CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Desiccant dehumidification technology has been used in industry more than a century. From about four decades ago; the application of desiccant has been widely used in cooling and air conditioning application. The simplicity and ease of implementation in addition to low cost and ease of maintenance put this technology strongly in the research portrait of the coupled heat and mass transfer thermal applications. These applications include food, medication, and chemical industries and the state-of-art technologies of cooling and air conditioning. The demand of air conditioning and many other applications depend on dehumidification increases day by day, with the phenomena of global warming and the high temperature the earth now suffering from, air conditioning is very essential for life almost everywhere. The benefits of desiccant dehumidification are better humidity control, more efficient latent load removal, and reduction of peak electric demands.

Dehumidification, as it deals with the latent load, is essential in many industrial applications food preserve, medicine and even some manufacturing process. This increase in demand of dehumidification process is combined with decreases in energy resources. The old fashion technology requires higher energy and combustion of fuel burning which is the main cause of the CO_2emission. The desiccant dehumidification considered one of the promising solutions to reduce the unwanted emission of CO_2 and green house gases such as CFC_S, $HCFC_S$ (Chlorofluorocarbons, Hydro chlorofluorocarbon).In addition this technology provides less noise and convenience in maintenance, it can be driven by low grade heat sources, e.g., solar energy, waste heat and natural gas.

Recent advances in desiccant materials have enabled the technology to become more practical for Space-conditioning applications. However, additional research needs to be conducted to further improve system efficiency and expand the application opportunities for desiccant-based systems. The recent studies have shown that the cooling load accompanying ventilation air is dominated by the latent load. This suggests that applications where the ventilation requirements are significantly increased by ASHARE [1] can get benefit from desiccant technology.

In this technology a desiccant material used to absorb moisture present in the area required to be dehumidified. Many desiccant materials are available, such as silica gel, activated alumina, molecular sieve, alumina gel, etc. However, silica gel, activated alumina and molecular sieve have the highest adsorption capacity.

Air may be dehumidified by cooling it or increasing its pressure, which reduces its capacity to hold moisture, or removing moisture by attracting the water vapor with a liquid or solid desiccant. Most of systems employ a combination of these methods to maximize operating efficiency and minimize installed cost. Figure 1.1 illustrates two methods by which dehumidification with desiccant materials or desiccant equipment may be accomplished.

Air in the condition at Point (1) is dehumidified and cooled to Point (3). In a liquid desiccant unit, the air is simultaneously cooled and dehumidified directly from Point (1) to Point (3).In a solid desiccant the process can be completed by dehumidifying from Point (1) to Point(2) and then by cooling from Point (2) to Point (3).

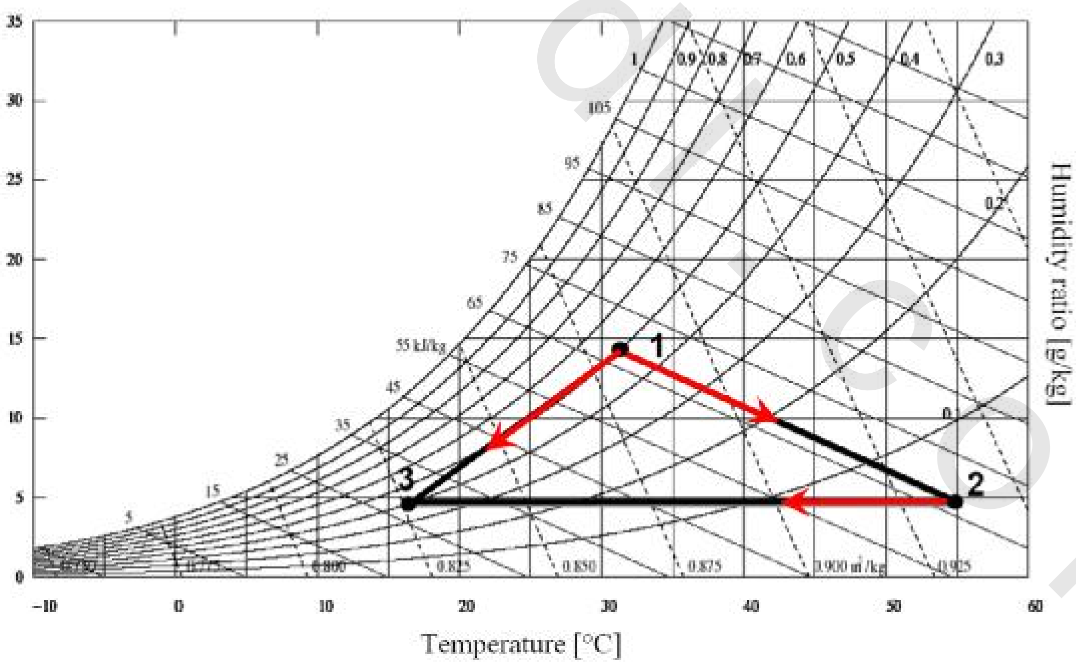


Figure 1.1 Methods of Dehumidification

1.2 The Hazards of Moisture Content

Dehumidification is important for space conditioning of most buildings in warm and cold climates; this is because moisture air gives the feeling of uncomfortable ASHARE Standard62-1989 recommends indoor relative humidities below 60% to prevent the growth of mold and mildew that may occur on surfaces where the local humidity exceeds 70%. In industry humid air may causes a lot of hazards, Moisture trapped within a product package or leaking into it during storage and shipping can cause many harmful effects. The stability of many pharmaceutical formulations and diagnostic reagents, as well as the maintenance of their physical product integrity, is often closely tied to the moisture conditions of the package environment.

In poorly sterilized situations, moisture can promote the growth of mold, mildew and fungus. Products using some polymers are prone to swelling in high humidity conditions as intermolecular bonding between polymer chains can be weakened by the presence of water. In some cases water can become an integral part of the bulk crystal structure of a product through the formation of hydrates. If a solid is very water soluble, such as a sugar coating, and the right conditions exist, dissolution into the sorbed layer can trigger irreversible water uptake and subsequent deliquescence [2].

In the case of electronics, the presence of moisture can cause not only corrosion but also can lead to "short" circuits, wherein the electricity powering the device reroutes through the water instead of its assigned conductive path. These will not lead to cinematic instance of panels blowing open and sparks flying. In fact, they will usually be much more subtle and untraceable by making the device's operation unreliable.

1.3 Hygroscopic

it is the ability of a substance to attract and hold water molecules from the surrounding environment through either absorption or adsorption with the absorbing or adsorbing material becoming physically 'changed,' e.g. by an increase in volume, stickiness, or other physical characteristic of the material as water molecules become 'suspended' between the material's molecules in the process.

Hygroscopic substances such as sugar, honey, glycerol, ethanol, methanol, diesel fuel, sulfuric acid, methamphetamine, many salts and many others substances. Zinc chloride and calcium chloride, as well as potassium hydroxide and sodium hydroxide (and many different salts) are so hygroscopic that they readily dissolve in the water they absorb. Because of their attraction for atmospheric moisture, hygroscopic materials are stored in sealed containers. When added to foods or other materials for the express purpose of maintaining moisture content.

1.4 Desiccant Materials

It is a hygroscopic substance has a high affinity for water vapor; its moisture content is a function of the relative humidity of the surrounding air. Exposed to low relative humidity desiccant materials come to equilibrium at low moisture contents and exposure to high relative humidity results in equilibrium at high moisture contents [3].

They can be classified according to many ways, their statues whether liquid or solid, sorption mechanism (adsorption or absorption), although it is mostly correct to assume that all liquid. Desiccant reactions are absorption and that all solid desiccant reactions are adsorption, there is one major exception. Hydrates of many metal salts are solid, yet they desiccate by absorption. Not that is there is another classification.

Two major categories of desiccants are absorbents and adsorbents. Absorbents go through a chemical change as they attract and retain water vapor. Lithium Chloride (LiCl) is probably the most common absorbent type desiccant. The LiCl and water combination results in a liquid solution after each LiCl molecule has absorbed three water molecules. LiCl continues to absorb water even after a solution has formed. Adsorbent materials hold water molecules in pores at their surface, no chemical change results. Absorbents generally can attract and hold greater quantities of water per pound of desiccant material [4].

As desiccants can be either solid or liquid, desiccant air conditioning systems can be classified into two categories, solid desiccant air conditioning systems, which consist of fixed bed type and rotary wheel type, and liquid desiccant air conditioning systems. Due to being advantageous in handling latent heat load, all these technologies have been used widely. Especially, rotary desiccant air conditioning systems, which are compact and less subject to corrosion and can work continuously, attract more attention. To date, extensive studies on rotary desiccant air conditioning have been carried out on the basis of mathematical simulation, thermodynamic analysis, experimental investigation and practical application. A lot of academic societies, research institutes, universities, companies, etc., have been involved into these works, and significant improvements in system performance, cost and reliability have been achieved.

Commonly encountered pre-packaged desiccants are solids, and work through absorption or adsorption of water, or a combination of the two. Desiccants for specialized purposes may be in forms other than solid, and may work through other principles, such as chemical bonding of water molecules.

The Pre-packaged desiccant is very common to remove excessive humidity that would normally degrade or even destroy products sensitive to moisture. Some commonly used desiccants are silica gel, activated charcoal, calcium sulfate, calcium chloride, montmorillonite clay, and molecular sieves. Silica gel is often used in musical instrument cases. A specific usage of a desiccant would be in insulated windows where it is placed inside the space between the air space and window edge. This prevents moisture condensation.

The basic idea of desiccant air conditioning is to integrate the technologies of desiccant dehumidification and evaporative cooling together. These indicate that desiccant air conditioning would be not only energy efficient and environment-friendly but also cost-competitive, especially for hot dry and hot humid areas.

Currently, ongoing research and development works for rotary/stationary desiccant air conditioning technology have been directed at advanced desiccant materials; optimum system configurations and corresponding practical applications.

1.4.1 Common Types of Desiccant Materials

The common desiccant types which are commercially available are listed in the following sections.

<u>Silica</u>

They have been manufactured to obtain very high surface-to-volume ratios and have been surface-treated to produce an affinity for water. Such gels are formed by condensing soluble silicates from solutions of water or other solvents. They have the advantage of being relatively low in cost and easily customizable in terms of pore size and pore distribution. Silica gel has many other properties that recommended it as desiccant. It absorbs up to one third of its own weight from water vapor, this adsorption efficiency is about 35%greater than typical desiccant clays ,making silica the good choice where weight or efficiency are important factors. Silica gel can withstand temperatures up to 400 °C. No special precautions are required when it is exposed to air at 100 % relative humidity.

- It has indefinite shelf life.
- It can be regenerated and reused; gently heating silica gel will drive off the adsorbed moisture and leave it ready for use.
- It is non-toxic, non-flammable.
- It is frequently used packed in a breathable bag; these are available in wide range of sizes suitable for use with a wide range of application.

Liquid Desiccants

Calcium chloride used widely in many desiccant applications. It is a salt of calcium and chloride. It is solid at room temperature. Common applications include brine for refrigeration plants, ice and dust control on roads, and desiccation [5]. Because of its hygroscopic nature, anhydrous calcium chloride must be kept in tightly sealed, air-tight containers [6]. Ethylene glycol solutions have been used by Niagara Blower Co. For many years on commercial refrigeration for no-frost units. They were used on air conditioners [7]; Test results indicated that the antibacterial effectiveness of glycol solutions is excellent.

Molecular Sieves

The commercial name of molecular sieves is zeolites. The natural zeolites are minerals that are mined in much the same manner as salt. The sediment beds of ancient bodies of water are the most common locations for these deposits. Synthetic zeolites are manufactured materials. The characteristics that relate the natural and the synthetic materials are their chemical and structural similarities.

Zeolites are Alumino-silicate materials. Their crystalline structure is cage-like; the cage structure forms the sites for preferential water sorption. It is this cage-like structure that also forms the basis for the other designation of zeolites, So-called molecular sieves.

Clay

Montmorillonite is a very soft group of minerals that typically form in microscopic crystals, forming clay. The particles are plate-shaped with an average diameter of approximately one micrometer. Members of this group include saponite. The water content of montmorillonite is variable and it increases greatly in volume when it absorbs water. Chemically it is hydrated sodium calcium aluminum magnesium silicate hydroxide. Potassium, iron, and other cations are common substitutes; the exact ratio of cations varies with source. In comparison with silica gel, and activated clays lower adsorption capacity means that activated clay has to contain 1.35more material to perform the equivalent job of a silica gel.

Mixtures

Using mixtures of desiccants is another common method of developing desiccant materials that have the desired sorption properties. For example, some desiccants have large total uptakes for moisture, but are not able to achieve very low humidity levels. Other materials may have marginal moisture uptake, but are capable of achieving extremely low humidity levels. For example, lithium chloride has an unparalleled capacity for moisture absorption at high relative humilities, but below 10% RH, its moisture absorption is negligible. Combining that desiccant with silica gel, which has a larger capacity at low humidity, can provide adequate moisture capacity throughout a wide range of operating conditions. For best performance, desiccant mixtures are selected such that both desiccants can be reactivated at similar temperatures.

Polymer Desiccants

Polymers are large molecules consisting of repeating chemical units. One polymer molecule, or ’macro-molecule’, can consist of 50 to 3000 units. Polymers are capable of being cross-linked, which is the condition of the polymer chains being bonded together to form a network.

The bonds responsible for cross-linking are covalent bonds. Once cross-linked, polymers will neither dissolve when put in solution nor flow when heated.

It is consider plastic polymers as advanced desiccant materials, the same general criteria as for any desiccant material must be satisfied. They must have a favorable performance/cost ratio, provides satisfactory performance, and have cost-effective lifetimes. Czanderna [8] made the following assessment of the currently available polymer desiccants

- Polymers have the potential for being modified so that sorption isotherms of both the desired shape and heats of adsorption of about 2508 kJ/kg are obtained.
- Polymers have the potential for sobbing water from 5% to more than 80% of their own weight.
- Polymers have the potential for being readily fabricated into shapes required for desiccant dehumidifiers.
- Polymer structures have the potential for being synthesized to provide high diffusivities of water vapor through the material.
- Polymers have the potential for being fully regenerated at temperatures below 176°F.
- Polymers have the potential for maintaining long-term stability through thousands of sorption-desorption cycles.

Commercial polymers are available at less than $2.00/lb, comparable to the cost of commercial grade silica-gel. Accordingly, polymeric materials could not only serve as both the desiccant and the support structure in a desiccant wheel, but also could be replaced easily and inexpensively. Czanderna [8] listed the isotherm data for 22 potential polymeric desiccant materials.

1.4.2 Properties of Desiccant Materials

Generally, many common materials have the ability to attract and hold large quantities of water vapor. Wool and paper are two materials that possess great affinities for water vapor, but only at vapor pressure close to the air saturation pressure. For many applications, the affinity for water vapor must take place at much lower vapor pressures in order to meet the needs of the application. Most desiccants don't chemically combine with water or the other substances they're present to protect against. They capture water vapor through adsorption, and stow them away where they can't cause harm to the product, the amount of absorbed water differ based on the characteristics of the desiccant, Table 1.1 gives a summery about the properties of desiccant materials[9].

Table 1.1 Properties of Adsorbents

Property	**Molecular Sieve**	**Silica Gel**	**Montmorillonite Clay**	**CaO**	**$CaSO_4$**
Adsorptive Capacity at low H_2o Concentrations	Excellent	Poor	Fair	Excellent	Good
Rate of Adsorption	Excellent	Good	Good	Poor	Good
Capacity for Water @77° F, 40% RH	High	High	Medium	High	Low
Separation by Molecular Sizes	Yes	No	No	No	No
Adsorptive Capacity at Elevated Temperatures	Excellent	Poor	Poor	Good	Good

Many of the materials that are able to attract water vapor do not remain stable during the sorption process. If the structure of the material is altered by the sorption process, chances are that its sorption properties will not remain stable with cycling. Many of the clay materials fall into this category. Variable commercial materials obviously must be able to cycle water in and out of the material many times reversibly.

Sorption process are classified in two major phenomena absorption and adsorption where, Adsorption is the process in which adhesion of substance molecules to another substance surface, with no chemical change occur physical change, as change only in volume and temperature, it involves relatively weak intermolecular forces ,separating both substances can be done by a source of heat, The higher the heat of adsorption for moisture on the desiccant, the stronger the bonding and the less easily that moisture can be subsequently removed.

Adsorption can be classified as surface phenomena, This phenomena helping in many industrial application, one of them which the research focus on, capturing and using waste heat to produce dehumidified air. Most porous adsorbents, such as silica gel, activated clay or molecular sieves rely upon physical adsorption rather than chemical adsorption to accomplish their function. Physical adsorption involves relatively weak intermolecular forces between the moisture and surface of the desiccant.

Sorbents, such as calcium oxide, involve an actual chemical bond. Physical adsorption of moisture is typically exothermic. The strength of the adsorptive bonds can thus be measured by the heat of adsorption. On the contrary absorption is the dissolve of substance molecules in another substance, so the absorption process taken up in volume not surface.

Research institutions and manufacturers have focused on material science to develop desiccants which are especially suited to air conditioning applications. These efforts have had two primary goals; to develop desiccants which use less energy for reactivation and therefore need less energy for cooling, and are more stable and fault-tolerant and therefore require less maintenance. Researchers have identified the sorption characteristics which are best suited to minimizing the costs of desiccant air conditioning systems in residential and commercial buildings. These characteristics are described by the term "Type 1 M" desiccant behavior [10]. The system classifies material behavior according to the shape of its sorption isotherm. Materials with type 1M behavior adsorb moisture very rapidly above a certain relative humidity, and desorbs moisture readily when the surrounding air falls below that threshold relative humidity between 35 and 55% relative humidity. Therefore, the material is described as having 'Type 1 - Modified" behavior, or more briefly, "Type 1M".

While some progress has been made by manufacturers, as yet there is no Type 1M desiccant material available commercially. A durable, low-cost Type 1M material will make significant improvements in desiccant system cost and energy consumption [11].

Some of desiccant properties are

- Chemical and physical stability over many cycles.
- Ability to hold large weight fractions of water.
- Ability to separate water vapor from other constituents.
- High sorption rates at low vapor pressures
- Low heats of adsorption

Though, the main five factors are to be considered, Absorption capacity, durability, and stability and regenerator temperature in selection a solid desiccant. Table 1.2 lists the parameters of several commonly used solid desiccants, which are all concluded from experiments [12]. DH-5 and DH-7(different types of molecular sieve) are the preferred choice of adsorbent owing to its high dehumidification capacity and low regeneration temperature. Silica gel is the second material to service high absorption capacity with lower regenerating temperature. Charcoal takes the following position owing to its higher absorption capacity as well as higher regeneration temperature. Activated alumina is the fourth with a lower adsorption capacity than Charcoal. Although 13X and 5A (types of molecular sieve) have high adsorption capacity, their high regeneration temperatures hold back their application.

Table 1.2 Comparisons of Adsorbent–Adsorbate Pairs

Adsorbents -Adsorbate	Max. desorption Capacity (kg/kg)	Regeneration Temperature (C°)
4A-Water	0.22	350
13X-Water	0.3	350
5A-water	0.33	350
Zeolite-Water	0.12	240
Mordenatite-Water	0.11	250
Chabazite-Water	0.17	250
Charcoal -water	0.4	250
Activated alumina-Water	0.19	250
Silica gel-water	0.37	150

1.5 Applications of Desiccant Dehumidification

Desiccant systems are especially useful with the latent load, because they remove moisture more economically than they remove sensible heat. Another desirable situation is when the cost of dehumidification with a desiccant is lower than the cost of dehumidification with a refrigeration system. This is where thermal energy comes into the picture. There are instances where desiccant regeneration is done by waste heat, natural gas, or off-peak electricity is more economical compared to regular electric refrigeration. Because there is no need for reheating with desiccant dehumidification systems, another appropriate use is when conditioned air must be reheated after coming out of a coil to reach a comfortable dry-bulb temperature.

Desiccant cooling consists in dehumidifying the incoming air stream by forcing it through a desiccant material and then drying the air to the desired indoor temperature. To make the system working continually, water vapor adsorbed/absorbed must be driven out of the desiccant material (regeneration) so that it can be dried enough to adsorb water vapor in the next cycle. This is done by heating the material desiccant to its temperature of regeneration which is dependent upon the nature of the desiccant used.

Finally, the use of a desiccant is well-suited to the case where dehumidification is required at levels below freezing dew-point temperatures. For example, an ice arena has is a great deal of humidity, but the cooling coil has to cool below the freezing point. In such an environment, dehumidification with desiccants can play a major role.

Some application on desiccant dehumidification are listed down as follow

- Lowering relative humidity to facilitate manufacturing and handling of hygroscopic materials
- Lowering the dew point to prevent condensation on products manufactured in low-temperature processes
- Providing protective atmospheres for the heat treatment of metals
- Controlling humidity in warehouses and caves used for storage
- Preserving ships, aircraft, and industrial equipment that would otherwise deteriorate
- Maintaining a dry atmosphere in a closed space or container, such as the cargo hold of a ship or numerous static applications. (ASHREA).

Desiccants provide the low humidity needed to eliminate the growth of microorganisms in duct work, building structures and in furnishings. The materials can also be used to adsorb many volatile organic compounds from indoor environments. Research and development can help enhance these end user benefits. These benefits include;

- Improving indoor air quality through reduced microbial growth. Dry air is known to reduce the growth of microorganisms both in the air and in humid materials.
- Improving indoor air quality by removing air pollutants with desiccants. Desiccant materials can collect more than just water vapor from air. In industry, desiccants are

widely used to perform separations from complex mixtures of organic and inorganic compounds.

- Improving useful life of buildings, materials and products through dry air technology.
- Preservation of food and medicine during shipping.
- Helping the cargo to be safe during sailing, by using desiccant as anti-corrosive materials.
- Keep the metal of tools rust-free and their wood strong.

In addition to the above, Dehumidifiers minimize the costly replacement of peeling wallpaper, cracking plaster, warping wood paneling, floor tiles and linoleum that comes loose because of a moist condition. It reduces mold, mildew, and rot and corrosion damage. People who may benefit from a drier climate because of sinus or respiratory problem may now dial the level of dryness of air that feels most comfortable. They plug into standard electrical outlets and are easily moved with concealed rollers.

1.6 Literature Review

Since the early century desiccant dehumidification was used as anti-corrosion material for industrial application, with the alarm of energy resources decreases researchers take desiccant dehumidification as promising solution for saving energy in air conditioning and dehumidification application as mentioned before[13].

Early desiccant applications in comfort control involved semi-process installations such as medical buildings, which profit from the air cleaning and sterilization effects of liquid desiccant systems. In general, comfort-related applications have been dominated by vapor-compression cooling technology because to date, it has enjoyed some basic advantages over desiccants in operating efficiency. By way of comparison, vapor-compression air conditioning systems may operate with Coefficients of Performance (COP's) of 2.5 to 3.5 in the comfort range, where typical COP's for desiccant systems have been below 1.0.

As most of new technology it faces many problems, one of them the requirements of large amount of fan power as it depends on difference in water vapor, To overcome this problem simply Lithium Chloride solution was selected as the working fluid in the dehumidifier and regenerator due to its advisable absorption capacity and low regeneration temperature, in addition some modification in design was made by introducing the fluted wheel, however lithium chloride doesn't give good results at high relative humidity . Silica gel was one of the earlier and most common desiccants, after developing it to form into a fluted wheel it becomes very suitable solution.

In 1940, an article [14] indicates that manufacturers of desiccant equipment retained an interest in comfort-conditioning markets. During the 1950's, liquid desiccant system successfully was applied to hospital ventilation systems. This application takes advantage of the bactericidal characteristics of lithium chloride to scrub the air free of microorganisms in addition to removing excess humidity and delivering air at a controlled temperature.

The enthalpy recovery wheel one of the most common types in commercial applications due to its high performance as a result of its large heat and mass transfer area. This area results from its honeycomb structure pictured in Figure 1.2, which provides numerous small, parallel channels. Air flows through these channels, exchanging heat and moisture with the surrounding desiccant composite structure. As indicated in Figure 1.3, the alternating ventilation and building exhaust airflows through the channels are counter current in the two sections of the wheel, to achieve the optimized performance of the rotating wheel. As a result of the numerous small channels, the airflows in the channels are of laminar characteristics. The honeycomb structure of the desiccant wheel was developed by Carl Munter, a Swedish inventor, in the late 1950's for low humidity applications in the defense industry [15].

The desiccant composite usually includes the substrate and the desiccant material, although no substrate is used in some dehumidification wheels. The substrate is normally a foil made from aluminum, stainless steel or fiber paper, which provides structural integrity and strength. The coating process involves adhering the particles of desiccant material to both sides of the substrate using some binder materials.

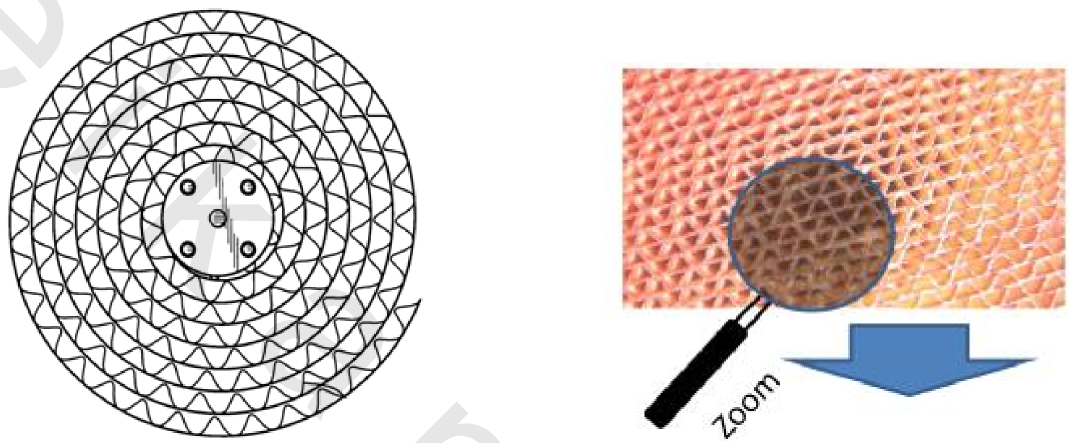
Recent researches in liquid systems have concentrated on reducing the cost and increasing the effectiveness of heat exchange components which remove the heat of absorption from the liquid desiccant. By 1979, Shelpuk and Hooker [16] contributed in desiccant technology development.

Desiccant wheels used honeycomb paper impregnated with lithium chloride, which functioned as the desiccant. This type of wheel was relatively easy to manufacture. However, deliquescence, loss of the desiccant material during operation, is a major problem associated with these wheels due to the nature of lithium chloride. More recently, silica gel and molecular sieves have been used because they are stable and do not deliquesce [17]. Compared to lithium chloride, silica gel and molecular sieves have lower equilibrium capacity [18] Therefore, the loading of silica gel or molecular sieves has to be higher.

In 1994, a simulating code developed of the desiccant wheel having matrix structure. The basic analysis of the sorption/desorption water from/to moist air flowing across desiccant passage, coupled with the measured equilibrium relations of the desiccant to establish the system equations, this verified by Abdou, A [19]. In 1995 the basic operating principles of dehumidifiers were introduced for explanation and comparing, and the thermodynamic analysis have been evaluated by Dhar et al [20].1996 Fathalah and Aly [21], contributed to the dehumidification technology with a modified version of the cross cooled desiccant bed, instead of gluing the desiccant particles to the side wall they divided the flow channel and packed it with silica gel grains.

Other manufacturing techniques have emerged. One of them is to mix the desiccant material with pulp and binder and to make desiccant paper from this mixture. The paper is then corrugated and wound into a desiccant wheel [22]. The other technique is to form the silica gel in-situ by making a honeycomb wheel from a glass fiber paper backbone which is first impregnated with concentrated water glass and then reacted with an acid wash [23]. The airflow channels can have different shapes such as triangle, sinusoidal and square, but the sinusoidal shape is preferred. The height of the channel ranges from 0.5 to 2.5 millimeters. The width ranges from 0.7 to 5 millimeters [24].

Concerning the application of desiccant in building ventilation and air conditioning systems, a packed column air-liquid contactor has been studied by Factor and Grossman [25] in application to air dehumidification and regeneration in solar air conditioning with liquid desiccants. They developed a theoretical model to predict the performance of the device under various operating conditions. Shrivastava and Eames [26] made a comprehensive review of adsorbents and adsorbates used in various investigations on solid–vapour adsorption heat pumps, with an aim of initiating a novel concept experimental investigation. Niu and zhang [27] have done the modeling of a desiccant wheel used for dehumidifying the ventilation air of an air-conditioning system. The simulation of the combined heat and mass transfer processes that occur in a solid desiccant wheel is carried out. Using the numerical method, the performance of an adiabatic rotary dehumidifier is parametrically studied, and the optimal rotational speed is determined by examining the outlet adsorption-side humidity profiles [27].



Main Application	Home Use	Industrial Use
P (mm)	2.6	3.4
H(mm)	1.5	1.8

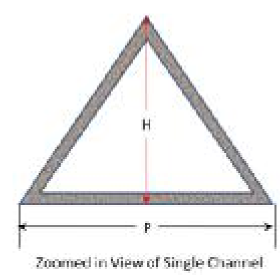


Figure 1.2 Honeycomb Structure of Desiccant Wheel

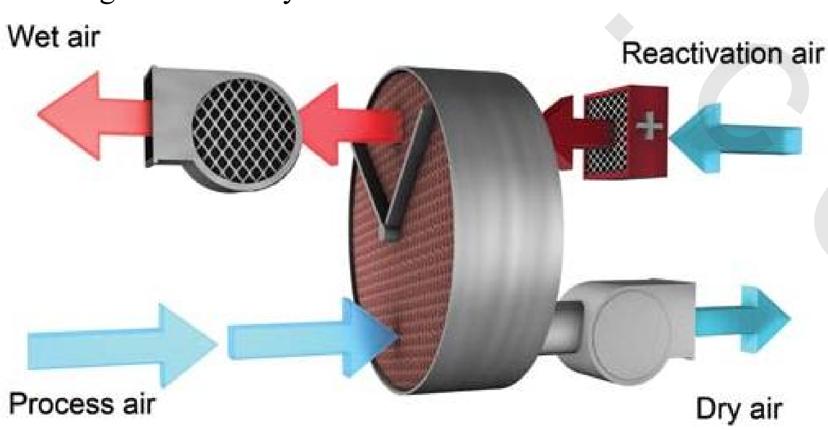


Figure 1.3 Rotary Wheel for Counter Flow of Ventilation flow and Exhaust flow

In 2004, Kanaglu et al [29], introduced a unit with COP 3.5 and reversible COP of 3.11 this by studying and developing the energy analysis of open cycle desiccant cooling system using Zeolite as a desiccant. In a trial to save energy and electricity a study of desiccant air conditioning system was made by Hirunlabh, 2007 et al [30], they installed a desiccant cooling system in a room under a certain test condition; they succeed to reduce the consumption of electricity in a remarkable rate. Dai [31] and Wanga [32] studied the factors affecting the desiccant dehumidification by using the developed mathematical modeling.

Recent research in desiccant materials has enabled the technology to become more practical for space-conditioning applications. However, additional research needs to be conducted to further improve system efficiency and expand the application opportunities for desiccant-based systems. Studies showed that the cooling load accompanying ventilation air is dominated by the latent load, Harriman,1997 [33] .this suggests that applications where the ventilation requirements are significantly increased by ASHRAE Standard 62-1989 can benefit from desiccant technology [1].

Many mathematical models on the rotary desiccant dehumidifier have been proposed in the past decades. The following are some examples of the commercial packages of these mathematical models. Maclaine-Cross [34] developed MOSHMX, a finite difference computer program based on a detailed numerical analysis. DESSIM was written by Barlow [35] where the dehumidifier was discredited and each node was treated as a counter flow heat and mass exchanger in that both the heat and mass transfer are assumed to be uncoupled. Collier and Cohen [36] developed ET/DESSIM, which is more accurate by means of incorporating several improvements over the DESSIM program. The research group of Worek [37-39] also developed a mathematical model and made success in predicting the performance and optimizing the operation parameters of rotary desiccant wheels. Yu et al. [31] have made efforts to complete a new mathematical model concerning the complicated heat and mass transfer in the rotary desiccant matrix.