Summary of NREL testing of Mojave ArctiDry

This report summarizes the testing of the Mojave ArctiDry ADA-020 dedicated outdoor air system. It provides a brief explanation of the experimental setup, tabulated values of the system's performance, and a comparison to a numerical model. More explanation of the system, the experiments, and the results can be found in a detailed article[i] on this testing. Using the data from NREL to estimate ISMRE2 demonstrates 9.9-11.4 lb./kWh at 3,000 cfm and 1,500 cfm, respectively. The data taken match our numerical model to within 3% average error.

Background

Maintaining comfortable conditions in buildings in warm climates requires significant electricity use. This electricity use leads to high operating costs for building owners and occupants and stresses the electric grid because of high electricity use during the hottest times of the year. Air conditioning provides two functions. First, it maintains a comfortable air temperature, typically between 70 and 76 °F in the summer. Second, it maintains a comfortable and healthy humidity, typically near dewpoints of 50 to 55 °F, or 50-60% relative humidity. These two functions are often referred to as controlling the sensible load (temperature) and latent load (humidity). Air conditioners consume electricity to maintain these conditions, and about half of the electricity is used for the sensible load, and half is used for the latent load. A liquid desiccant system, which absorbs water vapor into an aqueous solution, is an alternative way of providing latent cooling for these DOAS units. Liquid desiccant systems coupled with vapor compression heat pumps use the heat pump to cool the air and the condenser to heat and regenerate the desiccant. A liquid desiccant DOAS allows for lower compressor capacity and lower electricity use in most climates.

Experimental Setup

We conducted measurements of the ArctiDry ADA-020 as described below, most of them in accordance with AHRI-920. The unit was placed in a 46' x 26' insulated environmental chamber in Sunnyvale, California. The chamber temperature and humidity was adjusted to emulate outdoor air conditions defined in the test matrix. The process air flow rate was measured using a custom-built nozzle box adhering to ASHRAE standard 41.2. The box was configured with three, spun aluminum, ASME nozzles. Air enthalpy measurements upstream of the nozzle box provided the properties to determine the air density. Air density, upstream pressure, and differential pressure measured across the nozzles allowed us to calculate the air mass flow rate. From the combined uncertainty of the various sensors, this calculation resulted in a mass flow rate uncertainty of approximately 2%.

Calibrated RTDs measured entering and exiting air dry-bulb temperatures and chilled mirror hygrometers measured the entering and existing air dewpoint temperatures, using methods based on ASHRAE standards 41.1 and 41.6. The supply air sensors were installed in an air duct, while the entering conditions (chamber temperature and humidity) and regenerator outlet air were measured with psychrometer tubes. An extensive use of air side thermocouples provided intermediate or less critical temperature measurements throughout the experimental setup. We verified of our measured data by checking energy balance; the mean absolute percentage error for energy balance was 3.5%. We compare the measurements below with the output from a numerical model for the system.

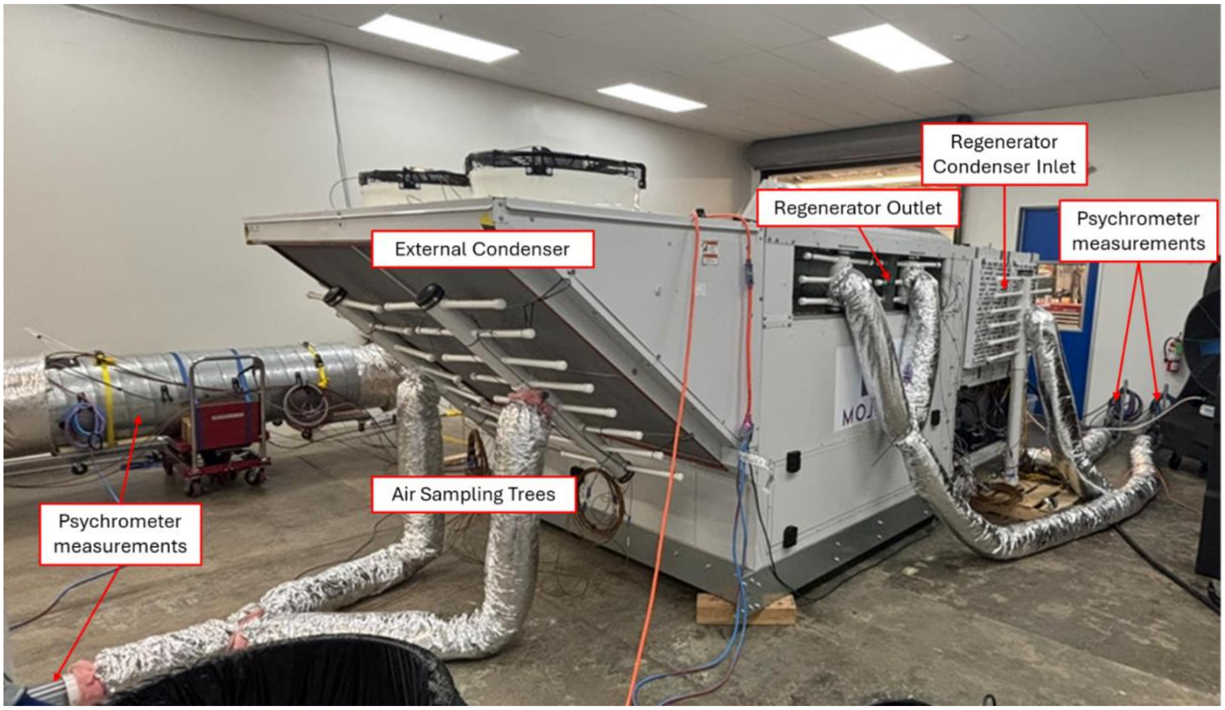


Figure 1 Mojave Energy Systems DOAS test unit instrumented for performance characterization.

Test results

The results of the measured performance are summarized

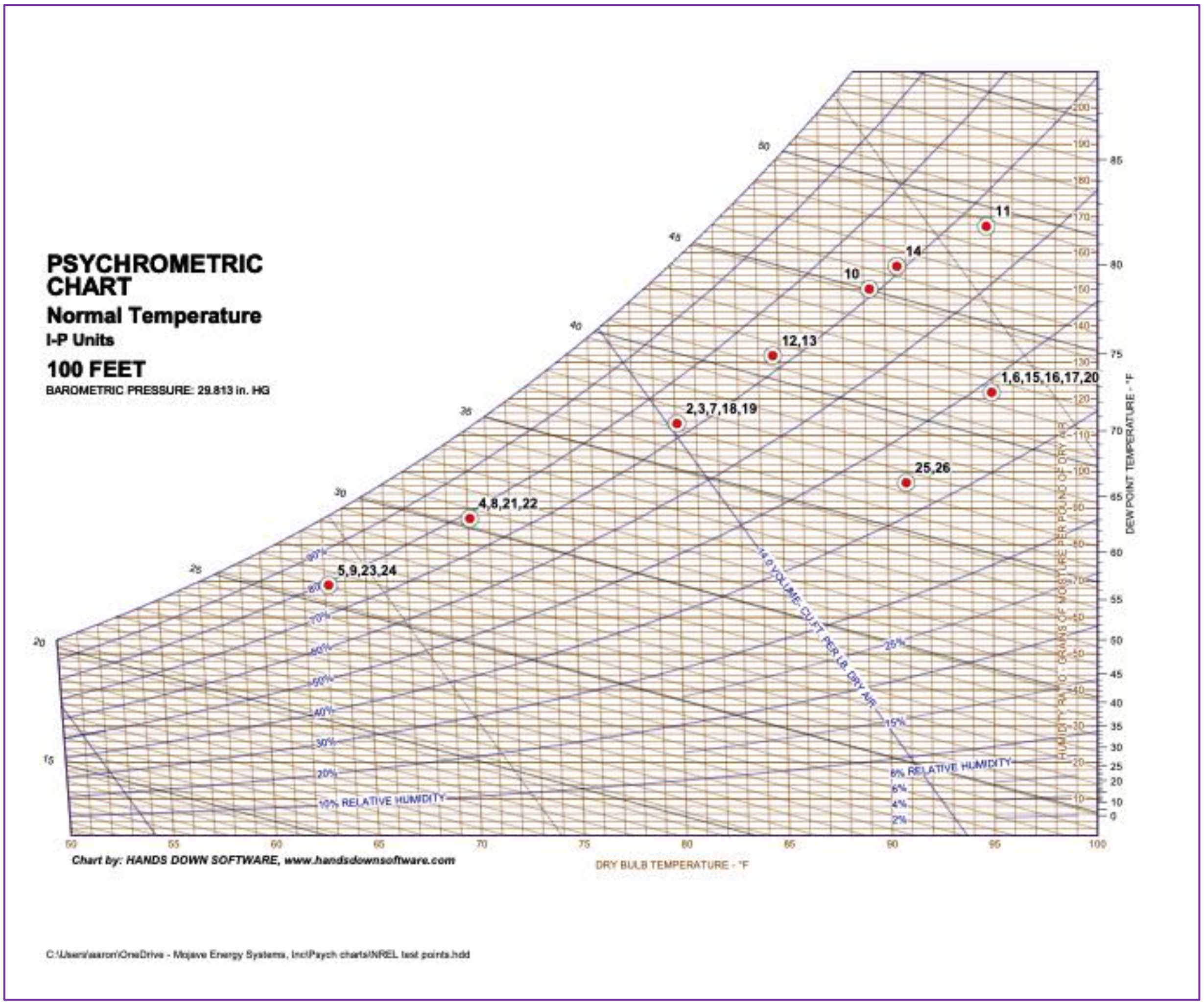
Table 1. This was not a rating test; some deviations from AHRI 920 are noted in the detailed article. If using the data from the four test points corresponding to the conditions specified by AHRI-920, **the estimated ISMRE2[ii] is 9.9 lb./kWh** at 3,000 cfm and 55 °F supply dewpoint (i.e., from points 1, 2, 4, and 5), and **11.4 lb./kWh** (from points 16, 19, 21, and 23) at 1,500 cfm and 50 °F supply dewpoint.

We compare these results to the numerical model that serves as the basis of performance prediction for development engineering and selection software. That model simulates each of the key heat and mass exchangers (external condenser, regenerator condenser, evaporator, liquid desiccant absorber, liquid desiccant regenerator) and the electrically-consuming components (variable-speed compressor, process air fan, regenerator air fan, external condenser fans, and liquid desiccant pumps). The numerical model results were calculated for each of the 26 test points. The model matches the data well: **for the system MRE, the model overpredicts the measurements by only 2.9%**, in-line with the test measurement uncertainty of 3.2%.

Table 1: Summary of energy performance for each test, including measured and propagated uncertainties.

Test	Nominal air flow rate	Ambient conditions		Supply conditions			Moisture removal rate	Total power	Moisture removal efficiency
		$T_{dry\text{-}bulb}$	$T_{dewpoint}$	Air flow rate	$T_{dry\text{-}bulb}$	$T_{dewpoint}$			
	ft³/min	F	F	ft³/min	F	F	lb/h	kW	lb/kWh
1	3000	95.1 ± 0.2	72.6 ± 0.3	2995 ± 60	72.3 ± 0.2	54.9 ± 0.3	106.7 ± 3.3	15.8 ± 0.03	6.8 ± 0.2
2		80.1 ± 0.2	70.5 ± 0.3	3004 ± 60	68.8 ± 0.2	54.6 ± 0.3	92.6 ± 3.0	8.6 ± 0.02	10.8 ± 0.4
3		80.1 ± 0.2	70.4 ± 0.3	3006 ± 60	68.0 ± 0.2	54.6 ± 0.3	92.2 ± 3.0	8.7 ± 0.02	10.6 ± 0.4
4		70.1 ± 0.2	63.1 ± 0.3	2993 ± 60	68.5 ± 0.2	54.8 ± 0.3	42.5 ± 2.2	3.9 ± 0.01	10.8 ± 0.6
5		63.2 ± 0.2	56.6 ± 0.3	3000 ± 60	62.1 ± 0.2	49.6 ± 0.3	30.1 ± 1.8	3.5 ± 0.01	8.6 ± 0.5
6	2500	94.8 ± 0.2	72.0 ± 0.3	2501 ± 50	66.6 ± 0.2	48.2 ± 0.3	109.1 ± 2.9	18.6 ± 0.04	5.9 ± 0.2
7		80.1 ± 0.2	70.0 ± 0.3	2495 ± 50	64.3 ± 0.2	48.5 ± 0.3	95.5 ± 2.7	9.8 ± 0.02	9.7 ± 0.3
8		70.1 ± 0.2	63.8 ± 0.3	2500 ± 50	61.5 ± 0.2	47.8 ± 0.3	63.4 ± 2.0	5.6 ± 0.01	11.2 ± 0.4
9		63.2 ± 0.2	56.4 ± 0.3	2504 ± 50	60.9 ± 0.2	48.4 ± 0.3	28.2 ± 1.5	3.1 ± 0.01	9.2 ± 0.5
10	2400	89.3 ± 0.2	78.7 ± 0.3	2390 ± 48	67.3 ± 0.2	51.1 ± 0.3	141.9 ± 3.6	19.4 ± 0.04	7.3 ± 0.2
11	2100	94.8 ± 0.2	81.9 ± 0.3	2151 ± 43	71.3 ± 0.2	51.1 ± 0.3	150.0 ± 3.7	19.9 ± 0.04	7.5 ± 0.2
12		84.7 ± 0.2	74.9 ± 0.3	2092 ± 42	63.0 ± 0.2	42.7 ± 0.3	121.7 ± 3.0	19.5 ± 0.04	6.2 ± 0.2
13		84.5 ± 0.2	74.5 ± 0.3	2143 ± 43	62.7 ± 0.2	42.9 ± 0.3	121.7 ± 3.0	19.5 ± 0.04	6.2 ± 0.2
14		90.6 ± 0.2	79.9 ± 0.3	2154 ± 43	69.3 ± 0.2	49.9 ± 0.3	139.5 ± 3.5	20.5 ± 0.04	6.8 ± 0.2
15	1500	93.5 ± 0.2	72.5 ± 0.3	1510 ± 30	70.0 ± 0.2	50.1 ± 0.3	64.0 ± 1.8	8.4 ± 0.02	7.5 ± 0.2
16		95.0 ± 0.2	71.9 ± 0.3	1495 ± 30	71.0 ± 0.2	50.1 ± 0.3	60.7 ± 1.7	8.2 ± 0.02	7.5 ± 0.2
17		95.4 ± 0.2	71.7 ± 0.3	1493 ± 30	66.0 ± 0.2	42.5 ± 0.3	73.3 ± 1.8	11.8 ± 0.02	6.2 ± 0.2
18		80.0 ± 0.2	70.1 ± 0.3	1512 ± 30	61.8 ± 0.2	42.7 ± 0.3	68.6 ± 1.8	8.1 ± 0.02	8.4 ± 0.2
19		80.0 ± 0.2	71.0 ± 0.3	1513 ± 30	63.7 ± 0.2	50.1 ± 0.3	59.0 ± 1.7	5.3 ± 0.01	11.2 ± 0.3
20		95.0 ± 0.2	71.8 ± 0.3	1495 ± 30	70.9 ± 0.2	50.1 ± 0.3	60.5 ± 1.7	8.0 ± 0.02	7.5 ± 0.2
21		69.8 ± 0.2	64.5 ± 0.3	1505 ± 30	63.4 ± 0.2	50.1 ± 0.3	35.9 ± 1.2	2.7 ± 0.01	13.4 ± 0.5
22		70.1 ± 0.2	63.9 ± 0.3	1515 ± 30	55.8 ± 0.2	42.3 ± 0.3	48.6 ± 1.4	4.7 ± 0.01	10.3 ± 0.3
23		63.3 ± 0.2	56.2 ± 0.3	1506 ± 30	56.4 ± 0.2	45.6 ± 0.3	21.6 ± 0.9	2.1 ± 0.00	10.1 ± 0.4
24		62.9 ± 0.2	56.3 ± 0.3	1518 ± 30	53.0 ± 0.2	42.3 ± 0.3	27.5 ± 1.0	2.5 ± 0.01	11.0 ± 0.4
25		90.9 ± 0.2	66.1 ± 0.3	1520 ± 30	51.2 ± 0.2	28.2 ± 0.3	74.4 ± 1.8	17.6 ± 0.04	4.2 ± 0.1
26		91.2 ± 0.2	66.2 ± 0.3	1512 ± 30	51.4 ± 0.2	28.2 ± 0.3	74.4 ± 1.8	17.7 ± 0.04	4.2 ± 0.1

Figure 2: Ambient test points shown on the psychometric chart.



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[i] Woods, J., G. Shoukas, Z. Lu, E. Kozubal. Experiments on a vapor compression air conditioner with liquid desiccants for efficient dehumidification. Applied Energy. (to be submitted) (2025).

[ii] NREL does not provide ratings of systems, and this was not a rating test. It should not be interpreted as an official rating.