Hybrid (Desiccant + Conventional) Dehumidification Air Conditioning: A Less Exploited Technology

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Abstract
Now a days, due to energy crisis/high energy costs, novel techniques/methods for air conditioning are to be explored. This paper explains how novel techniques can be used for air conditioning or dehumidification purpose and applies the same techniques to gain economical benefits. These techniques also improve indoor air quality a lot with a considerable savings in energy consumption. The working of desiccant dehumidifier & conventional dehumidifier air conditioner is studied here with the help of psychometric charts, a comparison is also done for better understanding.

Keywords
Hybrid Desiccant Cooling, CaCl, LiCl, Desiccant, Humidity Ratio, Air Conditioner, Dehumidification Etc.

I. Introduction

Generally drying of a solid/liquid substance can be done by supplying hot air stream upon that substance, but in this conventional method dehumidification is done by supplying hot (air at high temperature) & dry air. Humidity, temperature, air flow rate are the vital parameters of drying process. With this method, products quality may be affected, because of high temperature. Now, if we want drying process to take place at lower temperature then the solution is desiccant dehumidification, a novel technique, desiccants are the materials which attract the moisture from both liquids & gases naturally. This moisture (which is attracted & retained by the desiccant) is then released to the atmosphere. Desiccants may be solid or liquid ones. Some items which may be damaged at higher temperatures can be kept dry by using these techniques and also these techniques are cost affective too. Other drying techniques reduce air's humidity at higher temperatures [1]. There are three methods of lowering the humidity ratio of air & those are :- (1) cool it to condense the water vapor (a conventional method, used by vapor compression air conditioners). (2) Increase its total pressure, which also leads to the condensation. (3) Flowing the air over the desiccant, which sorbs its moisture, this happens due to the difference in their vapor pressure. Dry (conditioned) air can be use for human comfort or for preservation of vital goods. The most common desiccants are of two types solid as well as liquid, both collect moisture. Solid desiccants are silica gel, polymer sorbent, alumina silicate, zeolite etc. and liquid desiccants are lithium chloride (LiCl), calcium chloride (CaCl), tri-ethylene glycol (TEG). Their surface vapor pressure is a function to their moisture content and temperature. One important difference between these two types of desiccants is their reaction with moisture. Some collects the moisture upon their surface, just like towel. The water is held in-between small pores, these types are called adsorbents and these are usually solid in nature [1]. On the other hand those desiccants undergo chemical or physical change when they collect moisture i.e. LiCl, CaCl, sodium chloride- table salt etc. these are called absorbents [6]. They may be solid or liquid in nature, but after absorbing the moisture they become liquids. One more important difference between conventional dehumidification or desiccant dehumidification is that the operating temperature of dehumidifier is not necessary to be lower than DPT(dew point temperature) of the process air (which has to be dehumidified), as in case of conventional dehumidification system and also low grade heat energy (waste heat) can be used for desiccant dehumidification system. However, there are some problems with the desiccant dehumidification system which are: - pressure drop in solid desiccant, liquid desiccant carryover by air stream, low moisture adsorption capacity etc. These problems may be eliminated in future by using improved designs of desiccant systems.

II. Methods of Dehumidification & Air Conditioning

A. Conventional Dehumidification or Air Conditioning

when air is cooled below its DPT, moisture present in the air comes out of it & condenses in the vicinity [2]. The air is dehumidified by cooling & condensation. This method of dehumidification or air conditioning is mostly known method. The amount of moisture removed by this procedure depends upon the temperature of the cooling coil. Lower the temperature, drier the air will be. A conventional vapor compression air conditioner unit is used to get the task accomplished. its components are evaporating (chilling) coil, compressor, condenser coil, expansion valve. Conditioning of air is represented in fig. 1. Air is first cooled from pt. 1 to pt. 2 (sensible cooling), at this pt. air is reached to the point of saturation. Further cooling will cause the moisture to condense as temperature drops further, this 2-3 process is called dehumidification with cooling. Now from pt 3 to 4, air (dehumidified air) is re-heated to bring it to the comfortable temperature. Due to reheating, system has to do more work which is shown by TL (total load) in the fig. 1.

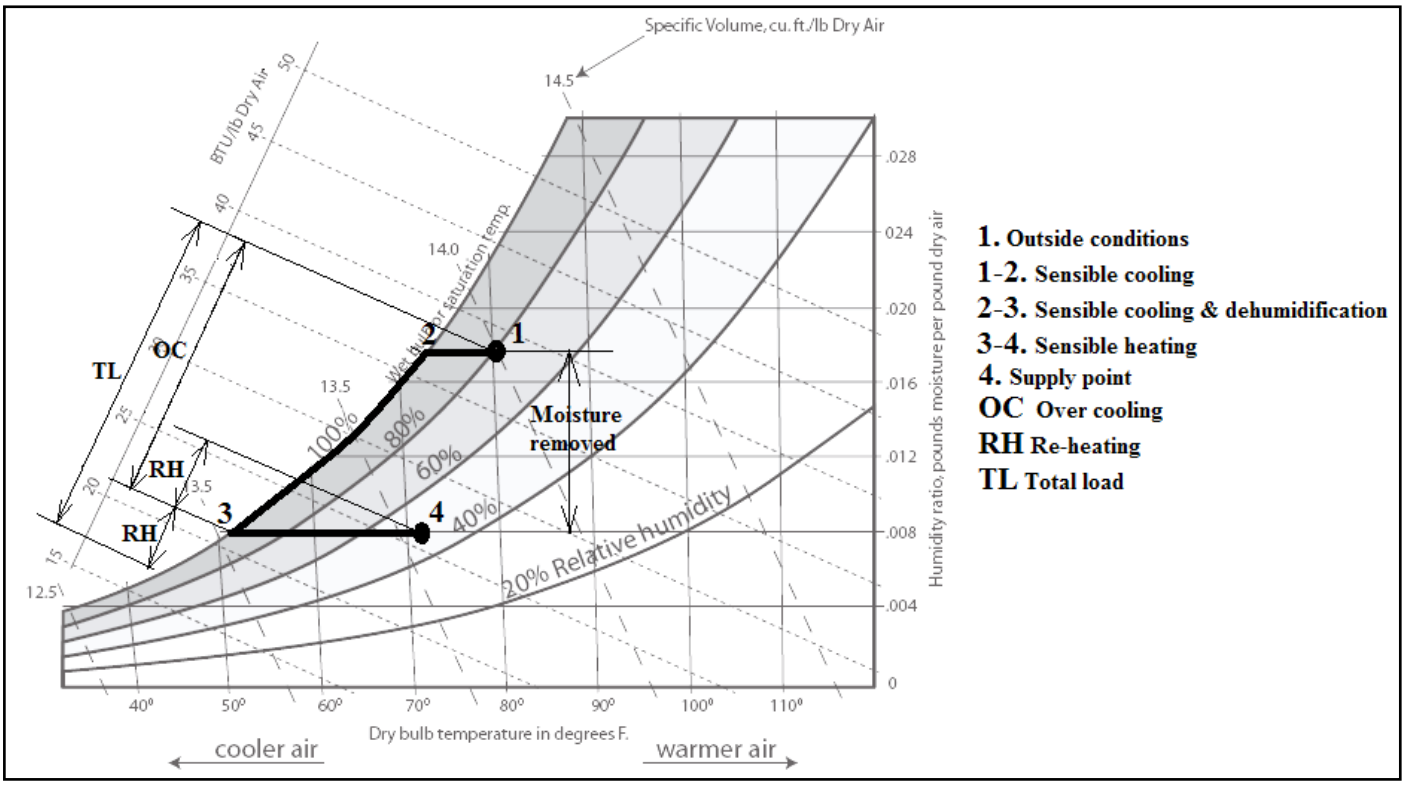

Fig. 1: Conventional Dehumidification & Cooling of Air Shown in Psychometric Chart

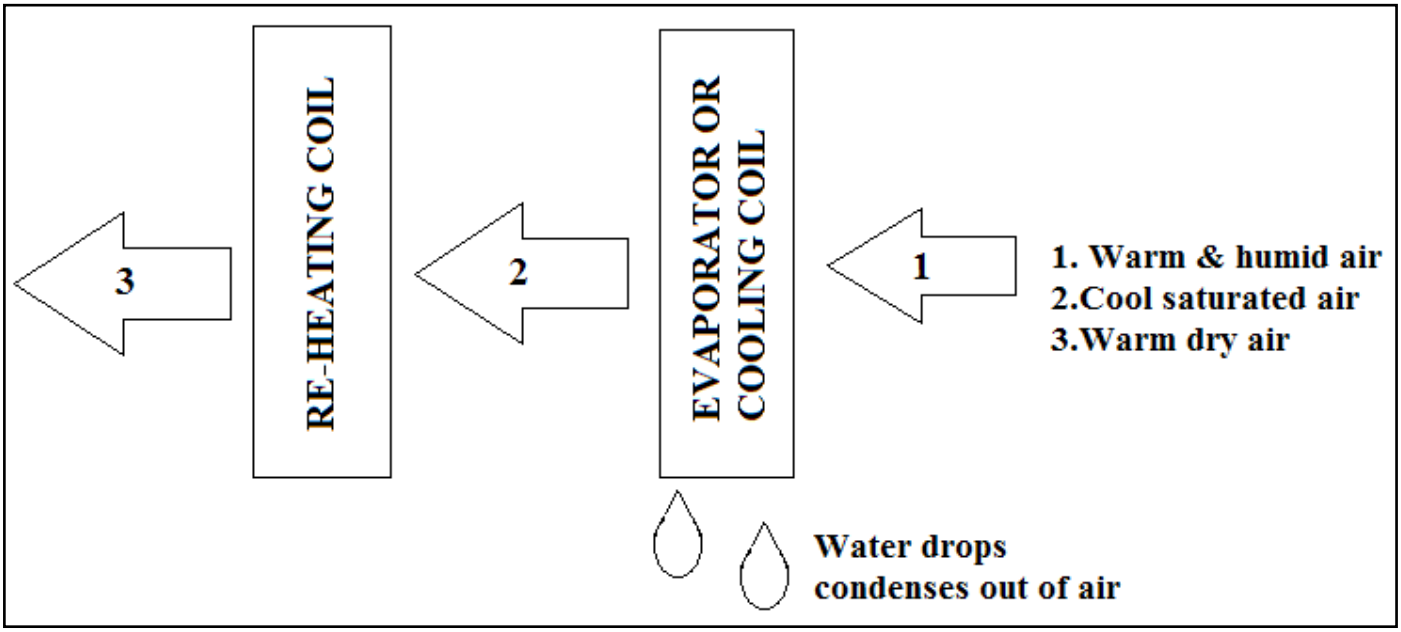

Fig. 2: Conventional Dehumidification & Air Conditioning

B. Desiccant Dehumidification Systems

Desiccant dehumidifiers' working principle is different from cooling based dehumidifiers. Desiccant dehumidifiers perform the two functions (1) Dehumidification (or conditioning) of air & (2) regeneration of desiccant, thus cycle is completed. They do not directly cool the air to remove its moisture, when the vapor pressure is low at the surface of desiccant, they attract moisture [2]. At that time the vapor pressure exerted by molecules of water is higher, so the water molecules enter into the desiccant & thus air becomes dry (this is known as dehumidification process). The required characteristic of desiccant is their low surface vapor pressure, when it is cool & dry. Its vapor pressure increases when it is wet & hot [2-3, 5]. This characteristic of desiccant is exploited to absorb the moisture of air for the dehumidification purpose & again releases the moisture to the air for the regeneration (when vapor pressure of desiccant is higher than the air) of desiccant. This system also improves the quality of conditioned air because we can use fresh air instead of used air as in conventional air conditioning [4].

C. Solid Desiccant Dehumidifier (SDD)

The rotor, shown in fig.3, is made up of corrugated sheets, which are filled with desiccant. It is divided into two sectors which are separated with the help of seals, the dehumidifier or process zone (approx 75%) and the reactivation or regeneration zone (approx. 25%) as shown in fig. 3. Air at pt.1 passes thru the rotating desiccant wheel (approx.0.5-1rpm), its moisture is transferred to the desiccant wheel then warm & dry air is passed to the pt.2

(conditioned air). Gain in heat is because of energy exchange while adsorption. Heated air stream at pt. 4 is sucked, this hot air will take away the moisture from desiccant wheel, thus reactivate (or regenerate) the desiccant wheel. Finally this warm & wet air at pt.5 will be thrown out. Whole process is shown below in fig. 3.

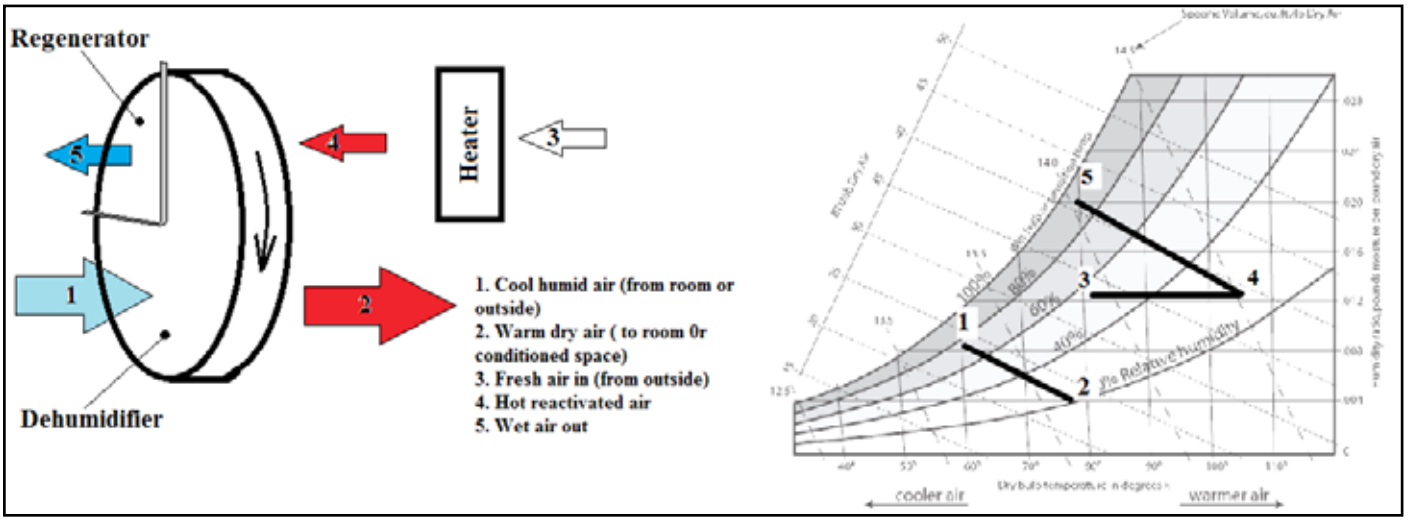

Fig. 3: Solid Desiccant Dehumidification

D. Liquid Desiccant Dehumidification (LDD)

Working of LDD is almost same to the SDD, here we are using liquid desiccant which absorbs humidity from air (in the dehumidifier unit) & finally it rejects that humidity in the atmosphere when it passes thru regenerator as shown in fig. 4. Outside humid air or return air is supplied to the dehumidifier where it loses its moisture to the cool concentrated desiccant solution and it becomes hot & dry, which is supplied to the conditioned space. Then this diluted or weak desiccant is heated up with heater (low grade heat/waste heat can be used) & sprayed in the regenerator [7-9]. Where its concentration increases (it becomes strong solution) after giving its water to the air. And this air is then exhausted to the atmosphere.

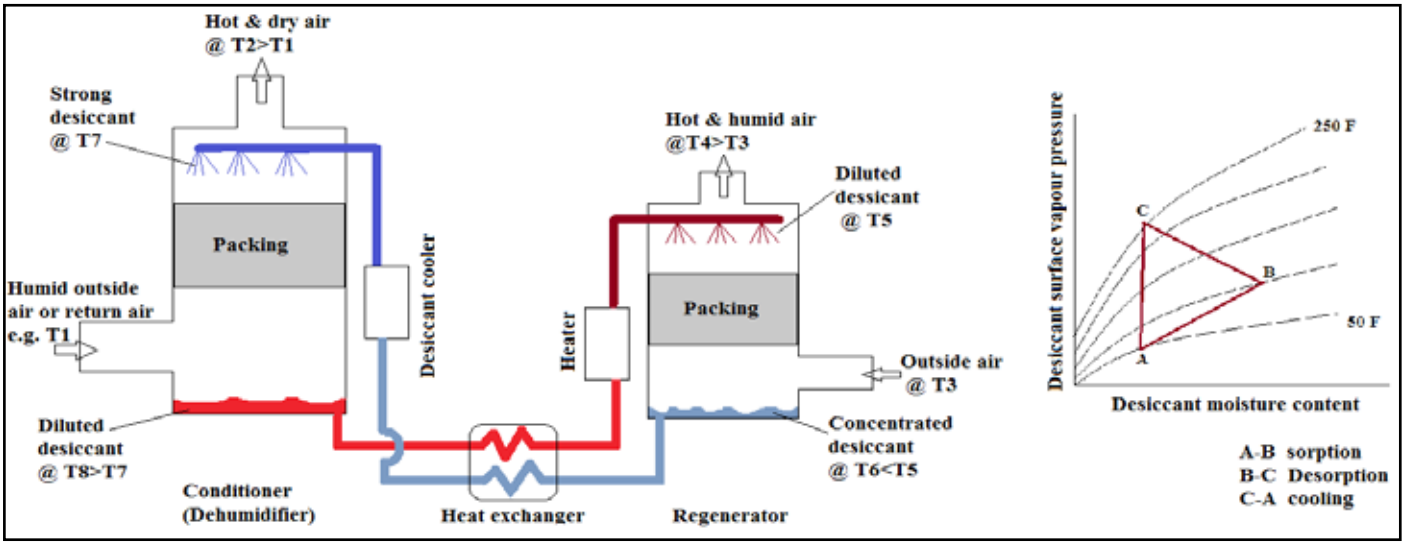

Fig. 4: Liquid Desiccant Dehumidification

E. Comparing Desiccant Dehumidification & Conventional Dehumidification (Air Conditioning)

Both types of systems perform the same function, now question arises which one is the best. Choosing between the best, there are no simple answers, however there are some guidelines that help us in choosing the best system for our requirement.

1. Both systems are much economical when used together [2].
2. If electricity is cheaper & thermal energy is expensive in the region then conventional dehumidifier should be preferred to remove bulk of the moisture otherwise desiccant based system will be a right choice [2].
3. Conventional dehumidifiers are best when used for higher temperatures & moisture levels. These are not suitable to dry air below 8°C dew point because condensation freezes on the coil, thus slowing the moisture removal process [2].
4. Desiccant dehumidification is best suitable when air is cold (@ 8°C or below) & humid or when low dew point is required [3].
5. If dehumidified air with 100% RH (relative humidity) is required then solution is conventional dehumidification, on the other hand if desired result is conditioned air whose RH less than 100% then desiccant humidifier is the only solution. Generally desiccant dehumidification system is used for applications below 45% RH down to less than 1% RH [3].

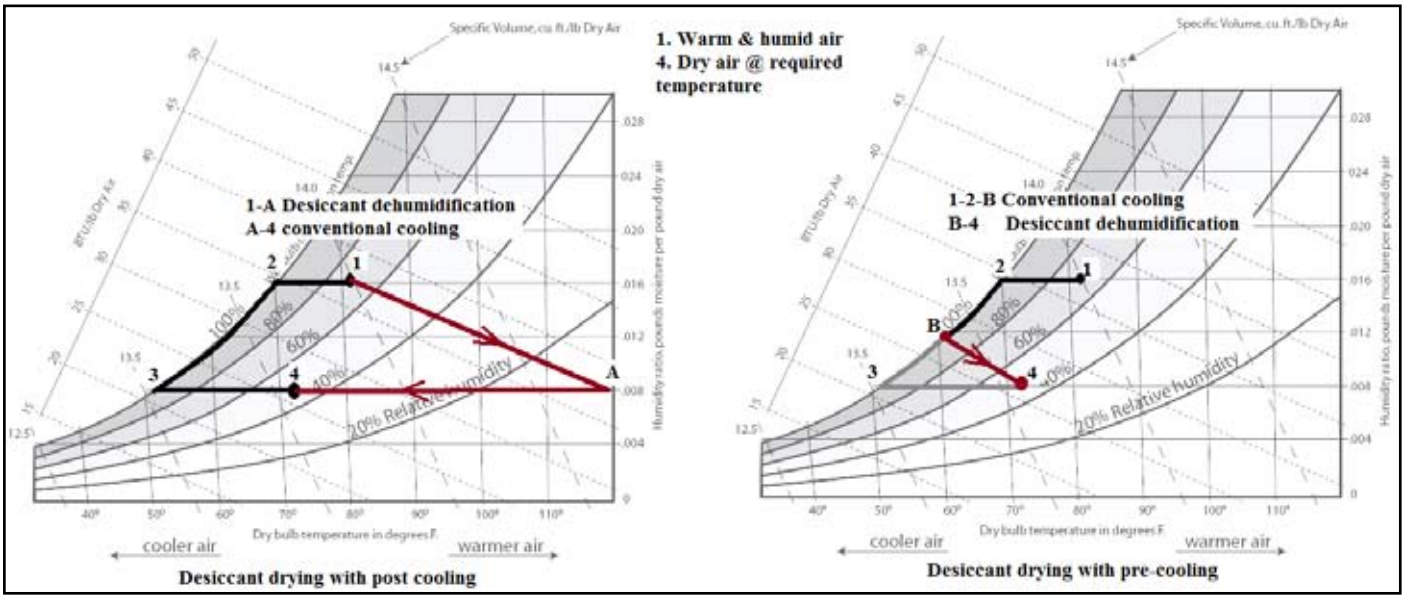

Fig. 5: Hybrid Dehumidification & Cooling System Combination of Conventional & Desiccant Dehumidifi-cation System

This system performs well when incoming air is warm & moist. During winters, the pre-cooling system is not required, it can be disabled and only dehumidification is achieved using the desiccant dehumidifier. Various types of combination (hybrid) systems are shown in fig. 5 for conditioned air.

III. Applications

By using hybrid technologies as shown in fig.5, very dry air can be produced (as low as negative 60°C dp) [3]. Desiccant dehumidifiers' applications are very diverse. Production of plastic bottles is doubled by using these technologies. Without dehumidifiers lithium batteries are impossible to produce. Dry air is required for corrosion protection at military storage, electronic protection, condensation prevention, ice rinks, injection molding, surface preparation & coating, mold/fungus prevention, seed storage, moisture regain protection at candy packing, glass lamination, composite manufacturing, product drying at candy coating, fish drying, dry cooling at supermarkets, hotels, advanced HVAC systems. These novel technologies are having wider scope in future.

IV. Conclusion

This theoretical analysis of various dehumidification/air conditioning techniques help us to decide which type of system is required in different conditions. Desiccant bases humidifiers/ cooling systems are environment friendly & added advantage of simple technology, robustness with low power consumption. Ones aim is to get desired humidity & temperature, this aim can be accomplished by selecting appropriate techniques at suitable conditions/locations or by using combination (hybrid) of techniques to save energy & to get optimum profits. After understanding the basic operating techniques, it's clear that today the user has number of options in desiccant dehumidification systems to choose from. By using right technology in right condition one can save a lot of energy & money.

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