Application of Liquid Desiccant Dehumidifiers

Liquid desiccant dehumidification is used in a blast booth at L&T Hazira, Gujarat

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Introduction

Liquid desiccant technology is a topic of interest in the HVAC industry, due to the large potential it carries for applications which need dry and cold air. The modern approach to dehumidification system design must focus towards conserving energy. Liquid desiccant technology has been successfully applied in a wide spectrum of applications including supermarkets, hotels, hospitals, fresh air treatment and overall latent load management.

Liquid Desiccant Air Conditioning (LDAC) goes hand in hand with Green building evolution. The technology is also beneficial for specific industrial applications like investment castings, plastic mouldings, paint booths, blast booths, food processing, product drying, cold storages, warehouse dehumidification and many more, mainly due to its inherent alignment with energy saving. Similarly, LDAC has been effectively implemented in many pharmaceutical applications like granulation, tablet compression, soft gelatine drying, encapsulation and blister packing.

The beauty of the technology lies in the thermodynamic shortcut across which it travels, gracefully touching base with the process, operational and functional requirements simultaneously.

Basics of Liquid Desiccant Technology

A desiccant is a substance that has affinity for moisture, and a desiccant in aqueous state is termed a liquid desiccant, which is a salt solution with a specific concentration. The affinity for moisture in a liquid desiccant solution increases as the solution is cooled to a certain temperature and vice versa. The challenge lies in making effective use of this phenomenon within a given set of conditions.

The strength of the liquid desiccant can be measured by its equilibrium vapour pressure (i.e. the pressure of water vapour that is in equilibrium with the desiccant), which increases exponentially with the temperature of the desiccant-water system. It also increases as the desiccant absorbs water, which means a dilute liquid desiccant will have a higher equilibrium vapour pressure than a concentrated solution.

Liquid desiccant can enhance latent heat transfer by a mechanism which is the inverse of evaporative cooling. When

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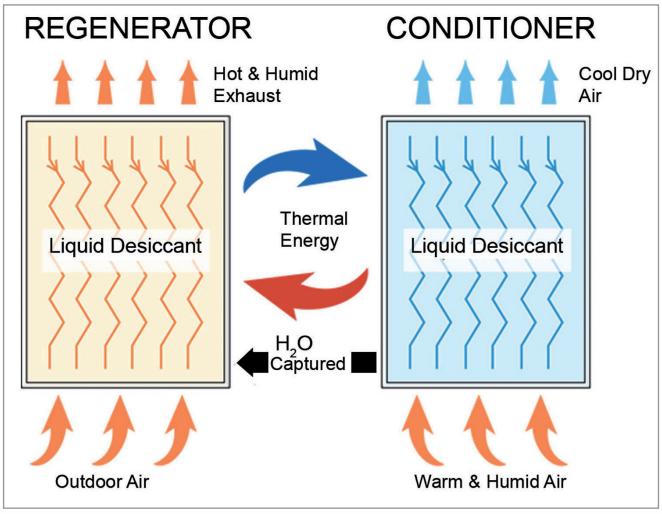

Figure 1: Liquid desiccant dehumidification process

air flows over a surface that is wetted with a liquid desiccant, it can either absorb or desorb water depending on whether the vapour pressure of liquid desiccant is above or below the vapour pressure of air passing over its surface. If the liquid desiccant absorbs water from air, heat will be released in the chemical reaction and desiccant temperature will increase, but it will simultaneously dry the air due to vapour pressure difference between the air and the liquid desiccant and provide sensible cooling to the air to some extent, depending on the temperature gradient between the air and the liquid desiccant solution. See *Figure 1*.

Major System Components

A contemporary liquid desiccant system consists of the following components:

Heat Exchangers

They facilitate cooling and heating of liquid desiccant solution by using an external or inbuilt energy source.

Heat Transfer Medium

It carries out the process of transfer of latent heat and the associated sensible heat.

Liquid Desiccant Transfer Mechanism

It ensures necessary movement of strong desiccant solution and weak desiccant solution in the respective sections simultaneously.

Fans

They carry out the desired air circulation across the heat transfer medium.

Pumps and Header Arrangement

They ensure flow of liquid desiccant to the heat transfer medium.

The Thermodynamic Shortcut

Liquid desiccant systems cool salt water to depress the dew point of the air inside the unit. This allows the unit to simultaneously remove moisture to the desired level and drop the air temperature. Cooling and dehumidifying air to the right condition in a single pass liquid desiccant dehumidification system eliminates or minimizes the need for post cooling or post heating, making it an intrinsically more efficient process than the conventional approaches. This is demonstrated graphically on a psychrometric chart, which shows the path of air from point A to point B through different modes (see *Figure 2*). Conventional air conditioning systems overcool the air to remove moisture through condensation followed by post heating to reach the desired condition. Solid desiccant systems overheat the air while dehumidifying it, so there is a need for post cooling. In simple words, running a solid desiccant system is like turning on heaters in an air conditioned room. Liquid desiccant systems stand out by taking the shortest route, and the footmarks of this route are embedded within the technology.

Lithium Chloride as a Liquid Desiccant

Lithium chloride (LiCl) is the most commonly used liquid desiccant, primarily because of its thermodynamic properties and due to the significant success that liquid desiccant technology has gained over the years by using it as a desiccant.

Lithium chloride is a salt that is a typical ionic compound, although the small size of the Li+ ion gives rise to properties not seen in other alkali metal chlorides, such as its extraordinary solubility in polar solvents (83 g/100 ml of water at 20°C) and its hygroscopic properties.

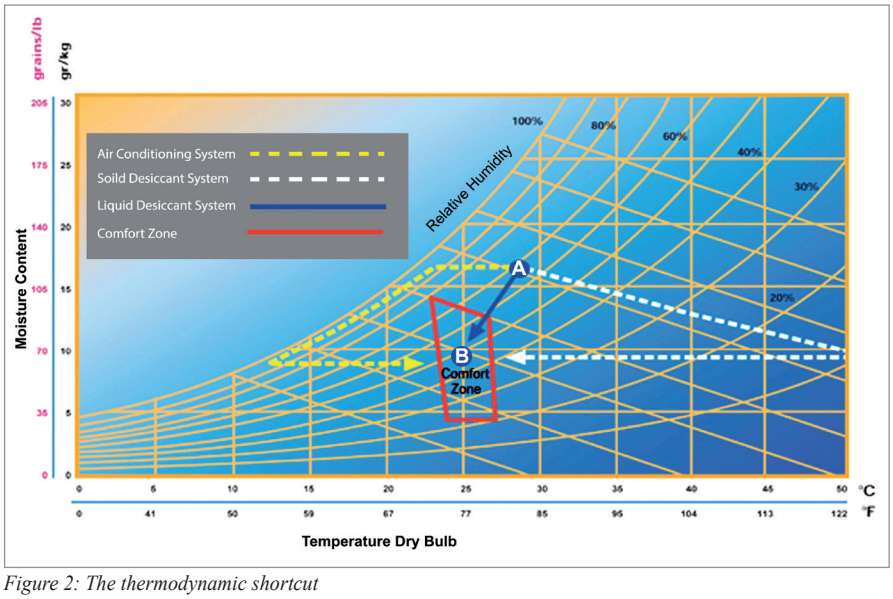

Figure 2: The thermodynamic shortcut

Functional Benefits of Liquid Desiccant Dehumidification

Liquid desiccants such as lithium chloride are biocidal; they kill micro-organisms they contact while remaining as safe for humans to handle as table salt. Therefore LDAC manufactures can

configure systems to remove over 90% of airborne bacteria, micro-organisms and mould while scrubbing out particles with filtration exceeding MERV 7 – all without a need for disposable filters. The technology also removes moisture from the building as vapour rather than condensate, thereby eliminating the need for drip pans or drain lines and the algae, bacteria and the system maintenance associated with them. In fact, a building using LDAC for all its dehumidification needs will run all its AHU coils dry, potentially eliminating their maintenance requirement.

Finally, because LDAC desiccants regenerate at lower temperatures around 65-74°C, liquid desiccant systems can be powered by renewable energy sources such as waste heat or solar thermal heat.

For decades liquid desiccant has been a small player in the HVAC market, but with higher focus on energy conservation and improved air quality the interest has increased and the number and variety of applications using liquid desiccants is growing rapidly.

Commercial Applications

Supermarkets are among the important commercial applications of liquid desiccant technology. A combination of a good liquid desiccant dehumidification system along with a conventional HVAC system proves to be a superior design than the conventional HVAC system maintaining comfort conditions inside a supermarket. If the entire latent load is handled by liquid desiccant dehumidification system, the conventional HVAC system can be downsized by approximately 30%.

The conventional HVAC system will handle purely sensible load, hence cooling can be precisely modulated to meet the requirements of the sensible load while selecting the centralised HVAC system. The chilled water temperature can be raised by approximately 2°C, due to which there is a substantial improvement in the COP of the chiller – 10% for every deg C rise in the chilled water supply temperature. The precisely metered sensible cooling of dry air completely eliminates the need for reheat. Thus overall energy saving by using LDAC is of the order of 25-30%.

Figure 3: Supermarkets are among the important commercial applications of liquid desiccant technology

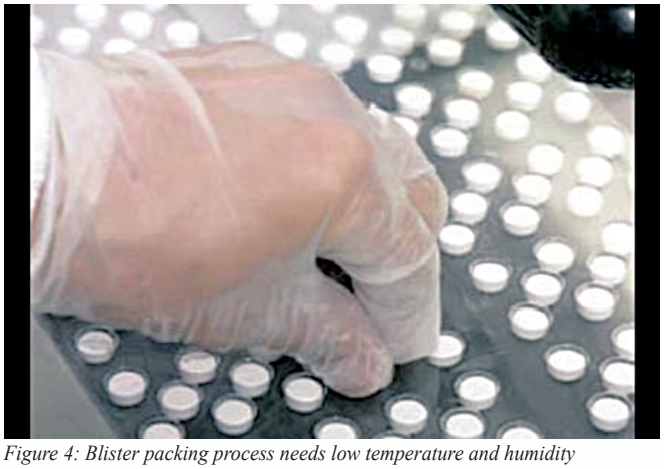

Figure 4: Blister packing process needs low temperature and humidity

Operational Benefits in Commercial Applications

Energy savings of the order of 25-30% result from the following factors:

- Reduction in operating load on chiller.
- Improvement in chiller COP.
- Elimination of reheat.
- Reduction in maintenance required as AHU coils will remain dry.

Functional Benefits in Commercial Applications

- Better comfort possible – with improved design conditions of higher dry bulb temperature i.e. 25 to 27°C, and lower relative humidity i.e. 45 to 50% RH.
- Improved IAQ – owing to germicidal properties of the liquid desiccant solution.
- LDAC, being specialised to handle latent load, enables treatment of the fresh air quantity required for human comfort, in sync with LEED criteria.

Industrial Applications

Some of the industries that use liquid desiccant dehumidification are mentioned below.

Pharmaceutical Industry

There are some specific pharmaceutical applications which need conditions to be maintained around 20-25°C and absolute moisture content around 3 to 6 gm/kg.

Specialty Sports Industry

Liquid desiccant dehumidification system is being used for paintball manufacturing application at Gelkaps Sports, Kandla, Gujarat – one of the major paintball manufacturers in the world. Paintballs are produced in a pharmaceutical type climate controlled environment, similar to soft gelatin capsule manufacturing. Maintaining conditions of 22±2°C and 15% RH is critical for satisfying the process and quality requirements.

Food Processing

Liquid desiccant dehumidification system is being used for spice powder conveying application at Everest Masala Factory, Mumbai. The conveying process of spice powder through the silos needs constant supply of dry air for free flow of material. Maintaining supply air at 20°C and less than 40% RH is essential for spice conveying process.

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Figure 5: Spice conveyor at Everest Masala factory

Heavy Industrial Applications

Liquid desiccant dehumidification systems are being used for heavy industrial applications like the blast booth at L&T Hazira, Gujarat, which requireds 100% fresh air treatment for the sand blasting operation at the installation located on a sea-shore.

Application in Green Buildings

LDAC can be a suitable system for Green building design due to the LEED credits it is capable of offering in the following areas:

Energy & Atmosphere

LDAC systems can serve many requirements under this category.

EAp2 i.e. minimum energy performance and EAc1 i.e. optimized energy performance: by treating indoor and outdoor air, liquid desiccant systems can reduce significant cooling load on AC systems of the building, which in turn helps minimize overall energy consumption of the building.

Some LDAC systems available in industry are aligned with EAp3 and EAc4 i.e. fundamental refrigerant management and enhanced refrigerant management respectively. LDAC is also in sync with EAc2 i.e. on-site renewable energy, as it has the potential to incorporate renewable energy sources such as solar energy or geothermal energy.

Indoor Environmental Quality

IEQp1 i.e. minimum indoor air quality performance: LDAC systems are capable of achieving MERV 8+ filtration using natural properties of salt.

Figure 6: L&T Hazira at the west coast of India

Liquid Desiccant Applications

- Latent load management for commercial complexes, supermarkets, shopping malls
- Hotels – fresh air treatment, better IAQ.
- Hospitals –operation theatres, special wards
- Health clubs – fresh air treatment, odour removal
- Schools – better IAQ for children
- Development of Green buildings
- Food processing – conveying, packaging
- Paint booths and blast booths
- Product drying
- Plastic moulding
- Investment castings
- Specialised manufacturing – abrasive wheels
- Warehouse dehumidification
- Cold storages
- Pharmaceutical production
- Soft gelatine drying
- Neutraceuticals
- Paint ball manufacturing
- Ice rinks

Figure 7: The liquid desiccant applications basket

IEQc2 i.e. increased ventilation: LDAC is capable of providing extra ventilation efficiently.

IEQc6.2 and 7.1 i.e. controllability of systems and thermal comfort in design: both these can be achieved in an effective LDAC system.

IEQc10 i.e. mould prevention: LDAC uses natural disinfectant salt solution, which is ideal for mould prevention and kills about 91% micro-organisms.

Innovation in Design

Liquid desiccant systems use innovative technology in a green building category not specifically addressed by LEED building rating systems.

Energy Savings

Research conducted by ASHRAE over many years on large numbers of people concluded that there is a range of combined temperature and humidity that provides comfort to most people. Most people are comfortable at higher temperatures if there is a lower humidity (see *Figure 8*). In the interest of energy conservation, it is advisable to keep the set temperatures as high as possible.

A space maintaining slightly higher dry bulb temperature, i.e. 25 to27°C and lower relative humidity i.e. 45 to 50% RH can deliver higher level of comfort than a space maintained at a lower dry bulb temperature and higher relative humidity, i.e. 22-24°C and 55-60% RH, at constant absolute humidity. Raising the design dry bulb temperature would provide an incremental saving on sensible cooling and thus the effect is dual, i.e. extra comfort with an extra amount of energy saved.

The sensible cooling benefit, which acts as a by-product of the liquid desiccant dehumidification process, principally helps to reduce the operating load on the sensible cooling equipment. In

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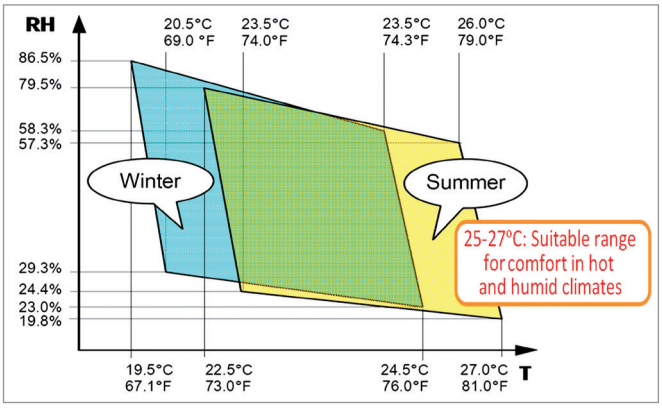

Figure 8: RH-temperature diagram based on comfort zone according to ASHRAE 55-1992

this case, sensible load = A, latent load = B, load handled by liquid desiccant dehumidification system = 0.4 A + B.

The balance load on sensible cooling system = 0.6 A only. Hence additional sensible cooling load is substantially reduced, and the energy consumed by the liquid desiccant dehumidification system is approximately 40% lower than a silica gel type system. Thus LDAC is a better choice for various applications (see *Table 1*).

Table 1: Liquid vs. solid desiccant dehumidification

Liquid desiccant dehumidification systems	Solid desiccant dehumidification systems
Simultaneous drying and cooling	Simultaneous drying and heating
Removes moisture by absorption process	Removes moisture by adsorption process
Significant reduction in overall energy consumption	Increase in overall energy consumption
No performance degradation after prolonged operation; no desiccant replacement required except 3-5% top up after 10,000 hours of operation	Desiccant wheel replacement required after prolonged operation
Improves indoor air quality owing to the germicidal properties of liquid desiccant solution	Indoor air quality remains unchanged

Challenges for Liquid Desiccant Technology

Looking at the current scenario, the biggest challenge for liquid desiccant based dehumidification systems is reducing the cost for the value it adds to the solution design. Also, in spite of being a proven technology, there is a lack of readiness for using it. A distinctively out of the box thinking and innovative design approach is needed to justify the value addition using the liquid desiccant technology in commercial comfort applications, which occupy a large segment of the HVAC industry.

References

1. *Review of Liquid Desiccant Technology*, HVAC & R Magazine, November 2008.

2. *ASHRAE Standard -55 -1992.*