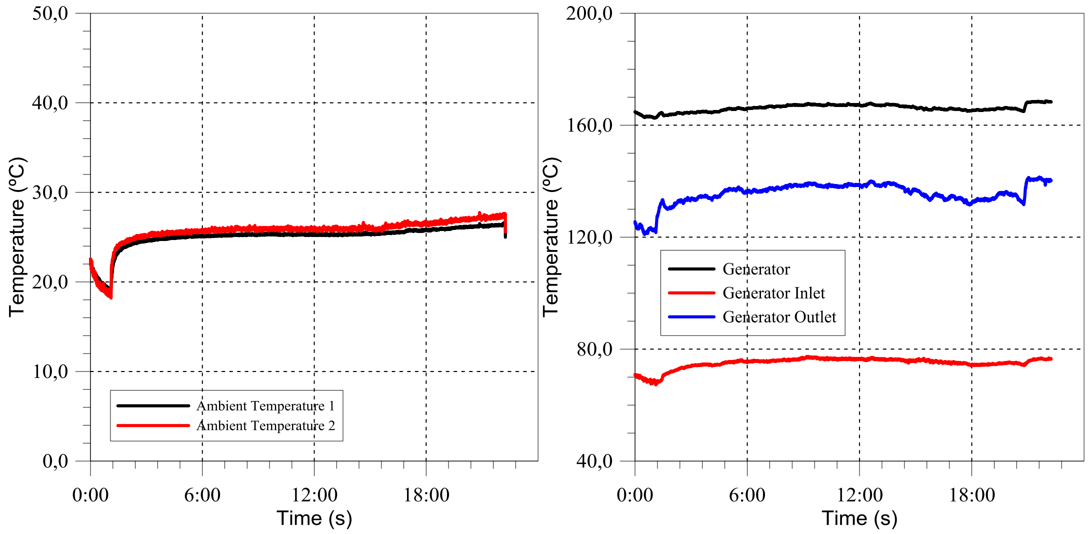
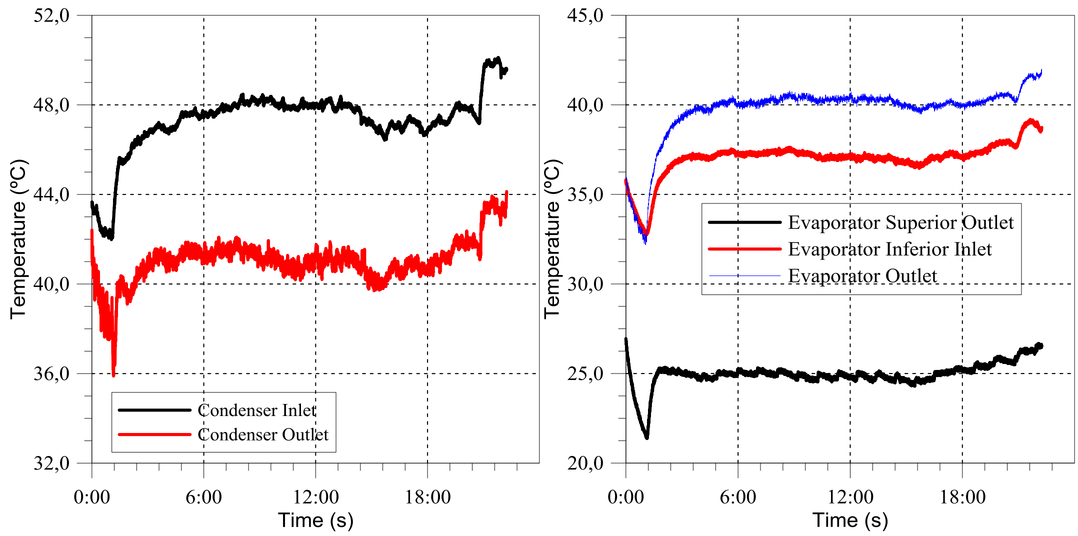


Figure 3. Inlet and outlet generator temperatures and relativity humidity.

The figures 4 to 13, demonstrate the results obtained in the experiment, the refrigerator were tested for the average ambient temperatures of 18ºC and 26ºC.



Figures 4 and 5. Ambient and Generator temperatures



Figures 6 and 7. Condenser and Evaporator temperatures

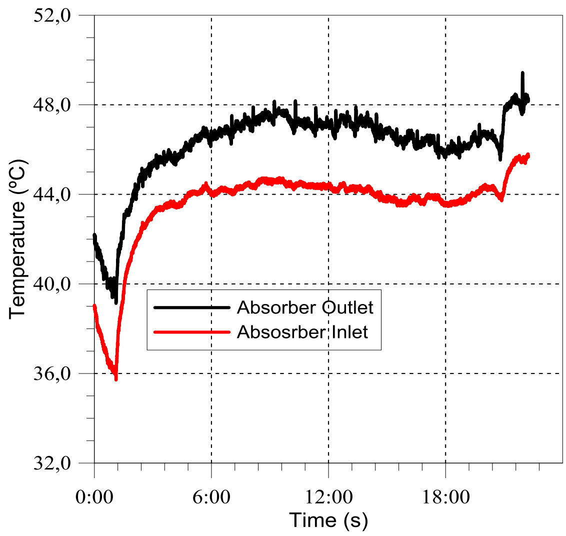


Figure 8. Absorber temperatures

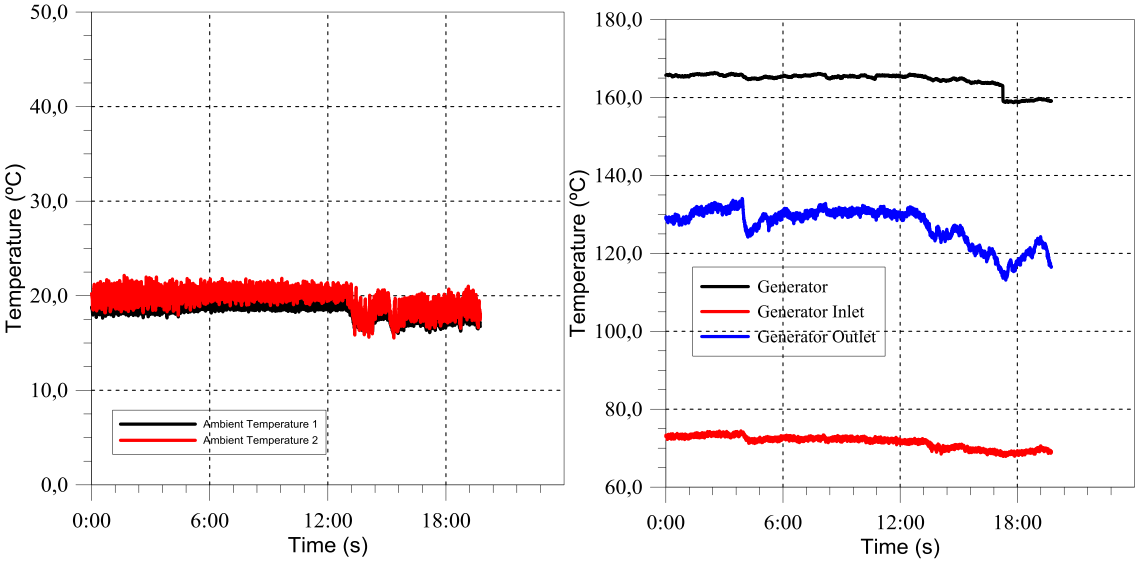


Figure 9 and 10. Ambient and Generator temperatures

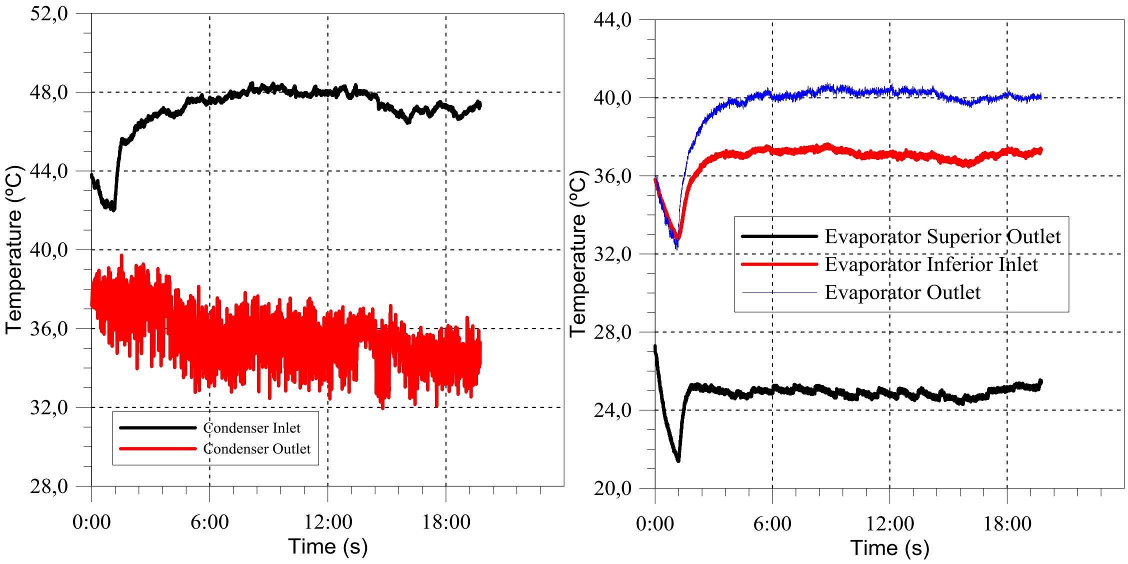


Figure 11 and 12. Condenser and Evaporator temperatures

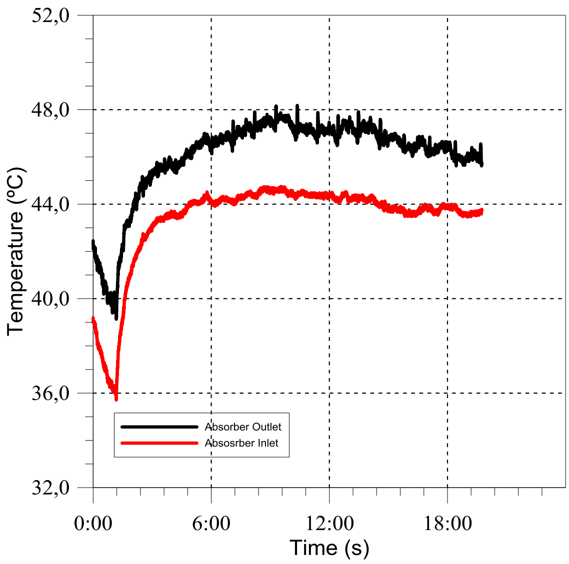


Figure 13 – Absorber Temperatures

Figure 14 Shows the comparative of the COP for both the 18ºC ambient temperature and 26ºC ambient temperature.

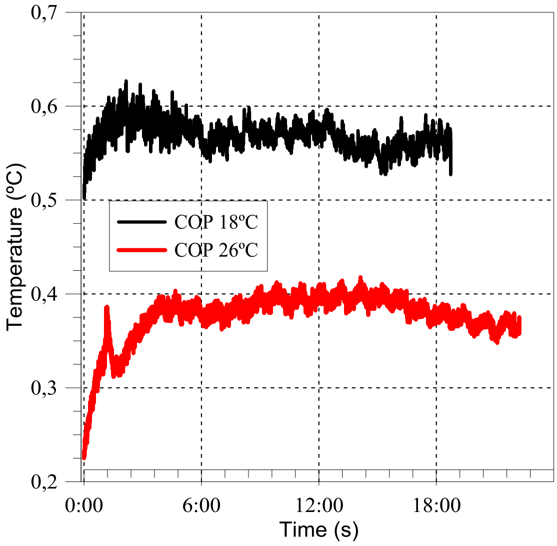


Figure 14. Comparative COP's.

The COP were calculated based on equation 3, and it was found the average COP of 0,50 for the ambient temperature of 18ºC, and for the ambient temperature of 26ºC the calculated average COP were 0,34, demonstrating that the ambient temperature affects the absorption refrigeration system COP, this happens because on the absorption refrigeration system, the absorber needs to reject heat to the environment, so, by the figures, it can be concluded that at lower ambient temperatures, the absorber rejects more heat, effect demonstrated by its lower temperature.

4. CONCLUSIONS

The results showed the importance of evaluating the changes caused to the COP by the variation of the ambient temperature. When the ambient temperature rises, there is a decrease in the COP due to the lower heat rejection rate of the absorber to the external medium and the condenser to the external medium. This decreases the amount of heat drawn from inside the refrigerator to the evaporator. The tests also showed that for a mixture of ammonia water the ideal working temperature of the generator is about 200°C, and that for an ambient temperature of 293 K, the internal temperature obtained in the refrigerator is about 265K.

5. ACKNOWLEDGMENTS

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7. RESPONSIBILITY NOTICE

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