DRAFT 2/10/06

AIL Research

SOA Series

Liquid Desiccants for Solar Cooling

Why solar cooling now?

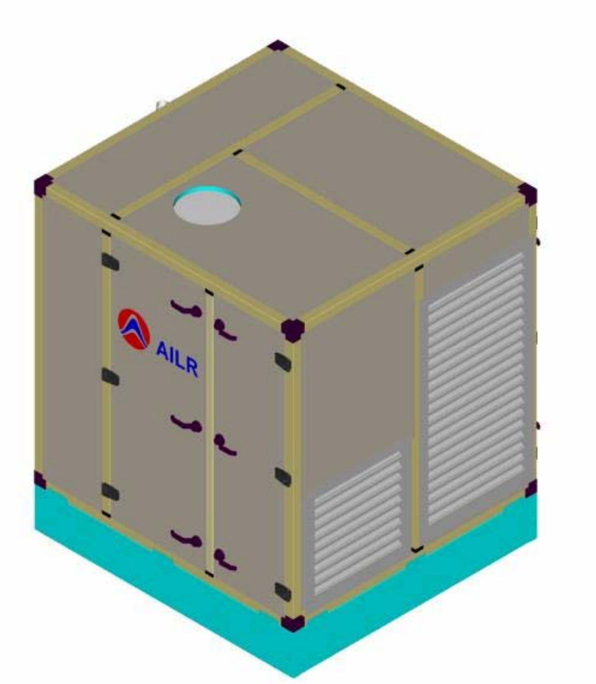
Our advanced liquid-desiccant technology has for the first time created an economic incentive to install air conditioners powered by solar thermal energy. AILR's SOA Series—the end products of a seven year, $5 million development program funded by the Department of Energy's SBIR program and the National Renewable Energy Laboratory—can convert hot water provided by solar thermal collectors into useful cooling and dehumidification. The patented low-flow technology that these units use has lowered the cost, increased the efficiency and reduced maintenance for liquid-desiccant air conditioners.

What would be a good application for solar cooling?

The SOA Series completely change the competition between solar cooling and conventional electric air conditioners. In the past, a cooling system that used solar thermal collectors would most likely use an absorption chiller. But the 45°F chilled water that this solar cooling system delivered is neither better nor worse than that provided by a conventional electric chiller. The larger size and higher costs of absorption chillers put solar cooling at an immediate disadvantage.

The SOA will do something that a conventional air conditioner cannot—they will meet high latent loads (i.e., dehumidification loads) without inefficient and expensive overcooling/reheating. So an important part to the answer to the preceding question is: A good application for solar cooling is one where latent loads are large and indoor humidity control is important.

Two broad classes of applications—one obvious and one not—meet this latent-load requirement.



The obvious one occurs in the humid eastern half of the country where the ventilation air to buildings during peak summer conditions creates latent loads that can be 2.5 times as great as the sensible loads. The SOA can over dry a building's ventilation air even in the most humid climates. In many applications, the building's entire latent load can be handled by this over-drying, leaving only sensible load for the main cooling system (which then can operate more efficiently with higher coil temperatures).

The less obvious applications are in the dry, western half of the country. In most western locales, electric vapor-compression air conditioners dominate despite the fact that in dry climates, evaporative coolers (both direct and indirect) are often much more efficient.

One reason evaporative coolers are not more widely used is that they cannot handle latent loads. Many western locations have "monsoon" seasons when latent loads become large and outdoor wet-bulb temperatures are too high to effectively use evaporative cooling. In other applications, internal latent loads are handled by flowing a large volume of evaporatively cooled air through the building. Fan power for moving this air is significant, as is filtration needed to eliminate the dust and pollen.

The SOA will overcome many of the barriers to evaporative cooling in the West. When used with cooling towers, they *are* evaporative coolers—that is they cool the building using the evaporation that occurs in the cooling tower. But they are evaporative coolers that can operate at high wetbulb temperatures and which handle latent loads. Our liquid-desiccant air conditioners will retain the benefits of an evaporative cooler, while reducing fan power and extending operating range. Adding solar energy captures still more environmental and energy benefits.

So far, our answer to the question of what are good applications for a solar cooling system has focused on the benefits of our advanced liquid desiccant technology: the ability to meet high latent loads and boost the performance of evaporative coolers. The answer is completed by looking for applications where the thermal energy needed to run the liquid-desiccant systems is most economically supplied by solar thermal collectors.

Can solar thermal collectors be the lowest cost source of heat?

Just as liquid-desiccant technology has become much more attractive over the last few years, so have solar thermal collectors. Glazed flat-plate collectors, evacuated-tube collectors and parabolic trough collectors can all provide the 160 F hot water that is needed to concentrate desiccant for the SOA. (The lower performance, lower cost collectors used for pool heating do not provided sufficiently hot water.) Starting in 2006, the federal government will give a 30% tax credit for an investment in any of these technologies. This tax credit, combined with the 5-year accelerated depreciation allowed by the IRS for solar thermal systems and additional state tax credits, have dramatically reduced the cost of solar hot water.

While solar water heating has become more competitive, natural-gas water heating has become less. Natural gas prices following hurricane Katrina topped $1.50 per therm, and the future direction of gas prices remains very uncertain.

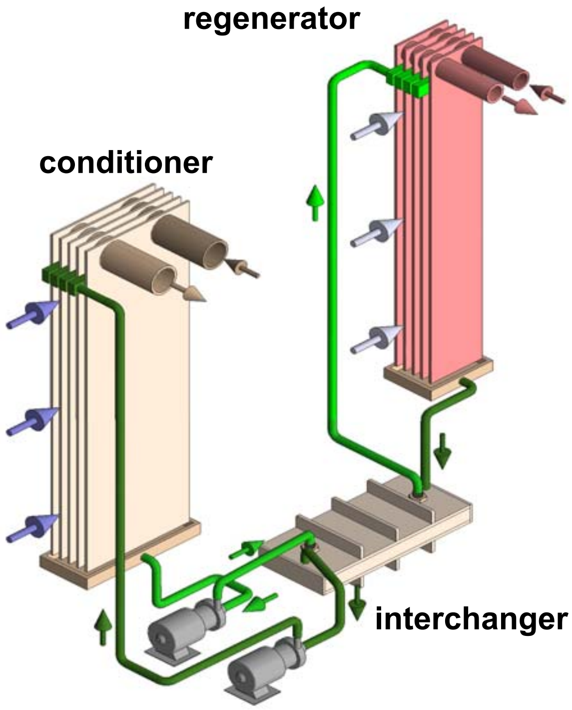
We can help you size the solar array needed for your cooling application. Your local dealer of solar thermal collectors can help you determine the cost. And, more information on state and federal incentives for solar energy is available at:

http://www.dsireusa.org/

Is a liquid-desiccant solar cooling system a PV technology?

For many people, solar energy means photovoltaic (PV) cells. This is not surprising since in this country the publicity, R&D funding and corporate investment is far greater for PV than all solar heating and cooling combined. We recognize the value of a technology that can convert sunlight into electricity, since electricity can be used in many applications. However, if you look closely at one critical application now served almost exclusively by electric equipment--air conditioning and dehumidification--*the most effective technology for converting this application to a renewable resource is solar thermal, not PV.*

How does a liquid-desiccant air conditioner work?



A liquid-desiccant air conditioner has three main components: the conditioner, the regenerator and the interchange heat exchanger. The conditioner is a parallel-plate liquid-to-air heat exchanger. A coolant, typically cooling tower water (but possibly water from a geothermal well, lake or chilled water loop), flows within the plates and a very-low flow of liquid desiccant flows down the outer surfaces of the plates. Thin wicks on the plate surfaces create uniform desiccant films. The air to be processed flows horizontally through the gaps between the plates. As this humid air comes in contact with the desiccant, water vapor is absorbed. The heat released by this absorption is transferred to the coolant. The air leaves the conditioner drier and at a much lower wet-bulb temperature.

The dilute desiccant that leaves the conditioner is pumped to the regenerator. The regenerator has the same configuration as the conditioner: a parallel-plate liquid-to-air heat exchanger. Again, very thin films of desiccant flow in wicks on the outer surfaces of the plates, and air flows in the gaps between the plates. For the regenerator, however, a hot heat transfer fluid flows within the plates. This hot fluid can be supplied by solar thermal collectors or other energy source. As the temperature of the desiccant increases, it evaporates water vapor into an air stream that is then discharged outdoors.

The hot, concentrated desiccant that leaves the regenerator and the cool, dilute desiccant that flows to the regenerator exchange thermal energy in the interchange heat exchanger. This exchange increases the efficiency of the regenerator and decreases the cooling load on the conditioner.

In both the regenerator and conditioner, the flow rate of desiccant is so low that the falling films on the plates are contained completely within the thin wicks. The air velocity over the films is far too low to entrain desiccant droplets. Since both the desiccant delivery to and collection from the plates are done without creating droplets, desiccant does not carryover from an SOA, and it can operate without droplet filters.

What is the status of the SOA-3000 and SOA-6000?

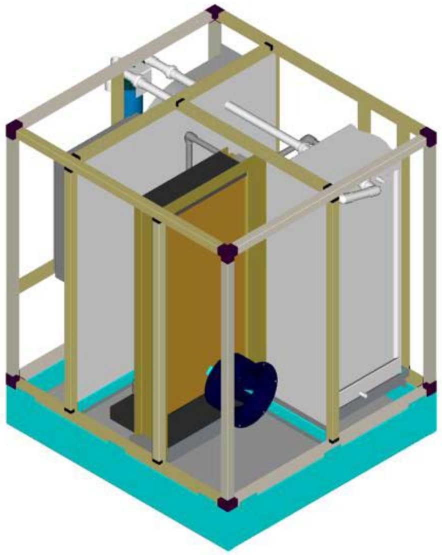
AILR is offering the SOA in two sizes: the SOA-3000 (nominal 3,000 cfm), and the SOA-6000 (nominal 6,000 cfm). Both models are pre-commercial products of AILR. As of February 2006 (the last update of this brochure), prototypes of both systems were in field tests that were scheduled to run through the summer of 2006. The thermal energy sources for these field tests include a gas-fired water heater, waste heat recovery from an engine-generator set and utility steam. Commercial sales of the SOA-3000 and SOA-6000 will begin in 2007.

Unfortunately, none of the on-going field tests use solar energy. We are now actively seeking partners who would be interested in a 2006 field test of a solar liquid-desiccant cooling system.

Field tests do entail additional costs, mostly for instrumentation, data logging and close supervision of the prototypical equipment. We expect that federal and/or state support will be available to cover some of these expenses. However, we are looking for field test partners that have an interest in this technology that goes beyond a single field-test site, and so could help cover some of the additional costs.

Individuals or organizations interested in demonstrating a solar cooling system should call or e-mail Dr. Andrew Lowenstein at 609-452-2950 x40, ail@ailr.com.

SOA3000



SOA-6000 with Optional Cooling Tower and Auxiliary Hot-Water Boiler

SYSTEM SPECIFICATIONS

Conditioner

total cooling	see tables
latent cooling	see tables
minimum air flow	2,000 cfm
nominal air flow	3,000 cfm
maximum air flow	4,000 cfm
cooling water flow	38 gpm
desiccants	43% lithium chloride 43% calcium chloride
desiccant additives	none
desiccant flow	2 gpm

Regenerator and Water Heater

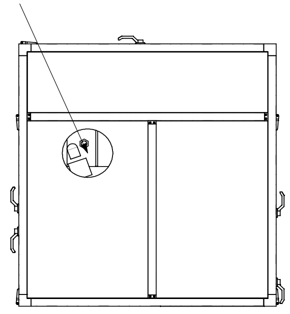
nominal air flow	500 cfm
hot water flow	20 gpm
hot water supply temperature	160 F to 210 F
regeneration COP	see tables
nominal thermal input	200,000 Btu/h

Pumps and Fans

main blower	1,000 W
(sized for 1.5” w.c. external pressure drop)	
regeneration blower	120 W
desiccant pumps (2)	150 W (each)

Dimensions/Weights

height	76 inches
width	61 inches
length	65 inches
shipping weight (est.)	1,400 lbs
operating weight (est.)	2,000 lbs



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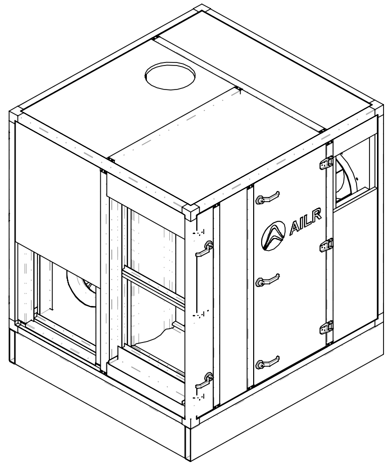

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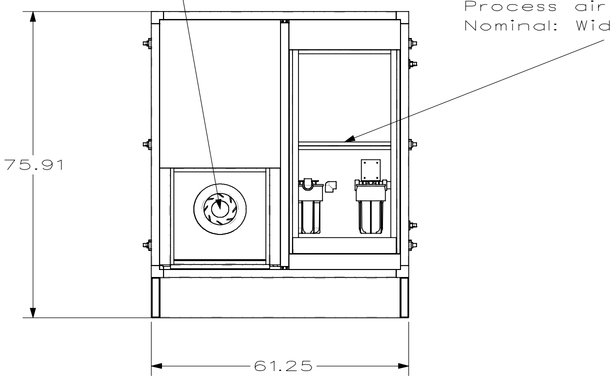

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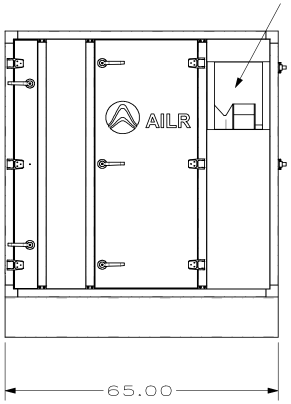

RIGHT

OA3000
AIL Research, Inc.
(louvers and exit ducts not shown)

OA-3000 Conditioner Performance

3,000 cfm
12" conditioner depth
10 F delta T for coolant **[Total Cooling / Latent Cooling]**
43% LiCl **Btu/h**
4 point change for desiccant

Air DB T (F)	Coolant T (F)	Air WB T(F)		
		74	78	80
85	65	171,990 / 137,290	210,357 / 175,679	230,202 / 196,232
	75	136,269 / 123,994	174,636 / 162,214	194,481 / 182,656
	85	95,256 / 105,864	133,623 / 144,043	153,468 / 164,414
90	65	170,667 / 124,582	209,034 / 162,859	228,879 / 183,426
	75	134,946 / 111,244	173,313 / 149,381	193,158 / 169,836
	85	93,933 / 93,044	132,300 / 131,167	152,145 / 151,552
95	65	170,667 / 111,958	207,711 / 150,053	228,879 / 170,607
	75	133,623 / 98,606	171,990 / 136,547	191,835 / 157,002
	85	92,610 / 80,309	130,977 / 118,291	152,145 / 138,691
100	65	169,344 / 99,349	207,711 / 137,654	227,556 / 157,801
	75	133,623 / 85,955	171,990 / 124,134	191,835 / 144,183
	85	91,287 / 67,531	130,977 / 105,822	150,822 / 125,815

OA-3000 Conditioner Performance

3,000 cfm
24" conditioner depth
10 F delta T for coolant **[Total Cooling / Latent Cooling]**
43% LiCl **Btu/h**
4 point change for desiccant

Air DB T (F)	Coolant T (F)	Air WB T(F)		
		74	78	80
85	65	226,233 / 174,053	275,184 / 221,759	301,644 / 247,329
	75	181,251 / 159,020	230,202 / 206,810	256,662 / 232,365
	85	129,654 / 137,766	179,928 / 185,934	206,388 / 211,602
90	65	226,233 / 158,446	273,861 / 206,025	300,321 / 231,595
	75	181,251 / 143,342	230,202 / 191,034	255,339 / 216,603
	85	128,331 / 121,934	178,605 / 170,088	205,065 / 195,770
95	65	224,910 / 142,950	273,861 / 190,292	298,998 / 215,875
	75	179,928 / 127,790	228,879 / 175,258	255,339 / 200,842
	85	128,331 / 106,172	177,282 / 154,200	203,742 / 179,924
100	65	224,910 / 127,454	272,538 / 175,090	298,998 / 200,141
	75	178,605 / 112,197	228,879 / 160,001	254,016 / 185,066
	85	127,008 / 90,326	177,282 / 138,831	202,419 / 164,064

OA-3000 Conditioner Performance

3,000 cfm
12" conditioner depth
10 F delta T for coolant **[Total Cooling / Latent Cooling]**
43% CaCl2 **Btu/h**
4 point change for desiccant

Air DB T (F)	Coolant T (F)	Air WB T(F)		
		74	78	80
85	65	141,561 / 106,382	178,605 / 143,959	198,450 / 164,050
	75	92,610 / 80,575	129,654 / 118,165	149,499 / 138,158
	85	27,783 / 41,331	71,442 / 82,410	91,287 / 102,824
90	65	140,238 / 93,717	177,282 / 131,223	197,127 / 151,314
	75	91,287 / 67,755	128,331 / 105,373	149,499 / 125,381
	85	47,628 / 42,256	68,796 / 69,324	89,964 / 89,850
95	65	138,915 / 81,135	175,959 / 118,473	195,804 / 138,579
	75	89,964 / 54,977	128,331 / 92,540	148,176 / 112,589
	85	46,305 / 28,862	67,473 / 56,084	88,641 / 76,848
100	65	138,915 / 68,526	175,959 / 106,130	195,804 / 125,843
	75	88,641 / 42,074	127,008 / 80,112	146,853 / 99,783
	85	43,659 / 13,927	66,150 / 43,125	87,318 / 63,734

OA-3000 Conditioner Performance

3,000 cfm
24" conditioner depth
10 F delta T for coolant **[Total Cooling / Latent Cooling]**
43% CaCl2 **Btu/h**
4 point change for desiccant

Air DB T (F)	Coolant T (F)	Air WB T(F)		
		74	78	80
85	65	190,512 / 139,419	239,463 / 186,929	264,600 / 212,302
	75	128,331 / 108,176	178,605 / 156,400	205,065 / 181,955
	85	70,119 / 75,139	101,871 / 111,608	129,654 / 138,354
90	65	190,512 / 123,769	238,140 / 171,209	264,600 / 196,596
	75	128,331 / 92,246	177,282 / 140,526	203,742 / 166,151
	85	68,796 / 58,620	99,225 / 95,188	128,331 / 122,186
95	65	189,189 / 108,176	238,140 / 155,461	263,277 / 180,890
	75	127,008 / 76,288	175,959 / 124,610	202,419 / 150,305
	85	66,150 / 41,625	97,902 / 78,571	127,008 / 105,906
100	65	187,866 / 92,568	236,817 / 140,232	263,277 / 165,157
	75	124,362 / 60,091	175,959 / 109,184	201,096 / 134,417
	85	62,181 / 22,683	96,579 / 62,207	124,362 / 89,472

OA-3000 Regenerator Performance

10 F delta T for hot water
39% LiCl **[COP / Water Removal lb/h]**
4 point change for desiccant
50% effective air-air heat exchanger

Air DB T (F)	Hot Water T (F)	Air WB T(F)		
		74	78	80
85	160	0.644 / 40.3	0.612 / 34.5	0.592 / 31.3
	180	0.736 / 80.2	0.723 / 74.9	0.715 / 72.0
	200	0.808 / 136.1	0.801 / 131.2	0.797 / 128.6
90	160	0.667 / 42.3	0.638 / 36.5	0.620 / 33.4
	180	0.749 / 82.2	0.737 / 76.8	0.729 / 74.0
	200	0.817 / 138.0	0.810 / 133.1	0.806 / 130.5
95	160	0.690 / 44.3	0.663 / 38.6	0.647 / 35.5
	180	0.762 / 84.1	0.750 / 78.8	0.743 / 75.9
	200	0.825 / 139.9	0.818 / 135.0	0.815 / 132.4
100	160	0.711 / 46.3	0.687 / 40.5	0.673 / 37.5
	180	0.774 / 86.0	0.763 / 80.7	0.757 / 77.9
	200	0.833 / 141.8	0.827 / 136.9	0.823 / 134.3

OA-3000 Regenerator Performance

10 F delta T for hot water
39% CaCl2 **[COP / Water Removal lb/h]**
4 point change for desiccant
50% effective air-air heat exchanger

Air DB T (F)	Hot Water T (F)	Air WB T(F)		
		74	78	80
85	160	0.798 / 92.7	0.789 / 87.6	0.784 / 84.9
	180	0.863 / 157.6	0.857 / 152.9	0.854 / 150.4
	200	0.933 / 246.7	0.930 / 242.4	0.928 / 240.1
90	160	0.810 / 94.6	0.801 / 89.5	0.796 / 86.8
	180	0.871 / 159.4	0.865 / 154.8	0.862 / 152.3
	200	0.939 / 248.5	0.935 / 244.2	0.933 / 242.0
95	160	0.821 / 96.5	0.813 / 91.4	0.809 / 88.7
	180	0.878 / 161.3	0.873 / 156.6	0.870 / 154.1
	200	0.944 / 250.3	0.941 / 246.1	0.939 / 243.8
100	160	0.833 / 98.4	0.825 / 93.3	0.821 / 90.6
	180	0.886 / 163.1	0.881 / 158.5	0.878 / 156.0
	200	0.950 / 252.1	0.946 / 247.9	0.944 / 245.6