LIQUID DESICCANT DEHUMIDIFICATION

While their dry counterparts are an HVAC industry standard, liquid desiccant dehumidification (LDD) systems have been common only in industrial applications. Small units have produced very impressive EER and COP results, yet only a handful are installed in commercial applications. While companies touting their "new" LDD systems have come and gone, there's a new generation of LDD commercial technologies in town. How will these "new and improved" LDD systems perform in terms of humidity control, energy, IAQ, and occupant health and comfort? Is now finally the time when they can revolutionize both humidity control and heat recovery to become the new, healthy, energy efficiency magic potion?

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Historically, HVAC systems were designed to deliver 72° and 55% rh air due to cooling coils' ability to condense out enough moisture to hit 55% rh. In humid climate zones, mechanical engineers regularly dial in reheat coils in order to raise the delivered air's temperature so that the cooling coil can wring out enough moisture to hit that 55% bull's eye. Not only is that expensive and energy inefficient, but if you want to dry to 45% rh or below, you'll need a supplemental technology to remove the extra latent load. Here's where Prince Desiccant rides up to slay the evil latent dragon.

DESICCANT DEHUMIDIFICATION TO THE RESCUE

ASHRAE provides a nice review of HVAC LDD in its 2008 HVAC Systems and Equipment and 2009 Fundamentals handbooks. Since I'll assume you're already familiar with solid desiccant dehumidification, I'll focus on LDD. LDD's breakthrough is that it can grab up to 100% of the latent load in one pass. One. Used within a dedicated outdoor air system (DOAS), LDD can dry your entire ventilation latent cooling load before it can ride into your building to wreak havoc. In my opinion, this creates the most exciting thing since the invention of air conditioning: dry cooling coils.

WHAT'S SO COOL ABOUT DRY COOLING COILS?

While we've leaned on Carrier's invention to dehumidify along with cooling, we've assumed that cooling coils must always function to condense airborne water vapor. Relying on inefficient cooling coils to dehumidify is getting more expensive with rising electrical rates. I've pontificated in *ES* ("How Humidification Affects Health, Mold and Airborne Germs," February 2010) about the negative health impacts of airborne mold and bacteria growth on any HVAC interior surface. Wet coils are mold and bacteria growth factories because condensate does an excellent job of plucking them out of the air and nestling them in the warm waters of life where they make million of clones.

Richard Shaughnessy et al.[1] measured a 1,000% increase in airborne mold after a coil was wet for only four months. This airborne attack was due to condensate-soaked cooling coils spewing their resident germs into the airstream. Imagine this: the rushing air flow in the AHU scrubs the mold and bacteria off the coil's surfaces and also aerosolizes them off the drain pan's frothy surfaces to lift them up into the airstream. Technically this is called "entrainment," but you get the picture of all those germs launching into the air like paratroopers jumping out of a plane. These paratrooper germs and their attending odors end up wafting into the occupant air spaces to be breathed by you or your clients. That's why HVAC cooling coils can stink up the air along with making occupants ill in condensate season.

Since LDD's dry coils aren't encased in a biofilm insulation layer of bacteria and mold, they don't suffer from Btu transfer performance degradation. The energy implications of mold-insulated coils can be

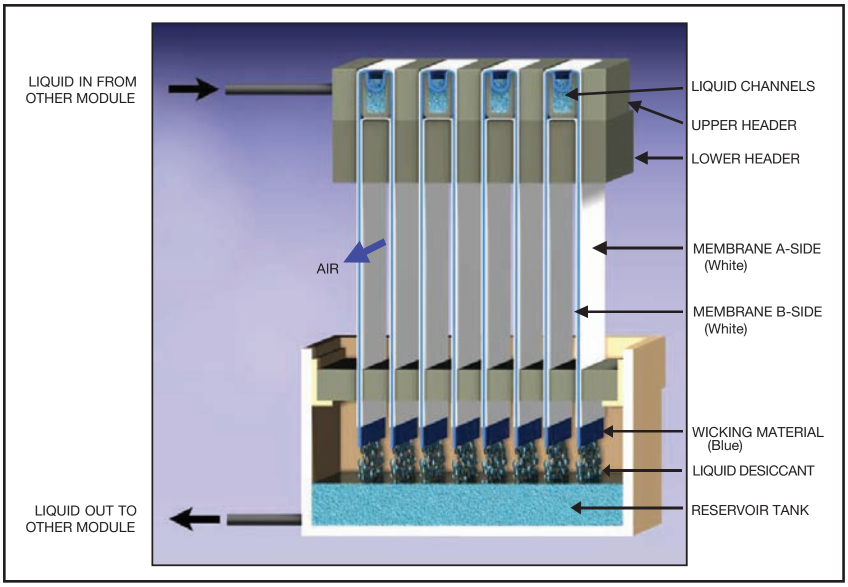

FIGURE 1. System 2's membrane protected LD wick allowing safe air contact

found in a 2003 case study documented in *Engineered Systems*[2] where a mold-clogged cooling coil was irradiated with UV light and brought back to as-new performance. The germicidal (germ killing) UV light removed the mold insulation layer surrounding the coil, allowing it to provide significantly better Btu transfer, which resulted in a 4° drop in exiting temperature along with improved airflow and dehumidification. This intervention delivered a 28% increase in the coil's energy efficiency while reducing fan amperage draws in the motors due to air pressure drops of 40% over the coil.

THE HEALTH BENEFITS OF DRY COILS

Another benefit of cool dry air within the HVAC system is it can eliminate condensation on all other HVAC interior surfaces, especially those downstream of the coil. In that February 2010 article, I call this germ condensation creation phenomenon "mold soup," and preventing its occurrence will also prevent any germs from entraining into the airstream to negatively affect people's health.

Dick Menzes et al.[3] documented the health impact of nearly eliminating mold and bacteria growth and entrainment from coils and drain pans in three office buildings finding that:

- 20% of all occupants felt healthier, and
- 40% of occupants with allergies or asthma felt healthier.

Another technology supports the benefits of a mold- and bacteria-free coils. Copper is toxic to mold and bacteria, and in 2009 Liv Haselbach et al. published the health effects of copper coils in a military housing facility[4]. They measured the health benefits to the soldiers living in rooms served by copper mold- and bacteria-free coils. They found that the soldiers fed by the copper coils had significantly less respiratory illnesses and lost sick time due to lowered airborne levels of bacteria and mold.

HEALTH BENEFITS OF LIQUID DESICCANTS (LD)

Liquid desiccant (LD) salts and solutions are toxic to germs by either killing the germ or stopping its replication. Any airborne germs impaling an LD solution will be killed or die soon thereafter. It's a beautiful thing when LDs yank germs out of the airstream and transport them away within the LD solution. It's like a bug flying into Niagara Falls and being washed downstream. In 1971, a study from Batelle[5] confirmed the power of desiccants' germicidal effects.

DESICCANTS AND ENERGY SAVINGS

In 2008, I saw Wal-Mart's Charles Zimmerman when he came to Washington and talked about how they dehumidify their stores down to 45% rh, allowing them to raise their setpoint temperature from 72° to 76°F. That 4° increase is saving those stores 15% or more on their HVAC energy due to a solid desiccant dehumidification system drying the outdoor air. Wal-Mart's U.S. operation's energy use at 25 kW/sq ft is one of the lowest in the world. Wal-Mart's stores save $50,000,000 a year from energy efficiency measures including strategies like desiccant dehumidification. Drying to 45% is cake for LDD systems that could easily provide 40%. Not only would that allow them to raise their setpoint even more, but Southern Edison documented the amazing refrigeration reduction energy savings in supermarkets that dehumidified to 40% rh. (A quick digression: I remember hearing about a study showing that women tried on 50% more clothing in retail stores that dehumidified to 45% rh.)

LD CORROSION CHALLENGES

LD systems use some mixture of desiccant salts typically lithium chloride (LiCl) and water to make up their liquid solution. Most LD systems choose LiCl as it is one of the strongest desiccants available due to its ability to absorb and desorb moisture. LiCl's disadvantage is that it is corrosive and not earth friendly. This makes it critical that LiCl be contained within the LD system so that it's not entrained into the airstream to be carried downstream into occupied spaces.

Airborne LiCl is one of the challenges that has plagued LD systems especially those used in industrial applications. One of the main impediments surrounding widespread acceptance of LD has probably been the consequences of downstream transportation of airborne desiccant droplets. Since LD salts are highly corrosive to metal, there have cases of corroded ductwork and even corrosion within the occupied spaces. My biggest concern is that occupants could breathe in airborne particles or droplets of corrosive desiccant. While this may be acceptable in industrial applications, it certainly isn't appropriate for schools, hospitals, or commercial buildings. It may have been stories like these that have given a black eye to previous versions of liquid desiccant systems.

TYPES OF LD SYSTEMS

There are three main methods of applying LD. The passing airstream is exposed to desiccants via:

- Spray nozzles creating a desiccant mist (the old standard);
- Vertical panels with wicking surfaces which desiccants flow down and over (System 1);
- Vertical wicking panels with permeable membranes encapsulating them through which the desiccant flows down (System 2).

Spray nozzle LD has been used since the 1930s, mostly in industrial applications where low humidity is required. The spray nozzles create an airborne desiccant mist in order to ensure that as much desiccant as possible encounters the airstream. The desiccant mist, along with the humidity it has absorbed, then drops into a reservoir. The saturated desiccant's moisture is dried out (regenerated) and sent back in a continuous loop. These systems still have the drawback of transporting airborne desiccants downstream though much less today.

The vertical panel systems come in two different configurations. System 1 uses plastic extruded panels covered by a 20-mil-thick wicking layer, which provides the surface on which the desiccants slowly flow over and are directly exposed to the airstream. The second vertical system (System 2) also contains the desiccant wicking material but separates it from the airstream by micro-permeable membranes. Airborne water vapor penetrates through these wicking membranes to be absorbed safely by the LD, preventing it from aerosolizing back into the airstream.

THE 'NEW' GENERATION OF LD SYSTEMS

Years ago, flexibility is what drew me to specify an LD system then made in Michigan. I specified it because the system's intake and exhaust modules didn't have to be mounted side by side like the existing dry desiccant systems. The intake module could be on the other side of the building from the exhaust module, which in that case was the only system that would work that way. The owner had patented the membrane enclosed LD system (System 2) and his 2004 patent #6,681,649 was granted 37 claims. While several of his custom LD systems were successfully installed, he was a "David" in the goliath HVAC world. In 2008, he sold the patent rights to his LD system to a major HVAC company. They have spent the last two years developing a production model in order to manufacture the system and intend to do final field testing later this year.

The other "new" LD system (System 1) was developed by a well-known LD expert who has been toiling away on LD systems for the last 20 years. He's racked up an impressive treasure chest of patents along the way. He's partnered with the U.S. National Renewable Energy Labs, backed with $5 million in Federal research funding to further develop his LDD system. He's has sold his patent rights to a California company which so far has installed their branded version of his system into two supermarkets.

NEW LD CAPABILITIES

I'll briefly describe each system to give you a feel for what they can do. System 1 uses LiCl and is currently available as a 6,000 cfm system designed to only dehumidify the air. This system uses a surface wick layer coating on an extruded plastic core which looks a little like foam core. Cool water from a cooling tower (or other source) simultaneously flows through the extruded plastic channels absorbing of some of the sensible heat created by the desiccant absorbing the moisture vapor on the other side.

After the airborne moisture is absorbed by the LiCl within the first module, the saturated liquid desiccant is pumped to a secondary module. There, again it drizzles down the wicking material to desorb its moisture into the air while heated water flows inside the plastic channels to increase the moisture desorption. This heated water may be either scavenged or generated by a heat source. The concentrated (regenerated) desiccant solution is then returned to the top of the vertical panels in the primary module. The system is in a self-contained unit which sits on a rooftop connected to the outdoor air intake and to a water line coming off the cooling tower (or other cool water source). This system also has the nifty ability to use solar thermal energy to regenerate the desiccant instead of gas or electric generated heat.

System 2 will be using a proprietary LD with the encapsulated desiccant system, which entrains no desiccant into the airstream. It will dehumidify just like System 1 but also has the capability to transfer sensible heat from the exhaust air system. The System 2 modules (Figure 1) look similar and are placed in front of the OA intakes and the exhaust air openings. The OA passes over the LD-soaked wicking material that is safely encapsulated behind a semi-porous membrane. The membrane freely allows the moist air to contact the LD, which absorbs the moisture.

In dehumidification mode, System 2's saturated desiccant is pumped from the intake module over to the exhaust air module. The building's exhaust air helps remove both the latent load and allows the LD to gain the sensible load. The sensible heat along with the regenerated desiccant then returns to the intake module to start all over again. In humidification mode, System 2 desorbs latent heat into the incoming air courtesy of the exhaust air module which has diluted the LD. Along with the latent heat comes the sensible heat from the exhaust air to condition the incoming outdoor air and to provide wintertime sensible heat recovery.

LD SYSTEMS AND ENERGY PERFORMANCE

The early data from System 1 is that it has a COP of between .7 and 1 and an even higher COP with a solar regeneration system. The last test data showed that System 2 had an average EER of 25 in the summer and could reach a whopping 50 EER in the winter due to both its latent heat and sensible heat transfer capabilities.

Here's a summary of the advantages of liquid desiccation:

- It allows you to downsize the cooling equipment capacity and raise temperature setpoints (#1 & #2),
- You can add solar to increase efficiency even more (#1),
- You can eliminate other air humidification equipment (#2),
- You can downsize your heating equipment capacity (#2),
- It has multiple health advantages (#1 & #2).

Each system will certainly have improvements and performance gains though feedback from the field. I'll be watching these liquid desiccant systems as they are installed in locations around the world. Once they've sorted out the kinks, liquid desiccation could well become the new, healthy, green energy efficient magic potion. **ES**

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REFERENCES

1. Levetin, Shaughnessy et al., "Effectiveness of Germicidal UV Radiation for Reducing Fungal Contamination within Air-Handling-Units," *Applied and Environmental Microbiology*, April 2001.
2. Firouz Keikavousi, "UVC: Florida Hospital Puts HVAC Under a New Light," *Engineered Systems*, February, 2003.
3. Dick Menzies et al., "Effect of Germicidal Lights Installed in Office Ventilation Systems on Worker's Health and Wellbeing: Double-Blind Multiple Crossover Trial," *Lancet*, November, 2003.
4. Liv Haselbach et al., "Airborne Transmission via HVAC of Acute Respiratory Infections in Military Facilities? Review of a Basic Training Cohort Study," *Journal of Green Building*, 4(1), 2009.
5. Battelle Memorial Institute, "Project N 09145200-1971," Battelle Memorial Institute, Columbus Ohio, 1971.