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Liquid Desiccant Technology Delivers Energy Cost Reductions and Indoor Air Quality Improvements

White Paper

Cooling represents the third leading use of energy and source of carbon emissions in commercial buildings.

Abstract

Air conditioning technology has advanced relatively little in the past few decades. To reach relative humidity targets, air conditioning systems are frequently configured to cool air far below the needed inlet temperature and then reheated, wasting substantial amounts of energy. Furthermore, conventional air conditioning systems rarely use renewable energy sources and the wet coils are conducive to the growth and entrainment of bacteria and mold into the air.

Liquid desiccant systems provide an innovative alternative that can overcome these and other concerns with conventional air conditioning. A key advantage of liquid desiccant systems is that they provide independent control of temperature and humidity, enabling sensible cooling (temperature reduction) and latent cooling (humidity reduction) to match the needs of the application and avoid the energy wasted in overcooling. In many cases a reduction in relative humidity (RH) also enables the temperature setpoint to be increased, providing additional energy savings. Liquid desiccant systems can also be powered by renewable energy sources such as solar thermal and waste heat from co-generation systems, providing energy savings of 30% - 80%.

Beyond the energy and cost savings, there are also functional benefits to adopting this technology. Liquid desiccant systems offer a substantial improvement in indoor air quality (IAQ) by eliminating condensation on interior surfaces and because the desiccants themselves are toxic to germs.

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Concerns with conventional air conditioning systems

Cooling represents the third leading use of energy and source of carbon emissions in commercial buildings (after lighting and space heating) and the fourth leading use of energy and source of carbon emissions in the residential buildings (after space heating, water heating and lighting). In both commercial and residential buildings air conditioning represents about 11% of total energy consumption.[1] Air conditioning as a whole utilizes about 4.3 quads of primary energy, nearly all of which comes from nonrenewable sources.[2] A quad is equal to 10^{15} or one quadrillion BTUs. Global primary energy production was 446 quads in 2004. In addition, peak loads generally occur during periods of heavy air conditioning usage so any reduction in air conditioning power consumption translates directly to reductions in required power generation and transmission capacity.

A fundamental problem with traditional air conditioning systems is that vapor compression heat pumps (which constitute 95% of conventional air-conditioning systems) as well as chilled water and direct expansion systems do a great job at sensible cooling, but provide a very inefficient system for removing humidity from air. A typical air-conditioner provides 80% of its total cooling as sensible cooling and only 20% as latent cooling. This is a poor fit for most indoor environments. Reaching a typical target of 72°F and 50% RH may require bringing the processed air to 52°F or lower to reduce humidity to acceptable humidity levels and then using reheat coils to raise the temperature of the delivered air back to the target.[3]

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It's also worth nothing that the typical 50-55% RH specification is primarily based on the capabilities of conventional HVAC system. Reducing humidity to lower levels offers the potential both to improve comfort and productivity

[1] Wikipedia. "Energy Use in the United States."
[2] Andrew Lowenstein., Steven Slayzak, Eric Kozubal. "A Zero-Carryover Liquid Desiccant Air Conditioner for Solar Applications. ASME International Solar Energy Conference. July 8-13, 2006.
[3] Steven Welty. "Liquid Desiccant Dehumidification." Engineered Systems. May 2010.

in the indoor space and to provide energy savings by enabling the temperature setpoint to be increased. After performing instrumented air conditioning tests on over 100 hospitals, Grahame Maisey concluded: ".. the ASHRAE comfort chart suggests that we can have humidity levels between 80% and almost 0% for the summer months and have a reasonable level of comfort. I suggest that the humidity should be between a 30% low in the winter and 40% high in the summer for best comfort conditions, with an operative temperature between 72 and 78, as indicated by the blank area almost in the middle of the comfort zone. The operative temperature is a combination of the radiant and air temperatures. … Controlling the humidity level at low levels in the summer, below 50%, allows us to raise the operative temperature and remain very comfortable."[4]

Sensible vs. latent loads

Lewis Harriman, Dean Plager and Douglas Koser have proposed a ventilation load index (VLI) that equals the load generated by one cubic foot per minute of fresh air brought from the weather to space neutral conditions over the course of one year. It separates the load into two numbers: latent ton-hours per cfm per year and sensible ton-hours per year.[5] Their study shows drastic differences in the latent and sensible loads and that except for desert climates that latent loads are always considerably higher than the sensible loads. The study provides sensible and latent loads only for American cities but it can easily be applied to European cities with similar climates. For example, in Boston latent loads are 2.0 ton-hours per CFM while sensible loads are 0.3 ton hours per CFM. Paris has a similar climate with an annual average temperature of 51°F vs. 51.3°F for Boston and a relative humidity of 76.5% compared to 73% for Boston. Their work clearly demonstrates how current HVAC technology represents a far less than ideal fit to air conditioning requirements in most parts of the country.

Another concern with current HVAC technology is the negative health impacts of airborne mold and bacteria growth on HVAC interior surfaces. Water that has condensed on coils serves as an ideal incubating ground for mold and bacteria. Estelle Levetin, Richard Shaughnessy, Christine A. Rogers

[4] Grahame Maise. "The Death of HVAC." Consulting Specifying Engineer. August 9, 2010.
[5] Lewis Harriman III, Dean Plager, Douglas Koser. "Dehumidification and Cooling Loads From Ventilation Air." ASHRAE Journal. November 1997.

and Robert Scheir measured a 1000% increase in airborne mold after a coil was wet for four months.[6] The air flow within the air handling unit provides an ideal, from the bacteria's point of view, transportation mechanism to launch pathogens into the building airspace where they can make occupants ill and cause expensive damage. American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Standard 62 promotes acceptable IAQ through recommended ventilation rates, space humidity levels and filtration.

How liquid desiccant technology addresses these issues

Liquid desiccant technology provides a potential solution to these problems. Typical liquid desiccant systems have two primary components, an absorber and a regenerator. Cooled liquid desiccant flows down into the absorber, often through a packed bed of particles or other media designed to maximize mass transfer between the desiccant and the air. The process air flows upward in the opposite direction through the bed. Heat and moisture is transferred from the air to the desiccant in the bed. As the desiccant absorbs water from the air, it becomes diluted and the water flows into the regenerator. In the regenerator, the solution is heated, then flowed over another media bed. The hotter solution then releases the moisture that was gathered, transferring the moisture to the counterflowing exhaust air stream.

Matching sensible and latent loads

A key advantage of liquid desiccant systems is that they can be configured to provide sensible and latent cooling capacity to match the requirements of the application. Latent cooling capacity can be set to 2 to 5 times greater than sensible cooling, which is a better match for most climates. The liquid desiccant handles the latent load, eliminating the need to overcool and reheat the air in order to meet humidity requirements. This feature alone can provide substantial energy savings, especially in humid climates.

Liquid desiccant systems also offer the ability to independently control temperature and humidity which usually makes it possible to provide a

[6] Estelle Levetin, Richard Shaughnessy, Christine A. Rogers, and Robert Scheir. "Effectiveness of Germicidal UV Radiation for Reducing Fungal Contamination within Air-Handling-Units." Applied and Environmental Methodology. April 2001.

more comfortable environment while generating additional energy savings. The superior dehumidification performance of liquid desiccant systems also typically makes occupants feel comfortable at a higher temperature, providing the opportunity to increase the temperature setpoint by 2°F to 5°F.

> Liquid desiccant systems improve indoor air quality by removing approximately 91% of the airborne microorganisms and 80% of particles larger than 5 microns in a single pass.

In a liquid desiccant system, low-grade thermal energy replaces the high electrical demand of the compressor in a conventional air conditioning system. This type of thermal energy can be found in abundance in many industrial facilities and even in many commercial HVAC installations. For example, the waste heat of conventional chillers can be utilized to power the liquid desiccant's latent cooling, thus reducing operating costs of cooling systems by about 40%. Cool water for the cooling process can be taken from any convenient source such as a cooling tower, geothermal well, river, etc. In a more sophisticated, but extremely energy efficient installation, heat can often be supplied by co-generated heat or process heat that would otherwise go to waste, or by a renewable source such as solar energy as its primary source of energy to provide high efficiency all year round. Such a system can reduce cooling energy requirements by 80% or more.

Improving indoor air quality

Another benefit of liquid desiccant air conditioning is that it can eliminate condensation points on interior surfaces of the HVAC system that provide an ideal breeding ground for mold and bacteria. The salty liquid desiccant solution acts as a bactericide by cleansing the processed air of microorganisms. The result is that liquid desiccant systems improve indoor air quality by removing approximately 91% of the airborne microorganisms and 80% of particles larger than 5 microns in a single pass. This capability is beneficial for a wide range of applications including food processing, hospitals, the pharmaceutical industry, laboratory clean rooms, electronic chip manufacturing, schools, or any application where cleaner, healthier indoor air is desired.

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Case study: 60% energy savings

A leading global confectionary company previously used a solid desiccant system with an electric heater drying the desiccant to condition air transmitted into a chewing gum production area. The company replaced this system with a liquid desiccant system that treats fresh air and works with the existing air handling unit (AHU). The liquid desiccant system maintains and improves indoor design conditions of 64.4 °F +/-1.8°F (20 °C +/- 1°C) and 45% +/- 5% RH. The liquid desiccant system supplies dry cool air, substantially reducing energy consumption of the AHU and heater. The net result is a 60% reduction in energy cost.

Case study: $125,000 savings per year

A major injection molder's injection molding operations saved $125,643 per year by switching from a desiccant wheel dehumidification system to a liquid desiccant dehumidification system. The molder requires low humidity to avoid condensation on the inside of the mold which can damage the surface of the molded part. The company previously used desiccant wheels to maintain these humidity levels. The desiccant wheel system provided 4,556 cubic meters of air per hour to two production rooms with a total of 32 injection molding machines. The desiccant wheel system used 12,362 cubic meters of LPG per year and placed a 28 TR heating load on the air conditioning system. It previously cost $102,269 in liquid petroleum gas (LPG) costs to produce the high temperatures required for regeneration plus $72,855 in electricity costs.

The company considered a number of alternatives and decided to switch to a liquid desiccant system. The company installed three liquid desiccant systems in one production room. The liquid units met all of the company's requirements in the first production area while substantially reducing energy consumption so the decision was made to duplicate the liquid desiccant installation in the second production area. The liquid desiccant systems eliminate the need for LPG because lower temperatures are required for regeneration and reduce electricity consumption by providing a cooling load of 17.4 TR, for a net gain of 45.4 TR in HVAC heat load. The liquid desiccant units consume $75,891 in electricity per year but reduce HVAC electricity costs by $26,410. Overall, the elimination of LPG and reduction in electricity cost to $49,481 provided an overall savings of $125,643.

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Case study: cooling cost reduced 43%

A meat processing plant in Germany has reduced the cost of cooling and dehumidification by 43% by installing a liquid desiccant dehumidification and cooling systems. The liquid desiccant system utilizes cold and hot water that are available in the plant from other processes to deliver dry and cool air as required. The plant is saving annually over $231,000 (□165,000) in electricity costs while improving working conditions, reducing safety hazards and prolonging equipment lifespan.

Conclusion

Unlike conventional air conditioning systems, liquid desiccant systems directly absorb humidity from the air while cooling. This approach substantially reduces energy consumption by eliminating the need for over-cooling and reheating the air. Liquid desiccant systems also offer the ability to independently control temperature and humidity which usually makes it possible to provide a more comfortable environment while generating additional energy savings. Liquid desiccant systems can be powered by renewable energy sources such as solar panels and geothermal water or by waste heat from co-generation systems.

For more information about liquid desiccant technology and how it can benefit your organization, please visit our website (www.advantixsystems.com) or contact us (sales@advantixsystems.com I 888.818.5171).

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