USE OF DISTRICT HEATING IN SUMMER FOR COLD PRODUCTION WITH THE AID OF AN ABSORPTION PROCESS

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ABSTRACT

The possibility of using district heating for cold production for lower cold capacities was investigated. A function model with a cold capacity of 50 kW was set up which operates according to the principle of single-effect absorption and manages with low supply temperatures (80°C)., A compact layout was achieved by installing plate packages. Numerous measurements show that the layout examined displays a stable operating behaviour and achieves a COP factor of about 0.8. At part-load >20% the COP factor is on the order of magnitude of 0.6.

KEYWORDS

Single-effect absorption, district heating, lower cold capacity, lower supply temperature

1. INTRODUCTION

Absorption chillers have reached a high technical standard and can be used as a series product for the production of chilled water. Other applications beyond air-conditioning can now also be developed. The following examples provide an overview:

- Integrated systems such as heat-cold co-generation, e.g. for a sports centre with swimming pool, sauna, ice-rink, air-conditioned gyms and sports halls. Even if primary energy is used, a high level of energetic efficiency can still be achieved. For example, the condensation temperature can be raised in order to make heat available at the same time, e.g. in conjunction with an outdoor swimming pool. The water from outdoor swimming pools can equally be used for the atmospheric rejection of the condensation and absorption heat I1I. Calculations of the economic feasibility show that with such combinations, not only energetic advantages but also benefits in terms of investment can be achieved, in comparison to compression systems.
- Peak compensation for air-conditioning systems. This instance occurs in some countries when, for example, electricity is in short supply in the afternoons yet cold demand increases. Here it is more the continuity of the cold production which is to the forefront. Therefore, the energetic disadvantages are accepted.
- Use of low-temperature heat such as waste heat or district heating.

The last mentioned area of application should actually show to advantage the decisive benefits of the absorption systems; the reality is however different. Most absorption chillers are either gas-fired or heated with steam. That means, high-value energy will be supplied. In many instances however low-temperature heat at 70-90°C is available and can be usefully deployed by means of an absorption process for cold production (e.g. cold for air-conditioning). An appropriate example of this is the use of district heating in the warmer time of the year. This has often been applied in the past I2, 3I. LiBr/H_2O is used as the working mixture. The plant in Mannheim I2I was designed as a single-stage plant for a cold capacity of 1 MW. The chilled water temperatures were 13/7°C, the supply temperatures of the district heating 86/80°C. Due to the low temperature difference in the heat supply, large quantities of heating water (up to 125 m^3/h) had to be pumped through the absorption chiller. The COP factor was 0.67.

The district heating in Gothenburg consists to over 70% of waste heat I3I. Part of this is used to produce 9 MW of cold in the summer. Apart from the district heating, the intention is also to develop a district cooling network. The supply temperature was 90°C, the return temperature about 80°C. Due to the relatively small temperature difference of 10°C (similar to that in Mannheim), the flow rate of the heating water was very high. At chilled water temperatures around 10°C, COP factors of about 0.7 were reached. Even at these COP factors, the primary energy demand is still about halved in comparison to compression plants.

In order on the one hand to reduce the volume of heating water and on the other hand to raise the COP factor, other thermodynamic cycles can be used I4I, in particular multiple-stage cycles which manage on a low heating temperature (e.g. 65°C). As a result the heating water in the absorption chiller can, for example, be cooled down from 90°C to 65°C. Apart from reducing the quantity of heating water, better energetic utilisation is achieved. By using a single-effect/double-lift cycle, for example, at temperature differences of 30 K on the heating water side COP factors between 0.42 and 0.8 can be achieved I5I. A plant with 400 kW cold capacity was erected and operated according to this principle I6I. The plant was designed for heating water temperatures of 95/65°C. At supply temperatures of 95° to 100°C in single-effect operation and cooling down to about 70°C, the COP factors were around 0.75. In single-effect/double-lift operation, the COP factors at cooling down to about 63°C were around 0.63. Switching from the one mode of operation to the other was effected by an appropriate control device.

By using further thermodynamic cycles, a larger degree of heat utilisation can be realised. An example of this is the so-called „Staged Absorption/Desorption Cascade“ I7I where additional pairs of absorbers/desorbers are arranged between the hottest desorber and the coldest absorber. Thus the heat carrier can be cooled down in the heat supply to very low return temperatures. Further cycle analyses for the use of low-temperature heat can be found in I8I and I9I.

The economic feasibility of cold production with absorption chillers which can be operated with district heating is dependent, apart from other factors I10,11I, on the following criteria as well:

- In many towns, the district heating temperatures are lowered in the summer. The order of magnitude is 80°C. The absorption chiller should therefore manage on such a low supply temperature, at the same time however also permit an effective lower return temperature after heat absorption, e.g. about 60°C. As a consequence the additional costs for raising the temperature and the higher quantity of heating water would be eliminated which in turn would increase the opportunities for using cold production via absorption.
- The difference in investment costs between absorption and compression chillers must be so low that these can be compensated for by the saving in electricity. This is indeed a difficult criterion since compression chillers are manufactured in considerably larger numbers and consequently are cheaper.
- In order to expand the area of application, smaller, decentrally operated absorption chillers ought to be available, e.g. for a cold capacity of 100 kW. As a result it would be possible to provide apartment blocks which are connected to the district heating system with cold. In this case there are also no problems with the quantity of the heating water.

The criteria listed above form the basis for the development of a newly designed absorption chiller which was operated in conjunction with low-temperature heat, in particular district heating.

2. APPROACH

As usual, the following were pre-defined: the chilled water temperatures at 12/6°C, the cooling water temperatures at 27/35°C as well as the temperatures of the heating water from the district heating network at 80/60°C (supply and return temperature). The supply temperature of 80°C is set in the Bremerhaven district heating network in the summer months. The district heating is provided via waste steam from turbines.

At the beginning of the development, the decision was made for cost reasons to go as far as possible to the thermodynamic limits of the single-effect process without relinquishing reliability. Better COP factor, simpler design and simpler control are points in favour of the single-stage process. The working mixture LiBr/H_sO was selected for the cycle. The following possibilities crystallised from thermodynamic and kinetic calculations as to how to manage with a single-stage process under the prescribed parameters:

a) Avoidance of circulations in the desorber and absorber so that in each case the most favourable concentration prevails at exit. This condition however raises problems with regard to the liquid distribution.
b) Good heat and mass transfer so that the heat transfer surface can be designed in a compact and economic way.
c) Modular construction for later production in larger numbers,

On the basis of criteria a, b and c, a literature search and pre-trials were carried out. In particular elimination of any circulation in the LiBr-solution as required under a) caused difficulties with regard to the liquid distribution on the heat transfer surface. Plate packages were subsequently selected as heat transfer surfaces for all apparatus. These are sprinkled with liquid from the top. The objective was to achieve good heat and mass transfer as well as a compact design in accordance with criterion b). The solution was to develop a suitable distributor device. Each plate has its own distributor device which even at low Reynolds numbers permits a very even distribution of the LiBr-solution. To improve the liquid distribution, some additives like 1 Methyl- 2 Hexanol I12I were applied. Such additives are extremely important for an even distribution and thus for an increase in the heat transfer coefficient. By adding a few ppm of additive, the heat transfer coefficient can be increased almost by a factor of 2 I12I.

The plate packages are arranged in such a way that a modular design can be easily realised. Thus criterion c) is also fulfilled. The heat carrier (heating or cooling water) flows in the absorber and in the desorber in counterflow to the LiBr solution. Thus the highest temperature differences corresponding to the nearly greatest concentration width could be achieved.

3. THE TEST PLANT

After the pre-tests, a function model for a cold capacity of 50 kW was set up and tested in simulated operation, whereby the thermodynamic cycle of the simple single-effect plant including a solution heat exchanger was used. Figure 1 shows a photograph and Figure 2 a process diagram of the function model. Both the desorber and the condenser as well as the absorber and the evaporator are arranged in each case in a square housing. The pumps are under the apparatus. A comprehensive measuring programme for balancing all apparatus and components was carried out. Thus effective results for the modification and improvement of the components could be obtained.

The plant is completely automated and connected to a measurement recording unit with process visualisation. It can be balanced at any time via the measurements recorded. It was also possible to initiate faults intentionally in order to investigate the plant's behaviour.

Figure 1: Photograph of the function model

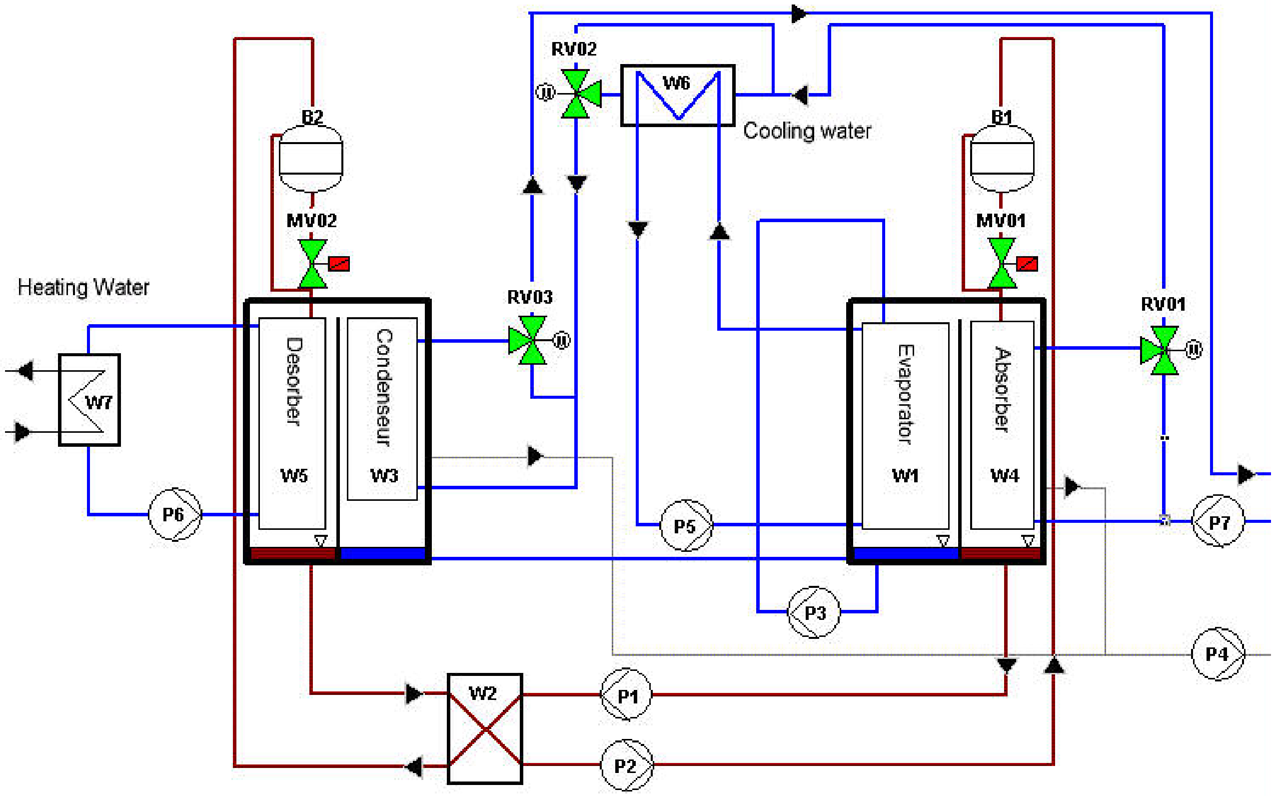

Figure 2: Simplified flow sheet of the function model (measuring points not indicated)

4. RESULTS

The results are summarised as follows:

Influence of the heating temperature

The condenser pressure was kept constant in all the tests via the flow rate of the cooling water; similarly, the evaporator pressure via the flow rate of the chilled water.

Figure 3 shows the cold capacity as a function of the inlet temperature of the cooling water for 2 different heating temperatures. At a cooling water inlet temperature of 27°C and a heating temperature of about 80°C, a cold capacity of 50 kW could be realised. With increasing heating temperature, the cold capacity naturally also rises. The optimal heating water exit temperatures were about 63°C. Even at entry temperatures of cooling water over 35°C the cold capacity was over 30 kW.

If the plant was run with the maximum cooling water flow, then considerably higher cold capacities could be produced. This can be seen in Figure 4 where the cold capacity as a function of the temperature increase of the cooling water in the absorber is presented, whereby again 2 heating temperatures (80 and 88°C) were set.

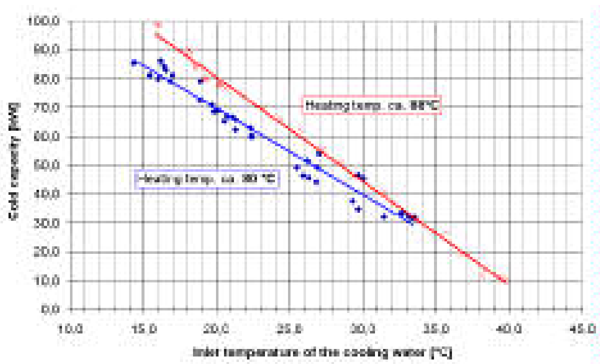

Figure 3 : Cold capacity versus inlet temperature of cooling water

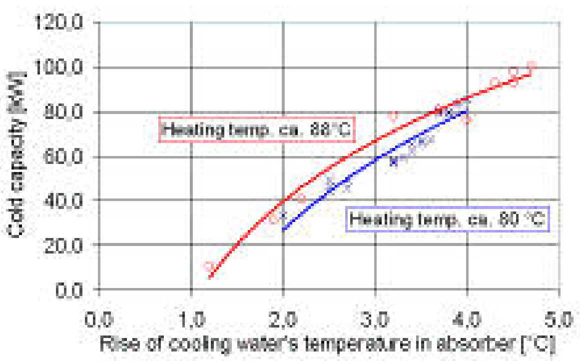

Figure 4: Cold capacity versus temperature rise of cooling water in absorber(Chilled water temperature 12 / 6°C / Li-Br + additives / maximum flow of cooling water)

Plant efficiency

The measuring points shown in Figures 3 and 4 indicated a stable operation and could be reached after a relatively short time. The plant could therefore be operated very flexibly at different cold capacities. Figure 5 shows the corresponding COP factors for various cold capacities, expressed in % of the nominal cold capacity. In nominal operation, a COP factor of 0.8 was achieved. The plant could be easily adjusted down to about 16% of the nominal load. Operation can therefore be easily adjusted to the required cold capacity. Even at a part-load of 30% it was possible to achieve COP factors over 0.65.

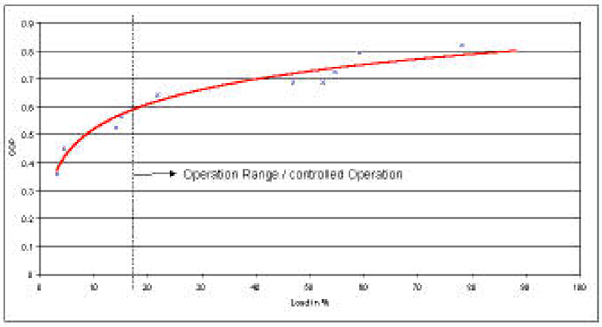

Figure 5 : COP factors at nominal part load (trial of 12.09.2000 / heating temperature 80°C / Chilled water 12/6°C / cooling water absorber inlet 29°C).

Influence of the chilled water temperature

The usual chilled water temperatures are about 12/6°C. Depending on the design of the air-conditioning plant or of the cooling convectors, chilled water temperatures of 15/10°C are sufficient. The two mentioned cases are compared in Figure 6. For higher chilled water temperatures, e.g. 15/10°C, the cold capacity could be increased by about 18% with the plant under examination.

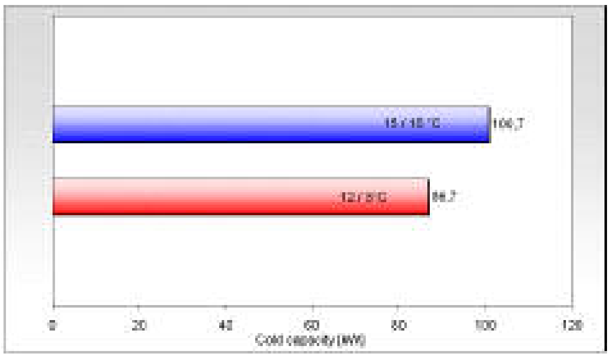

Figure 6: Effect of chilled water temperatures on cold capacity (heating temperature 88°C)

Influence of additives

The addition of additives played a very important role in the absorber and desorber, since, as already mentioned, very low wetability levels were worked with. Additives ensure that the plates are well wetted and thus allow the cold capacity to be more than doubled in comparison to operation without additives. Figure 7 shows the comparison between the types of operation with and without additives. As could be expected, the heat transfer coefficients also rose on the LiBr-solution side as a result of adding the additives.

Plant behaviour

Operation of the plant was extremely stable. Even after faults had been introduced, the plant returned to its previous operating level. Figure 8 shows the operating temperatures for a test which was carried out over 24 hours. As faults, the solution pump was intentionally switched off once and the cooling water pump once as well. Having switched them on again, the old state could be re-established.

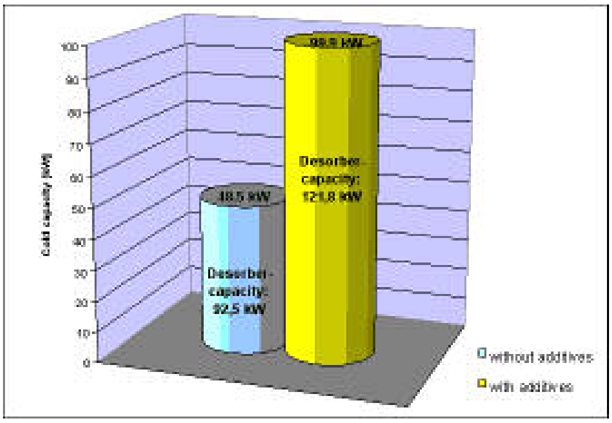

Figure 7: Raise of capacity by addin g additives (trials of 06.04.00 and 13.04.00 / heating temperature 85,0°C)

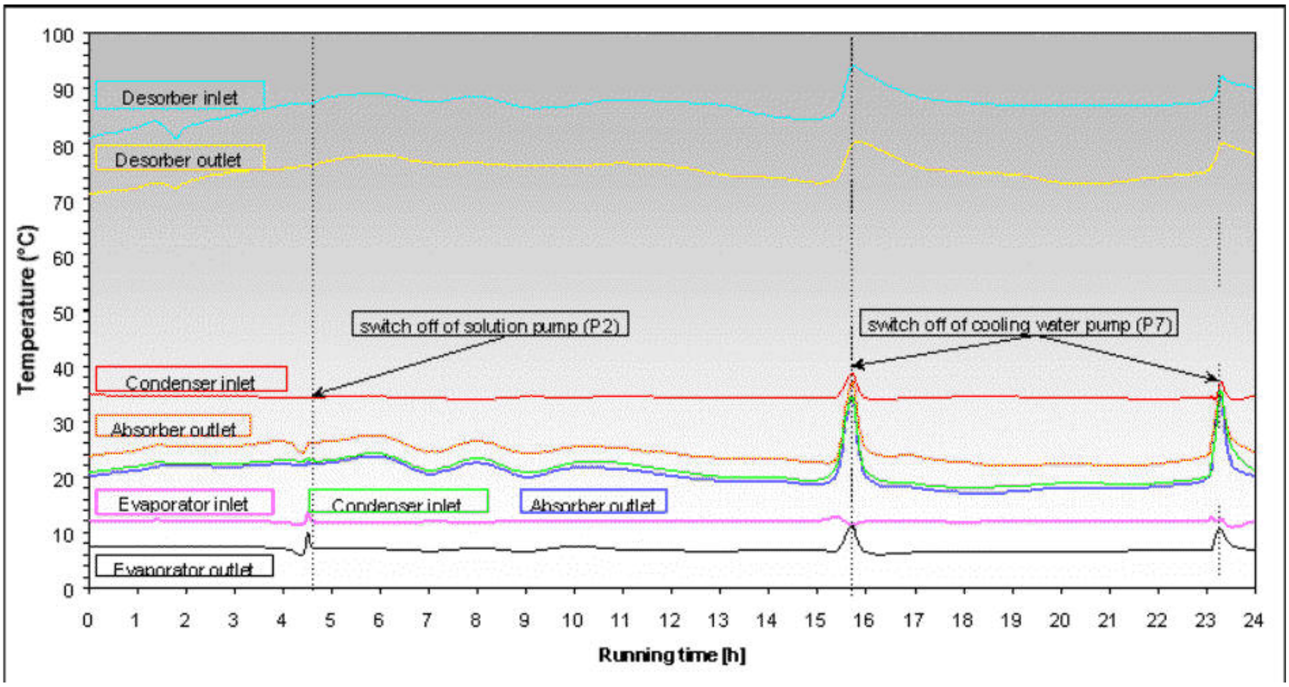

Figure 8 : Operation temperature during 24 hours (long time trial of 18.09.00, 9.00 to 19.09.00, 3.00 /LiBr with additives

5. CONCLUSIONS

For the use of district heating with a supply temperature of 80°C for the production of chilled water at 6°C a function model was set up which operates on the principle of a single-effect absorption chiller. Plate packages were used as heating and chilling surfaces which were fed by the heat carrier (heating or cooling water) in the counterflow. Thus a maximum concentration width could be achieved.

The following results could be obtained in numerous tests:

- The plant allows itself to be operated to under 20% part-load. In nominal load operation, the COP factor is about 0.8, in part-load operation between 0.6 and 0.8. The addition of additives is a key factor for the wetting of the heat transfer surfaces whereby especially the wetting plays an important role.

- The cold capacity can be increased by raising the supply temperature, e.g. to 88°C, or by raising the chilled water temperature, e.g. to 10°C.
- The plant runs in an extremely stable manner. Having eliminated a fault, the plant reaches its old operating state after a relatively short time (a few minutes). The start-up time is also very short.

A prototype of the function model investigated is currently being built. The prescribed cold capacity of 120 kW is to be used to cool offices and electronic installations. The results will be reported at a later time.

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