National Conference on Behavioural Economics and Intelligent Decision Systems for Climate Change and Sustainable Development
Journal of Advanced Research in Medical Science & Technology
Volume 12, Issue 3&4 - 2025

Review Article

A Review on Dehumidification using Desiccants along with Vapour Compression Cycle

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DOI: https://doi.org/10.24321/2394.6539.202509

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How to cite this article:
Kumar R, Singh H, Singh S, Kumar N. A Review on Dehumidification using Desiccants along with Vapour Compression Cycle. J Adv Res Med Sci Tech. 2025,12(3&4):87-90.

Date of Submission: 2025-10-04
Date of Acceptance: 2025-10-29

A B S T R A C T

In a country where the scarcity of energy is a common thing and the cost of energy is considerably higher, this paper may be useful for saving energy. This paper shows how new combinations (systems) can be used for air conditioning/dehumidification purposes. This combination improves air quality, along with a considerable saving in cost. Ahead, the working of the vapour compression air conditioning/dehumidification system, along with the desiccant system, is explained, both methods (vapour compression system alone and vapour compression along with desiccant) are elaborated for thorough understanding.

Keywords: Refrigeration, Desiccant system, LiCl, Relative humidity, Humidity ratio

Introduction

In general, drying of any substance is done by flowing a stream of hot air, which is the most commonly known technique. Though temperature, humidity and mass flow rate of air are the important parameters in the drying process. This technique usually affects the quality of the substance because of the higher temperature of the air itself. So, this commonly used technique can't be used for perishable items. The other option is to flow dry air at a lower temperature, which is only possible by using either a vapour compression system or a desiccant dehumidification system. However, in this paper, it is recommended to use a hybrid system which has the advantages of both (vapour compression and desiccant dehumidification) systems. Desiccants are those materials that attract moisture from gases as well as liquids, and then this water/moisture is discharged into the environment. Desiccants are available in two forms, solids as well as liquids. There are three ways of reducing the air's humidity levels, such as (a) reducing the air's temperature to condense moisture, (b) increasing the total pressure, which also results in condensation, and (c) bringing the air in contact with desiccant. This third way is quite interesting and cost-saving too. The desiccant absorbs air's moisture due to the difference in their vapour pressures. The frequently used solid desiccants are polymer sorbents, alumina, silica gel, silicate, etc., and liquid desiccants are calcium chloride (CaCl), lithium chloride (LiCl), triethylene glycol, etc. Solid and liquid desiccants both behave differently when they come in contact with moisture. Some solid desiccants are also called adsorbents because they accumulate moisture upon their surfaces, exactly like a towel. The water is collected in between their small pores.[1] On the contrary, liquid desiccants undergo a chemical/physical change when they accumulate moisture,

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so they are also called absorbents.[2] These absorbents may be in a solid or liquid state initially, but once moisture is absorbed, they become liquids. The other important observation in a desiccant dehumidification system is that there is no need to attain its operating temperature lower than the dew point temperature of the air (which has to be dried). Also, a waste heat energy source can be used to supply energy to the desiccant dehumidification system. Since there are some drawbacks of this system, i.e., low moisture removal rate, pressure drop in solid desiccants and liquid desiccant evaporation into the atmosphere, these problems can be reduced to a minimum by using better designs.

Dehumidification techniques

Vapour compression system

This system has four main components, i.e., condenser coil, expansion valve, evaporator coil and compressor unit. The air is passed through the evaporating coil (its temperature is less than the required or final air temperature). Air gives its heat to the evaporating coil and cools below its dew point temperature, thus, its capability to carry moisture also reduces, resulting in drier air.[3] Now this cool, dry air can be used for further drying of any substance. This method is generally used by our household air conditioners. Here, the temperature of the evaporating coil is the determinant of moisture content in the dried air, more dry air means lowering the temperature, which it should be. The whole process is shown in Figure 1, steps 1-2 are air's sensible cooling. Point 2 is on the saturation line, beyond this point, further cooling leads to the discharge of moisture from that amount of air. Steps 2-3 are dehumidification and further cooling. Steps 3-4 are the reheating of dry air to bring it to the required level. Now, reheating means more work has to be done by the system, which is represented in Figure 1. So, we can conclude that there is some sort of wastage of energy in the form of reheating.

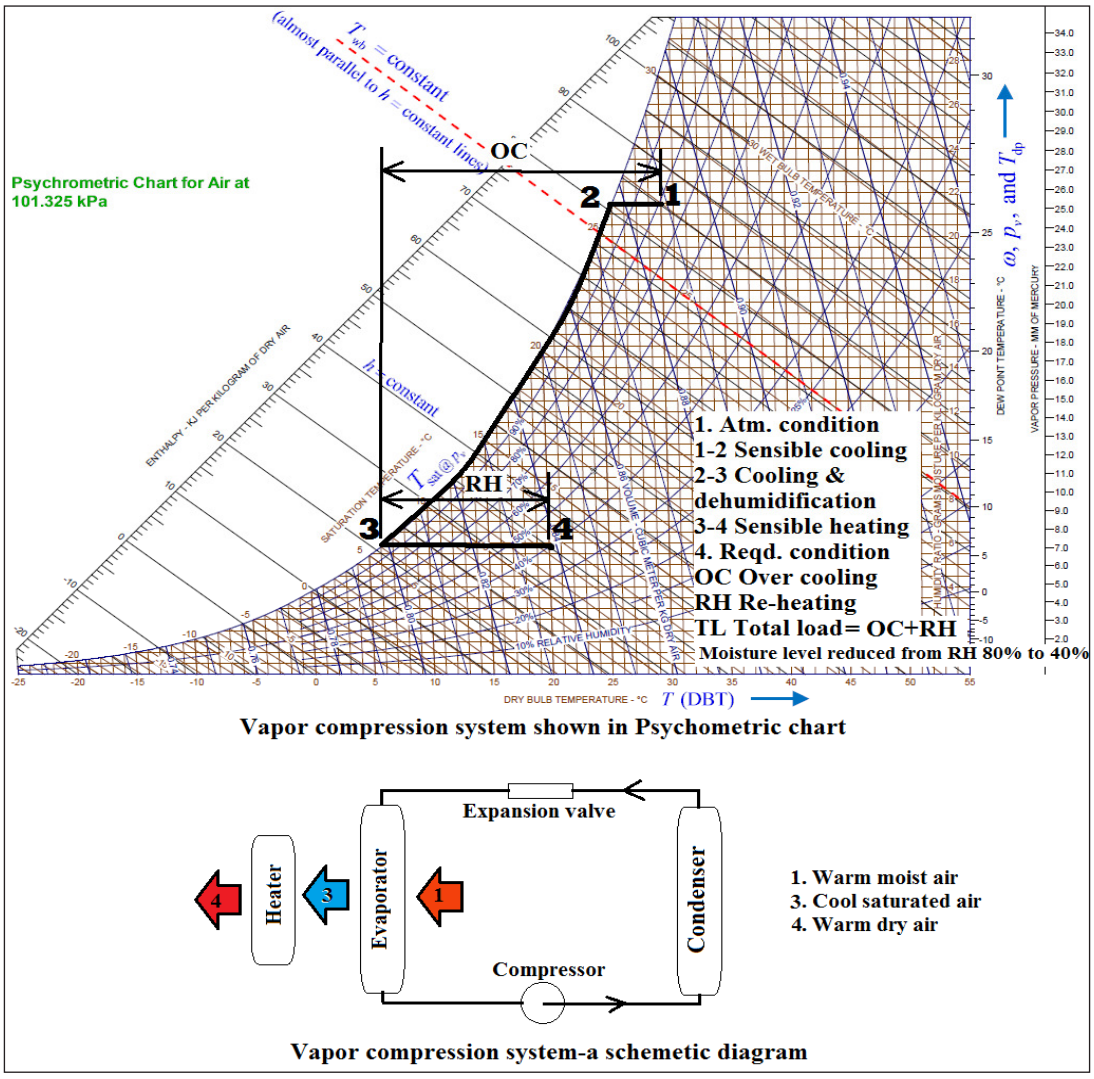

Figure 1.Vapour Compression System

ISSN: 2394-6539
DOI: https://doi.org/10.24321/2394.6539.202509

Desiccant system

This system's working is based upon the principle of absorption or adsorption of desiccant, which is completely different from vapour compression systems.[4] In this system, two main components are the dehumidifier and regenerator. The dehumidifier removes the humidity from the air, and the regenerator discharges that moisture into the atmosphere. Desiccants absorb/adsorb moisture when the vapour pressure is low on their surface and higher vapour pressure is exerted by water molecules in the air, thus moisture enters the desiccant from the air, and hence the air becomes dry.[3] The vital characteristic of a desiccant: a dry and cool desiccant should have low surface vapour pressure. When the desiccant becomes hot and wet, its vapour pressure increases automatically.[3,5] This behaviour of desiccant is used to attract the moisture from the air, and finally, this attracted moisture is discharged into the atmosphere via the regenerator. A desiccant system is also considered a better air quality system because it always uses the fresh air for dehumidification purposes, unlike a vapour compression system. Figure 2 shows how a solid desiccant dehumidifier system works. There is a rotor which is divided into two parts, one is the dehumidifier and the other is the regenerator. The dehumidifier comprises 3/4th of the total volume, and the regenerator comprises 1/4th of the total volume of the desiccant unit. The rotor has corrugated sheets, and desiccant is filled in them. The rotor disc rotates at approximately 1 rpm. When humid air is passed through this rotor disc, it gives its moisture to the desiccant and becomes warm and dry, which is suitable for other purposes. An increase in the temperature of this air is due to the energy exchange during the adsorption process. On the other side, the regenerator side, hot air flows into the regenerator, which collects moisture from it and finally discharges the moisture into the atmosphere.

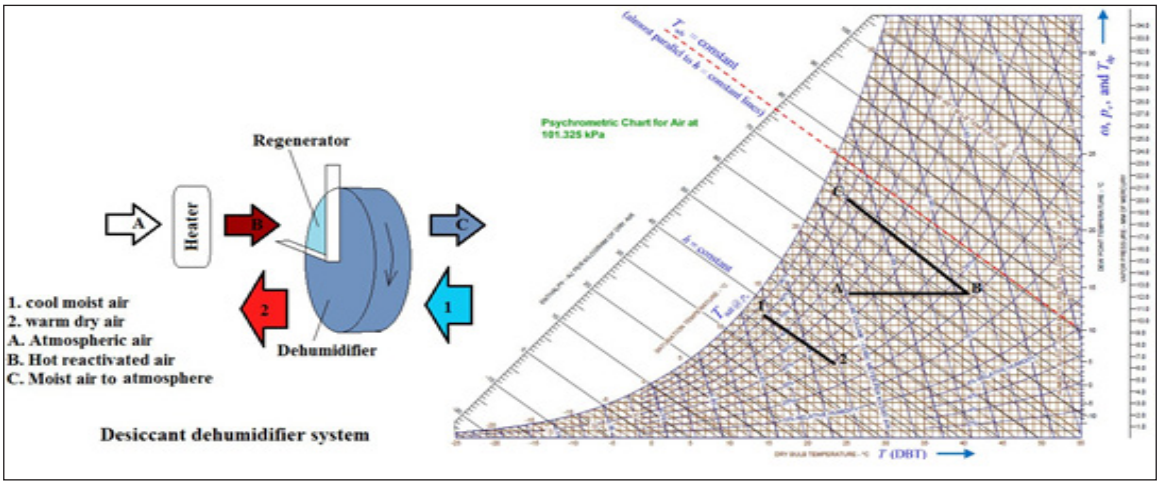

Figure 2.Desiccant Dehumidification System

Figure 3.A hybrid system, two combinations

ISSN: 2394-6539
DOI: https://doi.org/10.24321/2394.6539.202509

Comparison between the desiccant system and the vapour compression system

1. Both systems have their own advantages and disadvantages. Now the question is to select the best one for our needs. There is no rule of thumb to select the best, however, some guidelines are there to help us select the suitable one.
2. Vapour compression systems are best if used for higher initial temperatures and moisture levels of air. This is not appropriate to dry the air under an 8°C dew point, because the evaporation coil freezes due to condensation, which insulates the coil and retards the heat absorption rate.[3]
3. Vapour compression system is best if electricity is cheaper in the region, but if thermal energy is cheaper, then the desiccant system proves its worth.[3]
4. A desiccant system is the only solution for cold and humid air (under 8°C).
5. If the aim is to achieve 1% RH to 45% RH (relative humidity), then the solution is in a desiccant system.[6]
6. If a hybrid system is created out of these two systems, it would be much more economical.[3]

A combination of desiccant and a vapour compression system

A combination of both systems works well when the incoming air is hot and humid. During the winter season, the vapour compression system can be stopped, and dehumidification can only be achieved using a desiccant dehumidifier. Many types of combinations can be created, a few of them are shown in Figure 3.

Applications

A combination of both systems produces fruitful results, very dry air with RH 1% can be produced. Desiccant systems are very diverse. Desiccant dehumidification is currently being used in plastic bottle manufacturing units, lithium battery production units, corrosion protection of military storage, electronic protection, ice rinks, turbine – heavy equipment manufacturing units, condensation prevention, mould and fungus prevention, injection moulding, surface preparation and coating, glass lamination, seed storage, moisture regain protection, product drying, composite manufacturing, fish drying, dry cooling, and advanced HVAC.[7]

Conclusions

This theoretical report suggests to us and helps us to decide on a suitable system for our use. Desiccant-based systems are simple in construction and environmentally friendly too, so they are cheap from a construction and maintenance point of view. One can select a suitable system or create a hybrid system out of a desiccant and vapour compression system as per their requirements, which can save a huge amount of energy and money.

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ISSN: 2394-6539
DOI: https://doi.org/10.24321/2394.6539.202509