STUDY CASE REGARDING THE IMPROVEMENT OF ENERGY AND ECOLOGICAL PERFORMANCE OF A HEAT PUMP

George MARDARE ¹ and Gratiela TARLEA ¹,²
¹Technical University of Civil Engineering Bucharest Romania
²Romanian General Association of Refrigeration, Bucharest Romania

Abstract. The general objective of the study consists in analyzing the possibilities to grow the energy parameters of the heat pumps, under the conditions of ensuring an extended reliability. The specific objective of the study consists in the realization of a original heat pump having an open circuit, having an evaporator realized in a new conception, in the form of a special spiral, with capillary tubes, able to offer superior performances of energetic nature, in the conditions of much greater reliability and the use of a refrigerant with higher ecological performance. The experimental results confirmed the performances obtained by calculation. The conclusion was that the heat pump that uses a capillary heat exchanger guarantees superior performance to the classical installations ensuring electricity savings of up to 50%

Keywords: heat, refrigerant, performance, environment, heating.

1. Introduction

The current international situation is characterized by a drastic reduction in fossil fuel reserves in conditions where their use has become unacceptably harmful to the quality of the environment, which has generated climate change that if continued at the same rate, will drastically affect life on our planet. In this context, the contemporary world is facing major problems generated both by the nature of fossil fuels and their harmful impact on the environment. Concern about these perspectives and their consequences on global socio-economic developments has led to the emergence of the concept of "sustainable development" designed to streamline the consumption of primary resources and mitigate the consequences of using fossil fuels. [1]

In the EU, the residential housing the generators for aprox 40% of energy loss with proportional consequences in pollution, when using fossil fuels. Under these conditions, the economically efficient, long-term solution for reducing GHG emissions is the use of heat pumps. According to the European EPBD Directive, heat pumps are listed as systems that use renewable energy [2].
Equipment equipped with heat pumps are useful for both conditioning. These equipment absorb heat from the environment and transfer energy to the building. [3] For this reason, heat pumps have many applications [4].

2. Method

The use of capillary tubes as an expansion device was originally used for low-capacity refrigeration machines, such as refrigerators for residential use or air conditioning equipment, [5] due to the advantages of simplicity of equipment, zero maintenance cost and low torque, starting the compressor. Experiments done on evaporators equipped with capillary tubes dates about 20 years back and analyze the system performance according to the size of the capillary. The mentioned studies show that the mass flow in a spiral capillary is lower by up to 5% compared to a straight capillary. Zhou and Zhang (2006) [6] presented an experiment in which they studied the behavior of a serpentine capillary.

The experiments showed that at a 10K sub- cooling, for an enlarge of the dimension of pipe the variation of flow is as shown in the diagram Fig.1.

To analyze heat pumps efficiency, the coefficient of performance (COP) is used [6]. Generally, for heat pump collectors, horizontal piping systems are used, in ditches dug in the ground with a depth between 1.5-2.5 meters, which requires both a very large area of land and very long lengths. [6]. Usually, the length of the required piping is about 50 m / kW heat of the heat pump. However, this value depends very much on the type of soil, the diameter capillary, and depth of ditch, the flow of the fluid flowing through the pipe, etc. [6].

Bazkiaei. [7] suggested a type for optimizing these horizontal piping systems, using homogeneous profile soils. Esen [8] analyzed performances obtained by a system of
such a evaporator with horizontal pipes and the economic advantages of such a system. Ramniwas [9] found that the exchanger output thermal energy is the determining factor in realization of the best coefficient of performance.

Noorollahi [10] conducted a financial balance sheet for a plant equipped with such equipment for conditioning a greenhouse in Iran. This research led to the idea of using a capillary heat exchanger. Mariem Lazaar [11] conducted research on heating with a capillary heat pump located in the floor of a greenhouse, which provided a temperature of 12 °C during the night. Mejdi Hazami [12] have done research on the use of a capillary heat exchanger that uses seawater.

During the analysis of the cooling coefficient (EER), the R22 refrigerant was used [13]. The condensation temperature in the condenser was at sea level plus 10 °C [14]. Starting from these tests, this work and research represents a novelty regarding the construction and architecture of heat pumps which led to a new heat pump with capillary vaporizer in the form of a special spiral, according to fig.2.

At this type of heat pump, the operation is ensured by a battery of capillary tubes, the vaporization control being achieved by temperature control, ensuring the optimal values of sub-cooling and overheating of the refrigerant during the operation cycle, which also contains a heat exchanger regenerative.

### 3. Results and Discussions

From the analysis of the results obtained from the tests performed, it could be concluded that an increase of the EER performance coefficient of the heat pump was obtained 2.21
times compared to a regular refrigeration unit with heat pump, without capillary. Consequently, the use of this type of heat pump ensures considerable reductions in electricity consumption. Power consumption analysis. As it results from fig.3 and 4, the monthly heating meant a consumption increased, corresponding to an electricity consumption which also increased. Towards the end of the testing time, the heat consumption was 1501.12kw / h and the electricity consumption was 284.97kW / h.

![Fig. 3 GSHP monthly heating / cooling / consumption](image)

![Fig. 4. Sea water temperature](image)

In the test performed, the variation of the parameters was according to figure 4. As it results from fig.3, the energy efficiency was higher during the summer compared to the operation during the winter. It was also found that the COP and EER values
underwent changes for different values of the loading rate. Thus, there are large
variations of the COP and EER to the variation of the loading rate from 0.3 to 0.6, COP
varying between 3.4 and 5.32 and EER between 3.82 and 6.32. (Fig.5)

As shown in Fig 6, COP increased in direct proportion to seawater temperature. Also,
the COP value was higher the lower the temperature difference between the heat source
and the thermal load. Regarding the EER variation, it increased in direct proportion to
the sea water temperature.

Heating and cooling capacity. The tests performed showed that both the heating
capacity of the heat pump and its cooling vary depending on the load of the building.
In Fig 7, one can see that when the cold demand increased, the cooling capacity of the heat pump increased, the EER being slightly ascending.

4. Conclusions

Zhou and co-workers [14] conducted tests on a medium-sized hotel using a capillary heat pump with water as the capillary system, the Qindao River. The hotel had a built area of 500m². The average value of EER was 4.50 and the average value of COP when operating as a heat pump was 4.06. It should be mentioned that the COP / EER values obtained experimentally were lower than the values obtained by theoretical calculation. Thus, the theoretical value of the EER was 5.32 and the theoretical value of the COP was 6.32. It is assumed that the difference would be due to the motivation that the power of the system was too small compared to the required and that the capillary heat exchangers were in time buried in the sand.

These tests analyzed the behavior of heat pumps with capillary heat exchanger in various situations. The malfunctioning modes of the heat pump with capillary winter-for heating and during summer for cooling were analyzed. The following observations resulted:

- The use of heat pumps with capillary heat exchanger in buildings ensures significant reductions in electricity consumption, these reductions being higher during the summer than during the winter;
• Compared to ordinary air conditioners, the electricity consumption obtained by using the capillary heat pump was reduced by up to 1/2, the benefits being significant;

The researches of the heat pumps models having capillary evaporator, made by Zhou and co-workers [14] on the Qindao River where the capillary evaporator was placed on the river bottom as well as the researches of the heat pumps models having capillary evaporator performed by Mejdi Hazami et al. [12] in which the capillary vaporizer was placed in seawater, as well as other similar researches, had as a model the placement of the capillary evaporator in a liquid environment, from which to recover thermal energy. In all these cases, the experiments showed that the practical results obtained were inferior to the theoretical calculations. The conclusion for each case was that the operation of the capillary tube evaporator was severely affected by sand and alluvium deposits both in the case of the vaporizer located on the bottom of the Qindao River and in the case of placing the capillary vaporizer on the seabed.

To avoid the disadvantage generated by alluvial deposits, the authors of the article made a capillary evaporator in the shape of an archimedean spiral, in which water was pumped from a well drilled to the first groundwater level. This personal contribution of the authors was made in order to avoid clogging the capillary tubes with the alluvium in the evaporator. The water from the first groundwater level, used for pumping in the capillary evaporator, is not potable in most cases, being clogged due to pesticides used in agriculture over the years, but this does not affect too much. From the tests performed by the authors in several areas of Romania, the water temperature in the first groundwater level has the value of 11-14⁰C, with summer-winter temperature variations below 1⁰C, which allowed the heat pump thus equipped to achieve a performance coefficient higher than 5, very stable coefficient, being influenced by the relatively constant temperature of the water in the groundwater table. The special shape of the capillary evaporator, in which the water circuit does not suffer returns to 90⁰ or 180⁰, ensures a continuous self-washing of the evaporator, preventing any possibility of clogging it and thus ensures a very high reliability of the evaporator.

• Open circuit water heat pump with capillary vaporizer made as an own contribution in this research, having the vaporizer made in the form of a special spiral, quantifies these energy performances and eliminates the shortcomings of the mentioned researches caused by sand deposits and alluvium on capillaries, which led to the reduction of energy efficiency. This type of capillary evaporator offers extended reliability and increased resistance to clogging by having the phenomenon of continuous self-washing and ensuring a flow section without bottlenecks and returns to 180⁰, which generates clogging, as is the case with classic heat exchangers.
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