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REFRIGERATION SYSTEMS AND HEAT PUMPS, OPTIMAL IN TERMS OF ENERGY AND FOR ENVIRONMENT PROTECTION, WITH NATURAL HEAT CARRIERS

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Abstract: Global warming is a huge challenge for the future, for all countries, so the global warming potential of refrigerants is a major issue. Natural refrigerants are already an efficient, cost-effective and safe solution in many applications in refrigeration and air conditioning, including in developing countries and warm countries, even if solutions must be adapted. They often require different equipment than « chemical » refrigerants (CFCs, HCFCs, HFCs) for technical and safety reasons. They should be better promoted for new equipment and the replacement of old equipment. They still require improvements, research and development in various applications and we are working on these improvements. Natural Refrigerants are a cost efficient alternative.

Key words: Refrigeration, Optimization, Environment Protection.

1. INTRODUCTION

The current scientific research, regarding refrigeration systems and heat pumps is mainly oriented in the following directions:

- Optimization in terms of energy;
- Use of appropriate heat carriers for environment protection;
- Execution of compact equipments to lead to the reduction of investments and use of small quantities of heat carrier.

Optimization in terms of energy is mainly focused towards the use of renewable energy sources (solar energy, geothermal energy, eolian energy). The use of solar energy in the production of cold – SOLAR COOLING, is one of the major concerns of researchers, among them being the members of TUCEB (Technical University of Civil Engineering Bucharest) Heat Engineering Chair. Refrigeration systems powered by solar energy are those with absorption and those with mechanical compression. The systems with absorption are those with Br.Li/Water, and also those with Ammonia/Water. An installation with absorption Br.Li-Water YAZAKI 17kW powered by solar energy has been mounted inside the laboratory of the Faculty of Building Services. The basic diagram of the installation is given in Figure 1.

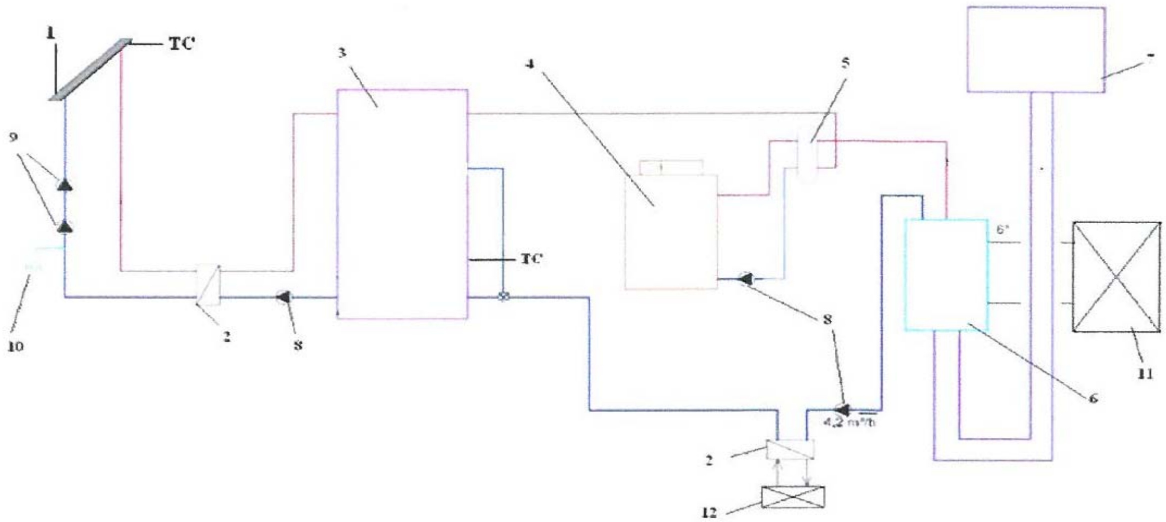

Fig. 1 Basic diagram of the solar cooling installation

Legend: 1 – flat solar collectors; 2 – plates heat exchanger; 3 – hot water storage tank; 4 – hot water boiler; 5 – distributor; 6 – absorption refrigeration machine Br-Li-water; 7 – cooling tower; 8 – recirculating pumps; 9 – pump hydraulic unit; 10 – automation system for operation of the hydraulic unit; 11 – chilled water consumer; 12 – hot water consumer; TC – temperature sensors.

The operation of the experimental system: the water heated by solar energy heats 4000 l water, stored in the system tank. In the water heating circuit, in the solar panels, an aqueous solution 10% ethylene glycol circulates. This solution transfers heat, inside the heat exchanger 2, to the water in the storage tank 3 (volume of 4000l). The temperature sensors (TC), mounted on the water circuit, solar heated, and on the storage tank give the signal to an automation system, whose role is to operate the pump hydraulic unit, as long as the water temperature in the tank is lower than the one measured at the output from the solar panels.

The hot water inside the tank is the heat source of the water vapour generator in the absorption refrigeration machine.

The system was designed bivalent so that, in case the water temperature inside the tank is lower than the one necessary in the vapour generator of the absorption machine, the hot water boiler 4 comes into operation.

The water having the necessary temperature for the generator is prepared in the distributor 5. The water temperature level at the output from the absorption machine is reduced inside a plate heat exchanger, 2. Its role is to reduce water temperature to around 30 – 350C, for efficient use of solar collectors.

The water cooled inside the refrigeration machine, with temperature around 60°C is directed to the cooling water collector, then to the air conditioning consumer.

The members, Prof. Florea Chiriac, Conf. Alexandru Serban and Prof. Ioan Boian proposed for the air-conditioning/ventilation of the rooms in the University Auditorium and for the New Campus, the Research Center of the University Transilvania in Brasov. In Figure no. 2 it is given the air-conditioning diagram of the Auditorium and the central Library, which consists of an absorption installation BrLi-Water powered by solar energy 90Kw and of a mechanical compression installation powered by electric energy generated by photovoltaic cells, having a refrigerating power of 60 Kw.

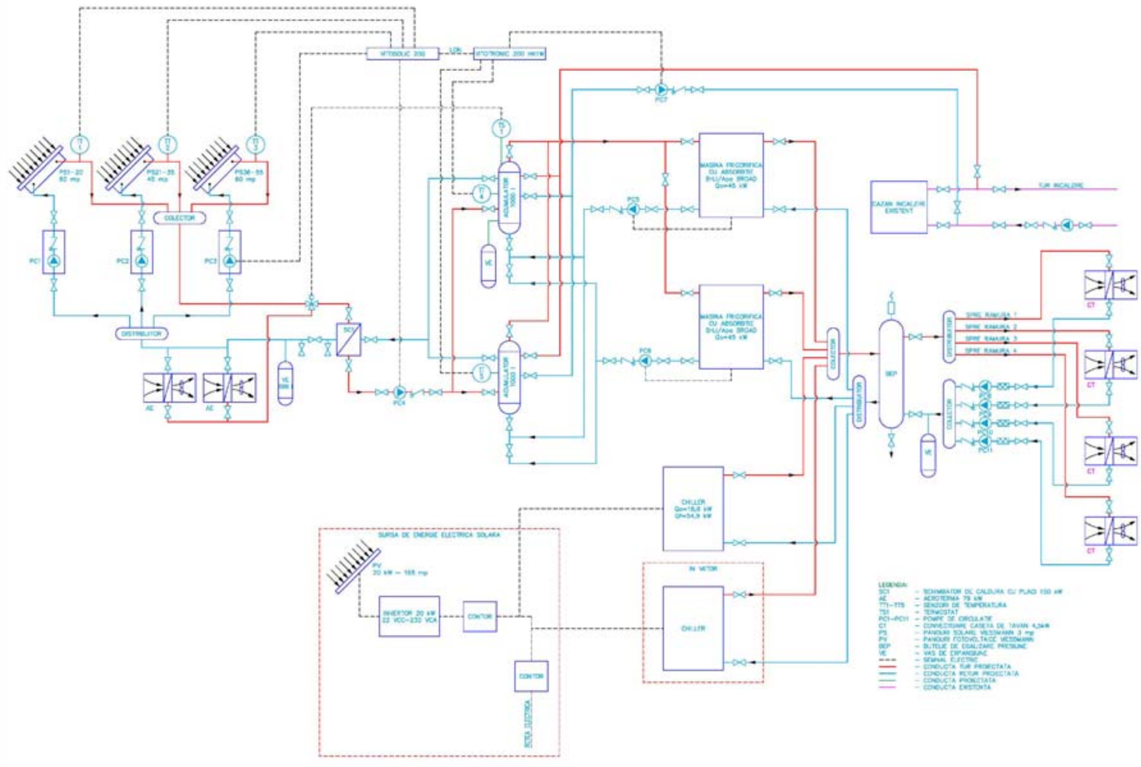

Fig. 2 The air-conditioning diagram of the Auditorium and the central Library

For the Research Center, the air-conditioning diagram given in Figure no. 3 was proposed, in summer there is SOLAR COOLING with absorption Br.Li-Water and in winter there is a Heat Pump with mechanical compression, having as heat source the soil and a water ring heated bivalent, solar – source of conventional power.

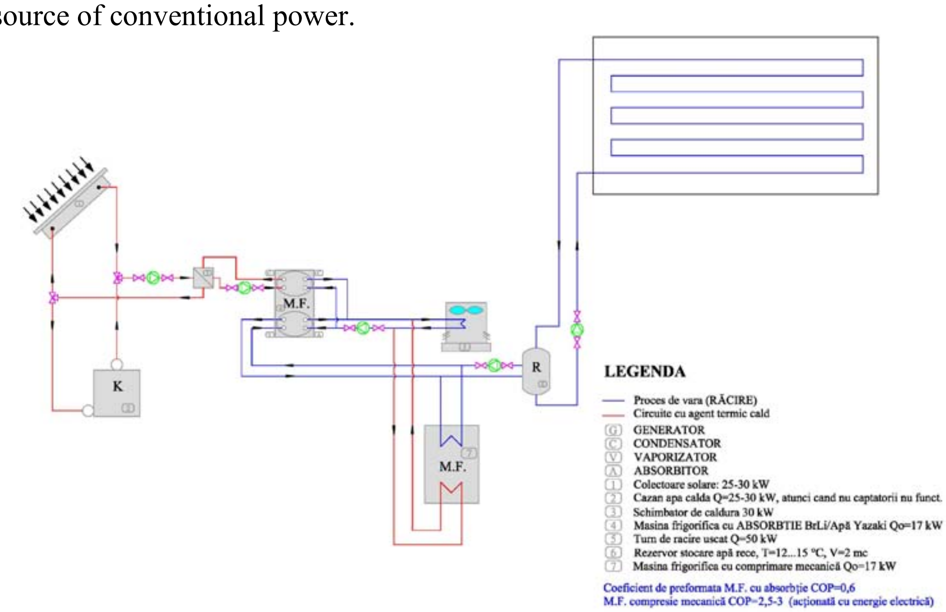

Fig. 3 Summer process

We also proposed SOLAR COOLING for the Ammonia-Water absorption system. In Figure no. 4, it is given the analysis and proposal of the Ammonia-water cooling system, at ARIZONA STATE UNIVERSITY in USA. Considering the climate characterized by high temperatures and low humidity, we analyzed the use limits of the systems with 1 compression stage and 2 compression stages.

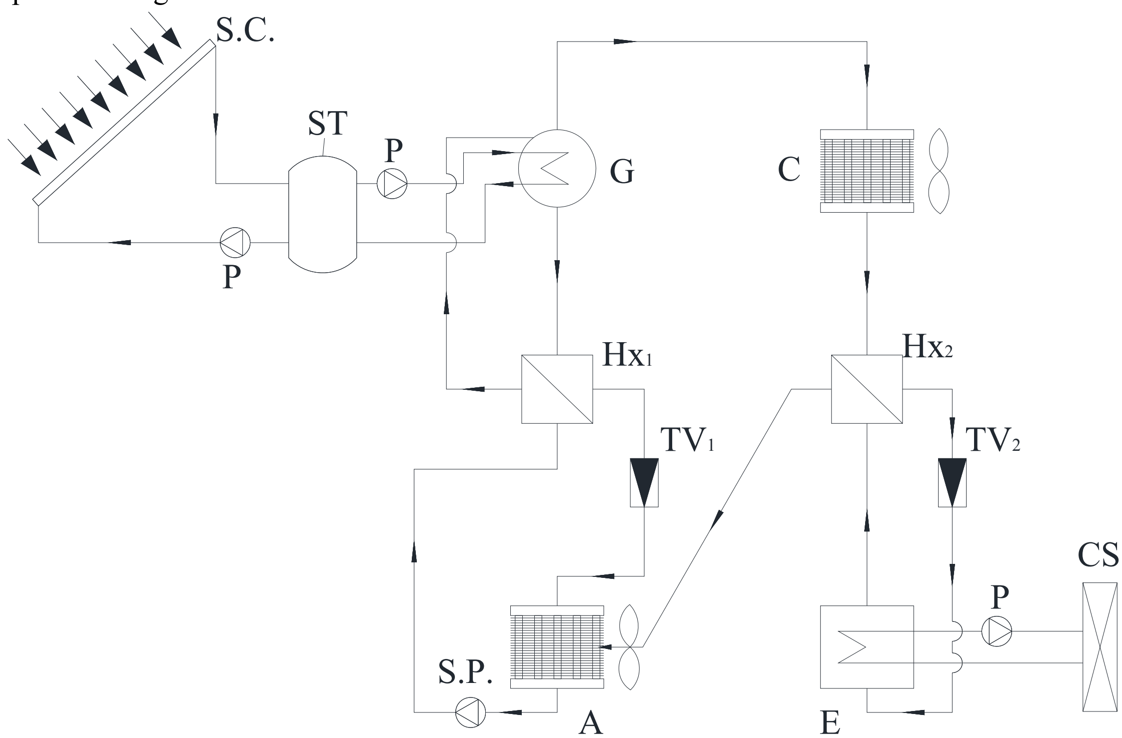

Fig. 4 Ammonia-water absorption Solar Cooling

2. ENVIRONMENT PROTECTION

Environment protection using natural heat carriers is another important concern of the worldwide scientific research. It is well known that after MONTREAL Protocol, the pollutant heat carriers HCFC category were removed and replaced with transition heat carriers HFC category. The index taken into account when analyzing heat carriers, is GWP (Global Warming Potential), which represents the contribution that the heat carrier has upon greenhouse effect, relative to CO_2 effect, which has GWP = 1. It is proven that HFC 134a (R134a) which could escape into the atmosphere is equivalent in terms of global warming with the effect produced by the exhaust gases of a car which would do 2.5 million miles.

Natural heat carriers are produced in the environment through biochemical processes: R717 (ammonia), R744 (CO_2), hydrocarbons used in refrigeration systems and heat pumps, water. The hydrocarbons used are the following: R600a (isobutane); R290 (propane), R1150 (ethylene), R1270 (propylene) and the mixtures of these substances. These natural heat carriers do not harm the ozone layer and their GWP is 0 (e.g. Ammonia), or they have negligeable values. Main fields for use of natural heat carriers:

*** Household refrigerators and freezers: in the next 10 years, 75% will use ISOBUTANE as refrigerant;**

*** Commercial cold:**

- in SPLIT systems, R-22 is replaced by R-134a and by R-404a; in future, hydrocarbons, ammonia and CO_2;

- indirect systems are used in centralized systems; R-22 is replaced by R-404a, R-134a, Ammonia, hydrocarbons and CO_2, R-32.

*** Cold transportation: Hydrocarbons and CO_2;**

*** High power refrigeration installations: Ammonia and where it is not possible, CO_2 is used.**

*** Air conditioning systems:**

- small equipment, R410a, R407C at present and with HFC-32 in future; hydrocarbons in systems with low loading;

- CHILLERS: for turbocompressors systems R-134a and HCFC-123 are still used; Ammonia in low and medium powered systems; hydrocarbons are rarely used; the use of CO_2 is recommended.

*** Air conditioning used in means of transportation, buses and trains: R-134a and CO_2; in future CO_2, R-152a and R-1234yf.**

The table below shows the fields and temperatures of use of natural heat carriers.

Table 1. The fields and temperatures of use of natural heat carriers

Heat carrier Temperature	HYDROCARBONS	CO_2	AMMONIA	WATER	AIR
90^0C		Hot water for heating	Heat pump hot water		
60^0C	Hot running water				
10^0C	Air conditioning	Cooling medium stage 1 Cooling	Air conditioning	Adsorption Absorption – for air conditioning	
-15^0C	Technological cooling	Cooling medium stage 1 Cooling	Technological cooling	Technological cooling	
-40^0C	Freezing	Freezing	Freezing		
-50^0C					Freezing through adiabatic expansion
-100^0C					Freezing through adiabatic expansion

Next, we shall present some examples of refrigeration systems and heat pumps with natural heat carriers.

Figure no. 5 shows the basic diagram of a CO_2 installation, having 2 compression stages, which operates in transcritical temperature regime and prepares cold water at -50C.... +50C and hot water at +900C. The installation supplies also hot water at +40....+500C.

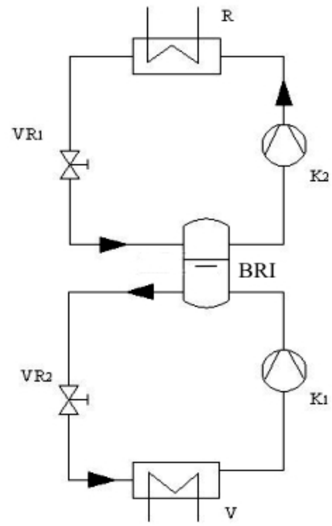

Fig. 5 CO2 Refrigeration installation (transcritical temperature regime):
pv ≈ 30 … 40 bar; tv ≈ -50C;
pi ≈ 60 … 70 bar; ti ≈ 40 … 500C;
pf ≈ 120 bar; tf ≈ 900C.

Figure no. 6 shows a cascade/multistag refrigeration installation, with CO_2 in low pressure stage and Ammonia in high pressure stage. The installation is designed to obtain temperatures of -300°C … -400°C.

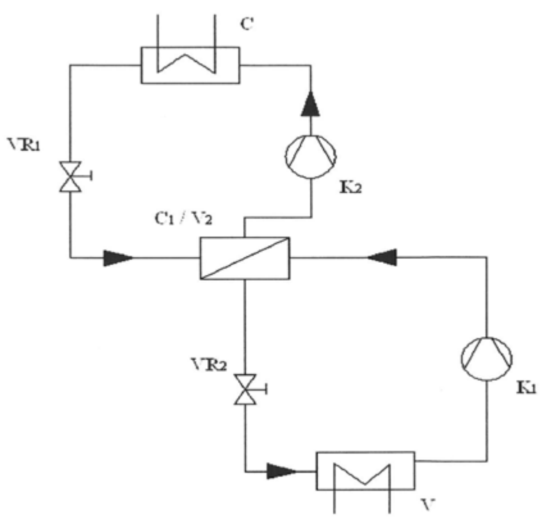

Fig. 6 Cascade refrigeration installation CO_2/NH_3
CO_2 pv ≈ 15 bar; tv ≈ -300C;
pi ≈ 45 bar; ti1 ≈ 100C;
NH_3 pv2 ≈ 15 bar; tv2 ≈ 50C;
pc ≈ 145 bar; tc = 360C.

Figure no. 7 shows the diagram of an Ammonia installation, having 2 stages, operating as a heat pump, for hot water, temperature of +900C, for district heating; the installation also prepares cold water with a temperature of +40C. The coefficient of performance of the installation is ~3.

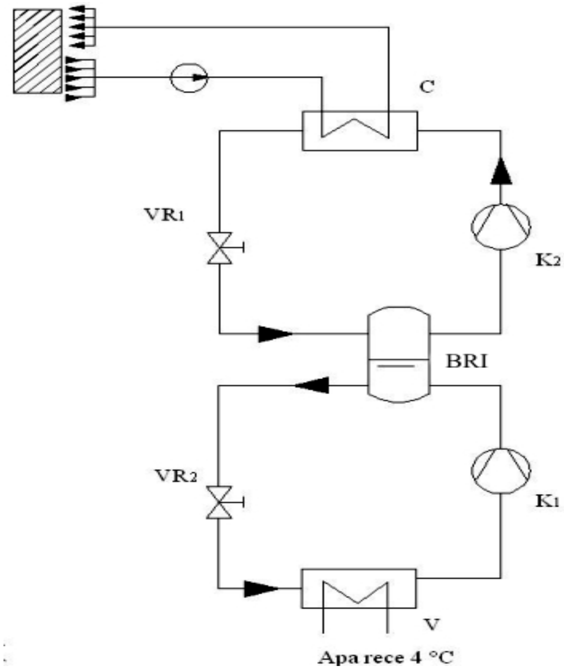

Fig. 7 Heat pump with ammonia heat carrier, for District Heating
pv ≈ 4,3 bar; tv ≈ 00C;
pi ≈ 7,7 bar;
pc ≈ 141,4 bar; tc ≈ 800C.

3. CONCLUSIONS

The use of natural heat carriers imposes compacting of installations equipments for use of small quantities of heat carrier. The compressors of these installations are almost exclusively compressors with bolt (bolt compressor), with one rotor and low power, scroll compressors. These type of compressors ensure high ratio of compression, imposed by natural heat carriers. The vaporizers and condensers are plate heat exchangers; some companies already use microchannel heat exchangers (diameters under 2 mm).

In conclusion, the governmental bodies, international institutions, such as UNEP, IIR, the Council of Europe are concerned with the use of new natural heat carriers, adopting measures of modification of standards and norms regarding refrigeration installations and heat pumps. In developed countries, companies already use new natural heat carriers, instead of transition heat carriers. In our country, the scientific companies must contribute to the modification of norms to protect the environment.

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