HAUTE ECOLE DE NAMUR-LIÈGE-LUXEMBOURG

DEPARTEMENT INGENIEUR INDUSTRIEL

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THESIS

Summary

Technical and economic optima of cold rooms based on their refrigerating fluid.

Academic Year
2017-2018

Paquet Lionel
110th Promotion

1. Introduction

1.1. Context

The C.H.U. of Liège ordered a new building. There are seven cold rooms in this one in order to keep at low temperatures several products like medicines, organs…

Refrigerating fluids which are used in that kind of rooms (HFC) are going to disappear before 2030 because of their impact on the environment. A policy of decrease of the production has been set in 2015. Thanks to this policy, the prices of the refrigerating fluids increased and new fluids are made to replace the HFC.

The point of this work is to compare the solutions for the cold rooms by looking at the financial and technical aspects to know which fluids to use for the cold rooms in the future.

1.2. Specifications

The student will have to look at the different applications and legislations about the refrigerating fluids.

Then, he will use what he learned to choose the right components for the cold rooms of the C.H.U. He will make the sizing by using several refrigerating fluids which are authorized by the standards and then he will compare the characteristics, the prices, the coefficient of performance and the frigorific cycles for all of these installations. This comparison has to be made for the two gases chosen by the customer (R134a and R449A) but also for the R290, R717, R744 and R1234yf. By using all the data he collected, the student will have to analyze which future is possible for the refrigerating fluids.

1.3. Interest for the company

The purpose of this work is to give to the company an idea of the most interesting refrigerating fluids for cold rooms depending of the temperature inside them. This work is also a way to discover the prices and the energy performances of the installations using other fluids that HFC.

2. Planning

This work has been done with a planning (figure 1) which is used to see what has been done yet and what has still to be done.

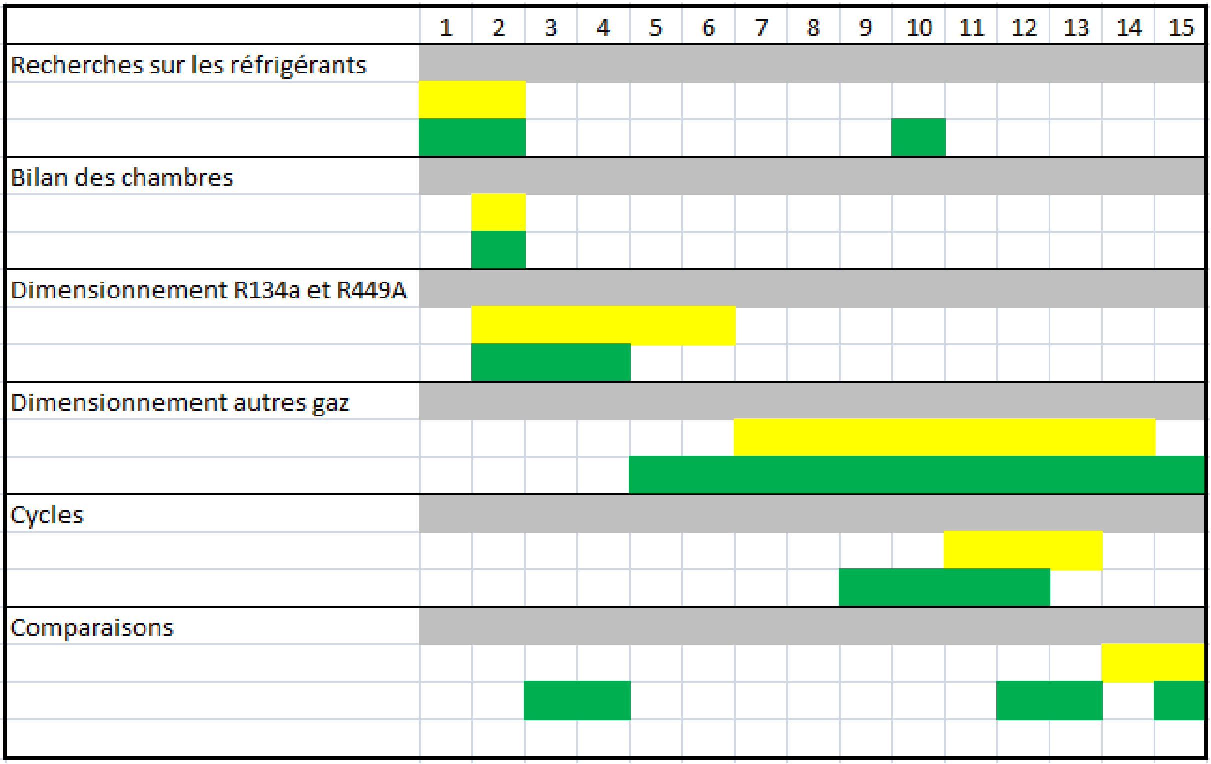

Figure 1 : planning

3. Refrigerating fluids

3.1. Presentation of the fluids

1) The halogenated hydrocarbons : they are set in four generations : the chlorofluorocarbons (CFC), the hydrochlorofluorocarbons (HCFC), the hydrofluorocarbons (HFC) and the hydrofluoroolefines (HFO). The two first generations have chlorine atoms and take part in the destruction of the ozone layer. A third generation without chlorine appeared. The problem of HFC is that they contribute to the global warming. The decision has been taken to decrease the use of these fluids (HFC) until their full destruction. The fourth generation has a global warming potential less high than HFC.

2) The hydrocarbons: these are organic compounds with only atoms of carbon and hydrogen (propane, butane…). They have good thermodynamic properties. The three main hydrocarbons uses as refrigerating fluids are the propane (R290), the butane (R600) and the isobutane (R600a). Nevertheless, these compounds are highly flammables so some security measures have to be taken to avoid any incident.

3) Inorganic fluids: Carbon dioxide and ammonia are used as refrigerating fluids. Their global warming potentials are respectively 1 and 0. This is quite few compared to the HFC. However, each one of them presents many problems. The ammonia is toxic and irritating and it corrodes zinc and copper and its alloys. Thanks to that, the pipes used have to be steel ones. Carbon dioxide has really high operating pressures and the compressors used with that fluid need a lot of electrical power. Moreover, the installations with ammonia or carbon dioxide are really expensive and difficult to size.

3.2. Interdictions

1) In 2020, it will be forbidden to put on the market installations for commercial refrigerating with a GWP>2500, which includes R404A (GWP=3922). Moreover, it will also be forbidden to use fluids with a GWP<2500 for the maintenance of refrigerating system with a quantity of fluid which is equivalent to 40 tons of carbon dioxide in term of global warming (this is more or less equal to 10 kg of R404A).
2) 2022 is the end of new installations with HFC because the higher GWP authorized for refrigerating system will become 150, which is lower than all the existing HFC.
3) The HCFC are supposed to completely disappear before 2030 in the developing world and before 2020 in the industrialized countries.

3.3. Evolution of the prices

Most of the refrigerating fluids are going to be forbidden in new installations before a long time. Because of this interdiction, the quantity of fluids put on the market decreases which means that their prices increases. The figure 2 shows the evolution of the prices for some fluids between December 2016 and March 2018.

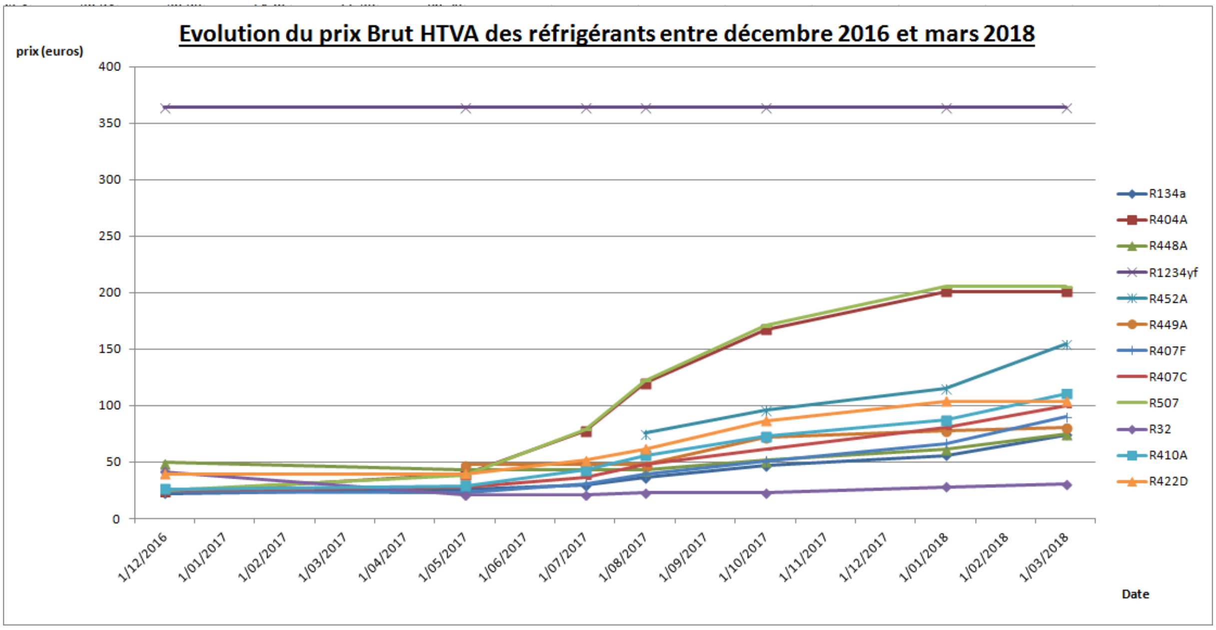

Figure 2 : evolution of the price of refrigerating fluids between December 2016 and March 2018

4. The cold rooms

They are rooms with a low temperature which enables to store some products like medicines, food… There are 2 kind of cold rooms :

- positive ones which have a temperature above 0°C ;
- negative ones which have a temperature under 0°C.

4.1. Principle of the refrigerating cycle

The production of cold works thanks to the principle of the refrigerating cycles. These cycles allow to cool a cold environment and to heat a warm environment by using mechanical energy.

These cycles are composed of 4 main steps (figure 3):

1) Evaporation [1-2]: the liquid from the expansion valve is at a temperature lower than the one of the room. The liquid will be heaten by the room and become a gas inside the evaporator. This operation enables to keep a low temperature in the room.
2) Compression [3-4]: after the evaporation, the fluid which is a gas arrives with a low pressure and a low temperature. The compressor anbles to increase the pressure of the gas by using mechanical energy.
3) Condensation [4-5]: the compressed gas goes into the condenser where it gives its heat to another fluid like air by example. While cooling, the fluid becomes liquid.

Indeed, because of its pressure which is higher than during the evaporation, the temperature of condensation is higher than the temperature while the evaporation.

4) Expansion [6-1]: while the expansion, the fluid, which is liquid is expanded. This operation enables to decrease the pressure of the fluid and by this way, to decrease its temperature of evaporation. It is the opposite of the compression.

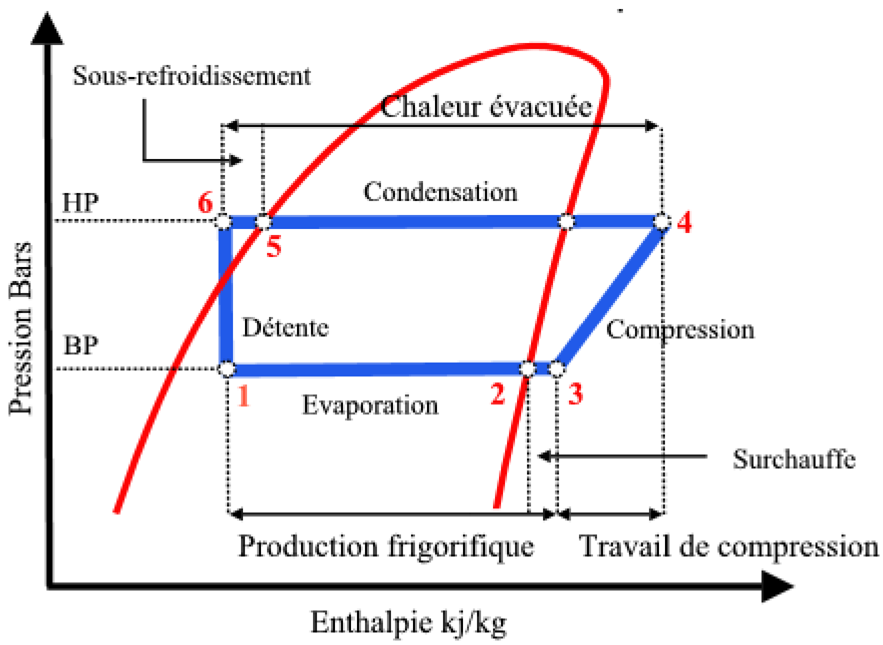

Figure 3 : refrigerating cycle [30]

4.2. Sizing

The sizing of a cold room is made through several steps. Indeed, the heat balance has to be done first to know the power needed to cool the room. Then, the compressor, the evaporator and the expansion valve are sized. Finally, the pipes are selected. In this work, sizing has been made with several fluids. The prices of each component of all the installations are used to compare them.

1) Heat balance :

It enables to know the power needed to cool the room in order to keep it at the wanted temperature. The heat balance is the addition of all the heat input inside the room. The temperatures, the dimensions and the power needed are in the tableau 1 for each one of the seven rooms studied. The balance is done thanks to the software cofriset UR which use the dimensions of the room, the type of cold room (positive or negative), the temperatures inside and outside the room and the material used for the isolation (roof, floor, walls) to find the power needed to cool the room. The kinds of products which are put in the room and their inlet temperature when we put them in the room are also used. The software sets the quantity of products thanks to the room's dimensions and then it shows the power needed every hour to cool the room. The compressor is working during 16 hours out of 24.

The heat balance is used for all the sizings, no matter the fluid used to cool the room.

	Température intérieure	Besoin frigorifique (W)	Dimensions (m)	Volume (m^3)
CF 1	4 °C	1897	4.5x2.4x2.1	22.7
CF 2	-20 °C	4151	2.7x2.4x2.1	13.6
CF 3	4 °C	1855	3.9x2.7x2.1	22.1
CF 4	-20 °C	4194	2.7x2.7x2.1	15.3
CF 5	4 °C	3053	4.8x4.5x2.1	45.4
CF 6	-20 °C	4238	4.8x1.5x2.1	15.1
CF 7	-30 °C	1398	1.2x1.5x2.1	3.8

Tableau 1 : characteristics of the rooms

2) <u>Compressor :</u>

The company is used to use Silensys compressors from Tecumseh. These compressors are quieter and more powerful than the others of Tecumseh. Moreover, they are cheap. These compressors have been chosen as much as possible but when Tecumseh didn't fit because of the power needed or because of the evaporating temperature or the chosen fluid, the compressors chosen were from Bitzer, Copeland or Frascold which are 3 big compressors' suppliers.

The sizings are made thanks to software like Tecumseh V4.4, Bitzer V6.8, FSS3 and Select 7.16.

3) <u>Evaporator :</u>

Evaporators are sized thanks to the online software « Kelvion RT select ». These are Küba's evaporator of the Market SP family because they are cheaper than others and the company is used to use them. Nevertheless, sometimes, the evaporators are chosen among the SG commercial and SG industrial families because the Market SP family doesn't fit to the application

4) The expansion valve:

The chosen expansion valves are thermal ones from Danfoss. They need a solenoid valve which is located between the expansion valve and the condenser and which control the quantity of fluid which goes through the expansion valve. That kind of valve is chosen by looking at the power needed to cold the room.

Each solenoid valve need a coil and each expansion valve need a stek connection FLSD.

Several refrigerating fluids need an electronic expansion valve. CCMT or AKV are the ones which are chosen in that kind of situation. These ones, unlike thermal expansion valves, don't need to be used with a solenoid valve.

The software Danfoss coolselector 2 is used for the sizing of the expansion valve, the solenoid valve and the pipes.

5. Paretto front

The Paretto front is composed by all the most appropriate refrigerating fluids according to the application (positive rooms, negative rooms or both) and to the ratio between the energy performances and the installations' prices.

5.1. Positive rooms

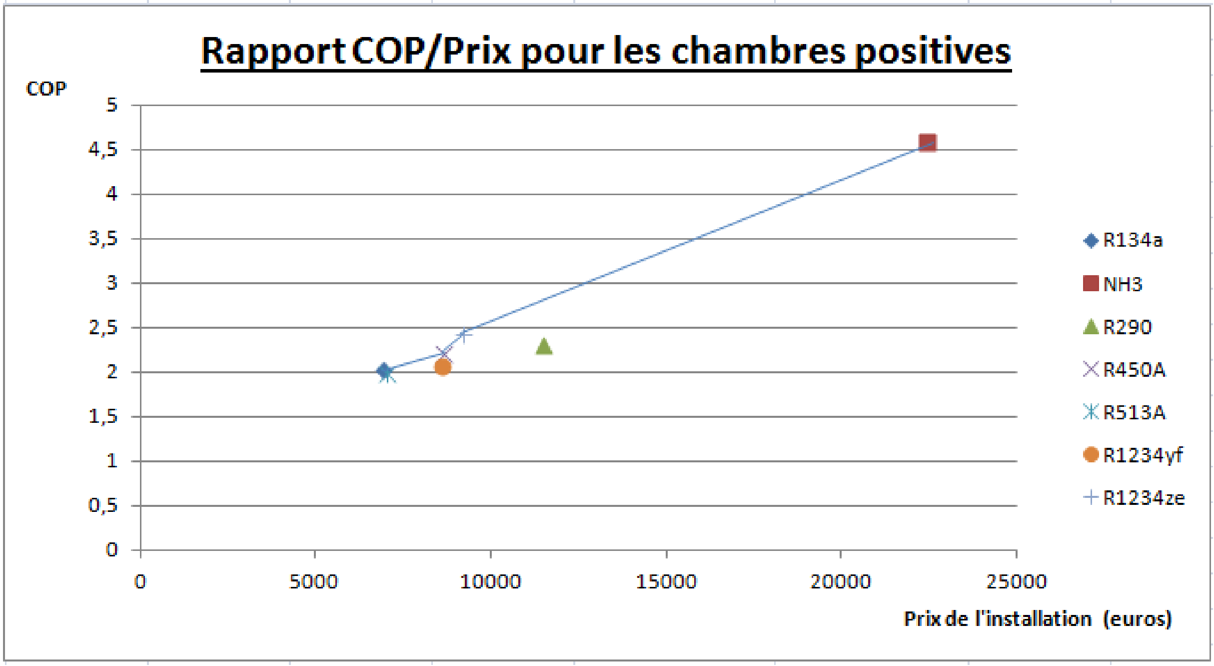

Figure 4 : Paretto front for an installation with only positive rooms

It is possible to see on the fourth figure that the solutions located on the Paretto front for the positive rooms are the R134a, the R450A, the R1234ze and ammonia.

5.2. Negative rooms

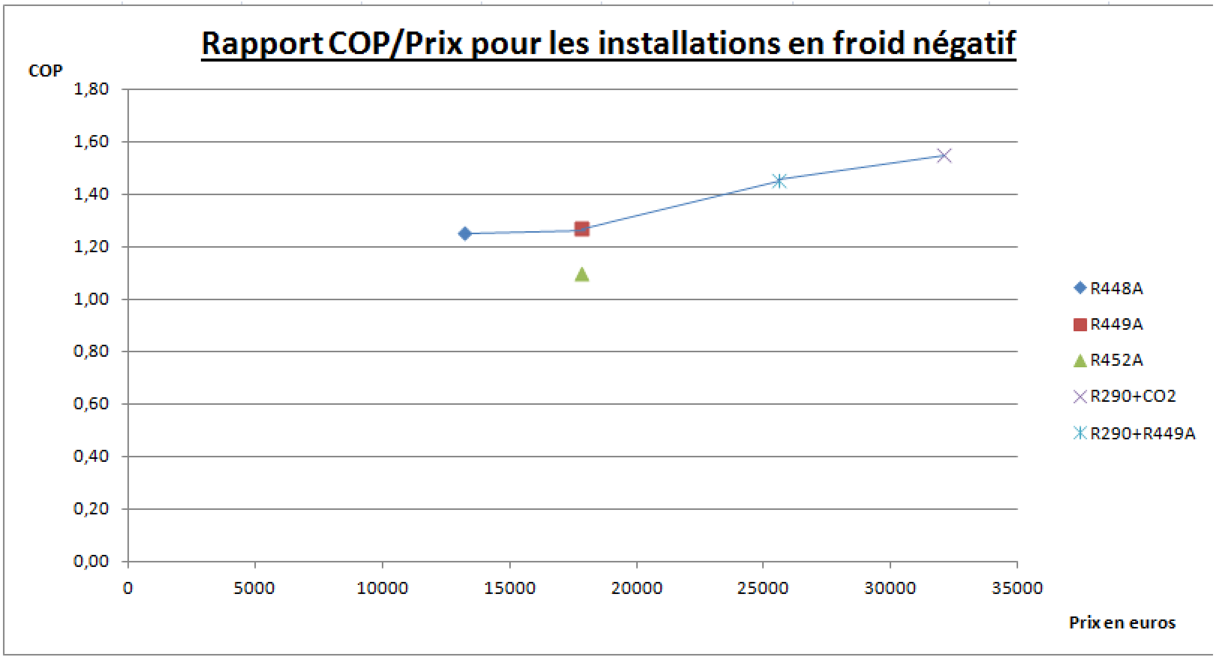

Figure 5 : Paretto front for an installation with only negative rooms

The fifth figure shows that the solutions located on the Paretto front for the negative rooms are the R448A, the R449A and the 2 installations with propane.

5.3. Installation with positive and negative rooms

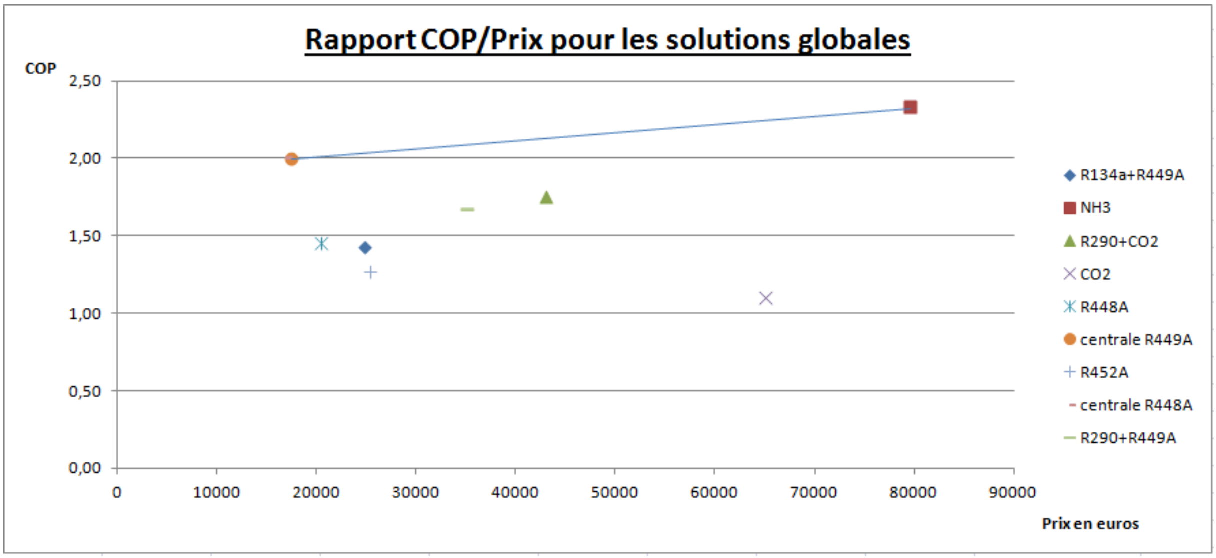

Figure 6 : Paretto front for an installation with negative and positive rooms

The R448A and R449A plant are, with the ammonia, the solutions shown by the Paretto front for the installations which have negative and positive cold rooms (figure 6).

6. Conclusion

In conclusion, we can notice that there are other fluids than HFC which are used. These alternatives are quite difficult to size but they will allow us to continue using cold rooms as we do.

The various comparisons show which refrigerating fluids are a good solution to size a frigorific installation. It is possible to see that for an installation with only positive cold rooms, the ammonia and the R1234ze are the most interesting long-term solutions. The R134a and the R450A are also good fluids in a short-term period. For installations with only negative cold rooms, the R448A and the R449A are good short-term solutions but in the future, the R290 is the best solution. However, this fluid can't produce cold for a room with a temperature of -30°C or less. For these applications, the ammonia or the carbon dioxide will have to be used. Finally, for an installation with positive and negative cold rooms R448A plants, R449A plants and ammonia are the more interested solutions if we look the COP/price ratio. It is important to know that ammonia is used for installations with a big frigorific power.

All the possibilities haven't been studied in this work. Indeed, the R717-R744 cascade, but also, the R744 and the R717 for the negative cold rooms and many others haven't been done. It could be an interesting thing to see if these possibilities have a good COP/price ratio.

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