High on comfort, low on energy

In the peak of an Australian summer, the refuge from scorching heat that an air-conditioner provides is particularly welcome.

Many more Australians are now using air-conditioners for their homes. One result is that electricity utilities are faced with larger summer demands than previously, since air-conditioners can soak up a lot of power. In South Australia, for instance, maximum demand on the utility now occurs in summer, instead of in winter as it used to.

Evaporative coolers have the merit of low power consumption. They use electricity only to drive a fan and their 'coolth' is derived from evaporating water.

The drawback, of course, is that the humidity of the air is increased, sometimes enough to be unpleasant. Moreover, in locations like Darwin where the humidity is high to begin with, the unit will often fail to produce an adequate cooling effect.

Hot, but not always muggy

	number of hours per year when cooling required	percentage of those hours when dehumidification not needed
Darwin	7837	10
Port Hedland	6156	31
Townsville	5836	21
Brisbane	2900	46
Cloncurry	6223	56

The shaded area on the map is nearly always humid. But other places could frequently use open-cycle cooling without dehumidifying, saving power.

One other limitation of evaporative coolers is that they cannot be made to heat in winter. Of course, reverse cycle air-conditioners can, and with coefficients of performance of, typically, 3, every unit of power pumps 3 units of heat into the living space.

Nevertheless, there are plenty of locations in Australia where heating in winter isn't much needed and neither is dehumidification in summer. The area lies somewhere between Melbourne in the south and Brisbane in the north. Within that zone tens of thousands of evaporative coolers provide their owners with economical comfort on most of the days when called upon.

In the United States, by contrast, winters are much more severe, so in that country evaporative coolers take a very small share of the market.

Suited as they are to a wide section of Australia, evaporative coolers have been the subject of research by CSIRO. The Division of Mechanical Engineering has developed elaborations of the basic principle so as to overcome the drawback of increased humidity.

One such development is the PHE cooler (for plate heat exchange). In this device thin plastic plates separate an evaporatively cooled air-stream from air to be conditioned, and heat exchange occurs continuously between the two air-streams. PHE coolers have recently appeared on the Australian market (see *Ecos* 24).

Scientists have come to call systems using evaporative cooling 'open cycle', in contrast to refrigeration types where a refrigerant is pumped through a closed cycle. In open-cycle systems the refrigerant is the very air that conditions the room. In the latest investigations, engineers are testing the feasibility of open-cycle cooling schemes in which the use of silica gel, to dehumidify, pushes the capabilities of evaporative cooling further. Solar energy is used to reactivate spent silica gel.

An example of such a scheme — it is one of the simplest configurations — is shown in the diagram. It uses a rotary dehumidifier, a rotary heat exchanger, and two (although one may do) evaporative coolers.

The rotary (or regenerative) dehumidifier is a shallow drum packed with a desiccant such as beads of silica gel, which slowly rotates. The drum, called a 'wheel', is typically 10 cm deep and 1–3 m in diameter. The beads usually average 3 mm in diameter and are held in place by wire mesh on each end of the wheel.

Humid air drawn from outside passes through one half of the wheel, and is dried by the silica gel beads. Moisture-laden beads in the other half are dried (regenerated) by solar-heated air.

A similar wheel, without the desiccant but wound with heat-absorbing ribbon, is used in the system as a heat exchanger. Rotary heat exchangers are commonly used in air-conditioning systems in commercial buildings, where they are used to recover heat or 'coolth' from spent air being exhausted from the buildings and to transfer it to fresh incoming air (see 'A wheel to recycle energy' in *Ecos* 17). They perform a similar task in the arrangement here.

Rotary dehumidifiers are already commercially available, but their performance is far from ideal, and their operation is not well understood theoretically. No design rules or methods exist to allow an engineer to optimize all the factors involved. The wheel's rate of rotation, diameter, thickness, and so on have all to be guessed, and adjusted by experience.

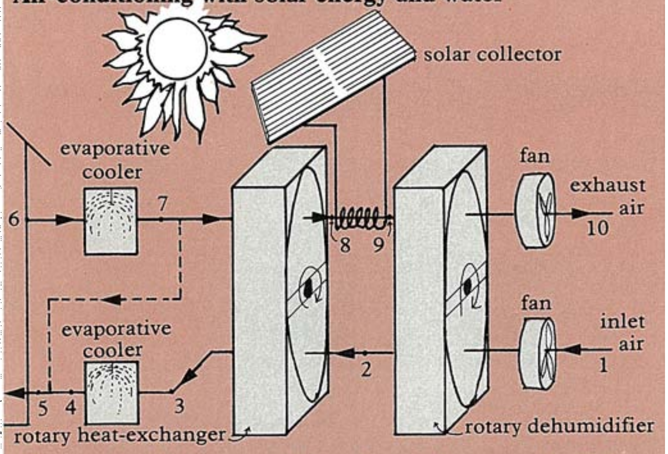
As the desiccant, present units use lithium chloride, a solid material that at high humidities is apt to turn to liquid and drip off. Furthermore, the substance cannot dehumidify air to less than 11% relative humidity.

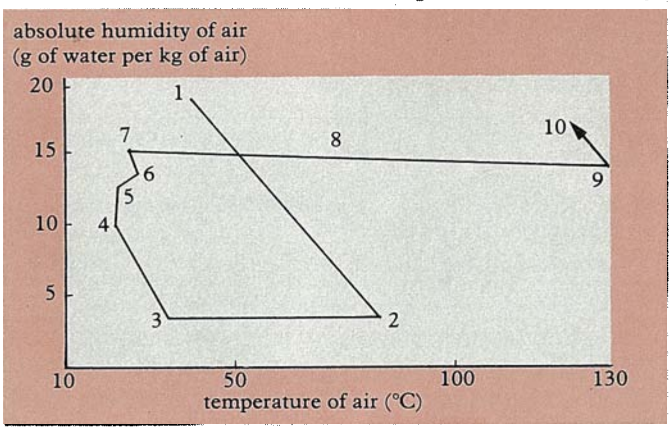
However, it is an alternative, silica gel, that is presently attracting the interest of the Division's scientists. The material is a commonly used desiccant, and comes in the form of variously sized beads. The difficulty in packing a regenerating wheel with it lies in the need to compromise between size of the beads and resistance to air flow.

Small beads have a large surface area, but obstruct the flow of air, so the associated fan would consume large amounts of power to push the air through. Large beads let air through, but have a smaller surface area for contact with the humid air.

According to Dr Don Close of the Division, a desirable configuration of silica gel would be a rotating matrix of the substance formed into parallel passages. This would let air pass through freely and at the same time let it contact a good expanse of the gel. If the dehumidification cycle appears promising, then he and his colleagues may attempt to make such a unit.

Air-conditioning with solar energy and water





How a simple 'open-cycle' cooling scheme works. The chart shows how each component affects the air's temperature and humidity.

Meanwhile, they are using silica gel beads and trying to determine their theoretical thermodynamic characteristics using an experimental rig. The basis of the rig is a wheel packed with silica gel through which hot and humid air can be blown. The United States Department of Energy has provided $185 000 to investigate this. The grant recognizes the Division's expertise in open-cycle cooling and the potentially large energy savings that the technique could make possible in America.

The big unknown is the efficiency of a desiccant dehumidifier under various conditions of incoming air. How readily does the material absorb and release water vapour and how big does the wheel have to be to service a needed air supply? On this point hinge the economics of the scheme, because a big wheel with a large resistance to air flow would require a powerful fan. Working against the air resistance set by the bed of silica gel, the fan could consume as much power as a compressor-type air-conditioner, or more.

Another problem is the high cost of the material. Combined with its limited lifetime, a factor about which little is known as yet, this makes the economics of its use very uncertain at the moment.

One advantage of open-cycle air-conditioning is that the dehumidifying function is not always required. On many days, simple evaporative cooling is sufficient, or maybe evaporative cooling plus heat exchange. On these days the rotary dehumidifier would be by-passed, saving power. The table shows, for different locations, the percentage of days when this could be done. Only muggy days call for dehumidification. Darwin is nearly always humid, and Dr Close thinks that open-cycle cooling is probably not a good proposition there. But for Cloncurry and other places where dehumidification is required on only 50% of cooling days, the concept shows promise.

Note that the system uses solar-heated air for drying (regenerating) the desiccant. It therefore calls for air-filled solar collectors, rather than the more familiar water-filled ones.

Research has only just begun, but within a year Dr Close hopes to know how much power solar dehumidification can save. It's a promising avenue of investigation, and an important one in Australia's hot climate.

Open cycle and related cooling systems. D.J. Close. *Proceedings, Solar Cooling Workshop conducted by the Solar Energy Research Institute of Western Australia and the National Energy Research Development and Demonstration Council, Perth, April 1980.*