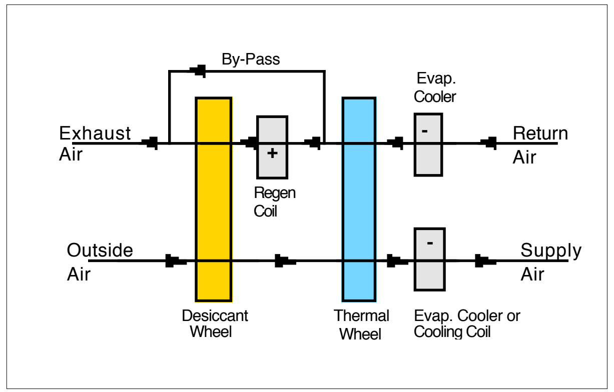


A typical desiccant cooling air handling unit

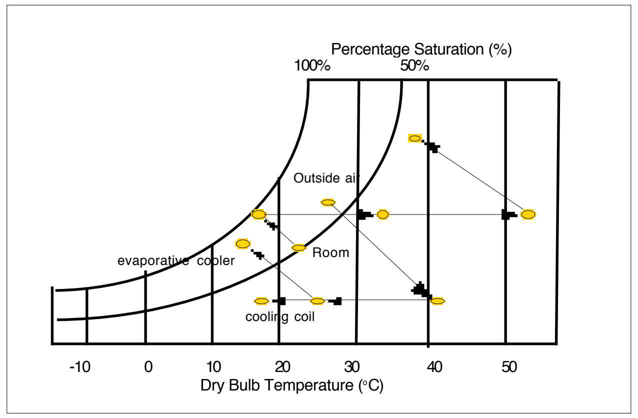
Desiccant System

Desiccant cooling is a potentially environmentally friendly technology which can be used to condition the internal environment of buildings. Unlike a conventional air conditioning system which relies on electrical energy to drive the cooling cycle, desiccant cooling is a heat driven cycle.

Contemporary desiccant systems treat latent and sensible cooling requirement separately and more efficiently by using equipment specific to that load. Heat recovery is also available during the heating season. Desiccant full air conditioning systems were first developed in the 1950s. There have been many recent developments and desiccant cooling is now acknowledged as a viable technology for the air conditioning sector and the technology is advancing rapidly. There are presently around 12 solid desiccant systems installed in the UK.

A typical solid desiccant cooling system comprises a thermal wheel and a desiccant wheel located in series. On the supply side, a cooling coil and/or an evaporative cooler is located after the thermal wheel. A heating coil may also be located after the thermal wheel, for use in winter time if required.

Typically during the summertime moisture is removed from the warm moist supply air by a desiccant material such as silica gel and the dry bulb temperature of the air increases. It is then cooled by passing through a heat exchange wheel. An auxiliary system, typically evaporative cooling, but in some recent UK installations mechanical cooling, is used to provide delivered air at an appropriate supply temperature and humidity. In order to drive off the moisture absorbed by the desiccant surface, the desiccant then has to be physically moved into a dry hot air stream. The extract air is used for this part of the process. The extract air is first cooled by passing through a second evaporator unit and then takes up heat from the heat exchanger wheel and is passed through a heating element in order to raise the temperature to dry the dehumidifier wheel. The moisture laden section of the wheel slowly rotates from the moist air stream to the hot return air stream where it is dried out in a process called 'regeneration'. The cooling/dehumidification process is illustrated in the psychrometric chart.



Desiccant system in Cooling/Dehumidification mode

Unit	Type	Availability	Capacity kW	Cost £/kW	COP	Source Temp. deg. C
Desiccant	Solid Rotor	current	>50	?	1.40	<80
	Liquid	future	<50	100	2.00	<100
Absorption	H2O/LiBr - single effect	current	>70	140	0.60	>80
	H2O/LiBr - double effect	current	>70	210	1.10	>120
	H2O/LiBr - triple effect	future	>70	~260	1.50	>160
	NH3/H2O - single effect	current	<70	220	0.45	>130
	NH3/H2O GAX	current	10	220	0.60	?
Adsorption	NH3/Carbon	future	10	?	0.90	>200
	H2O/Zeolite	current?	20-350	?	0.60	<100
Dish Stirling		future	<75	?	0.80	650-800

Heat Driven Cooling Systems

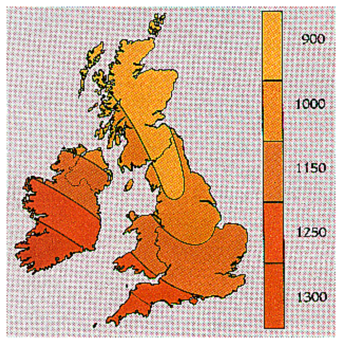
Regeneration

The required heating to raise the temperature of the return air for regeneration of the desiccant can be supplied by any low temperature warm air or water source. Waste heat, CHP, gas or solar can make a contribution. Under European and UK design conditions an elevation of temperature of 55°C would give sufficient cooling performance in most situations.

Context

The air conditioning industry has, in recent years, come under sustained attack from a range of economic, environmental and regulatory pressures. Global environmental concerns, improving standards of ventilation and increasing concerns about indoor air quality have all contributed to a change in design thinking. Professional guidance is increasingly steering clients and consultants away from full air conditioning to natural ventilation and mixed mode solutions in new and refurbishment projects. Nevertheless inefficient lighting, increases in computing equipment, and architectural fashion mean that overheating is now the predominant design consideration for new offices in the UK. Older buildings often constrain natural solutions. The situation is likely to worsen if global warming scenarios are accurate. According to UK Government information "it is unlikely that an expansion in the amount of air conditioning used in the UK can be resisted" Driving forces are seen as "The continuing deterioration of the quality of air in cities and the increasing levels of noise due to traffic growth."

It is vitally important that the building industry seeks innovative methods of maintaining and improving the quality of the indoor environmental impact. The research has therefore been undertaken in the context of reducing the demand for air conditioning through the use of passive measures and low energy cooling strategies but with the knowledge that there are perceived limitations to the use of natural ventilation strategies.



Climate

At present the distribution of solar energy across the UK varies from 900 - 1300 kwhr/m²/yr. The annual value rarely exceeds 750W/m². Climate change predictions indicate a small rise in solar insolation of less than 0.5 % however the major change will be in the number of cooling days.

	1961-90	2020s	2050s
	Cooling degree days (T_{mean}>18.0°C)		
Plymouth	42	83	123 (+193%)
Oxford	136	191	236 (+74%)
Santon Downham	142	199	247 (+74%)
Hillsborough	2	20	44 (very high)
Durham	33	71	105 (+218%)
Fortrose	0	1	7 (n.a.)

Market Research

Recent research has predicted an increasing share of the air conditioning market for solid and liquid desiccant systems up to 3% by 2002. A survey identified a number of important factors affecting consultant and client choice.

In Favour of Desiccants

avoidance of refrigerant
better indoor air quality
heat recovery
waste heat could be used
same capital cost lower running cost
lower maintenance cost than chillers
longer life
less equipment

Against Desiccants

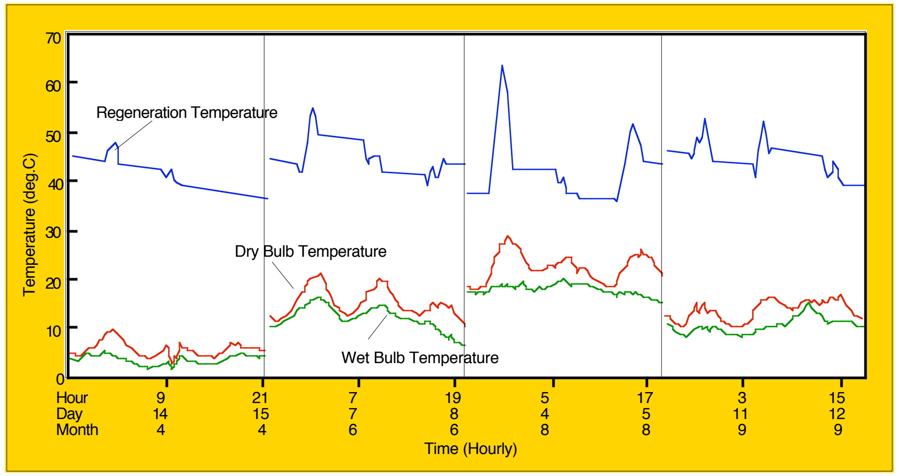
concern re- legionnaires' disease
could restrict choice of maintenance staff
limited cooling capacity
current pricing strategy
concern about lithium bromide
inefficient summer operation
concern about good filtration of external air
low quality of American products

Solar Model

Using an interactive program the model calculates the regeneration temperature based on a meteorological data set, solar collector algorithm, heat loss and fluid flow rates.

Number of collectors	5
Net absorber area for each collector	1.92
Specific flow rate of collector fluid	0.016
Flow rate of heat exchanger fluid	0.05
Storage volume / collector area ratio	45
Storage tank height / diameter ratio	7
Heat transfer coefficient for the exchanger coil	300
Tube diameter for the exchanger coil	0.02
Storage tank insulation thickness	0.1
Thermal conductivity of insulation material	0.026
Top loss coefficient for the solar collector	6
Temperature of water entering the exchanger	30
Panel orientation (azimuth, tilt)	190,25
Panel characteristic	0.86,2.32
Albedo	0.24
Latitude (London)	51.5

Sample of input data



Regeneration temperature from solar on sample days - London 1994

The Desiccant Model

A solar desiccant computer model was developed in which solar collectors were indirectly coupled to a desiccant system via a water storage tank and a solar regeneration coil was inserted in the exhaust air stream.
The model simulated the psychrometric and thermodynamic processes associated with desiccant cooling, and made the following assumptions:

- The desiccant cooling system was employed solely to dehumidify the incoming fresh air supply, and to provide when required supplementary sensible cooling. It was assumed that the bulk of the sensible cooling would be performed by a separate water based system (max. sensible cooling 40W/m² from chilled ceiling).
- The desiccant cooling system did not contain a cooling coil. The required degree of sensible cooling being achieved through the use of an evaporative cooler.
- The desiccant cooling system incorporated a 20% bypass on both the 'solar' heating and regeneration coils.
- The room condition was allowed to float
- Solar collector to floor ratio of 1:10 - giving 25-50W/m².

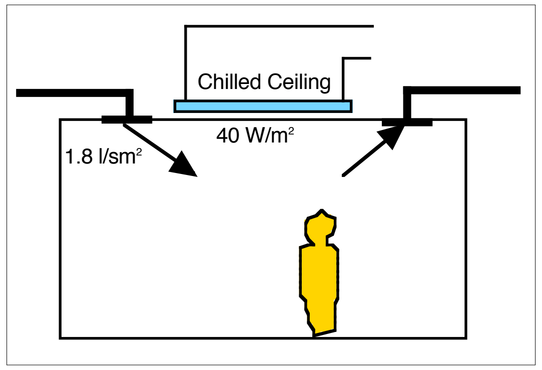
Unit cost of gas	1.50 p/kWh
Unit cost of electricity	5.00 p/kWh
Efficiency of heating system	70 %
COP of DX/chilled water coil system	2.5
Electrical generation efficiency	35 %
CO_2 coefficient for gas consumed	0.21 g/kWh
CO_2 coefficient for electricity consumed	0.68 kg/kWh

Cost and energy input data used in analysis

Loading	Date	Time (Hrs)	Sensible Heat Gain (W/m²)	Latent Heat Gain (W/m²)	Outside Air DB Temp. (°C)	Outside Air WB Temp. (°C)	Outside Air Moist. Cont. (g/kg)	Flow Water Temp. (°C)	Return Water Temp. (°C)
Peak	3.8.94	15.00	50	7	28.9	19.2	9.8	61.0	30
Mid	6.6.94	15.00	40	7	20.4	16.1	9.6	54.9	30
Low	12.9.94	15.00	30	7	16.1	12.1	7.1	41.1	30

Load data used in Parametric Study - London 1994

Under part load the desiccant system would supply air to the space at room temperature. If dehumidification was not required, then the system would push through untreated outside air. Under these conditions the chilled ceiling output would decrease to compensate for the free cooling provided by the ventilation system.



A chilled ceiling application in an office building where fresh air is introduced at high level

Loading Condition	Supply Air Volume Flow Rate (l/sm²)	Regen. Air Temp. (°C)	Moisture Cont. Leaving Desic. Wheel (g/kg)	Ceiling Cooling (W/m²)	Sensible Cooling From Desiccant Output (W/m²)	Supply Air Cooling System
Peak	1.8	55	6.7	40.0	10.0	20°C & 9.3 g/kg
Peak	1.8	65	5.6	40.0	10.0	20°C & 8.5 g/kg
Mid	1.8	55	5.2	40.0	0.0	21°C & 5.6 g/kg

Operating data for the various loadings

The greater the regeneration temperature the lower the supply temperature available. The impact of varying the regeneration temperature on the energy consumption and supply conditions was examined

Coupling the desiccant cooling system to solar collectors produces significant savings both in running cost and CO_2 emissions. The greatest savings are achieved at peak load when the system is operating with a regeneration temperature of 55°C. This is because:

- the flow of water from the solar collection system is at a high temperature; and
- the return air leaving the thermal wheel is at a high temperature.

System	Regen. Air Temp (°C)	Supply Air Condition Temp.	Room Air Condition	Regen. Coil Duty (W/m²)	Delivered gas (Wh/h/m²)	Cost per hour (p/h/m²)	CO_2 produced (kg/h/m²)
Non-solar (Peak)	55	20.0°C & 9.3 g/kg	24.6°C & 10.6 g/kg	35	50	0.08	0.011
Solar (Peak)	55	20.0°C & 9.3 g/kg	24.6°C & 10.6 g/kg	13	19	0.03	0.004
Non-solar (Peak)	65	20.0°C & 8.5 g/kg	24.6°C & 9.9 g/kg	48	68	0.10	0.014
Solar (Peak)	65	20.0°C & 8.5 g/kg	24.6°C & 9.9 g/kg	28	40	0.06	0.008
Non-solar (Mid.)	55	21.0°C & 5.6 g/kg	21.0°C & 7.0 g/kg	42	60	0.09	0.013
Solar (Mid.)	55	21.0°C & 5.6 g/kg	21.0°C & 7.0 g/kg	22	31	0.05	0.007
Non-solar (Low)	N/A	17.1°C & 7.1 g/kg	21.0°C & 8.5 g/kg	0	0	0.00	0.000
Solar (Low)	N/A	17.1°C & 7.1 g/kg	21.0°C & 8.5 g/kg	0	0	0.00	0.000

Analysis results (incorporating evaporative cooler)

It is noticeable that for all the outside air conditions, an acceptable room condition was achieved without resorting to the use of a supplementary cooling coil in the supply air stream. It was found however, that the contribution of the evaporative cooler on the supply side was minimal. At the mid-load condition the evaporative cooler provided a mere 1°C of sensible cooling and would be working at very low efficiencies.

In the study outlined it was assumed that the fresh air volume flow rate supplied to the room space was constant at 1.8 l/s per m² of floor area (18 l/s per person). In most applications this value would be considered to be high. A short parametric study was undertaken which considered only the peak load condition and assumed a regeneration temperature of 65°C, for a variety of supply air volume flow rates. The results of this study indicate that the 0.0018m³/s supply air volume flow is justified as the lower rates resulted in unacceptably high humidity.

Conclusions: Air Conditioning Powered by the Sun

Solar air conditioning offers an elegant exemplar of a clean, sustainable technology which is consistent with UK and International commitment to sustainable development. By using solar/gas hybrid desiccant cooling technology it may be possible to offer a benign solution to cooling of buildings, in new as well as refurbishment situations, and significantly reduce greenhouse gas emissions.

The technology utilises full fresh air and is refrigerant and compressor free.

The energy study clearly demonstrates that it is feasible to include a solar heater in the desiccant cooling cycle in UK applications. Savings in primary energy consumption and associated CO_2 emissions in excess of 50% should be achievable.

Due to desiccant cooling being an open cycle, solar energy can only be effectively used in applications where the supply air volume flow rate is small. This effectively limits its application to installations where the bulk of the sensible cooling system is undertaken using a water based system.

In applications where the bulk of the sensible cooling is being performed by water based systems, it may be necessary to supply larger than normal fresh air volume flow rates, in order to perform the required degree of latent cooling. Supply volume flow rates in the order of 1.8 l/s per m^2 of floor area should be acceptable for most applications.

The regeneration air temperature should be kept as low as is practically possible, in order to minimise fossil fuel energy input.

Provided that the room air temperature is allowed to float, it is possible in the UK to achieve an acceptable air condition within the room space under most external conditions, without the use of a supplementary cooling coil. Despite this, the benefit to be derived from using an evaporative cooler on the supply air side is questionable, since the inclusion of such a devise if not closely controlled, may result in increased energy consumption and unacceptably high air humidities in the room space, especially under conditions of high ambient humidity. Consequently, it may be preferable to include a small refrigerated cooling coil, for use under conditions of peak load.

Insufficient operational data exist to determine the conditions for optimum design and costing and this is a direct consequence of lack of feedback on existing desiccant installations.

No reliable information exists on the extent of parasitic losses.

Solar thermal technology is presently expensive although developments are likely especially in respect of transpired collectors

More information is required on other heat sources which may be applicable and cost effective.

Health concerns raised in relation to desiccant cooling, in particular the risk of legionellosis from evaporative cooling systems have been addressed in modern desiccant systems and components of solid desiccant systems, such as silica gel, potentially provide a sanitising effect on incoming air.

This research to-date has provided information to industry and suppliers and a technical appraisal of the potential but real benefit would accrue from a demonstration project which reviewed, initially desiccant, and then solar desiccant in detail.

It is possible, and appropriate, to develop a cost-effective and pragmatic demonstration project which would significantly enhance present understanding of health, cost and performance issues.

Further Information

Halliday S.P., Beggs C.B. "The potential for solar powered desiccant cooling" CIB World Building Congress, Gavle, Sweden, June 1998

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Hanson L., Giles A. "Desiccant Cooling Report" MRJ/97, BSRIA 1997

HMSO "Review of the Potential Effects of Climate Change in the UK" DOE, 1998z

The technical report and seminar proceedings are available from Gaia Research

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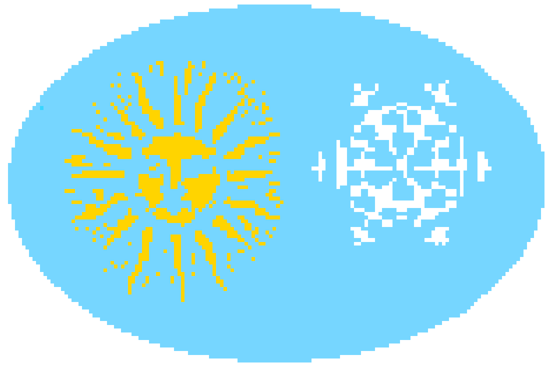

Solar Air Conditioning

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