

PAXSTREAMLINE



Cooled by the Sun

High Efficiency Air Conditioning

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STREAMLINING THE INDUSTRIAL WORLD

Air conditioning: a challenge to the grid

A \$100 billion industry, air conditioning uses over 4.9 quads (4.54 billion GJ) of primary energy¹ and accounts for 5% of the total energy consumed in the United States. In California alone, air conditioning consumes up to 50% of the state's peak electrical demand and accounts for between 10% and 15% of a building's overall energy consumption.² Improving the energy efficiency of air conditioning (AC) systems—particularly those in commercial buildings—has the potential to significantly reduce overall energy use both in the US and across the globe.

How air conditioning currently works

Traditional vapor compression air conditioning systems control temperature by blowing air across a cold surface. These systems use a refrigerant gas (such as Freon) in a cycle of compression and expansion to create a cold surface in one place and a hot surface in another. This compression and expansion cycle is energy intensive and the traditional refrigerant gases used can contribute to global warming or erosion of the ozone layer.

In summer, people are most comfortable, healthy, and productive in a building where the temperature is around 72° F (23° C) and 50% relative humidity (RH). This is the ideal "comfort zone" for people. An air conditioner must reduce both the temperature ("sensible cooling") and humidity ("latent cooling") of the air it supplies to the building if it is to maintain this comfort zone. Unfortunately, air conditioners perform the second task—latent cooling—very poorly. Conventional air conditioners achieve latent cooling by chilling the air to very low temperatures to condense out the water. In many instances, an air conditioner will provide much more sensible cooling than a building needs in order to provide sufficient latent cooling—essentially overcooling the air to remove the moisture. When this happens, the supply air must then be reheated to return it to a comfortable temperature. This roundabout process—over-cooling followed by reheating—can increase an air conditioner's electricity use by over 25%.

Reheating to maintain comfort is expensive, and building owners frequently ignore the need. Instead, they let the air conditioning system deliver excessively cold air, and allow a building's heat load (from lighting, equipment or its inhabitants) warm the air to a comfortable temperature. This is why, during the summer months in some particularly humid climates, you might need to don a sweater while indoors. (In the future, this problem will get worse, since many new energy-efficient technologies will reduce a building's heat load while leaving the humidity problem unchanged.)

Moreover, when air conditioning systems fail to effectively dehumidify the air, the resulting clammy conditions can promote the growth of mold and the so-called "sick building" syndrome. Even when a traditional vapor-compression air conditioning system is operating normally, it consumes a tremendous amount of electricity.

The high cost of comfort

To see how this cooling strategy affects the bottom line, let's look at an environment with a high latent load: the supermarket. A typical 45,000 square foot supermarket will

¹ Current Industrial Reports, MA333M - Refrigeration, Air Conditioning, and Warm Air Heating Equipment <http://www.census.gov/cir/www/333/ma333m.html>

² 2008 Buildings Energy Data Book, <http://buildingsdatabook.eren.doe.gov/Default.aspx>

have a total load of 120 tons³—80 tons of refrigeration and 40 tons of air conditioning. Compressor loads in a typical supermarket are close to 4 W per square foot (compared to less than 2 W per square foot for the AC compressors for a typical office building). California, for example, has approximately 90 million square feet of supermarkets and groceries; their annual energy consumption is 6.6 billion kWh.

As reported by Kosar and Dumitrescu,⁴ significant electrical demand and energy savings can be achieved in supermarkets by reducing indoor humidity to very low levels. With a store HVAC system commonly kept at 75 °F/55% RH, electrical use for the low and medium-temperature refrigeration will decrease by up to 20% if indoor humidity is lowered to 35%. (These savings are driven in part by reductions in defrost cycles and anti-sweat heater operation made possible with lower humidity.) If only 20% of California's supermarkets could realize these energy savings, for example, demand savings would be on the order of 20 megawatts. This is the amount needed to provide electricity to 116,000 homes a year, reducing the need for additional power plants. It also represents the reduction of about 117K tons of CO², or the removal of 20,000 cars from the road per year.

Unfortunately, conventional dehumidifiers simply cannot achieve these low humidity levels. Air at 75 °F and 35% RH has a 45 °F dew point; even in a dry location, outdoor ventilation must be deeply dried before it is brought into the building if a 35% RH is to be maintained. Attempting to supply air at the low dew points needed to keep a supermarket at 35% RH using a conventional system would cause the cooling coils to ice over.

Liquid desiccants: a better way to cool

Low-flow liquid desiccant air conditioning (LDAC), a new technology developed with the support of the Department of Energy's National Renewable Energy Laboratory (NREL), could save as much as 40% of the electricity used by commercial AC systems—and be powered by the sun. LDAC systems work by chemically dehumidifying air; removing the moisture from the air *before* cooling with a conventional HVAC unit.

The liquid desiccant itself is a non-toxic concentrated salt solution (for example LiCl or CaCl₂) that has a high affinity for water vapor. Desiccants are unique in that they can dry air without first cooling the air below its dewpoint.

Desiccants in air handling

High-flow liquid desiccant systems have been used for industrial air drying since the 1930s. These systems typically use beds of porous contact media flooded with a liquid desiccant that has been cooled in a separate heat exchanger. The process air is drawn



Figure 1: One of two AILR LDAC beta prototypes field-tested in 2008.

³ In cooling, a ton is a measurement of the heat removed by an air conditioning system. A ton of cooling is the amount of heat needed to melt 1 ton of ice in 24 hours.

⁴ Kosar, Dumitrescu, "Humidity Effects on Supermarket Refrigerated Case Energy Performance," ASHRAE OR-05-16-1, 2005.

through the bed and humidity is removed as the air contacts the liquid desiccant. Because heat is released as the desiccant absorbs the water vapor, flow rates must be sufficiently high to prevent more than a few degrees rise in the desiccant's temperature.

One characteristic of high-flow industrial liquid desiccant systems is that the process air flowing through the bed will entrain desiccant droplets, so filters are employed to limit desiccant loss. These filters must be well maintained to prevent droplets from escaping downstream where they corrode ductwork. This "desiccant carryover" is the primary reason high-flow liquid desiccant systems are rarely used in HVAC applications. One manufacturer, however, has marketed a product that keeps supermarkets at 35% RH using a *solid* desiccant. The Munters Superaire is a gas-fired dehumidifier with a solid-desiccant rotor. Munters reports 139,000 kWh savings on a 33,300 square foot supermarket after installing a Superaire unit. Although marketed for over 15 years, the Superaire's very large size and high capital and operating costs have prevented its broad adoption by supermarkets.

By contrast, recent innovations in low-flow liquid desiccant technology offer a compact and economical solution for dehumidification without the problems of carryover found in the high-flow systems. The LDAC's ability to regenerate using low-grade heat, and the system's ease of maintenance provide further adoption incentives to commercial environments with a high latent load seeking to reduce the impact of humidity on HVAC-related energy costs.

PAX Streamline, AIL Research, and NREL

Our innovative LDAC technology was developed during a nine-year, \$5 million program sponsored by NREL and the Department of Energy. Field tests in 2006-2008 proved that LDAC technology could operate without desiccant carryover. Pilot systems consistently met their performance targets for cooling, dehumidification, and thermal efficiency.⁵ Laboratory tests at NREL also confirmed zero desiccant carryover, while meeting design cooling/dehumidification and thermal efficiency⁶ targets.

PAX Streamline is commercializing this LDAC technology in all fields of use, with early introductions targeting supermarkets. PAX Streamline is an engineering and development firm focusing on efficiency solutions, which include high efficiency HVAC and power generation. The company uses its unique methodologies and patented design geometries to design cost-efficient fluid-handling equipment that provides greater output, uses less energy, reduces noise, and minimizes cavitation damage to materials.

The resulting system (**Figure 2**), the Aqueous product line of the **Sonoma Cool** brand, will be available to commercial clients in Fall 2009.



Figure 2. Sonoma Cool

⁵ Miller, Lowenstein, "The Field Operation of a Thermally Driven Liquid-Desiccant Air Conditioner," Proceedings of the 37th ASES Annual Conference, San Diego, May 2008.

⁶ Test results available from Mr. Steve Slayzak, NREL.

How Sonoma Cool saves energy

The **Sonoma Cool** system combines reliable, low-cost components and heat exchangers with liquid desiccant to make a commercial LDAC system that is simple, dependable, affordable, and competitive. Compared to industrial technology currently available, this liquid-desiccant air conditioner offers:

- much lower pressure drops
- reduced size
- greater moisture removal capacity (100-300 lb/hr) to more deeply dry the process air to close to zero RH (if required)
- greater cooling effect (lower cfm/ton)
- no desiccant carryover

How Sonoma Cool works

The principal components of **Sonoma Cool** (Figure 3) are the conditioner, the regenerator, and the interchange heat exchanger (IHX).

- **The conditioner dries the incoming air.**

The conditioner consists of a set of water-cooled parallel plates. Concentrated desiccant flows down the outer surfaces of the plates while process air (dark blue arrows) flows through the gaps between the plates.

The liquid desiccant absorbs humidity from the air and drains into the bottom of the conditioner. Any heat that is released is transferred to the cooling water inside each plate.

- **The regenerator returns the diluted desiccant to a concentrated state.** The humidity absorbed by the desiccant in the conditioner must be evaporated out of the desiccant in the regenerator. Another parallel-plate heat exchanger (the regenerator) has hot water flowing within the plates. The hot desiccant flows down the outside of the plates while air is blown across the plates. The humidity locked in the desiccant is released to the exhaust air and the liquid desiccant is restored to its original concentration. The system is available with different methods of providing the hot water used in the regeneration: a gas boiler; a two-stage regenerator, which increases the efficiency by a factor of 2; and a solar thermal array, which is the most energy-efficient configuration.

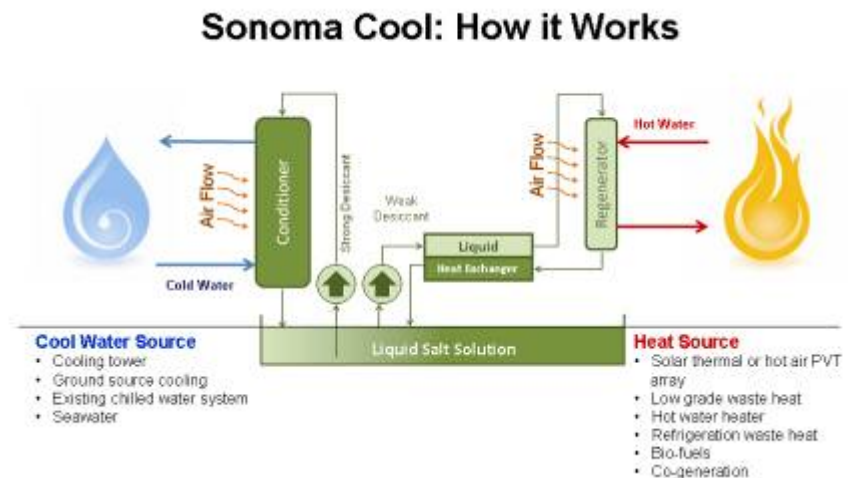


Figure 3. Sonoma Cool's dehumidification strategy.

- **The IHX improves the efficiency of the system.** The interchange heat exchanger transfers heat from the hot, strong desiccant that *leaves* the regenerator to the cool, weak desiccant *flowing to* the regenerator. This provides a dual function: it improves the efficiency of the regenerator by preheating the weak desiccant; it also increases the cooling provided by the conditioner by reducing the heat load from the strong desiccant.



Figure 4. A solar/thermal array can be used to recharge the liquid desiccant—saving as much as 80% of the total electrical energy of conventional air conditioning.

Sonoma Cool compared to solid desiccant systems

As noted earlier, current solid desiccant technologies are large and require natural gas-fired heaters to regenerate. In contrast to those systems, the patented water-cooled conditioner within the Sonoma Cool simultaneously cools and dries the process air. By combining cooling and drying in a single unit, the Sonoma Cool system can be compact—comparable in size and weight to a standard rooftop air conditioning system.

A key feature of Sonoma Cool is the interchange heat exchanger, which both reduces energy use and eliminates the “heat dump” into the process air that characterizes solid-desiccant systems. Air-side pressure drops are also much lower than with the solid desiccant.

Another benefit is that liquid desiccant can be regenerated at much lower temperatures than can a solid desiccant. This allows a solar thermal system (**Figure 4**) to perform the regeneration. The LDAC can also employ waste heat from other building systems (such as heat from compressors, co-generation, fuel cells, cooking facilities, or existing hot water supplies) to regenerate the desiccant. Additionally, large volumes of liquid desiccant can be dried during the day in a watertight container. This enables the LDAC system to cool and dry the air 24 hours a day.

Other benefits

Beyond the straightforward electricity savings available from cooling the air to a low RH, Sonoma Cool’s dehumidification approach offers a number of benefits not available from conventional air conditioning technology.

- Because air conditioning demand typically coincides with peak electrical demand, Sonoma Cool can shave off the most expensive electricity during the day, and lower the overall demand on the electrical grid. Furthermore, by directly controlling humidity, Sonoma Cool can reduce or eliminate the potential for mold and mildew growth inside buildings.
- In addition to supermarkets, ice rinks and indoor swimming pools experience high levels of indoor humidity, as do movie theaters and other sites where large numbers of people congregate in a (relatively) small space. Buildings such as these consume less HVAC energy when the indoor humidity level is lowered; this is much easier to maintain with Sonoma Cool than with a conventional system.

LEED points

The Leadership in Energy and Environmental Design (LEED) Green Building Rating System, developed by the US Green Building Council, sets standards for environmentally sustainable buildings. LEED certified buildings generally use resources more efficiently, and have improved air quality and reduced waste when compared to traditional buildings. Additionally, capital costs of meeting LEED certification are often counterbalanced by savings in operations costs that are typical of a LEED building. Some state and local governments have implemented or are considering tax-based and other incentives for LEED-certified buildings.

A LEED accredited professional is evaluating the Sonoma Cool system to determine the span of LEED points available to facilities installing and using the system. Awardable points will vary, depending upon the heat sources employed by the system.

Adoption incentives

Many governments throughout the industrialized world, including US state and local municipalities, offer tax-based incentives and/or direct rebates to commercial buildings that reduce operational energy usage, including HVAC. Those that employ solar to power Sonoma Cool's regeneration stage may be eligible for incentives that target use and adoption of renewable energy resources.