THERMODYNAMIC HEAT WATER BY THE CONDENSER OF REFRIGERATOR

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ABSTRACT

The present innovation relates to the coupling of a refrigerator to a cumulus to heat water and this, thanks to the heat yielded to the level of the condenser of the refrigerating system even. The heating of water is carried out thus without energy over consumption. The quantity of heat transferred by the water-cooled condenser is sufficient to raise the temperature of this latter with 60 °C at the end of five hours. This can satisfy completely or partially the requirements out of hot water of a family which can distribute its requirements out of hot water all along the day and the week. The quantity of heat recovered by water to heat rises with four multiples the power consumption by the compressor. The system thus makes it possible to save energy and to safeguard the environment.

KEYWORDS Cooling, Condenser, heat exchanger, hot water, refrigerating circuit

NOMENCLATURE

cp	heat mass (J/°K kg)
COP	Coefficient of performance
h	Enthaplie (J)
Pcomp	Compressor power (W)
Qc	Heat condenser (J)
Qf	Heat evaporator (J)
m	Mass (kg)
t_{comp}	Functioning compressor duration (s)
Tc	Heating temperature (°C)
Tf	Cooling temperature (°C)
Wcomp	Compressor consumption , Wth (J)
ΔT	Temperature increase (°C)

INTRODUCTION

This research relates to a process to heat water by recovering the heat released on the level of the condenser of the cooling systems such as refrigerator, air-conditioner, cold room etc. The most system refuted is obviously the refrigerator that has more the share of the families in Tunisia and in the world.

Behind the refrigerator for example, an exchanger of heat is named condenser. It releases and dissipates, with the ambient air, the heat accumulated on the level of the evaporator and the compressor. We had the idea to recover this heat to heat domestic water if the need is

made feel, which is often the case such as in the kitchens, the restaurants, the barracks, hospitals etc.
In fact, one can note that in the refrigerating systems, it is the evaporator which is only used. In the heat pumps, it is rather the condenser which is only used. In fact, we learned how to use judiciously the two exchangers: evaporator and condenser simultaneously in another former energy system not quoted here; the total coefficient of performance of the system is thus increased to reach an unusual value.
Thus in the present innovation, the two exchangers are used effectively: the existing evaporator in the refrigerator is not touched, when with the condenser it is removed completely or partially and is replaced by another exchanger to heat water.
Knowing that the quantity of heat released on the level of the condenser is 3 to 4 times the electric power consumed by the compressor, and even with an operation discontinuous of the compressor (presence of thermostat), this energy is equivalent the useful energy delivered by two m² of solar collectors, which generally receives the solar water heaters installed. Therefore the coupling of the refrigerator to the water-heater can be only one success in the heating of water and the rise in its temperature to an acceptable threshold.
Conversely, in cold weather, water can not heat sufficiently; there can then be recourse to an electric supplement or gas; nevertheless our system could satisfy up to 90 % of the annual needs.
The device according to figure 6 gives its most preferential form. The outgoing hot gas of the compressor will yield its heat to the water of the cumulus to the place that is lost with the ambient air. It carries on then its way towards the pressure reducer followed by the evaporator and finally returns to the compressor to begin a new cycle.

The refrigerating systems are recognized effective to produce cold such is the case for the refrigerators, the air-conditioners, cold rooms etc. (Crazzini, 2001) On the other hand the heat pumps rather provide heat such as for example for the heating of the buildings, greenhouses, etc. However, there are heat pumps with compression or absorption used in systems of desalination and drying [Hawlader, 2006).
More close to our subject, there is water-heaters known as thermodynamic including a heat pump (fig.1) indeed making it possible to consume only one the third of the current in comparison with a traditional electric water-heater (Huang, 2008; Li, 2007; Chyng, 2003; Huang, 2001; Huang, 2005).
In other systems, the evaporator is connected to a solar collector sufficiently to raise the water temperature level to be heated.

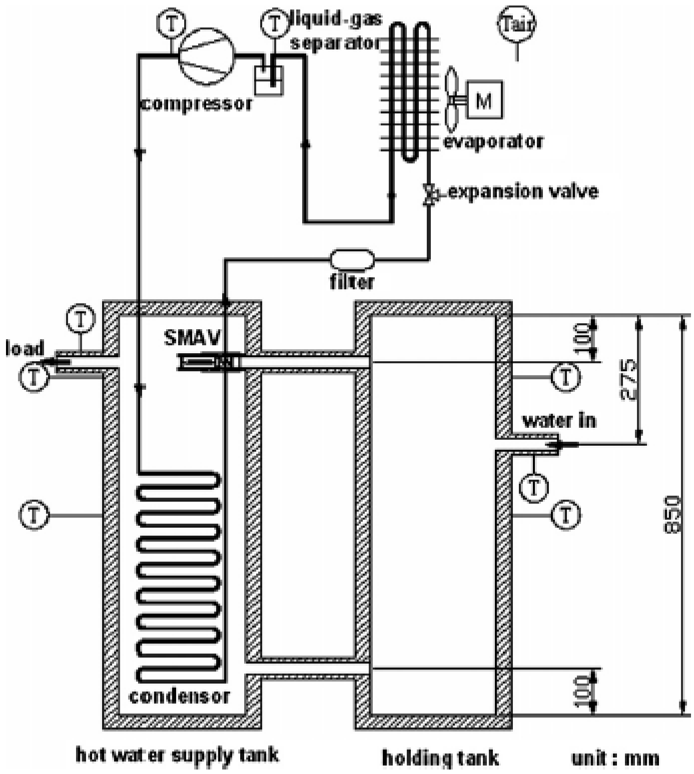

Figure 1. Schematic diagram of the FRHP. (Huang 2008)

In addition, another axis of our research consists in the solar desalination of sea water with which one coupled a refrigerating system where the two exchangers are used: the condenser to heat water at the same time as the sun and the evaporator to condense the produced water vapor and to form condensed it (Ben Slama, 2006 a-c, 2007 a-c).
However, we have recently found in the bibliography an application relating to the rational use of the two exchangers condenser and evaporator of the refrigerating machines which consists in cooling milk after the feature and the common production of the hot water used for washing milking accessory (Skrivan, 1984) and (Stinson, 1987)
In fact, the heat pumps are qualified by many people as being sources of renewable energies, since where they are used; the heat pumps are always effective. We try here to use a refrigerator doubly: to produce cold and heat simultaneously.

THEORETICAL STUDY

Operation life of the compressor Before entering this "adventure", and to leave on solid bases, with a calculated risk, we have measured the operating time of a refrigerator during 24 hours in March in Kasserine, Tunisia and deducted the quantity from heat loss by the condenser which one hopes to recover to heat water.

Operation life of the compressor (mn) The cumulated time of daily operation is 453 mn, that is to say an operation of the compressor during one the third of time.

By taking a COP of 3 (acceptable minimum for the heat pump) and a power of 120 W consumed by the compressor, the quantity of heat yielded by the condenser is:

$Q_c = COP.\, W_{comp}$ (1)
$= COP.\, P_{comp}.\, \sum t_{comp}$ 3 x 120 x 453 x 60 = 9785 kJ.

The quantity of water which one hopes to heat and raise his temperature of 25 °C for example is, by supposing that all the quantity of heat yielded by the condenser is received by water to heat:

$$Q_C = m_{water} \cdot C_p \, \Delta T \qquad (2)$$

$m_{water} = Q_C \;/\; (C_p \, \Delta T)$ = 9785 . 10^3/(4185 x 25) = 93 kg

As it is about a first prototype, that one must often move, one will limit this mass to 20 kg even if it means to multiply the use of the water-heater several times per day.

Enthalpic Diagram of freon

- *Hypothèses Assumptions*
  - ❖ the compression of fluid 1-2 (fig.2) is isentropic (not loss of heat)
  - ❖ there is no pressure loss in piping and the exchangers (the stages of condensation and evaporation are with p = cte, c.à.d. isobars)
  - ❖ expansion 4-5 is isenthalpe (H = cte) with H = m.h

One then represents this cycle idealized in a diagram (P,H) called diagram of Mollier

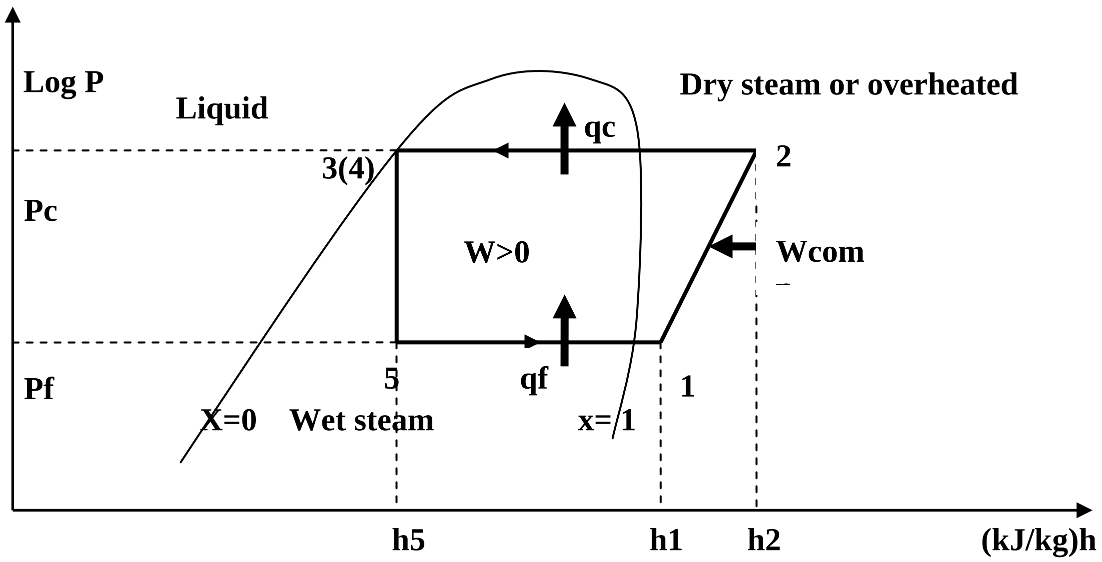

Figure 2. Theoretical Mollier Cycle

- **Energy assessment of the machine**

Under the terms of the first principle of thermodynamics, there is conservation of energy: c.à.d. that the quantity of heat rejected with the condenser (Qc) must be equal to extracted heat with the evaporator (Q_0) more work (W_{HT}) consumed to make turn the compressor.

From where the equation:

$$\mathbf{q_c = q_f + w_{th}} \quad (3)$$

This equation thus translates the energetic balance of the idealized refrigerator machine.
The choice of scale in X-coordinate (enthalpy H in kJ/kg) is very practical for the quantitative exploitation of the cycle of Mollier, because it makes it possible to read directly energies Hi at various items i (1, 2, 3,4) of the cycle of the machine.

One thus checks the first principle on the scale in X-coordinate, because it is noted that:

- quantity of heat released with the condenser: $\mathbf{q_c = h_2 - h_4}$
- quantity of cold produced with the evaporator: $\mathbf{q_f = h_1 - h_5}$
- work spend to the evaporator : $\mathbf{w_{th} = h_2 - h_1}$

And consequently, the relation (4) is well checked:

$$h_2 - h_4 = (h_1 - h_5) + (h_2 - h_1) = h_2 - h_4 \text{ (because } h_4 = h_5) \quad (4)$$

- **Coefficient of performance COP**

In diathermy machines DT (FM and HP), one replaces the term of output of the machine by his coefficient of performance (COP), because the efficiency would be superior to one (Kelvin' Paradox).

The COP of the machine refrigerator H $_F$ is defined by the following relation:

$$COP = \frac{produced\ cold}{provided\ work} = \frac{Qf}{W} \quad (5)$$

However, $\mathbf{q_c = q_f + w_{th}}$ (first principle of thermodynamics) (fig.3).

$$\frac{q_f}{W} = \frac{h1 - h5}{h2 - h1} \quad (6)$$

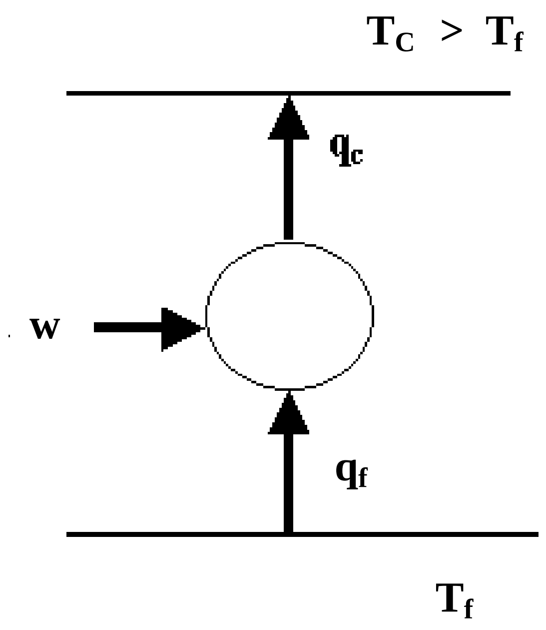

Figure 3. Schema of the machine MF

It is noted then, that COP **> 1** (because $T_c > T_f$). In practice, the COP **= 3 to 5.**

Consequently, we extract more calories with the cold source T_F than that of energy-work provided to the engine: this explains the advantage of DT machines for the buildings and houses heating and air-conditioning.

EXPERIMENTAL STUDY

Prototype

The made modifications are thus the removal of the current condenser, the removal of the condenser and its replacement by a spiral exchanger immersed in water to heat as the following diagram of figure 4 indicates it.

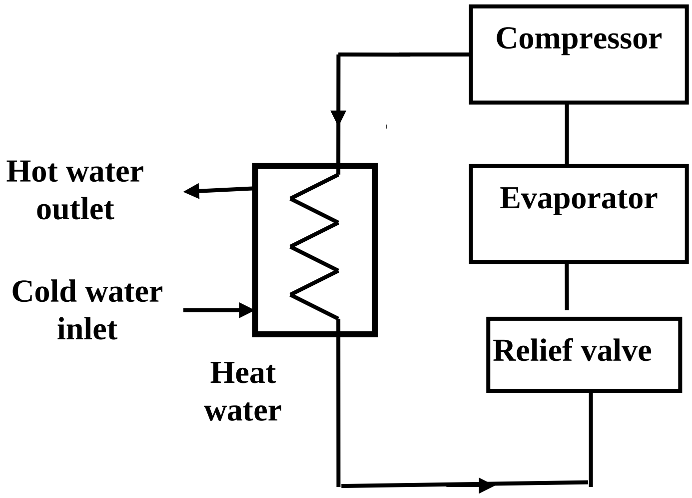

Figure 4. Diagram of the modified refrigerating circuit to heat water

As for with the built cylindrical tank, it is out of sheet stainless, insulated by glass wool from conductivity λ = 0.03 W/m²/°C and covered outside by a very thin sheet stainless jacket. Figure 5 shows the assembly and the connection of the water-heater with the refrigerator.

Figure 5. General sight of the refrigerator coupling coupled with heating water

EXPERIMENTAL RESULTS

Measurements related mainly to the level of temperature of water to the exit of heating water, the ambient one of the room and the interior of the refrigerator, the operating time of the compressor. We deduced the two thermal and refrigerating COP.
Figure 6 shows, that on the basis of the rest, the temperatures evolve to be stabilized to 60 °C for the water, -7 °C inside the refrigerator and 28 °C for the ambient one which is located at approximately the average, and this in the absence of use of hot water.

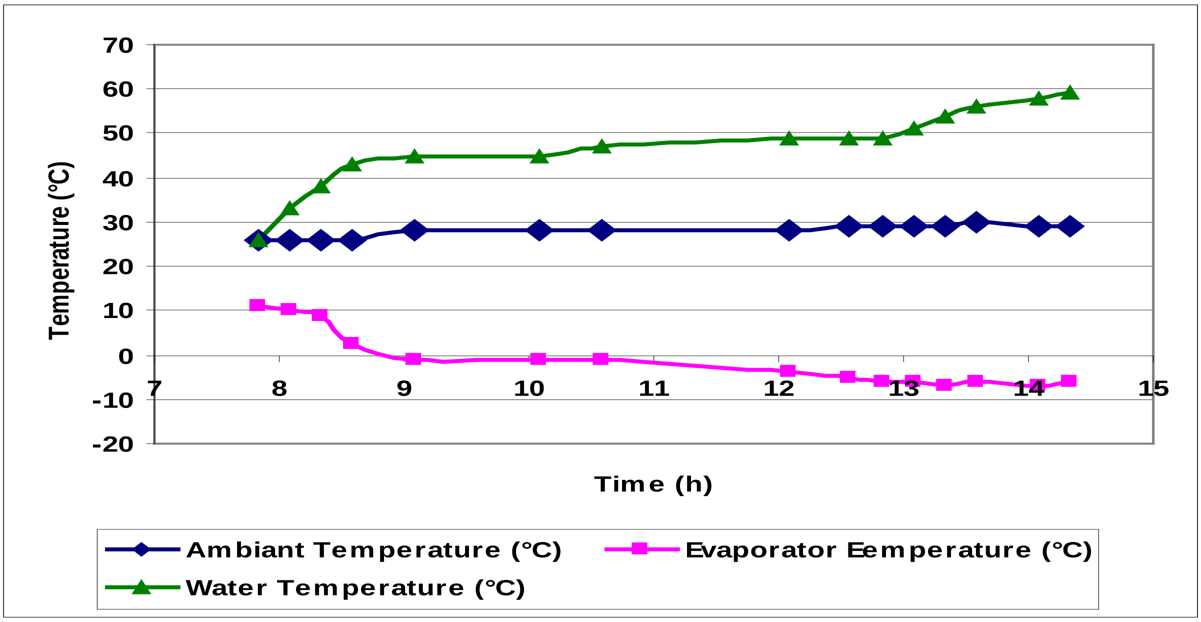

Figure 6. Change of the interior, ambient and water to be heated temperatures

We measured also the high and low pressures which are stabilized with 15 bars and 0,1 bar respectively. These pressures can further increase if water heats more; for this reason it is necessary to use water to cool gas and to reduce its pressure.

On figure 7, we show the thermal and refrigerating coefficients of performances evolution in transitory and permanent modes. The first mode, which lasts five hour, causes a drop in the COP from 20 to 7, because the variation in temperature between the two sources of heat (hot and cold) narrowed with time.
In permanent mode, the COP has usually recorded values.

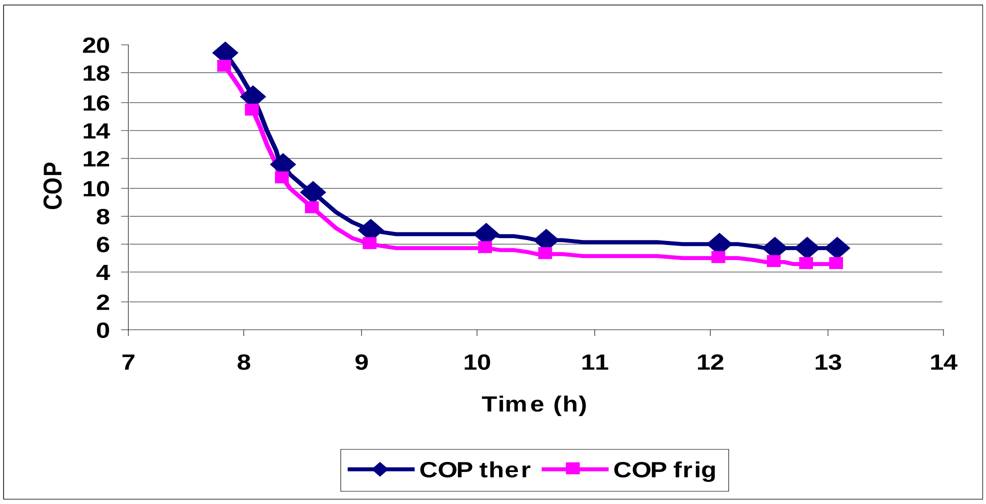

Figure 7. Evolution of the refrigerating and thermal COP vs the hour

Economic Interest

Heat water without supplement of energy enters within the framework of what is lately called " production of négawatts " belonging to the economies and of control of energy and of the rational use of energy.

According to our Agency of Control of Energy, the water-heaters in Tunisia consume two gas bottles monthly, that is to say 15 dinars Tunisian TND (1USS = 1.2 TND). For one year (ten months of heating), the cost of heating is of 150 TND. This is of the same order of magnitude as the price of the cumulus to be installed with the refrigerator. The time of return of the investment is approximately a year. Moreover, there is possibility of taking again the instruction of the gas bottle (either 50 TND of economy).

If, according to the Tunisian Minister for the economy, the real price of the load of a gas bottle rises with 20 TND, then the profit is 400 million TND annually.

Also, there is no more risk of asphyxiation by gas and its combustion.

Its use in the world would make it possible to save 400 Mtoe and to avoid emitting in the atmosphere a billion ton of CO2

Indeed for six billion individuals forming a billion families in the world. On average world 0.4 toe /family, is 400 Mtoe for the world.

At this, is added the applications in the tertiary sector (hotels, hospital, restaurants, deposits of conservations, refrigerators of tradesmen of food...), that is to say practically the double: consumption of 800 Mtoe /year and emission of 2000 Mt CO2.

CONCLUSIONS

Coupling of the refrigerator to a cumulus to heat water is proved a successful operation. Indeed, the temperature of water reached 60 °C and could be more if the system was not put dead voltage during the night by security measure. Thus the refrigerating machine is used doubly. As the refrigerating COP is of 3 and the thermal COP is of 4, we deduced that the total COP is of 7, which proceeded it very distinguished energetically speaking. It is thus awaited that this system could render a great service to the humanity from the point of view energy saving, fight against pollution and the accidents of the asphyxiations by the gaz water-heaters which cause many victims each year.

The addition of a regenerator of heat on the level of the condenser and evaporator will increase more the performances.

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