LOW TEMPERATURE DRIVEN ABSORPTION CHILLER

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ABSTRACT

A 1,15 MW absorption chiller utilizing down to 70 °C hot water from district heating system have been developed and installed at Chalmers Technical University in Gothenburg, Sweden. The main features of the chiller is that the chiller is flexible with respect the geometrical configuration thus being adaptable to the conditions of the customer. The surfaces for heat and mass transfer are of lamella type instead of the commonly used tubular heat exchangers. As heat transfer additive 2-methyl-pentanol is used instead of 2-ethyl-hexanol.

The projected cooling demand is met whereas the coefficient of performance (COP) is lower than expected. The reason for this is the high rate of circulation of lithiumbromide solution between absorber and generator. Also the solution heat exchanger plays an important role for the low efficiency.

During the cooling season 2001 an optimization of the chiller will be performed. It is assumed that this will lead to higher COP and still sufficiently high cooling capacity of the chiller.

KEYWORDS

Absorption chiller, Lamella heat exchangers, Additive, Lithiumbromide, Corrosion, District heating

1.0 BACKGROUND

The demand of energy for comfort cooling is steadily increasing all over the world. This demand is usually satisfied by compression cooling. The electricity consumption is therefor increasing and the peak demand is shifted from wintertime (for heating purposes) towards summertime. Where waste heat is available to a low price the cooling demand could be satisfied by absorption cooling.

District cooling based on natural cold or cold from heat pumps is becoming increasingly popular. When district heating is available, and at least part of the heating load stems from waste heat from municipal solid waste incineration or industrial waste heat, locally produced cooling utilizing the district heating water as driving energy becomes an option. This enables the utilization of the district heating system for energy distribution. It also gives a heat sink and a utilization of waste energy the whole year around.

The temperature in district heating systems ranges from 70 – 120 °C. The lower temperature range is used in summertime when heating of tap water is the main heat sink. Absorption chillers available on the market are usually designed for a driving temperature of 120 °C or more. Since the design has to be based on the generator the choice of such an absorption chiller for low temperature applications leads to a too large absorber and evaporator.

1.1 Goal

The goal for this work is to develop an absorption chiller driven by district heating water with a temperature down to 70 °C. The cost and the efficiency should not deviate substantially from alternative methods for comfort cooling. A Swedish company should manufacture the chiller and a commercial customer should be found.

1.2 The company

Berglunds Rostfria AB is a manufacturing company from Boden in the north of Sweden. They have approximately 35 employees. They are specialized in manufacturing heat exchangers and process equipment in advanced materials for chemical and pulp and paper industries. They are manufacturing a special heat exchanger, the lamella heat exchanger. This heat exchanger has previously been tested for efficiency as a surface for heat and mass transfer in absorption heat pumps. It has been found to be more efficient than tubular heat exchangers.

1.3 The customer

Göteborg Energi is a company providing heat and cold to customers in the region of Gothenburg. Most of the heat stems from waste heat either from municipal waste incineration or from industrial enterprises such as oil refineries and car manufacturers.

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Göteborg Energi provides cooling in summertime by absorption chiller originally designed for a high driving temperature but used for 90 °C or less driving temperature. The heat to drive the absorption chiller is delivered by district heating water.

Akademiska Hus is managing all houses and localities to Swedish universities and is thus responsible for buying heat and cold to Chalmers Technical University in Gothenburg. At this university is installed already an absorption chiller with a capacity of 1,15 MW. York has manufactured this chiller. Since the cooling demand is steadily increasing another 1,15 MW capacity was requested.

1.4 Philosophy of the chiller

Since the company, Berglunds Rostfria AB, does not intend to have a large serial production of absorption chillers it has been decided to make the chiller flexible with respect to geometrical appearance. Thus it could be delivered in two units, one unit for the low-pressure side (absorber and evaporator) and one for the high-pressure side (generator and condenser). . Further the surfaces for heat and mass transfer could be both high and long or low and wide. This makes the chiller more easy to adapt to the room where it should be situated.

Lamella heat exchangers has been chosen both because the company is specialized in this type of heat exchangers and because these are known to be efficient in an absorption application.

From this philosophy follows that the chiller size will be adapted to the need of the customer and that the design will be optimized with respect to available temperatures of driving energy, cooling water and coolant.

1.5 Differences between lowtemperature driven chiller and normal temperature driven chiller

The main difference between a chiller driven with different temperatures is the pressure in the generator/condenser. With a low temperature driving energy the pressure in the generator/condenser is lower than 100 mbar whereas at 120 °C driving energy temperature the pressure is approximately 3 times as high. The low pressure creates difficulties in two respects: in the condenser and in the flow of the liquid between the high-pressure side and the low-pressure side of the chiller.

In the condenser the condensing temperature will be a little bit above 30 °C in the low temperature case whereas in the high temperature case the condensing temperature could be more than 20 degrees higher. This will effect the size of the condenser. It will also limit the possibilities to utilize cheap cooling water or effect the size and cost of the cooling tower.

The low pressure difference between the high and low temperature side of the chiller makes it difficult for the liquids to flow freely between the two sides. It might be necessary to introduce a pump for transportation of the liquids between the different parts of the chiller.

1.5 Time schedule of the project

The project started early 1999 and according to the plan the full-scale absorption chiller should work in the cooling season year 2000. This means that the manufacturing had to start in the end of year 1999 and all design values are ready in good time before that.

2.0 EXPERIMENTAL SET-UP

Experiments were performed in three different units of different sizes; 1kW, 30 kW and 1,15 MW cooling effect respectively.

2.1 Phase 1: 1 kW unit

The first unit, called “the baby”, was used primarily to study the hydrodynamic behavior of the absorption chiller. This includes the spreading of the liquid on the surfaces for heat and mass transfer and the effect of the heat transfer additive.

The spreading was studied also on the lamellas in a parallel open equipment without heat and mass transfer taking place. In this way visual observations could be performed more easily. These experiments however could not utilize lithiumbromide solution since in presence of oxygen lithiumbromide is highly corrosive on most metallic materials. Instead water was used and the viscosity of the water was manipulated with cethylmethylcellulose (CMC) in order to simulate the lithiumbromide solution.

Corrosion tests were performed by placing small samples of different materials in tubes containing solutions of 60 % lithiumbromide in water. The tubes were subjected to elevated temperature for 6 month. The samples were weighed before and after the test and visual observations of the corrosive behavior were made.

The results from heat and mass transfer measurements were the basis for design of the second unit.

2.2 Phase 2: 30 kW unit

The second unit, called Klabbe, was designed for a cooling effect of 30 kW. The purpose of this unit was to verify the transfer coefficients used in the design. Further it was used for testing control strategies and for testing the behavior of the chiller at part load and low temperature of the driving energy.

2.3 Phase 3: 1,15 MW unit

The third unit was installed in April 1999 (called the pilot) and started to deliver cold in the beginning of June 1999. Rebuilding was necessary in order to fulfill the capacity requirements.

The piping between condenser and evaporator had to be changed to overcome the large pressure drop. The large pressure drop caused the control to stop the energy supply to the generator. The control is based on the level of water in the evaporator. A high level indicates a low concentration of the lithiumbromide solution and thus causes the valve in the district heating supply line to open in order to deliver more heat. A low level indicates a high concentration of lithiumbromide solution and will therefore cause the valve in the district-heating valve to close. If the level is far too low there is a risk of crystallization in the generator and the valve is completely closed. A high pressure drop in the pipe between the condenser and the evaporator will cause a time-lag between a change in the concentration in the generator and the level of water in the evaporator. The control system will erroneously assume that the concentration in the lithiumbromide solution is too high and thus close the energy supply from the district heating water.

A second rebuilding was caused by the low pressure in the suction line of the pumps for transporting the lithiumbromide solution from the absorber to the generator.

3.0 RESULT

3.1 Heat transfer additive

In our department we have been studying the influence of additives on the rate of heat and mass transfer. The additive is believed to cause flow in the liquid surface. This is due to differences in surface tension on different parts of the surface. This flow will in turn cause mixing in the liquid film flowing on the heat transfer surface. This will increase the rate of heat and especially of mass transfer across and into the film.

Different mechanisms have been suggested for the onset of this flow, usually referred to as Marangoni instabilities. A theoretical study by Wei [1] describes different causes to the instability. The surface tension difference could be caused by

Absorption of water into the film

Desorption of the additive from the film

Absorption of the additive from the vapor into the film

Slow diffusion of the additive to the surface

It has to be said that all of these phenomena cause instabilities in the liquid falling film. However the theoretical analyses does not give an answer regarding the relative magnitude of these instabilities.

These explanations lead to different strategies for choosing the best additive. The commonly used additive, 2-ethyl-hexanol, added to the liquid in the absorber probably best corresponds to the hypothesis of the instability being caused by the absorption of water into the film.

Based on the work of Wei, Gustafsson [2] discussed different additives in order to find the best additive for absorption chillers. He suggested that the absorption of the additive from the vapor into the film should cause the best flow for increasing the rate of mass transfer. He suggested a more volatile additive and that the additive should be introduced into the evaporator. In this way the additive should come into the vapor phase into the absorber and thereby be absorbed into the liquid film.

He suggested 2-methyl-pentanol as a candidate for our project.

Glebov [3] tested this additive in the baby, e.g. the first generation of the chiller. He concluded that 2-methyl-pentanol added to the absorbent in the absorber caused an increase of the cooling effect of 20% whereas an injection into the refrigerant in the evaporator caused an increase of 32%.

Based on those results 2-methyl-pentanol is used as additive in both the 30 kW unit (Klabbe) and the 1,15 MW unit (The pilot).

3.2 Corrosion

Samples of five different materials were subjected to a 60% lithiumbromide solution in water. The test samples were put into a E-flask and were covered with the solution. The flasks were subjected to elevated temperature, 40 ^{o}C for two month and thereafter 70 ^{o}C for four month. The samples were weighed before and after the testing period. The materials were

1 Stainless steel SMS 2343

2 SMO a high molybdenum containing steel

3 Titanium

4 Inconel

5 Mild steel

The results are found in Table 1

Table 1. Corrosion of LiBr on different materials

Material	Starting weight, g	Ending weight, g	Weight reduction, g	µm/ year
SS2343	29,5846	29,5804	0,0042	0,8
SMO	29,7988	29,7951	0,0037	0,7
Titanium	13,0837	13,0817	0,0020	0,8
Inconel	30,6820	30,6756	0,0064	1,2
Mild steel	28,3030	28,3012	0,0018	0,4

3.3 Spreading of liquid

Studies were made on the spreading of the liquid on the lamellas to form a uniform falling film. These studies were made outside of the chiller itself. This was made i order to be able to make observations on the degree of spreading. Water mixed with cethylmethylcellulose (CMC) was used. The purpose of the CMC was to increase the viscosity of the liquid to simulate the lithiumbromide solution. The spreading is dependent also on surface tension and on the rate of absorption. These parameters could not be studied since lithiumbromide solution due to the corrosive properties could not be used.

It was found that the liquid load was an important parameter for the spreading of the liquid. 3 m^3/h and meter of lamella was a approximate measure for good distribution on the surface. This value was used in the design of the pilot unit.

4.0 DISCUSSION

Despite the very short time available for the project an acceptable result was achieved. The pilot unit has a cooling capacity of more than 1,15 MW. The COP however is only in the order of 0,6, which is lower than what is achieved with other types of absorption chillers. The reason for the low COP is the relatively high rate of circulation of lithiumbromide solution between the absorber and the generator. This high rate of circulation also leads to a high consumption of electricity for this pumping.

One other reason for the low COP is the construction of the solution heat exchanger. Due to the large rate of circulation also the heat load is very high. This led to that the solution heat exchanger in the pilot unit is divided into two units. In one unit the lean and the strong solution exchanges heat between each other whereas in the second the strong solution is cooled down further by the cooling water. This was done in order to utilize the absorber for absorption only, not for cooling down the strong solution to absorption temperature. Optimization might lead to that also the second heat exchanger will be utilized for cooling of the strong solution and heating of the lean solution. This will substantially increase the COP. It is our belief that those two measures will lead to a COP in the same range as conventional chillers.

During the cooling season year 2001 the flow rate will be optimized with respect to capacity and efficiency.

5.0 REFERENCES

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