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Criteria for Heat Recovery and Dehumidification

Dipl.-Ing. Frank Dehli

Marienburger Str.6, D-69124 Heidelberg, Germany

CRITERIA FOR HEAT RECOVERY AND DEHUMIDIFICATION

1. Synopsis

Two factors - CO_2 emissions from heating and cooling systems and restrictions on the use of CFC refrigerants - have accelerated the development and introduction of new and more environmentally friendly cooling systems. These new cooling systems also include the so-called "Desiccant Cooling Systems (DCS)" [1]. The desiccant cooling systems consist of a rotating dehumidifier, a rotating heat exchanger and evaporative coolers. For design, control and operation of desiccant cooling systems new criteria have to be considered because of the specific properties of these new technologies. Therefore consulting engineers as well as installers of air conditioning systems are hesitating to trust the efficiency and performance of these new components. Dehumdification of moist air is one of the least known and understood thermodynamic processes. On the other hand the same rotating desiccant wheels and the same rotating heat exchangers are used for many years in a similar joint combination in thousands of installations in the field of air dehumidification for industrial processes for heat recovery and cooling.

In general the dehumidification rotor is devided into two sectors (Fig. 1). One is the process zone where humidity is accumulated. The other zone is the regeneration zone where humidity is removed by the counterflow of heated air. The typical operation is unbalanced with a ratio of 1:3 for regeneration to process zone area or air flow. For a balanced ratio the regeneration temperatures can be below 80° C. To reach high efficiency for the dehumidification process the rotor is divided in three sectors to have in a multistep operation an intermediate cooling in the so-called purge sector.

In the following a standard design of an industrial air dehumidification system is described in order to show that design criteria as well as experience can be derived and transferred to the desiccant cooling systems in the comfort field application.

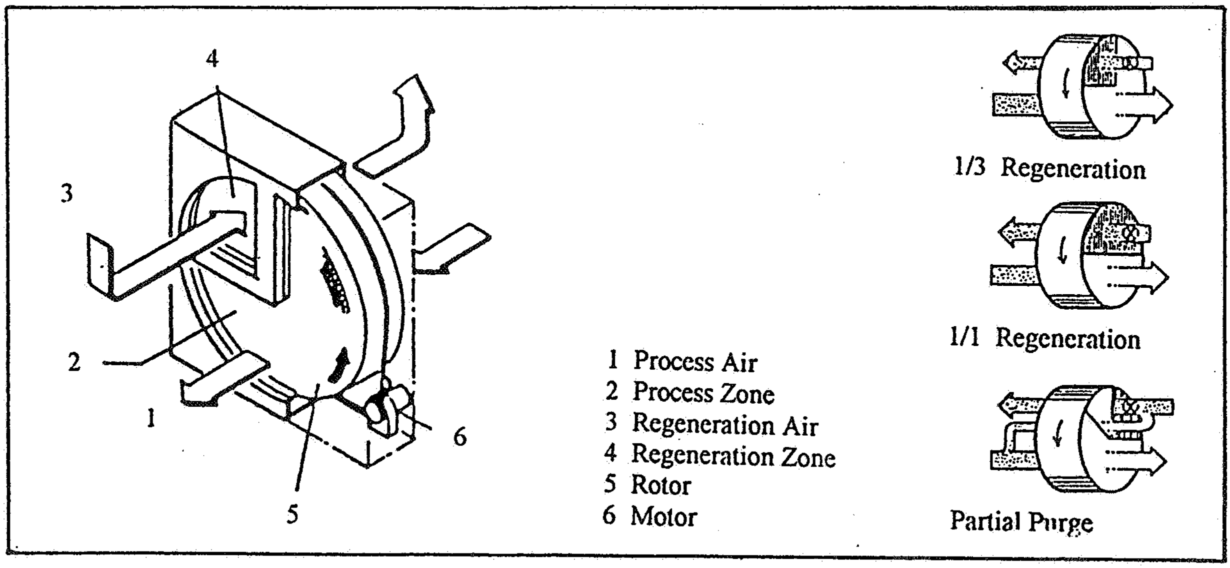

Fig. 1: Desiccant Wheel for Dehumidification of Process Air

2. Desiccant Cooling Systems

According to Fig. 2 (diagram and psychrometric chart) the desiccant wheel “A“ rotates within the outdoor air stream and removes the moisture from it (1→2). The most suitable rotor is fabricated of silica gel reinforced with inorganic fibres and formed into a honeycomb shape. It has an excellent water adsorbing ability. The adsorption of moisture on the silica gel causes the temperature of the air to rise. The heat generated during the drying step is removed from the air by the rotating heat recovery wheel “B“ with high efficiency (2→3) . This heat recovery wheel is non-hygroscopic and made of corrugated aluminium. The evaporative cooler “C“ humidifies the dried air to further reduce the dry bulb temperature of the supply air stream (3→4). For the reactivation cycle the return air is used by first reducing the dry bulb temperature in the evaporative cooler “D“ (5→6). The heat originally generated during dehumification of the supply air is then removed and transferred back into the reactivation cycle by the heat recovery wheel “B“ (6→7). In the heat exchanger “E“ external heat energy brings the reactivation air to the required temperature for desorbing the desiccant wheel “A“ (7→8). Due to the synthesized silica gel this temperature can be set to a minimum which allows to use low level waste heat available from many heat processes, cogeneration processes and also solar energy. When desorbing the desiccant wheel “A“ the exhaust air temperature is reduced by increasing the absolute humidity (8→9).

The new desiccant cooling systems can operate during winter (Fig. 3) and summer seasons for heating, humidifying, cooling and dehumidifying the supply air in the same way as a traditional air conditioning device according to a special control equipment. A lot of proposals were added to the basic configuration and are compared to each other and the conventional mechanical cooling systems in terms of performance coefficients. This values depend strongly on the efficiency of each component of the desiccant cooling system as well as the total configuration. The highest efficiency is required in any case for the heat recovery exchangers since the enthalpy reduction of the supply air and the heat recovery for regeneration process occur just there. It is important to understand that the evaporative coolers cannot reduce the enthalpy of the air leaving the dehumidifier in spite of reducing the air temperatures. As the dehumidification is also an adiabatic process, the dehumidification requires the reduction of air temperature with the mentioned high heat recovery efficiencies and the subsequent step of evaporative cooling. Only under this conditions the desiccant cooling systems are able to operate in terms of competing with mechanical systems.

Heat recovery devices and evaporative coolers are very well known in many engineering applications and their efficiency has been improved close to the maximum especially for rotating heat exchangers. The continuous desiccant dehumidification is a relatively recent technology and its operation characteristics and design procedures remain fixed in many respects to the product manufacturers and specialized companies working in the field of industrial air dehumidification and the endusers applying the main technology - the regenerative desiccant dehumidifier.

Controlling both supply air temperature and supply air humidity in an overall yearly desiccant cooling operation mode needs very new design strategies. Supply air temperature and humidity depend on the rotation speed of the adsorption wheel and the heat recovery wheel as well as on the reactivation temperature and the inlet moisture content and temperature of both air streams. However the main characteristics for the design of a desiccant cooling system depend of the properties of the various desiccant materials used such as silica gel, molcular sieves, lithium chloride and activated carbon. The structure and the material of the honeycomb core are also very important for fixing the desiccant on the surface of the rotor matrix.

3. Industrial Dehumidification Systems

Dehumidification of air is essential in nearly every segment of industry, in research and in preservation and storage of products, raw materials and even foofstuffs. Dehumidification is often the key to higher productivity by significantly reducing product rejection and production time.

As industry looks for new ways to improve productivity, moisture control is experiencing broader application as a means of producing higher quality products or greater product volume using existing manufacturing equipment.

Many areas of high technology cannot function today without controlled climate. Development of efficient, dependable and versatile dehumidification systems has frequently been the key to the success of a new technology.

The pharmaceutical industry is a classic example of both productivity improvement and new technology availability attributable directly to the utilization of dehumidification. Extremly dry air is required for processing hygroscopic pharmaceutical products such as capsule forming, tablet compressing, sterile filling, powder drying, ultra clean handling, gelatine based coatings, fabrication of laminated materials and so on. The factories are therefore classified according to the room air humidity. The requirements for controlled low humidity room air conditions are during the winter operation 20 to 22° C at 15 to 30 % r. H. and during the summer season 24 to 26° C at 15 to 25 % r. H. . To guarantee these room air conditions it is necessary to have highly qualified air condition systems with dehumidification of the supply air to dewpoints down to -15° C and lower in a 24 hour operation per day.

Choosing a dehumidification system involves a series of decisions, beginning with a review of the comparative merits of refrigerant and desiccant dehumidifiers. Basic factors are capital investment, operating costs and maintenance costs. In terms of capital investment, mechanical refrigeration systems are usually less costly for delivered air dew points above 5° C. Maintenance costs may be equal to or higher than desiccant systems. In general, operating costs will be a very important selection factor. However, as a guideline for dewpoints less than 5° C , desiccant dehumidifiers should be used. Above the 5° C dew point both mechanical refrigeration and desiccant systems can be evaluated on the basis of comparing operating costs. A comprehensive assessment requires consideration of refrigeration efficiency, dehumidifier efficiency, heat recovery efficiency, moisture removal rates, delivered dry bulb and dew point temperatures.

A typical application for dehumidification of room air and process air in the pharmaceutical industry is presented according to Fig. 4 and Fig. 5. The air treatment for heating, cooling and dehumidifying outdoor air is done by the combination of three heat recovery wheels, a desiccant dehumidifier wheel and a cooling coil. Normally process air is outdoor air only without mixing return air to prevent process air contamination.

During summer operation (Fig. 4) the outdoor air is cooled and dehumidified by the enthalpy of the room return air with a rotating total heat exchanger "A" (1→2). The return air is raising humidity and temperature (6→7). The dehumidification of the outdoor air down to the required dew point of -15° C (1 g/kg) follows with the desiccant wheel "B" (2→3). The first cooling step of the process air is in the rotating sensible heat exchanger "C" (3→4) using the return air after the total heat exchanger (7→8). The second cooling step is the cooling coil (4→5) down to the required supply air condition. The main advantages of this design is an impressive reduction of the cooling capacity and cooling energy by the combination of two heat recovery wheels with the desiccant wheel.

The winter operation (Fig. 5) is very simple. After the total heat exchanger (1→2) which is operating as a preheater the outdoor air is dehumidified to the supply air condition by controlling the rotation speed of both rotors (2→3).

The reactivation of the desiccant wheel needs thermal energy for summer and winter operation. The required capacity and the energy demand for this reactivation cycle is also reduced by using a rotating sensible heat exchanger "D" with an efficiency of up to 80 %.

4. Summary

For both desiccant cooling systems and dehumidification systems humidity and temperature control are important to meet the room air or process air conditions. Such cases require that dehumidifiers and heat recovery systems together with other components as cooling and heating coils, evaporative coolers, filters, air-moving devices and sensors are integrated into an overall efficient and effective air handling system. The basic design parameters of these air handling systems are different from conventional air conditioning systems. It is obvious that longlasting experience and research with desiccant and heat recovery wheels in industrial dehumidification systems can be transferred to the new desiccant cooling systems and design and operation criteria can be applied without any restriction [2].

5. References

[1] ASHRAE: "Desiccant Cooling and Dehumidification", 1992, ISBN 0-910110-90-5

[2] ASME Solar Energy Conference Proceedings, 3/1995, Kuma, T. et al.: "Thermally Activated Honeycomb Dehumidifiers for Adsorption Cooling Systems"

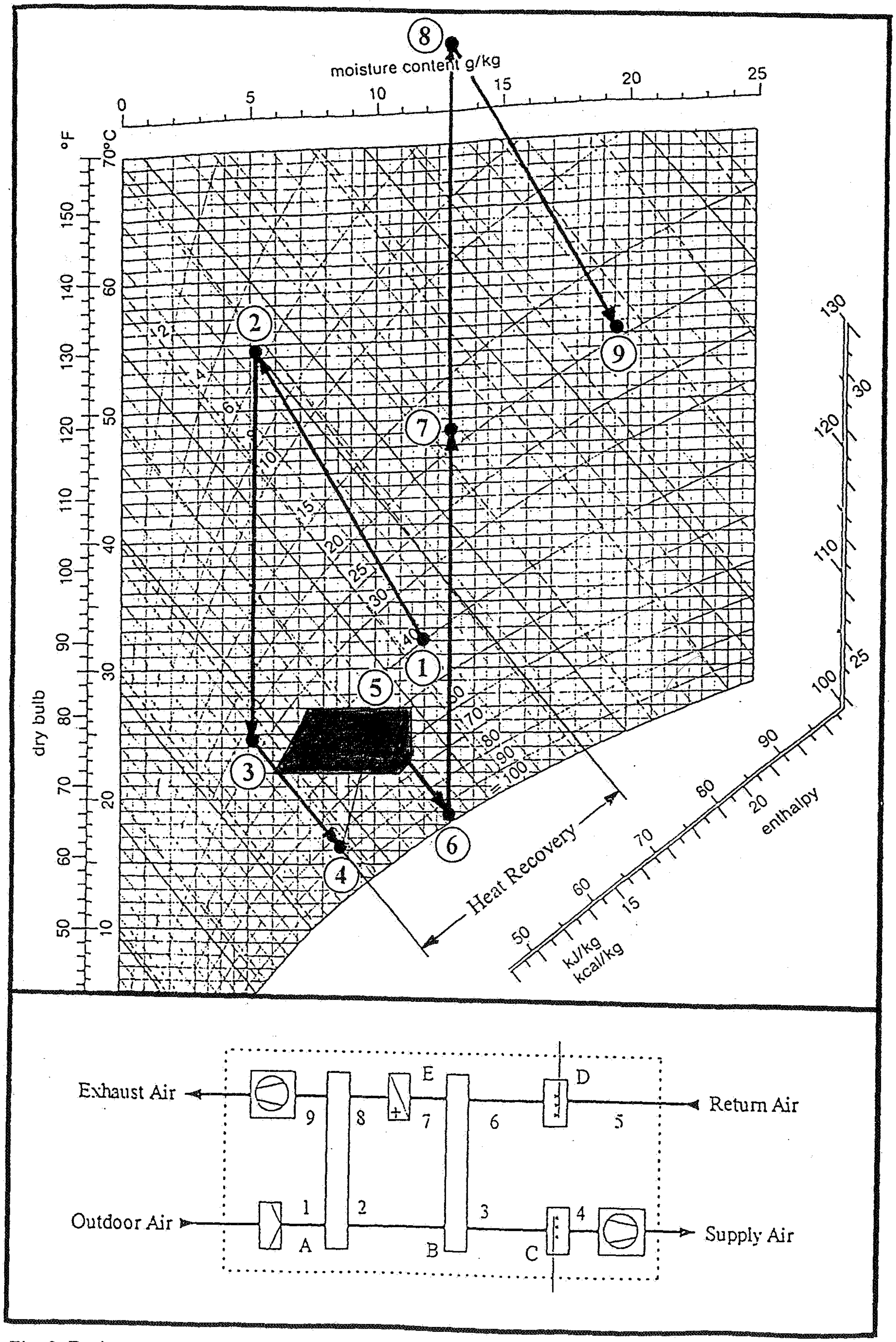

Fig. 2: Desiccant Cooling Summer Operation

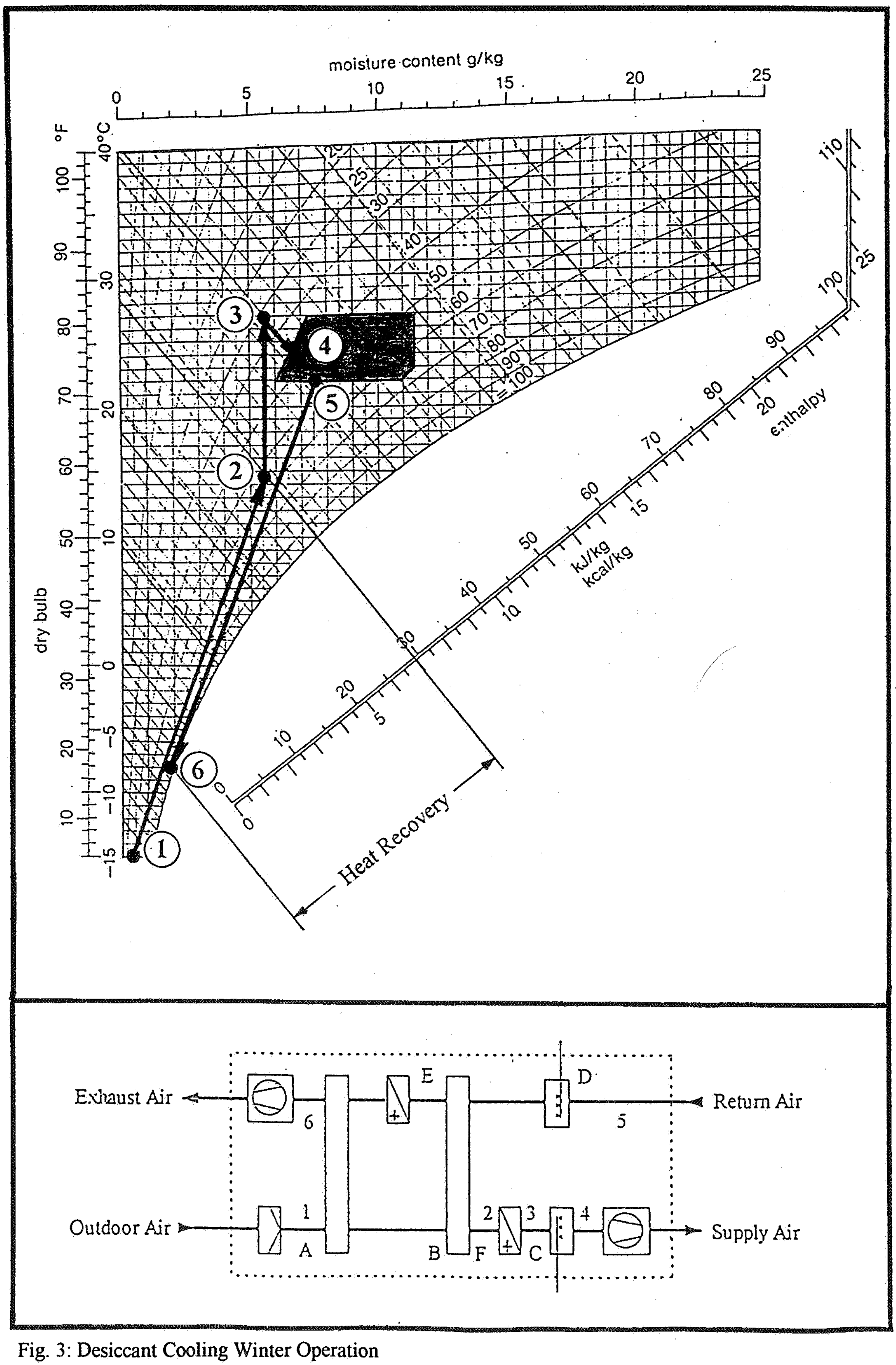

Fig. 3: Desiccant Cooling Winter Operation

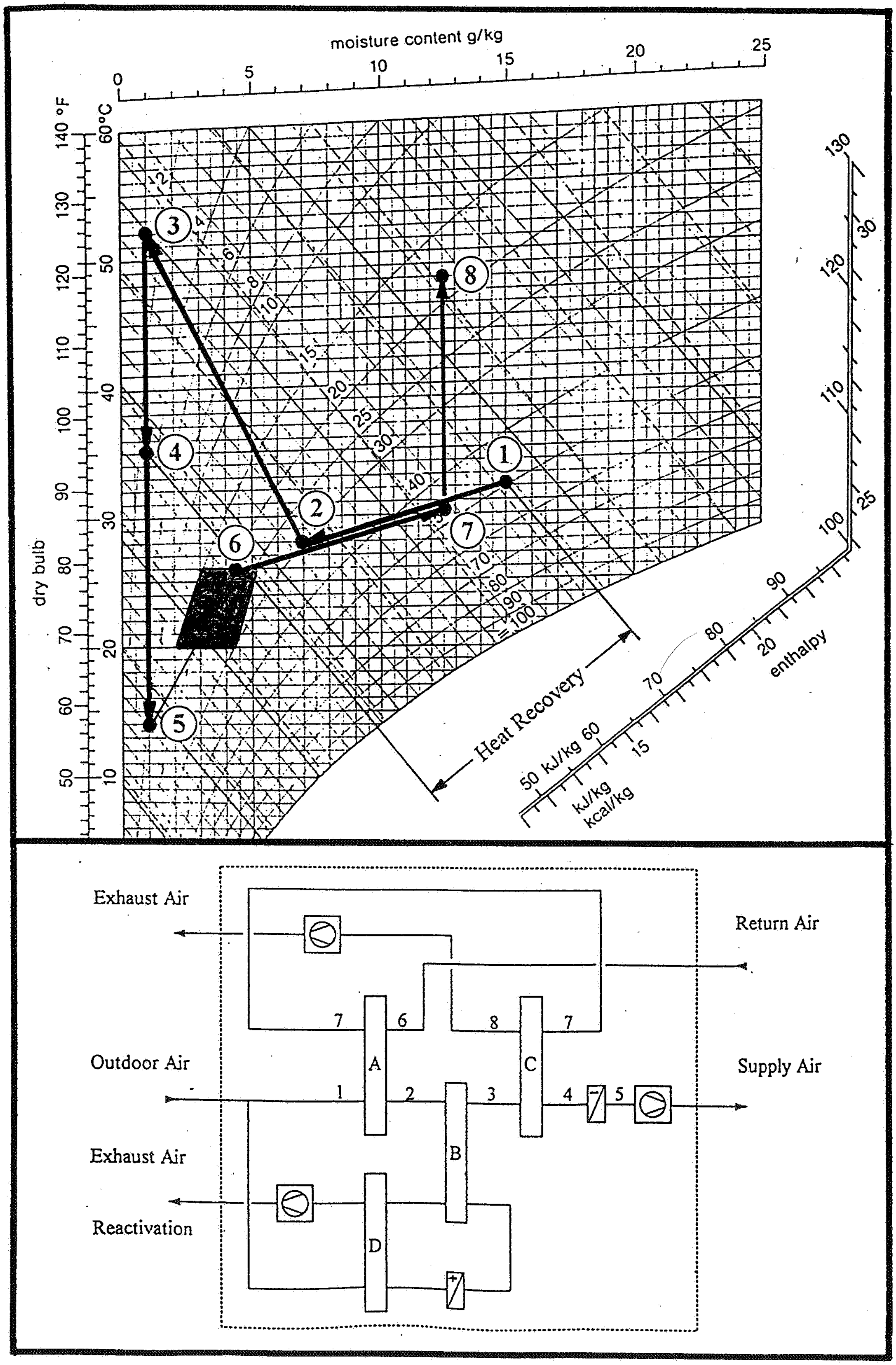

Fig. 4: Industrial Dehumidification Summer Operation

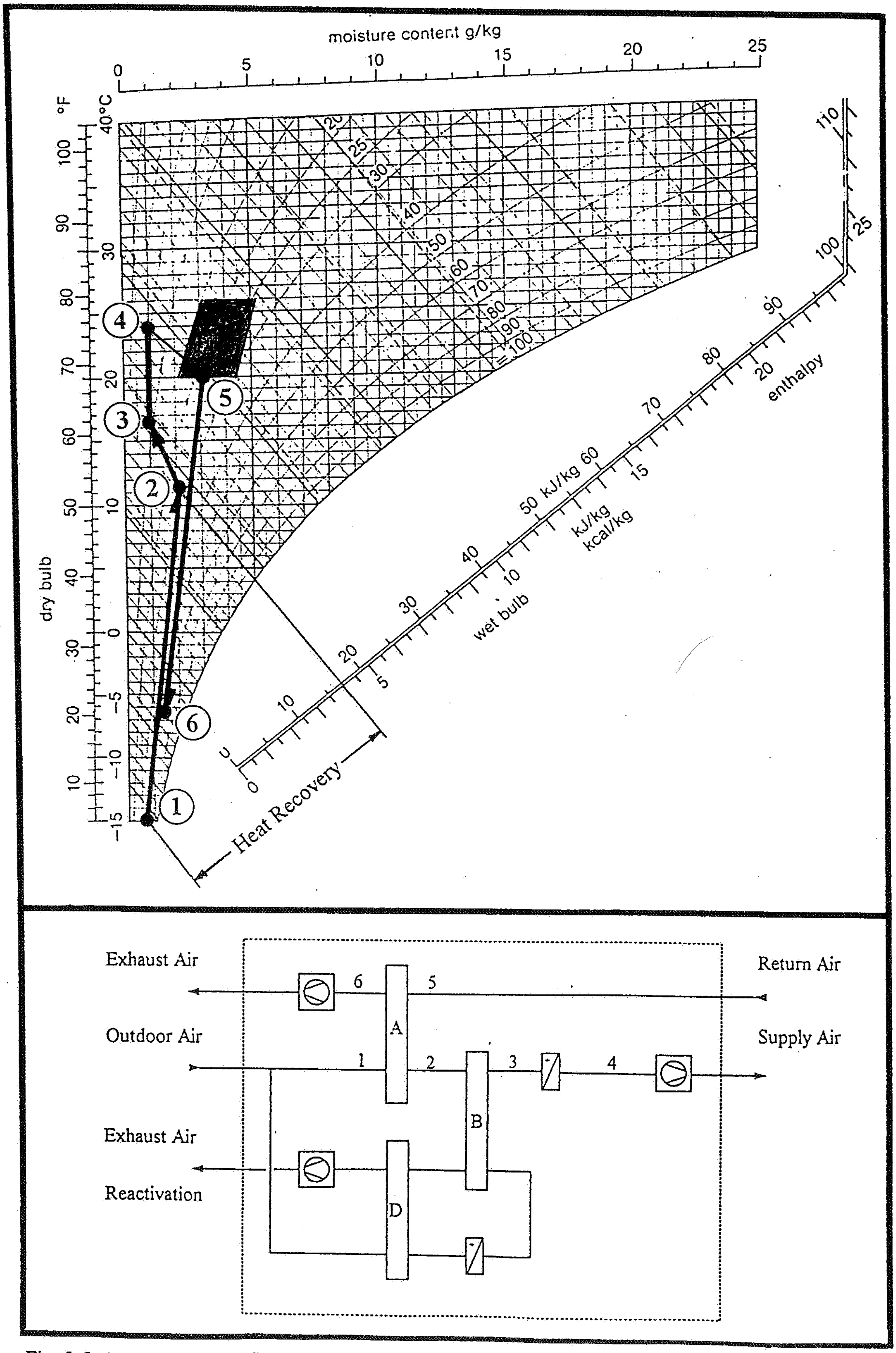

Fig. 5: Industrial Dehumidification Winter Operation