International Journal of Applied
and Natural Sciences (IJANS)
ISSN(P): 2319-4014; ISSN(E): 2319-4022
Vol. 7, Issue 6, Oct – Nov 2018; 1-8

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

STUDY OF THE ENERGY BEHAVIOR OF DIFFERENT REFRIGERANTS: ENERGY COST AND ENVIRONMENTAL IMPACT

G. Bop D. Sow

Research Scholar, Department of Chemical Engineering and Applied Biology,

Ecole Superior Polytechnique, Dakar-Fann, Senegal, West Africa

ABSTRACT

This study comes within the framework of the energy savings policy initiated by our statements from the surge in oil prices seen in recent years. In this article, we want to show that there is a compromise in the substitution of old refrigerants such as R12, which has the particularity to have a low compression ratio and a low-pressure condensation, which explains its low energy consumption compared the other refrigerants. This gas can present energy savings in the order of 20 to 40% compared to those counterparts.

KEYWORDS: *Refrigerant, R12, R134a, R22, R404A, Compression Ratio, Condensation Pressure, GWP*

Article History

***Received:* 05 Sep 2018 | *Revised:* 12 Sep 2018 | *Accepted:* 20 Sep 2018**

INTRODUCTION

The production of cold [1] is intended to remove heat entering a cold room by the exchange on the surface of a cold battery. Today, the cold battery is the evaporator of a compression refrigeration machine. In the evaporator circulates a fluid, said refrigerant, which changes from the liquid state to the vapor state at a sufficiently low temperature and pressure (temperature and evaporation pressure) to maintain the temperature of the cold chamber to the desired value. The vapor of the refrigerant is compressed by a compressor of the evaporation pressure at a so-called condensation pressure to which the condensation temperature corresponds. This temperature is high enough that the heat, taken by the evaporator, is rejected to the natural environment (water or air) and for the fluid to re-liquefies in a second exchanger called the condenser. The fluid condensed at the condensing pressure is expanded to the evaporation pressure by a valve called a pressure reducer. system [2] for producing refrigeration consisting of the evaporator, the expansion valve, the compressor, the condenser, etc. is only a mechanical unit whose role is to facilitate the change of state of the refrigerant, which has the effect of absorbing heat to the evaporator and rejecting it to the condenser. It is the refrigerant that accomplishes the heat transfer. The term "refrigerants" refers to readily liquefiable chemical compounds whose physical state changes are used as a source of cold production (release of latent heat of vaporization). There are a lot of refrigerants, we cannot list them all. Among them, a certain number have been or are used by the refrigeration industry, others are used only for the production of cold at low temperatures in petro chemistry in particular, and more particularly for the liquefaction of combustible gases such as methane ; the rectification of by-products of the oil industry, or the industrial manufacture of gases (especially chlorine), this is the case of light hydrocarbons such as methane, ethylene, propane which, themselves oil, are used as refrigerants despite their high flammability. The refrigeration cycle described by a simple compression refrigeration machine is shown in figure 1.

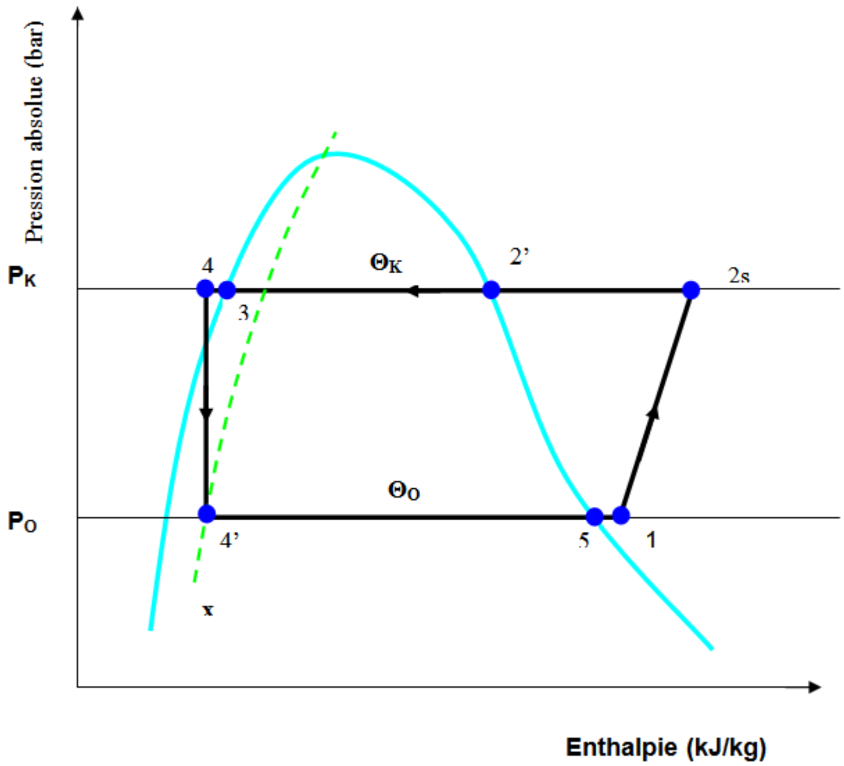

Figure 1: Refrigeration Cycle of a Single Compression Machine

The characteristics of the machine are:

- The Mass flow of refrigerant

$$q_m = \frac{\Phi o}{h_1 - h_4} \quad (1)$$

- Mechanical power to be supplied on the compressor shaft

$$P = q_m * (h_{2s} - h_1) * \frac{1}{\eta_i} * \frac{1}{\eta_m} \quad (2)$$

- Real performance coefficient

$$\varepsilon_r = \frac{\Phi_0}{P} = \frac{h_5 - h_4}{h_{2s} - h_1} * \eta_i * \eta_m \quad (3)$$

- ATheoretical coefficient of performance

$$\varepsilon_c = \frac{\theta_o}{\theta_k - \theta_o} \tag{4}$$

- Yield in relation to Carnot

$$\eta_c = \frac{\varepsilon_r}{\varepsilon_c} \tag{5}$$

The mechanical efficiency in general is taken equal to 0.9 and the yield indicated equal to the volumetric efficiency. The cooling capacity Φ_0 is the quantity of cold produced per unit of time.

MATERIALS AND METHODS

In this part, we studied the energy behavior of different refrigerants. To do this, we cooled 16 liters of water at 27°C contained in an insulated vase to a temperature of 5°C.

The machine consists of a serpentine evaporator immersed in a vessel containing water at 27°C, a hermetic piston compressor, an air condenser (forced convection), a manual pressure regulator, a temperature selector with five probes (T_1 to T_5) and two pressure gauges: high pressure (P_K) and low pressure (P_0).

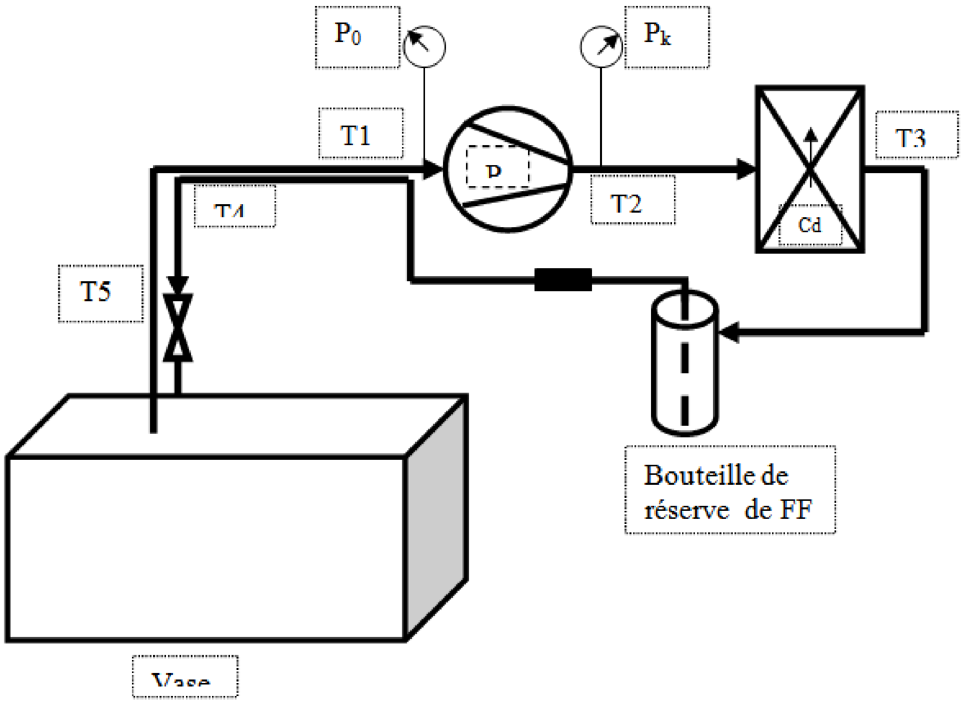

Figure 2: Liquid Cooler Machine

In this study the cooling capacity of the compressor is given by the following relation:

$$\Phi o = m.C.\Delta\theta/\Delta t \text{ (kW)} \tag{6}$$

with: m: mass of the liquid in kg

C: specific heat of the liquid in kJ/kg.K

$\Delta\theta$: the temperature difference between the initial and final states of the liquid

Δt: the running time of the machine in the second

The liquid used is water, its specific heat is 4.185 kJ/kg.K.

RESULTS AND DISCUSSIONS

The results obtained allowed us to draw the different curves illustrating the temperature decrease during the cooling of the water. In the vicinity of 8°C, we notice an abnormal dilation of the water because it has in the interval [8°C, 4°C] a maximum density [3], which explains the slight deformation of the lines in this zone. We also note that the refrigerant 22 allows a faster temperature decrease than the other refrigerants, which can also be explained by its latent heat of vaporization at the very high atmospheric pressure compared to its counterparts which are the R12, R134a and the R404A. Figure 3 below illustrates the behavior of refrigerants with respect to R22 from an thermodynamic point of view.

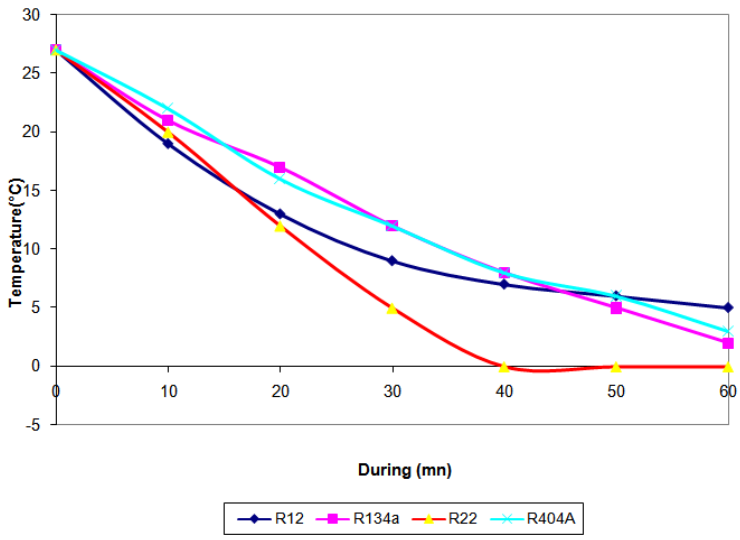

Figure 3: Evolution of the Water Temperature for Different Refrigerants

Comparing also their volumetric refrigeration production, we see a clear predominance of R22 as shown in figure 4; the refrigerant production of the other refrigerants remaining substantially equal.

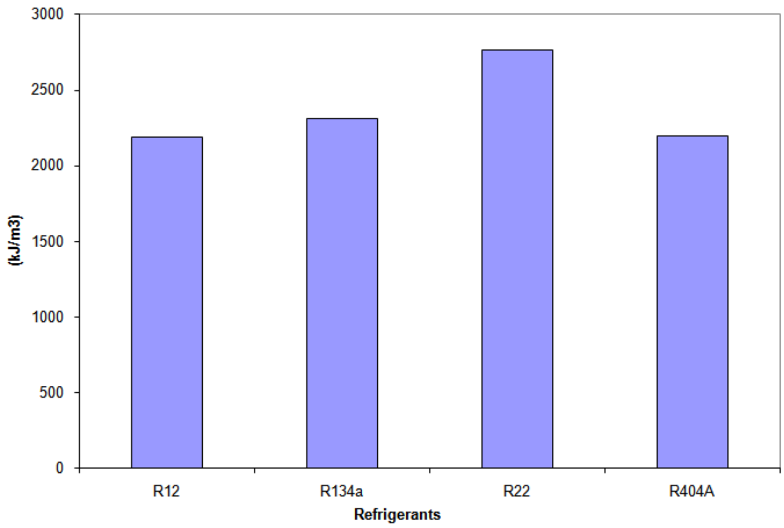

Figure 4: Volumetric Refrigeration Production

From a thermodynamic point of view, the refrigerant 22 has the particularity of being the best refrigerant previously used in the domestic cold. It has a very large cooling capacity, unlike the others. The only disadvantages it shows is its energy consumption and its impact on the environment (destruction of the ozone layer, greenhouse effect).

As for refrigerant 12, it has a low energy consumption due to its relatively low compression ratio and condensation pressure in the appliances in which it is used, but its impact on the environment has been much criticized in recent years [4]. It has an energy saving advantage of the order of 30% to 43% compared to its substitute R134a as shown in Figure 5.

As for the R404A substitute R22, it has a low cooling capacity and extended operating time, but it has the advantage of not requiring a high energy demand for its use in refrigeration systems.

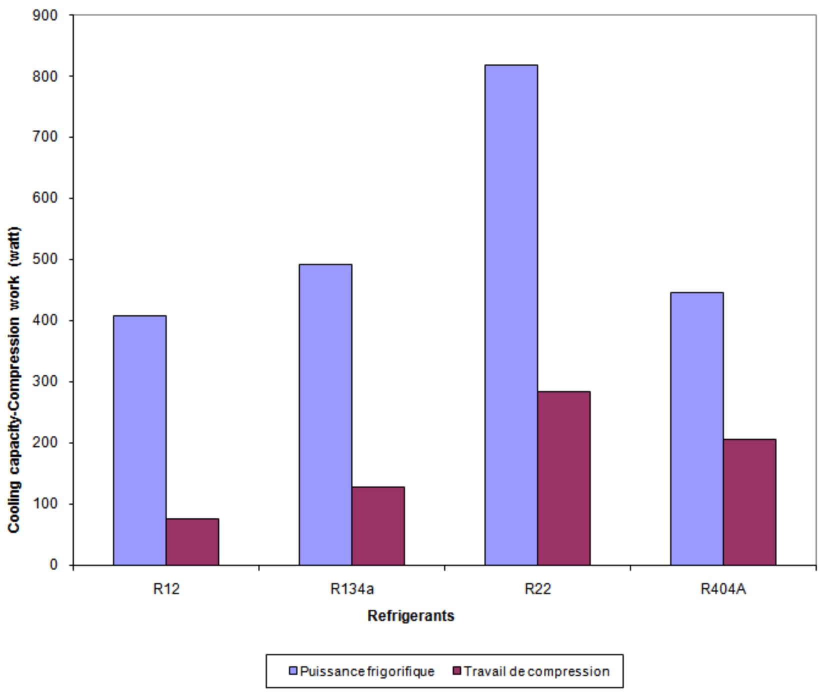

Figure 5: Evolution of the Cooling Capacity and Compression Work

Table 1: Comparative Characteristics of Refrigerants

Refrigerants	R12	R134a	R22	R404A
Adiabatic compression coefficient (γ) at30°C	1,138	1,17	1,177	1,333
Condensation pressure (bar)	8,8	12	19	20
Discharge temperature (°C)	53	59	80	88
Compression ratio	2,8	4,1	4,5	5,5
Compression work τ_{ra}(W)	75	128	283	206
Cooling capacity Φ_0(W)	409	491	818	446
Volumetric refrigeration production(kJ/m^3)	2.191	2.316	2.773	2.200
Volumetric yield	0,86	0,79	0,77	0,72
Actual volume flow (dm^3/s)	0,184	0,213	0,297	0,203
Energy consumption (Wh)	75	107	142	189
Yield(%)	72	65	57	49

The study of the discharge temperatures corresponding to each refrigerant (Figure 6) and taking into account the different adiabatic coefficients shows that the higher the adiabatic compression coefficient moves away from 1, the higher the temperature of the discharged vapors. This explains the high compression overheating for R404A and R22. The pressure limit in a refrigerating machine is of the order of 20 bar beyond this pressure, the installation presents the risk of explosion. It should also be noted that the higher the discharge temperatures, the lower the lubrication quality because of the viscosity of the lubricating oil decreases. This reduction leads to a decrease in the volumetric efficiency of the compressor and promotes the rapid aging of the mechanical member which is the compressor.

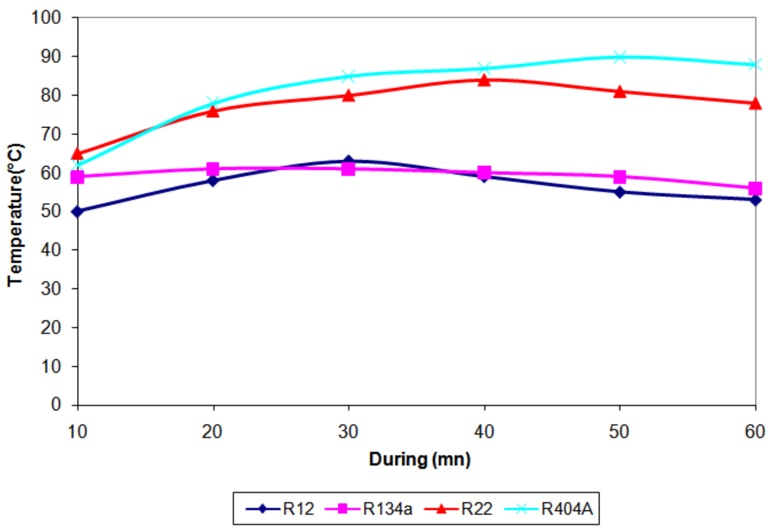

Figure 6: Evolution of the Temperature of the Discharged Vapors

Table 2: Impact on the Environment and Availability

Réfrigérants	R12	R22	R134a	R404A	R744
State	pure	pure	pure	mixture	Pure
GWP(100a)CO_2=1	8.500	1.700	1.300	3.260	1
Flammability	no	no	no	no	No
Cost per kg(FCFA)	6.000	3.000	6.000	12.000	400
Relative cost R22 = 1	2	1	2	4	0,1
Availability	high	high	average	low	Average
Destruction of the ozone layer	1	0,05	0	0	0
Toxicity	no	no	no	no	Yes

CONCLUSIONS

The replacement of R12 by R134a is justified because it has the advantages of having a higher volumetric refrigeration output, an acceptable compression ratio, neighboring discharge temperatures and a low degree of environmental impact. However, it is quite interesting to replace the R12 devices with R134a, it is simply enough to drain the oil contained in the compressor and replace it with a synthetic oil especially polyol esters.

The increase in efficiency through the use of special compressors for R134a would be of great interest. The energy consumption difference of 43% could be offset by the use of suitable machinery and appropriate cooling capacity. Underutilization decreases the efficiency of the machine. In air conditioning, the replacement of the R22 by the R134a would be of great interest and would save a lot of energy when we know that the energy consumption in our countries is due to 60% air conditioning and conditioning air [5]. As energy control is a crucial issue for developing countries, it is clear that R12 will remain and remain for a long time the most used refrigerants in home appliances. Notwithstanding its destructive effect of the ozone layer, it has the particularity of being of lower cost, increased availability and very low energy consumption.

Its very low discharge pressures and repressed vapor temperatures, as well as its low compression ratio, generally less than 3, give it the property of requiring only weak compression work, thereby reducing energy consumption in households. However, it is being replaced by R134a, which has similar characteristics from an energy point of view and presents the opportunity to have no action on the ozone layer. But this fluid is also a greenhouse gas and consumes 43% more energy than R12.

Moreover, car air conditioning does not generate any billing, it is strongly recommended to use the R134a in these air conditioning systems. Indeed, the replacement of R22 by R134a in central and individual air conditioning systems is strongly recommended and would allow a saving of energy of about 32%. The compression work required by an R22 system is much greater than that of R134a, this is explained by the very high discharge pressures for R22. Finally, in the industrial cold, the substitution of R22 by R404A is strongly recommended because the latter has no destructive action on the ozone layer although requiring more energy. Note that the R717 which is not studied in our work occupies an important place in the industrial cold, but its toxicity makes that it must be handled by qualified personnel aware of the danger which it can generate. The substitution of R12 in the domestic cold is today a compromise between developed and developing countries because it is known that for a long time, more than 2/3 of the gas emanations of PAO and GHG come from industrialized countries [6] [7]. The energy saving policy of emerging countries goes against the overconsumption that would result from such an energy substitution in our households. The debate remains open on this question, what fluid is used in the least developed countries? However, it is very difficult to define criteria of choice for a refrigerant but nevertheless we will keep some essential properties as for their use: - "Yield" and Refrigeration Production - Construction and type of compressor - Security, equipment and personnel - Supply - Environmental impact.

REFERENCES

1. *A. GAC, Manual of Cold Storage in Hot Developing Countries (1990) I.I.F / I.I.R (327p). [2] P. Rapin, P. Jacquard, Cold Form, Tenth Edition, ISBN: 2-10-002693-3, Dunod, Paris, 1996.*
2. *P. J. Rapin and P. Jacquard, Refrigeration Plants, Volume I (400p).*

3. *Babu, P. "TERNARY MIXTURES AS LONG TERM ALTERNATIVE REFRIGERANTS FOR R12 AND R134A–A REVIEW." Int. J. Res. Eng. Technol. 3.5 (2015): 9-16.*
4. *Co. S. T. I. C - EDF, Technical Guide for Individual Air Conditioning (1997) Air Conditioning and Development.*
5. *PRISME (Control of Energy in Buildings, YAOUNDE Act: May 10 to June 4, 1993).*
6. *D. Clodic, L. Palandre, Refrigerant Emissions Inventories for 2002, MAD ISSN Cool Tool No. 1287-4574, 44, 2002, 38-46.*
7. *J. T. McMullan, Refrigeration and the environment issues and strategies for the future, International Journal of Refrigeration, 2002, 25, 89-99.*