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Air Dehumidification by Absorptive and Evaporative Cooling

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Synopsis

Especially in modern buildings with small capacity of humidity storage it is necessary to reduce the humidity in the supply air. Normally a refrigeration system containing CFC's is used. There are some alternative fluids available, but mostly they show a high global warming potential. These systems all need electrical energy to be driven and therefore it is necessary to consider other possibilities with alternative systems.

The most promising systems are sorptive systems which are used now in open cycles. In these systems the air is dehumidified by a liquid sorbens and cooled indirectly by evaporating water in an open circuit. In this paper a design of an open cycle liquid desiccant system is shown as well as two possible system configurations. Very interesting possibilities for the regeneration are given in using low temperature energy and also solar radiation in sunny areas.

1. Introduction

Heating, ventilating and air conditioning (HAVC) systems are build to process outdoor air to a special indoor air condition. The demand of the air quality depends on the kind of building. In an industrial building the quality of the products is very important, but in an office building the thermal comfort of the employees must be guaranteed. Basically the parameters temperature and humidity can be changed by special components of a HVAC-system.

Especially in modern office buildings with small capacity of humidity storage it is necessary to reduce the humidity in the supply air. The classical way to dehumidify the outdoor air is using a refrigeration system. Everybody knows the problems and the discussions about the refrigerants. For that it is very important to find alternative components to dehumidify the air.

An interesting technique to dehumidify air is using hygroscopical solid or liquid substances. The ad- respectively absorption technology used in HVAC-systems is nowadays a good enlargement to the existing refrigeration systems but particulary by using liquid desiccants a high demand of research work is necessary. In this paper an open cycle liquid desiccant dehumidification system combined with an evaporative cooling system is described.

2. Methodes of dehumidification

In the HVAC technology the following dehumidification systems are usual:

❶ Condensation on cold surfaces of chillers or water droplets.

❷ Desiccating by the contact with hygroscopic materials.

To ❶:

This kind of dehumidification is the frequent applied technology. To get condensate temperatures below the dew point of the dehumidifying air are necessary. These low temperatures can be realised by an evaporating refrigerant (direct evaporater) or by cold water (water cooled chiller).

The cold water is made by a refrigeration plant and its usual preliminary temperatur is approximately 6°C. The refrigeration systems are formed basically in the three following groups:

- Compression-refrigeration system
- Absorption-refrigeration system
- Steam jet-refrigeration system

The employment of steam jet-refrigerators in HVAC-systems is secondary. The both common refrigeration systems are schematically shown in figure 1 and 2. Further the process is presented in a lg p, h respectively a lg p, 1/T-diagram.

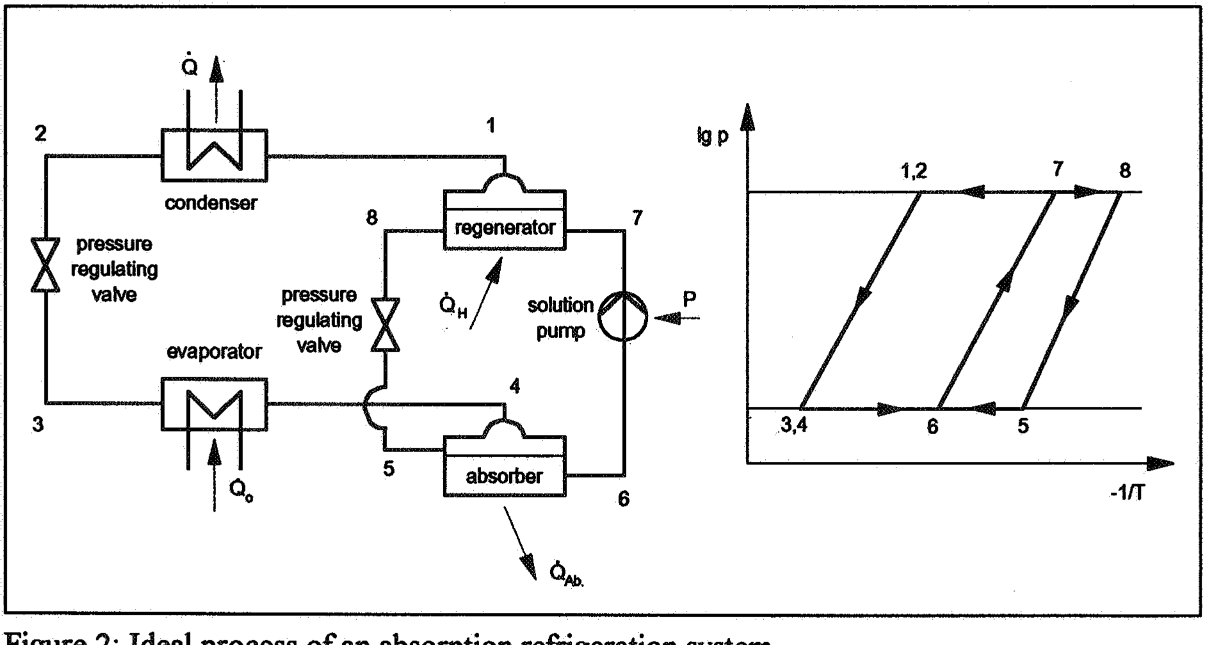

Figure 2: Ideal process of an absorption refrigeration system.

Disadvantageous by using this kind of systems is:

- Poor controllability due to constant water temperature in the cold water chiller.
- Disadvantageous high energy demand for the refrigeration.
  - ⇨ For the air conditioning it is not always necessary to have preliminary water temperatures of 6°C.
  - ⇨ Energy demand for the compressor.
- Reheating of the dehumidified air is often necessary.
- Only limited usability of low temperature heat by the refrigeration systems.

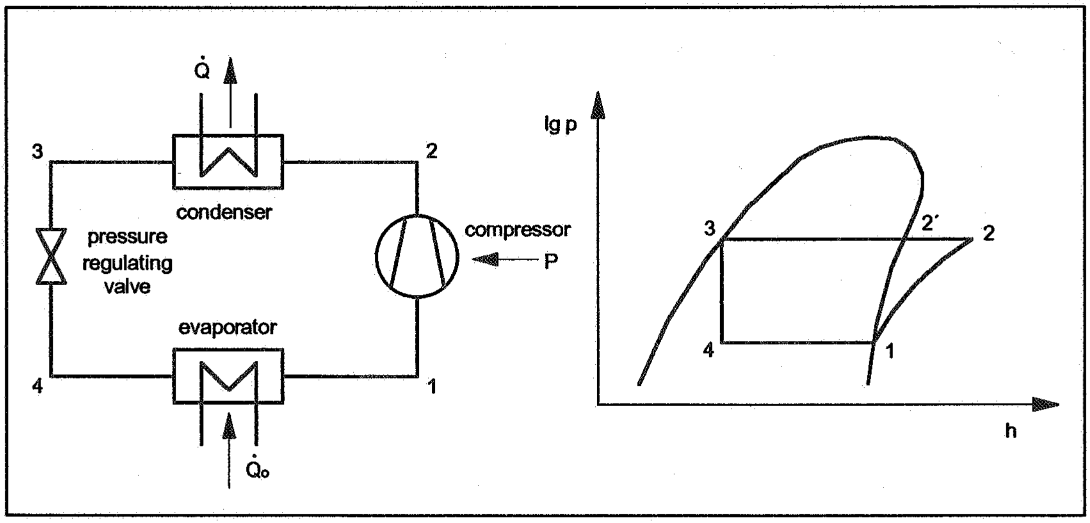

Figure 1: Ideal process of a compression refrigeration system.

By increasing the preliminary water temperature it is possible to reduce the energy demand for preparing the cooling water with refrigeration systems. By increasing the water temperature of about 1 K the improvement of the coefficient of performance (COP) is approximately 3 %.

To ❷:

Desiccating by contact with hygroscopic materials are distingushed by the kind of the used materials:

- solid hygroscopic materials and
- liquid hygroscopic materials.

There is a great variety of solid materials which can be used for dehumidifying air. Active carbon, active alumina, silicagel, zeolithes as well as hygroscopic salts are mostly used for technical drying. Silicagel and hygroscopic salts are privileged for the air dehumidifier. Continuous working rotary wheels or discontinuous working packed beds are equipped with such solid desiccants. In this paper the solid desiccants and the design of belonging plants is not described because the main emphasis is the use of liquid desiccants.

One of the first liquid desiccants which was used for the dehumidification of air was triethylenglycol. Due to the high vapor pressure the application of this desiccant in open cycle systems is unfit because there are high losses of desiccants which have a negative influence to the environment. However open desiccant cycles working with solutions of lithium chloride-respectively calcium chloride are partly successful in practice or investigated in promising research projects.

3. Design of open absorption systems

The described system is an absorptive system for air conditioning. The outdoor air is dehumidified by a liquid desiccant and cooled indirect by evaporation of water in an open cycle. The following figures show schematically possibilities of different processes. Figure 3 presents the arrangement of an open liquid desiccative and evaporative system with the main belonging components. It describes a system working with 100% outdoor air.

Warm humid outdoor air passing the salt solution is dehumidified in a crossflow absorber. To

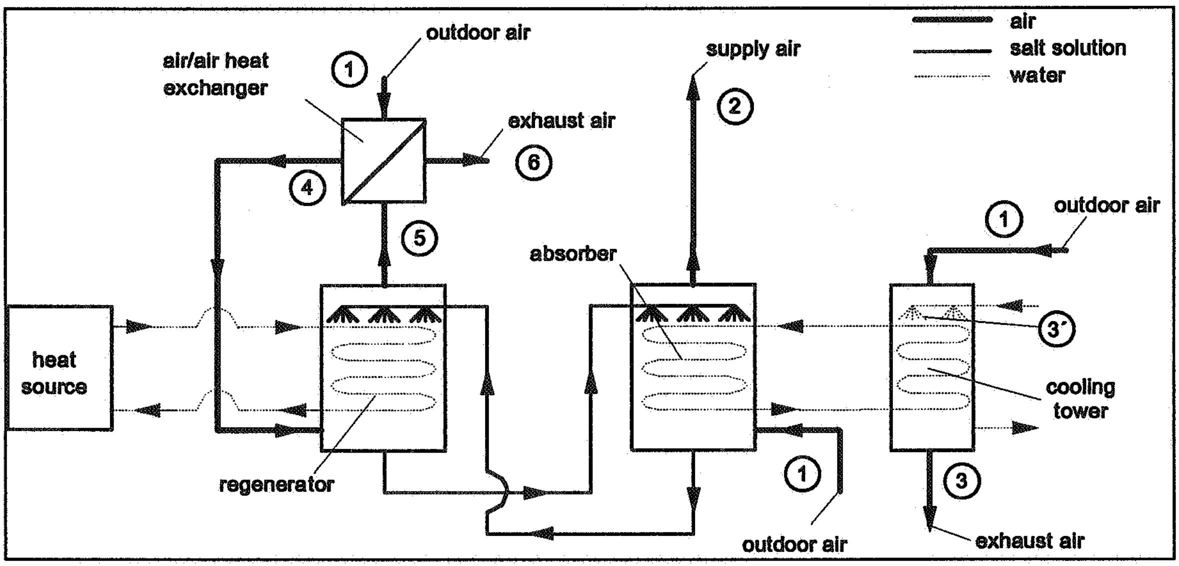

Figure 3: Open cycle liquid desiccant cooling system (100% outdoor air).

get a constant dehumification performance it is necessary to take away the absorption heat by a cooling tower.

By the absorption of steam the salt concentration of the solution is decreasing so the ability of the absorption is reduced. To achieve a constant concentration of the salt solution a regeneration after the absorption is necessary. This is happend in the regenerator where the solution is heated and the water evaporates. The steam and the regeneration air (outdoor air) pass an air to air heat exchanger and leave to the environment.

The change of air conditions for the case of 100% outdoor air is sketched in a Mollier-h,x-diagram in figure 4. Point ① describes the outdoor air situation on a warm humid summerday. The change of condition from ① to ② shows the dehumidification in the absorber with simultaneously cooling by an indirect cooling tower. So the supply air ② has a lower temperatur as well as a lower water content than the outdoor air.

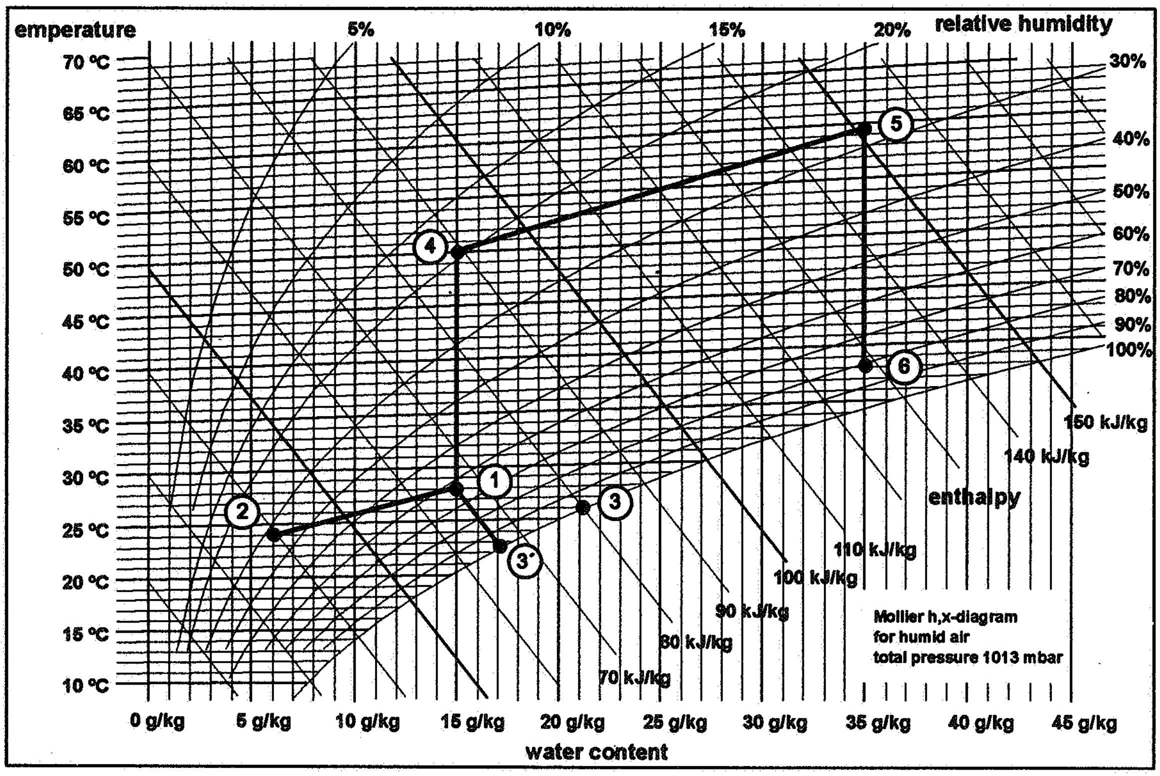

Figure 4: Change of air condition in a h,x-diagram (100% outdoor air).

Moreover in figure 4 also the change of air conditions in the cooling tower as well as the regeneration process are skeched. Such as already mentioned the outdoor air is humidified in the cooling tower by the principle of evaporation (① → ③′). With assumption of a complete wet mode of operation in the cooling tower it is possible to reach point ③. The outdoor air which is used for the regeneration is warmed up from ① → ④. By heating the salt solution the water evaporates in the regenerator (④ → ⑤) and leaves together the system with the air after the heat exchanger (⑤ → ⑥).

The air conditioning of buildings is normally done with a part of return air. It means, that a part of the exhaust air is mixed with the conditioned outdoor air in a mixing chamber. Such air conditioning process is shown in figure 5. The main difference in the absorption process to the system which is explained before is after point ②. In this process it is necessary to dehumidify the outdoor air to a low water content because there is a mixing of humid return ⑦ air with already conditioned outdoor air ②.

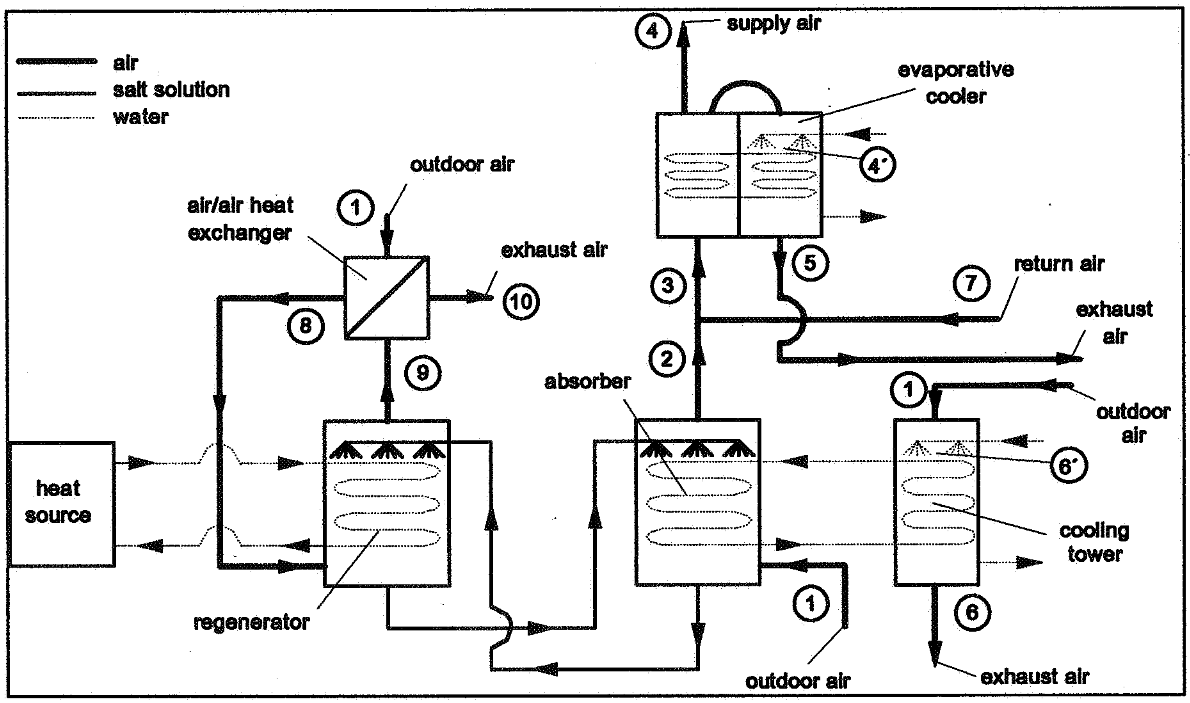

Figure 5: Open cycle liquid desiccant cooling system (With a part of return air).

By mixing the return air ⑦ and outdoor air ② the temperature in point ③ is increasing so that it is necessary to cool the mixed air before entering the room. The cooling of this air is done by an indirect evaporative cooler which operates with a part of the supply air. The

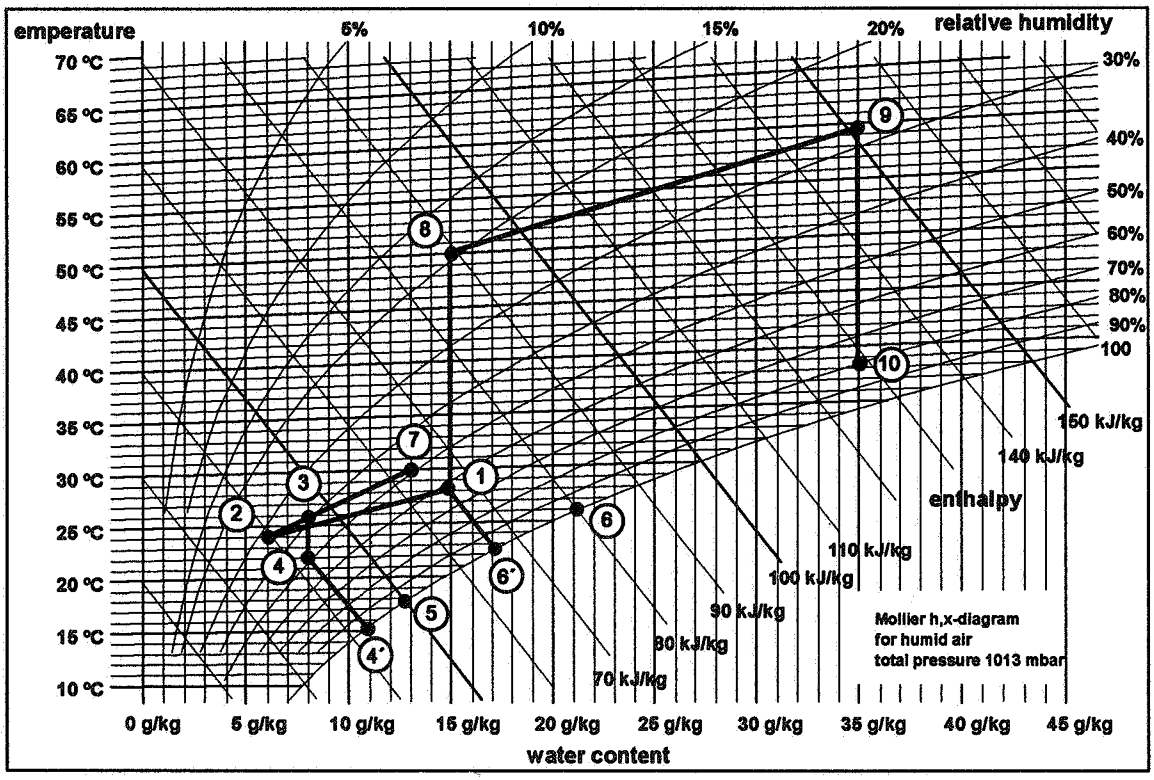

Figure 6: Change of air condition in a h,x-diagram (With a part of return air).

change of the mixed air condition from ③ → ⑤ is sketched in figure 6 on the condition of the complete wet operation of the cooler to reach point ⑤.

3.1 Dehumidification by the "Kathabar"-system

The "Kathabar"-sytem is used in different fields of air conditioning. The desiccant (the so-called Kathene solution) of this system is a 40 % Lithium chloride solution. Figure 7 shows a schematic diagram of the system with the main components: a heating- and a cooling coil, a conditioner, a regenerator, a sump and a pumping unit.

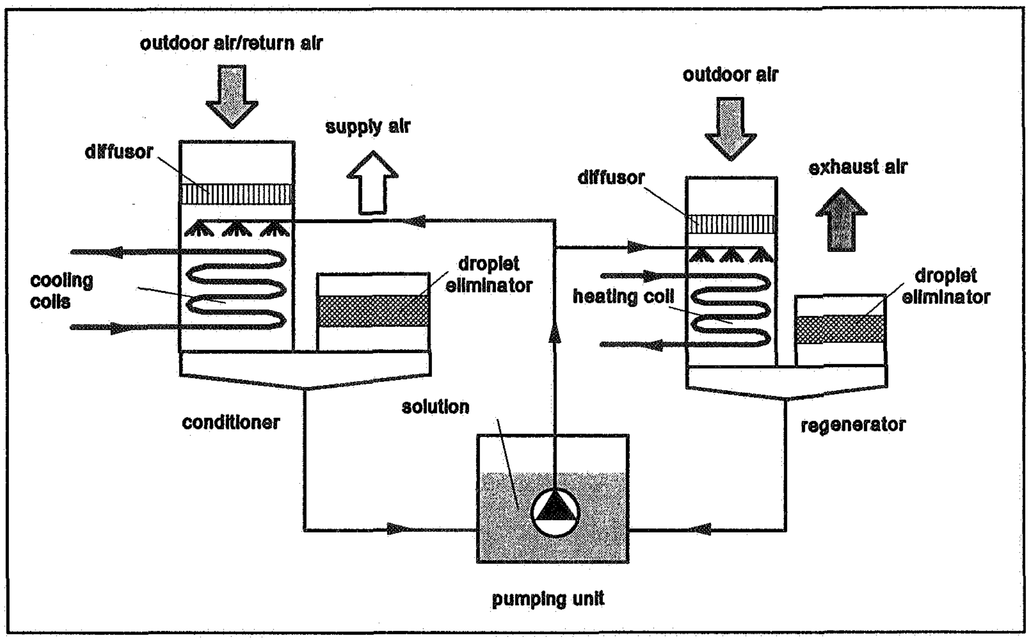

Figure 7: Schematic diagram of the "Kathabar"-system.

The solution is sprayed over the cooling coil in the conditioner and the outdoor air respectively the return air comes in direct contact with the solution. The absorption heat is taken away by the cooling coil and the dehumidified air passes a droplet eliminator to guarrantee that there are no particles of solution in the supply air. The weak solution flows back into the pumping unit. Steam is pumped to the regenerator heating coil to warm up the solution. For that reason the water is evaporated and is exhausted with the air flow.

3.2 Regenerators

To guarantee a stationary operation of the dehumidifying process it is necessary to regenerate the weak solution. This can be made by different ways. Basically it is possible to use the same construction for the regenator as for the absorber. Instead of a cooling unit a heating unit is installed and it is only low temperature energy necessary to drive out the water of the solution. Temperatures between 60°C to 80°C are sufficient so that it is possible to use district heating

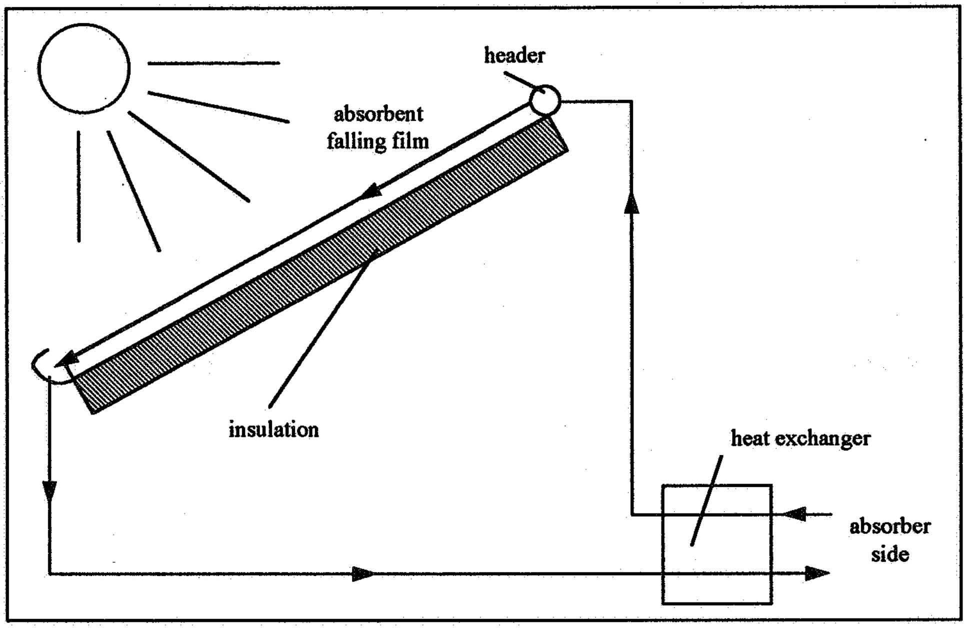

Figure 8: Example of a solar-collector-regenerator.

for example. Further the use of solar-collector-regenerators in sunny areas is an efficient way to regenerate the weak solution. Figure 8 shows an example for a solar-collector-regenerator. Usually the surface of a solar-collector is blackened to facilitate the absorption of solar energy and the back is well insulated. The surface can be corrugated, V-grooved or a textured surface to aid the even distribution of liquid film.

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