ABSORPTION COOLING UNIT DRIVEN BY SOLAR ENERGY

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ABSTRACT

This article describes an absorption cooling unit using two working fluids, lithium bromide and water, with the possibility of connection to a solar heating system. It presents the possibility of using renewable sources of energy for cooling. The influence of different temperatures of the driving fluid coming from a solar system on a cooling power is shown in this work. The results of the experiments are used as the foundations for the construction of a new experimental unit with a cooling output of 10 kW. In the energy balance of this application with a solar cycle, the possible energy savings, in comparison with compressor cooling systems are shown. In the application a showed heat exchanger is used in the evaporator of the cooling machine, which requires water circulation as the primary cooling medium. The primary cycle is powered by a circulation pump sucking water from the evaporator and showering the exchanger. The article discusses the theoretical possibilities of designing a primary circuit and its influence on the total effectiveness of the cooling unit, based on a mathematical model

Keywords: absorption, cooling, solar energy, showered heat exchanger, low pressure,

INTRODUCTION

At this time of energy crisis, themes like saving energy and the financial costs attached to these energies are coming to the forefront. The area of savings is carefully considered with a view to keeping the internal environment of buildings untouched. One of the alternatives is the possibility of producing cooling by means of solar energy [1]. This theme is described briefly in this article, where we pay attention to coupling an absorption cooling machine and a solar system. In this article we introduce the possibility of using cooling machines based on the principle of absorption, powered by heat energy, to cool residential environments. The principle of cooling is based on the absorption of water vapours by a solution of Lithium bromide and fluid water. We present the enthalpy model of an absorption cooling machine and we propose a brief design of a unit with cooling output rating of 10kW. We compare the measured values on a small physical model of the absorption cooling machine with the results of the mathematical simulation. We evaluate the advantages and the value of such a system also from the standpoint of increasing the percentage coverage of heat needed for certain building, because the problem with overproduction of heat by most solar systems disappears in the summer months.

ABSORPTION COOLING MACHINE

The unit consists ~~from~~ of a low pressure and a high pressure part [2]. In the case of working fluids, H_2O and the solution of H_2O and LiBr, the pressures in the low pressure part is 1800 Pa and in the high pressure part it is 8000 Pa. In the low pressure part are the evaporator and the absorber, and in the high pressure part are the generator and the condenser. These parts were designed for producing a nominal cooling output of 10 kW. Picture 1 shows the working cycle of such a cooling unit, coupled to secondary circuits feeding in and taking out the heat needed for running the cycles. We assume that 10 kW of cooing power should cover the heat gains of the average house.

In the absorption cooling unit ~~is~~ the expansion effect from the compressor cooling cycle is replaced by a decrease of pressure through the process of absorption of water vapour by the solution of LiBr and water in the absorber. The vapour is produced in the evaporator by low pressure and corresponding temperature.
A certain degree of heat is then needed for separating the absorbed water. This part of the process takes place in the generator which uses the heat gained from the solar system. The connection of solar system to the cooling unit is through a bivalent water storage vessel in which ~~is~~ hot water is needed for the running of the accumulated unit. Part of this cooling machine is either a closed cooling circuit or an open cooling tower circuit needed to take away process heat produced by absorption and condensation. The cooling of the absorber is needed because of the exothermic reaction through which the vapour is absorbed. If the heat was taken away, the temperature of the process would rise and that would stop the absorption. The condenser cooling is needed in order to condense the vapour coming from the generator and pass it further to the evaporator. The last part of the system is the system of cooling units located in the building according to need. Here, the energy is taken away from the cooled air and brought to the evaporator, where it acts as the source for boiling the water described earlier.

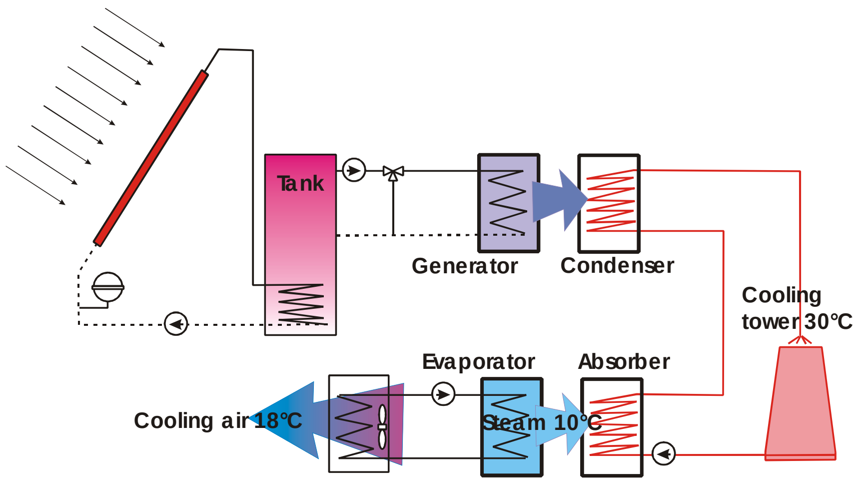

Fig. 1 Absorption device with solar collectors and cooling unit.

MATERIAL-ENTHALPY CALCULATION MODEL

The material-enthalpy calculation model simulates the absorption cooling unit, Figure 2. It consists of basic unit operations which are run according to conditions obtained from the computer simulation. The model consists of the following main apparatus: evaporator, absorber, generator and condenser. In order to make the simulation exact, the following apparatus are added: pumps, heat exchanger, mixer, balanced separator. For defining the state and other thermodynamic characteristics the following equations were used: Redlich-Kwong for the vapour phase and Elektrolyte NRTL for the fluid phase.
Measured temperatures are connected with the primary axis and the secondary axis shows the pressure conditions in both pressure separated vessels of the absorption unit.
From the material-enthalpy model we gained theoretical information on the dependency of the thermal output of generator Q depending on temperature difference. In Figure 3 values shown are calculated and measured.

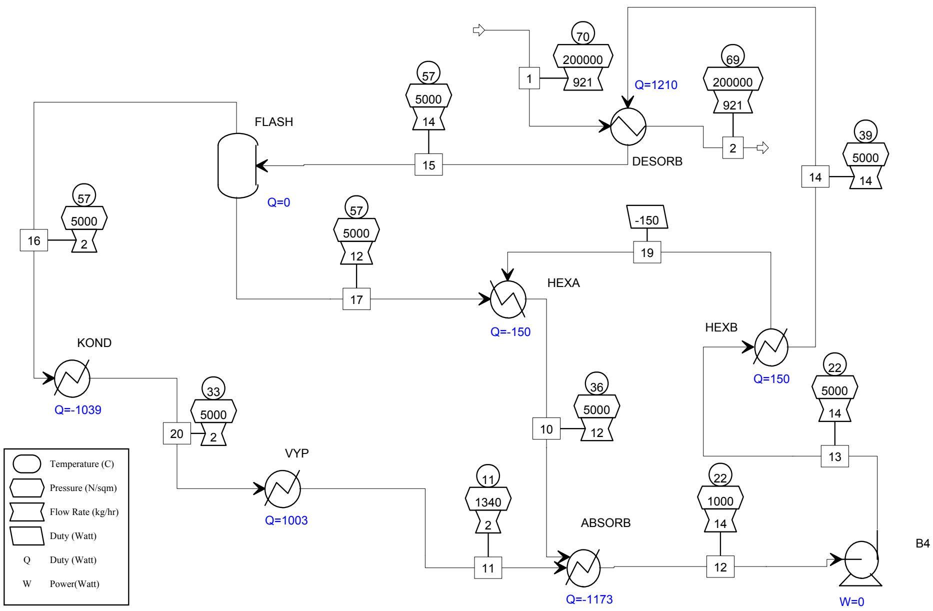

Fig. 2 Material-enthalpy model of absorption cooling unit.

It is obvious from picture 3 that the dependency of heating output on temperature is important. Measured values on the experimental cooling unit show big deviances especially in higher temperatures. The comparison of the measured and the calculated temperatures is in table 1. Maximal deviance did not exceed 30.7% in the measured range. This big difference, between the mathematical model and the experimental results is because the material used in the heat exchanger in the experimental device was glass which has poor conductivity.

Linear regression through the calculated and measured values of heat output Q was carried out. The shape of the functions is shown in Figure 3.

After evaluating the measurements, we came to the conclusion, that the output of the unit is directly influenced by the quantity of LiBr and water flowing through the absorber, as well as in which state this solutions enters the absorber [3,7]. Temperature, pressure and solution state affect the process of absorption. During the experiment the pump of the solution cycle was permanently regulated in order to keep the process continuous, and the quantity of fluid was proportional to 1 kW which was measured. These measured values help us to design the machine with a cooling output of 10 kW, Picture 5.

From the mathematical-enthalpy model we gained theoretical understanding of the dependency of the cooling output in evaporator Q on pressure change. These are shown on the graph in Figure 4 under "calculated values". Into the same graph were added measured values from experiments. From this picture it is obvious, that the–cooling output depends only minimally on pressure in evaporator. The measured values from the experimental unit confirmed the theoretical assumptions. The comparison between calculated and measured values is shown in table 1. The deviation did not exceed 8.6% over the measuring range.

Linear regression lines were overlaid onto the calculated and measured values of cooling output Q. The shape of these functions is shown as well in Figure 3. The same trend can be seen from the direction of both sloping lines.

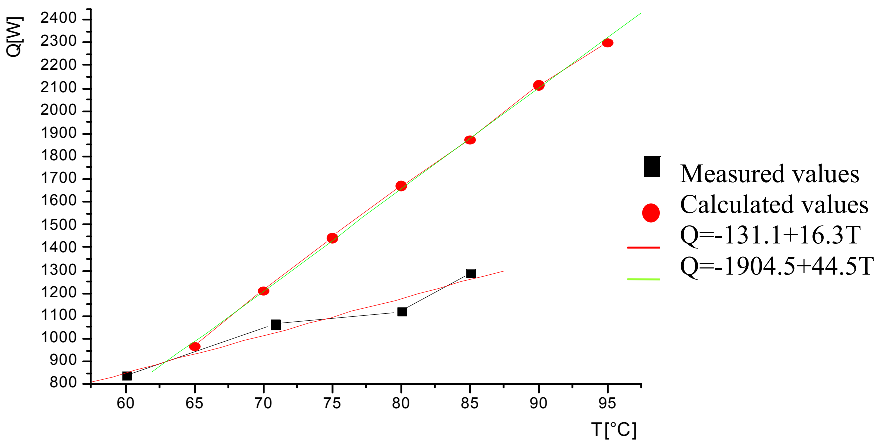

Fig. 3 Dependency of measured and calculated cooling outputs on temperature in the generator.

Comparing the calculated and measured values we came to following conclusion. The change in the cooling output depended only minimally on the pressure change in the evaporator. This assumption was proved as well by the experiment in the chosen range of pressure measurements.

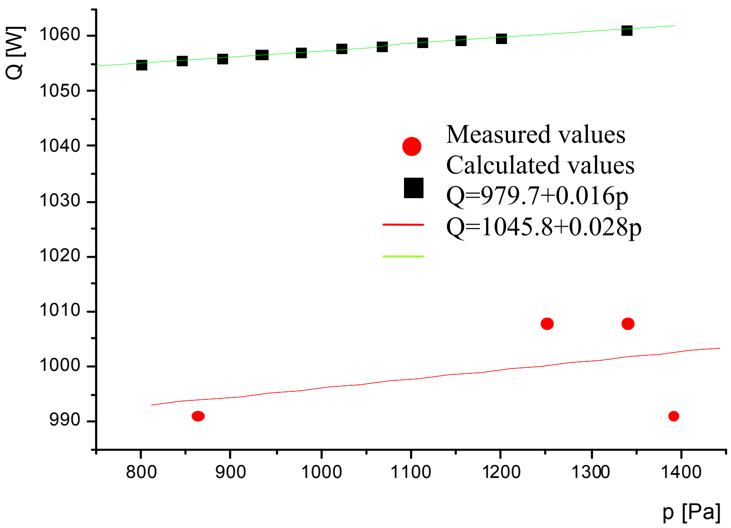

Fig. 4 Dependency of cooling output on pressure in evaporator – calculated and measured values.

Tab. 1: Measured temperatures, pressures and output in evaporator and its comparison to calculated output.

T_{in}[°C]	T_{out}[°C]	T_{calc}[°C]	Pressure [Pa]	Output [W] measured	Output [W] calculated	Deviation [%]
27.2	21.2	19.8	1340	1008	1083,3	7,0
26.7	20.8	19.3	1391	991.2	1084,7	8,6
25.7	19.7	18.4	1250	1008	1080,8	6,7
25.5	19.6	18	863	991.2	1069,94	7,4

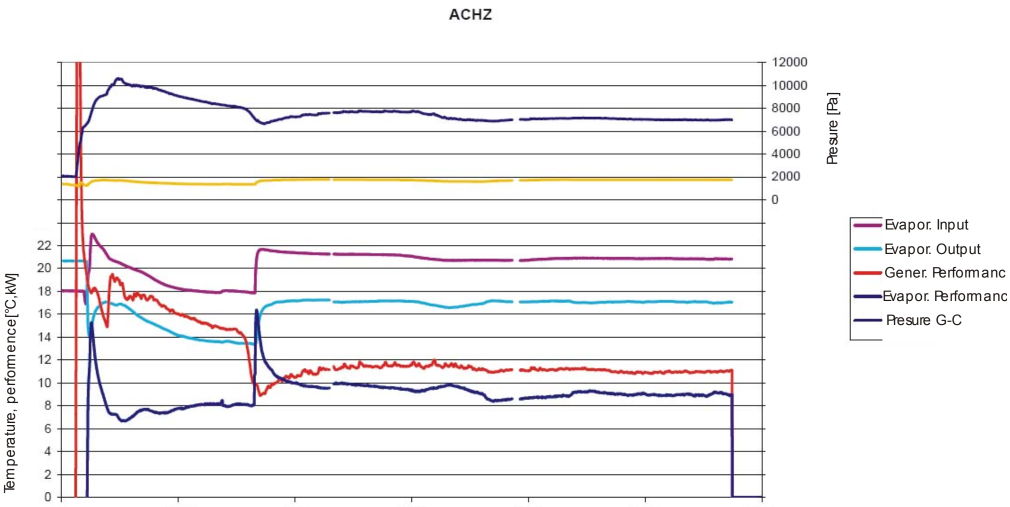

Figure 5: Temperatures, pressure and performance in Absorption cooling unit

The Figure 5 shows the measurements from the absorption cooling unit coupled to secondary circuits feeding in taking and out the heat needed for running the cycles. We can see between 4000 and 11000 seconds that the cooling performance is about 10 kW, shown under the dark blue coloured curve.

The red coloured line represents the performance of the generator. The dark blue coloured line, which is uppermost, shows the pressure in the generator. The yellow line is the pressure in the absorber. The violet and light blue coloured lines represent the input and output of the secondary circuit of the evaporator. This prototype was built in laboratories of Institute of thermal power engineering in cooperation with industry. More experiments are in process at this time. The value of COP of this unit is about 0.8 on the base of the mentioned measurements.

CONCLUSIONS

The principles of the absorption cooling cycle operation were used for the development and design of an energy system for combined heat and cold generation, on the basis of an adsorption refrigerating plant utilizing solar energy as the primary source of energy [8, 9, 10]. We described the prototype of the absorption cooling unit with working fluids LiBr and water in this article. Analysing the mathematical-enthalpy model of absorption cooling consists of basic unit operations, which are run according to the conditions and restrictions, which permit computer simulation. Comparison of measured and calculated parameters gave us the following results: The heat output is significantly influenced by temperature in the generator [6, 4]. We can say that it is amongst the most important parameters influencing the cooling output of the unit. The difference between values gained from the model and values gained from the experimental unit is caused mainly by heat losses in the generator. In conclusion, the most significant factors influencing the design of the 10 kW cooling machine have been demonstrated.

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