AIR DEHUMIDIFICATION

by

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INTRODUCTION

Why dehumidify?

Air humidity is of importance in many fields in both agriculture and the processing industry. Where low relative humidity is required, the dehumidification of ambient air is usually necessary; average humidity of ambient air in Thailand is too high for many processing industries, such as electronic equipment manufacturing and food processing.

In materials handling, most materials are hygroscopic to a certain extent, and contain some amount of moisture. The amount of moisture depends on the temperature and relative humidity with which they are in equilibrium. This can have several effects on the materials, including:

1. It encourages bacterial activity, thus resulting in mold, mildew attacks, and unpleasant odors.

2. Caking of powders, etc.

   To prevent mold and mildew attack, it is necessary to keep materials in an environment of 65% relative humidity or below. To prevent caking of powders, it may necessary to maintain relative humidity at 50% or lower.

3. High moisture content in seed results in high metabolic rates in the embryoes and stored materials. This may drastically reduce the germination capability of the seed.

Since local ambient conditions have an average relative humidity (RH) of 75-80%, dehumification is an essential requirement for a wide range of applications in Thailand, from preservation of electrical and electronic goods to upkeep of metal components, in seed storage, etc.

DEHUMIDIFICATION METHODS

There are two ways of lowering the relative humidity: One is by heating the atmospheric air, and the other is by reducing moisture content of the air. The former method is often used in economic processes while the latter is used where the former cannot fullfil the requirements of the product or process.

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In the drying process, the drying rate may be assumed to be proportional to a driving force which is the difference in vapor pressure between the air and the material being dried:

$(\phi^* \, P_{ws} - P_{wair})$

ϕ^* = RH in equilibrium with the material being dried.

P_{ws} = vapour pressure of saturation at current temperature.

P_{wair} = partial pressure of the vapor in the air.

As P_{ws} is a strong function of temperature, a low ϕ^* - value can often be compensated by increased temperature.

It is often the case that drying must be accomplished at a low temperature, sometimes lower than the ambient. In such cases, the drying driving force can only be achieved by reducing the moisture content of the drying air.

Dehumidification as used herein, is the reduction of the relative humidity of the process air; this can be done in either of two ways:

1. Increasing the air temperature.

2. Reducing the moisture content of the air.

Either of the above methods results in reduced relative humidity as can be seen from the Mollier-graph (Figure 1).

It should be noted that moisture reduction also results in some temperature increase, due to evaporative heat emission of the water vapor following condensation.

Low-Temperature Dehumidification

Many applications call for low-temperature dehumification, such as in food processing, comfort-air conditioning, and seed storage. In this case, heating the air is not considered a suitable or safe method; reduction of the moisture in the air is thus the only alternative.

Moisture reduction can be done by either of two methods:

1. Condensation

   Condensation occurs when air is cooled to a temperature below its dewpoint. Cooling the air can be achieved by compressor refigeration (Fig. 4). The method works when conditions for the dehumidified air lie within the dashed area in the diagram in Figure 5. When the air's moisture content is less than 6-8 g/kg, there is risk of frost formation on refrigerating surfaces.

Temp. -30°C – +30°C. Fuktig luft av 101 kPa. Moist air at 760 mm Hg.

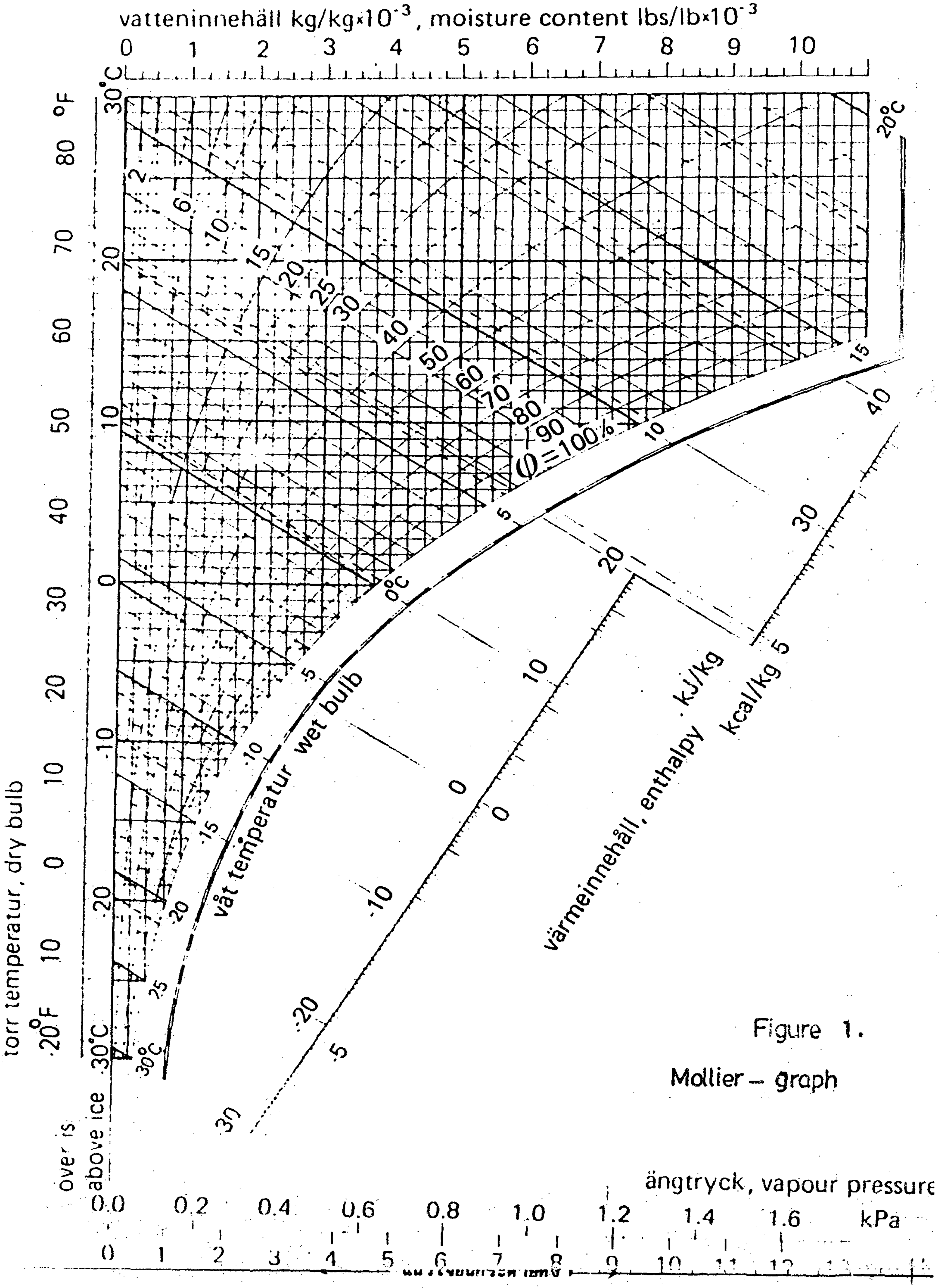


Figure 1.

Mollier – graph

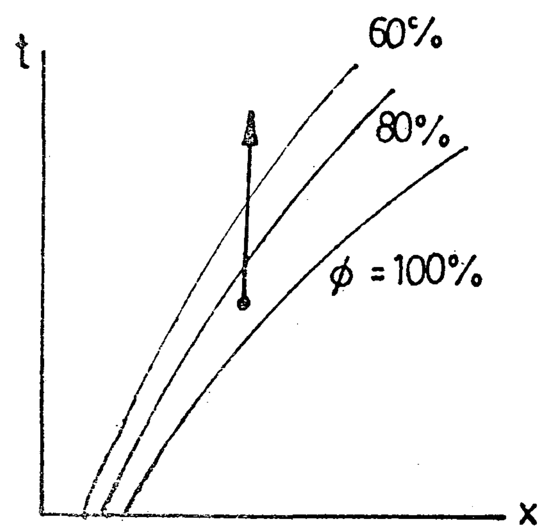


Figure 2.

Dehumidification by heating.

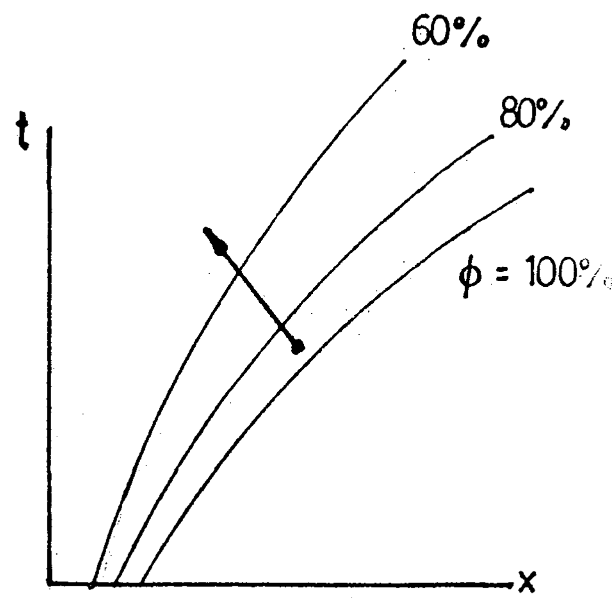


Figure 3.

Dehumidification by moisture reduction.

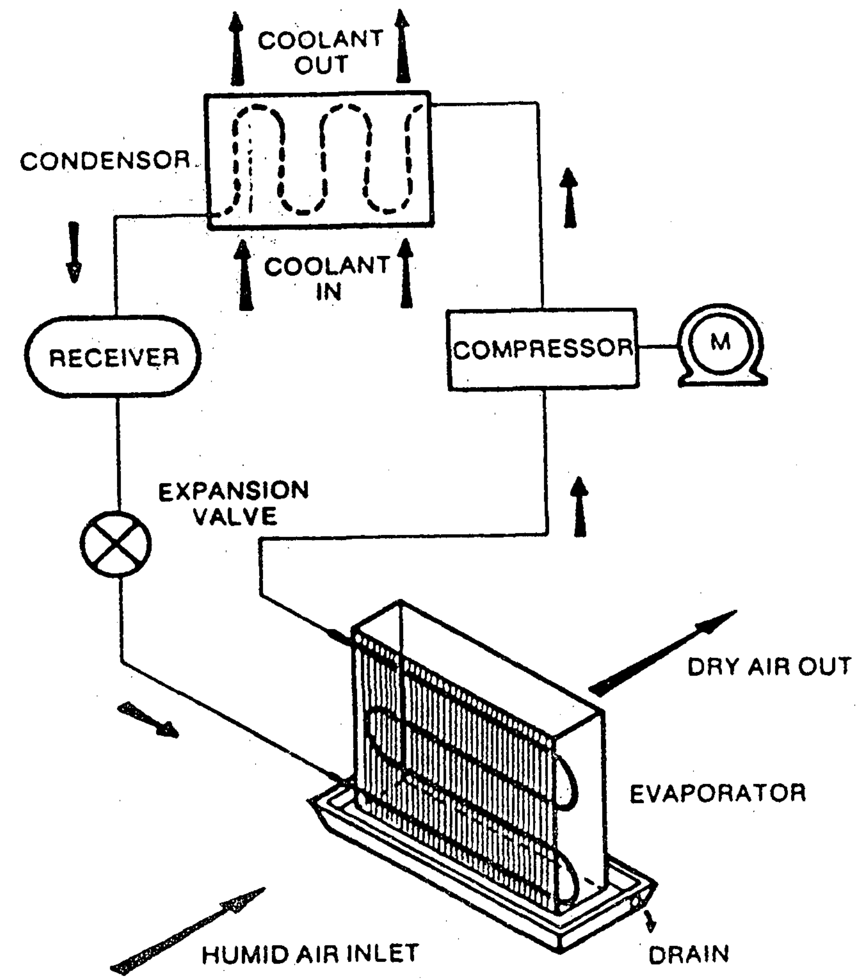


Figure 4 A Mechanical Refrigeration Dehumidifier

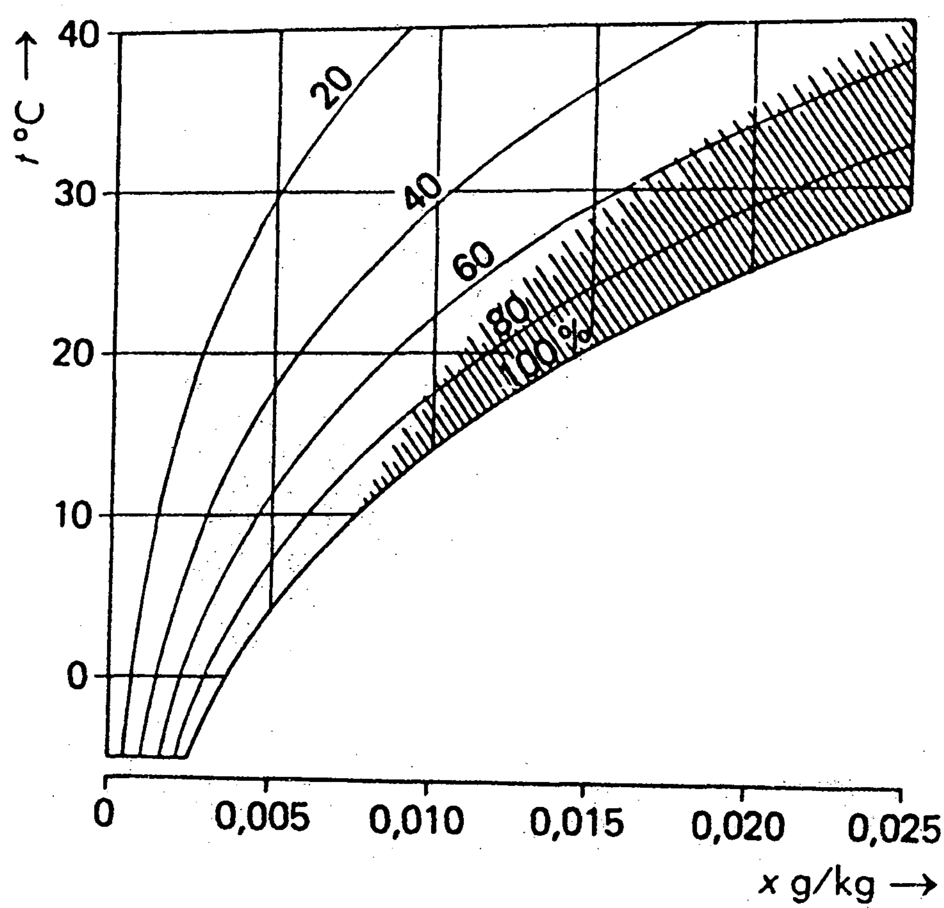


Figure 5

Feasible region for condensation method of dehumidification.

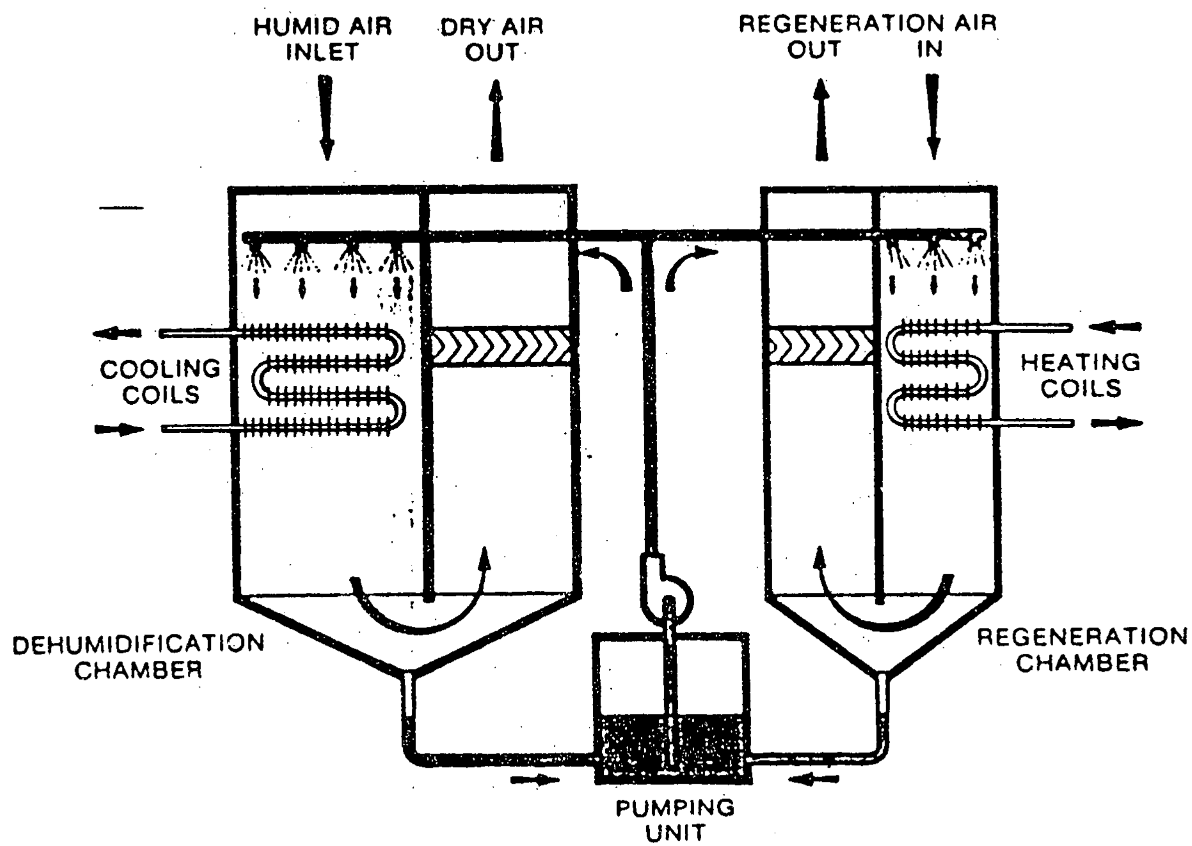


Figure 6 Liquid Absorbent Desiccant Dehumidifier

2. The Sorption Method

The sorption method entails binding moisture from the air onto a hygroscopic material. Latent heat is also liberated in this process; since there is no offsetting refrigeration, the air temperature rises. The method works with equal efficiency under all air conditions.

Various sorbents are available. Silica gel and lithium chloride are the most common sorbents employed for practical dehumidification. Air to be dehumidified is blown through a mass of the sorbent material, and the moisture is removed as it is absorbed or adsorbed in the sorbent. Several arrangements are possible to accomplish sorption dehumidifications; some of them are shown schematically in Figures 6, 7, 8 and 9.

Examples of Commercial Dehumidifiers Using Adsorption

Several dehumidifiers are available commercially, which use the principle of adsorption. The sorbent condenses atmospheric moisture into the form of liquid, which then adheres to the sorbent's surface. Most sorbents can carry water up to 50% of their dry weight. The process of dehumidification consists of two operations:

1. Drying the air. The air to be dehumidified is blown through the sorbent to release water vapor to the sorbent in the liquid form. The leaving air is dried.

2. Reactivation of the sorbent. After absorption of water for some time, the sorbent material becomes saturated. In order to restore its drying capability, the sorbent must be re-activated, which is normally done by blowing hot ambient air through it. This hot air, with its low RH, carries away water from the sorbent and leaves the system to the atmosphere.

Two types of sorbent are used commercially, silica gel and lithium chloride; they are generally used in the solid from. These sorbents generally require a reactivation temperature of about 120 degrees C. Construction of dehumidifiers varies with the type of sorbent used and the arrangement of air flow.

1. Silica gel dehumidifier.

Many dehumidifier manufacturers use silica gel as the sorbent; two common units are made by the Dryomatic Division of Airflow Company, and Bry-Air, Inc., both of the U.S.A. Their designs are quite similar in that both employ rotating silica gel beds. The silica gel beds are either disk type or cylindrical type. With one exception, Bry-Air has one model called MVB type using an arrangement of carrousel moving beds (Fig. 10). The cylindrical silica gel bed type is shown in Fig. 11. The common feature of all these types is that the desiccant (silica gel) bed is divided into two compartments, each being air-tight sealed from the other. One compartment is the moisture extraction side, while the other is the moisture releasing side (reactivation). The former is for drying the process air, and the latter for regeneration of the desiccant. The air flow rate ratio of the two compartments is normally about 1 to 2, with the lower one being the reactivation side.

Disadvantages of silica gel dehumidifiers are generally:

1. High energy consumption for reactivation.

2. Low performance as compared to some other types.

3. High air cross-leakage between the process air and the reactivation air compartments.

2. Lithium Chloride type dehumidifier.

This type normally employs the rotary honeycomb desiccant bed, as shown in Fig. 9. As in the case of the siliga gel type, the desiccant bed is divided into two sections, one for drying the process air and the other for regeneration of the desiccant. AB Carl Munters of Sweden manufactures this type of dehumidifier, of various capacities. They have claimed with a series of comparison tests that the lithium chloride rotary honeycomb type dehumidifier has many advantages over the silica gel type, such as lower energy consumption, higher capacity-to-weight ratio, and longer service life. However, one of their major drawbacks is the prohibitively high cost.

APPLLICATION OF DESICCANT DEHUMIDIFIERS TO SEED DRYING

Drying is necessary if seed are to be stored for a long time. The normal rule of thumb is that 1% moisture content reduction from the seed lengthens the storage life by the factor of two. It is important that seed not be exposed to temperatures above 41 degrees C for a long period. It follows that under Thai conditins, desiccant dehumidification is necessary to dry seed to below 10% moisture content. If ambient air were used to dry seed without reduction of its moisture content, it would have to be heated to above 41 degrees C. in order to dry seed to below 10% moisture content. Such high temperatures would destroy the seed. The dehumidifier can produce air below 41 degrees C that is dry enough to drive off water and dry the seed to below 10% moisture content, as the airtight closed-circuit drying system is most appropriate. Figure 12 shows the schematic diagram of the airtight closed-circuit desiccant-dehumidified seed dryer.

FUTURE APPLICATIONS OF DEHUMIDIFIERS IN THAILAND

As humid as the weather in Thailand is, dehumidification finds a vast application, ranging from comfort air conditioning to drying of heat-sensitive materials. Atthough the operating energy cost for dehumidification is considerably high, it could be much lower by employing a heat exchanger as the energy regenerator. Due to high commercial dehumidifier cost, there is an attempt to locally built dehumidifiers using silica gel as the sorbent, with the airtight close- circuit seed drying system. This project is under the guidance of the Seed Division, Department of Agricultural Extension. The performance of the dehumidifier being built is expected to be comparable to commercial models.

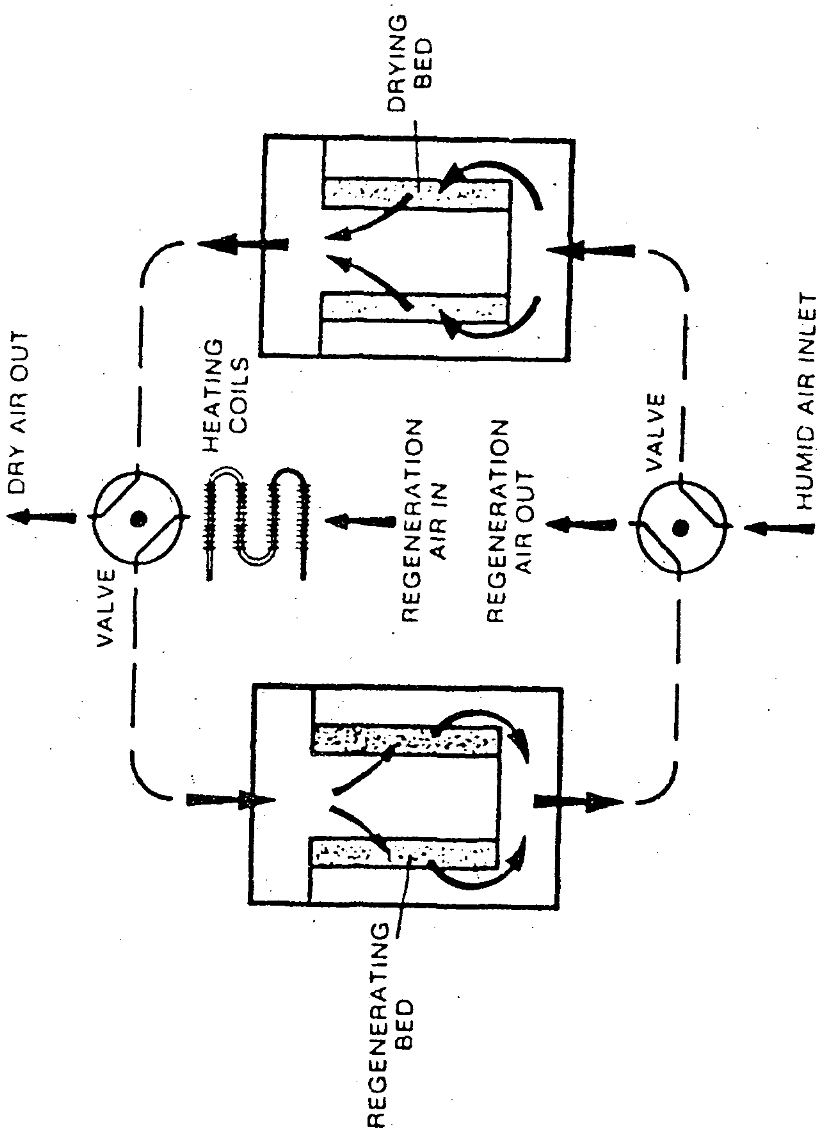


Figure 7 A Dual Bed Packed Tower Dehumidifier

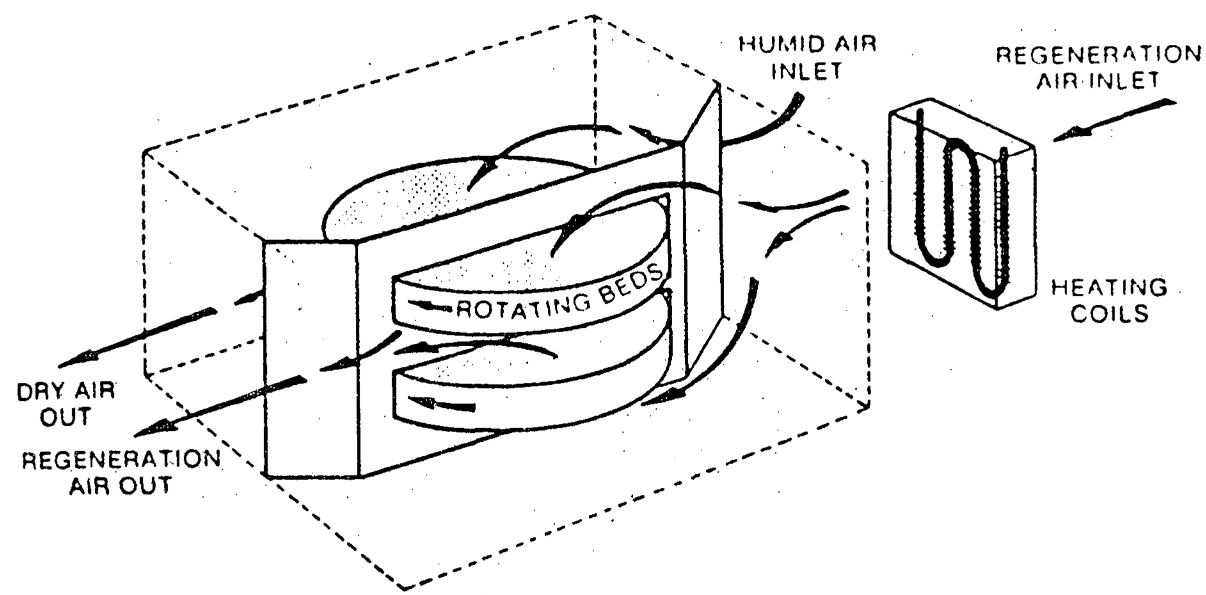


Figure 8 A Typical Rotary Bed Adsorbent Dehumidifier

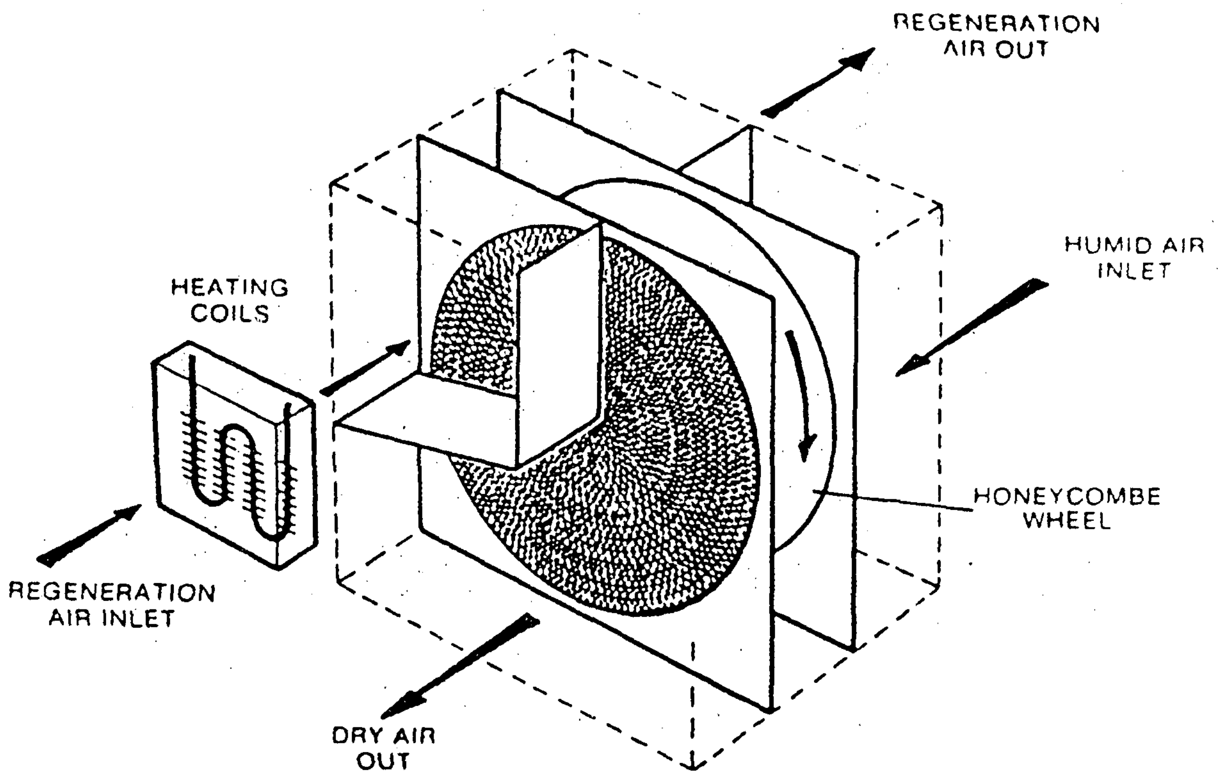


Figure 9 A Rotary HoneyCombe Dehumidifier

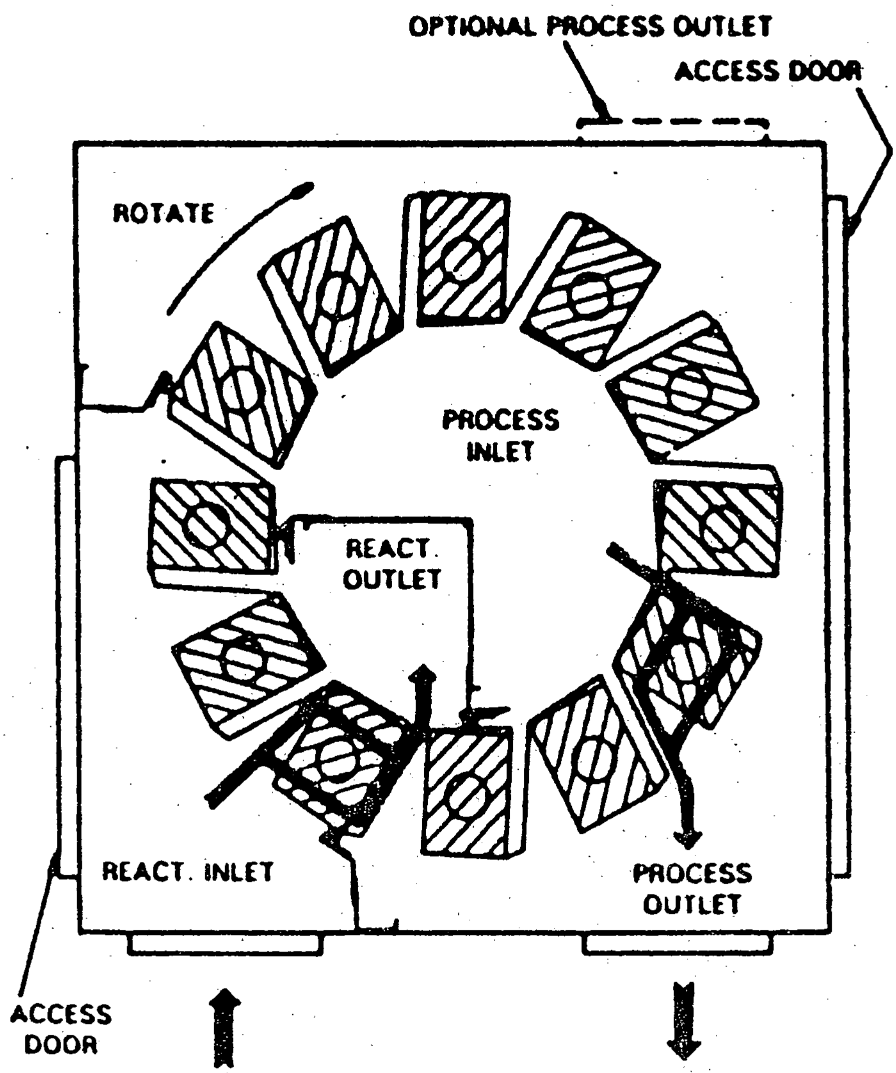
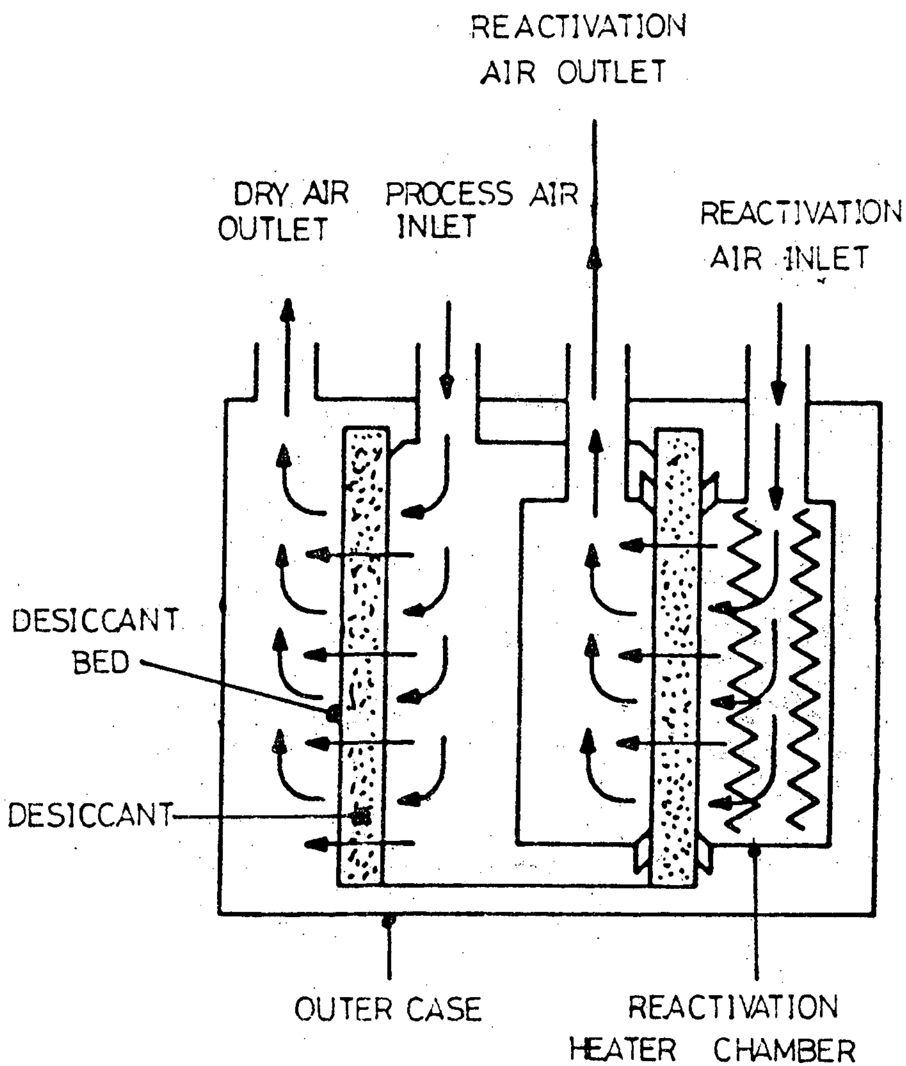


Figure 10

Carrousel moving bed silica gel dehumidifier.



PRINCIPLE OF OPERATION

The 38-1/8" diameter by 4" thick by 60" long perforated metal desiccant bed containing 625 lbs. of silica gel rotates clockwise at one (1) revolution every 2 hours. The desiccant bed adsorbs moisture on the process side and is regenerated on the reactivation side of the unit on a continuous basis. The process side is sealed from the reactivation side by silicone rubber cushion seals. This, together with blow-thru design, minimizes leakage and eliminates air balancing problems.

Figure 11.

Cylirdrical silica gel bed dehumidifier.