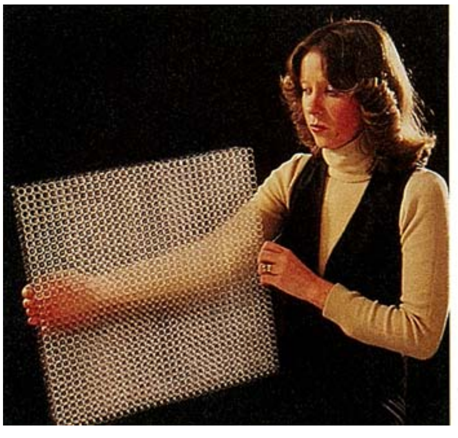
Towards industrial use of solar energy

Solar water heating has come a long way in Australia since the 1950s, when early enthusiasts installed the first simple and often unsightly collectors on the roofs of their houses. Home-made collectors gave way to the products of small but innovative engineering enterprises as interest in solar hot-water systems grew. Now collector manufacture is becoming big business.



A prototype convection-suppression device for high-temperature flat plate collectors.

Owens Illinois evacuated tubular high-temperature collector.

The growth rate is staggering. The total area of collectors built in Australia in 1972–73 was about 7000 sq m. In 1978–79 the figure was about 100 000 sq m. Substantial export markets have been established, and Australian-designed collectors are being manufactured under licence in Japan. More than 70 000 domestic solar hot-water systems have now been installed in Australia.

In Western Australia, where solar water heating has caught on in a particularly big way, an estimated one in five new houses is equipped with a unit. Indications of the expected continued growth of the industry are the purchase by Shell Australia last year of a half interest in the manufacturer of 'Solahart' heaters and the move by the large Rheem company into the solar heater field.

The CSIRO Division of Mechanical Engineering provided much of the initial research backing for the industry. In recent years it has focused its attention in this area on methods for testing the performance of domestic water heaters, and is playing a major role in the production of standards by the Standards Association of Australia. A code of practice for solar-heater installation has been finalized, and standards covering design and construction, and testing and performance, are being prepared.

With domestic systems firmly accepted as practical means of reducing household requirements for non-renewable energy, the Division is now putting most of its solar research effort into industrial applications. The potential for fuel savings is much greater: manufacturing industry consumes some 40% of Australia's primary energy production, while households use about 14%. A CSIRO survey in the food processing industry found that nearly 90% of the energy used in the factories examined was in the form of heat. Therefore, it could, in principle, be supplied by solar collectors.

However, industry usually needs hotter water than the collectors developed for domestic use can supply. These heat water satisfactorily to around 60°C, but efficiency falls off rapidly above that temperature. The reasons for the heat losses that occur, and the many approaches that can be adopted to reduce them, were described in *Ecos* 17.

Collecting heat

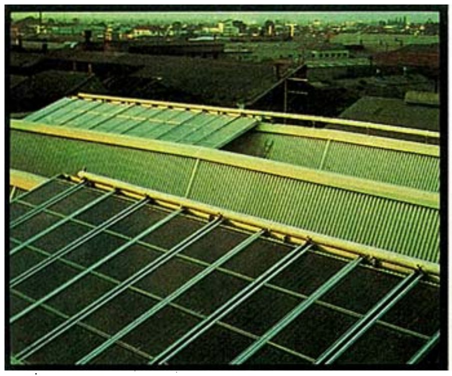
Collectors can be broadly divided into four types — low-temperature models that operate well at temperatures up to 40°C, domestic collectors (up to 60°C), and medium-temperature (60–100°C) and high-temperature (above 100°C) models.

The low-temperature collectors are usually simple 'absorber plates' — copper panels with pipes, through which the water flows, attached. The side facing the sun is painted black so that solar energy is absorbed rather than reflected. The main commercial use for low-temperature collectors at present is for heating swimming pools.

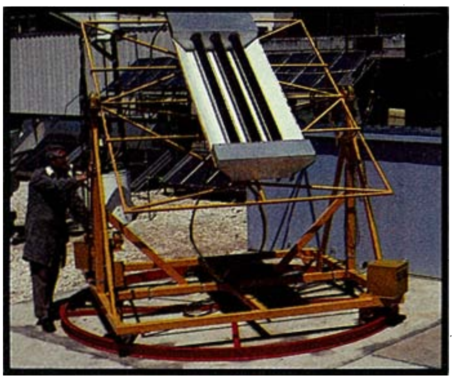
In domestic collectors, the absorber plate is mounted in a galvanized iron or aluminium box with a glass or transparent plastic cover. The sides and back of the device are insulated with a common insulating material such as mineral wool or fibreglass. The cover prevents most of the heat radiated by the absorber from leaving the collector and reduces losses due to convection by limiting the opportunity for air heated by the absorber to carry the heat away. The insulation cuts back heat loss by conduction.

Medium-temperature collectors require further measures to reduce heat losses. One approach is the application of a selective surface, such as nickel black or chrome black, to the absorber panel. This greatly reduces radiation of heat from the panel while maintaining efficient absorption of solar energy. Another approach is to use two or even three glass covers. This further reduces losses by both convection and radiation.

For high-temperature collectors, one of



The Southwark brewery installation — part of the collector array (left) and insulated water storage tanks.



This high-temperature test rig automatically tracks the sun's movement.

The 'integrated' collector type developed at the Division.

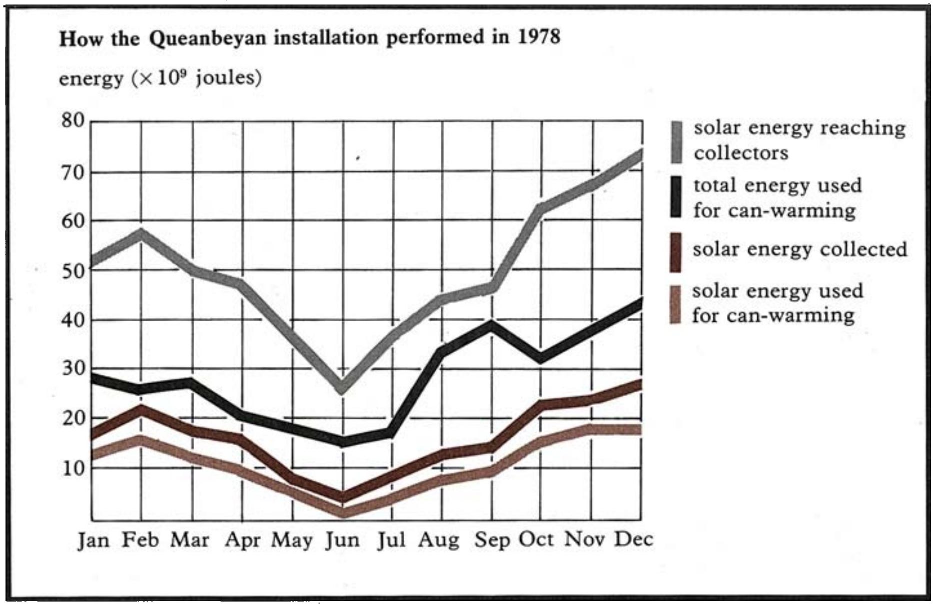
the requirements is high-transmittance glass, or an equivalent material, for the cover. Ordinary window glass, used in most domestic collectors, transmits about 84% of the incident solar radiation whereas low-iron-content glass transmits more than 90%. Also required are a highly selective absorber surface and efficient insulation.

High-temperature solutions

But all this is not enough. Unless special measures are taken, convection losses increase greatly as a collector's operating temperature rises. The solution to this problem receiving most attention is removal of the air between the cover and absorber. Experimental tubular collectors using this approach, which eliminates convection losses, can heat water effectively to 200°C and above. However, their high cost has so far prevented commercial production.

Another approach that looks promising as a means of producing temperatures up

The solar simulator in operation.



The flat plate collector gave better results at temperatures up to 110°C.

The graph shows somewhat similar seasonal trends for the solar energy supplied and total energy used by the can-warmer. On average, the collector efficiency was about 32%, and 72% of the collected energy was put to use. The collector area was increased from 77 to 94 sq m in March 1978.

to about 150°C is being studied in a project supported by a grant from the National Energy Research, Development, and Demonstration Council (NERDDC) to Divisions of Mechanical Engineering and Mineral Chemistry. It involves the use of an efficient, but essentially conventional, flat plate collector. The feature that reduces convection losses to acceptable levels is a honeycomb structure of glass or transparent plastic inserted between the cover and absorber. This greatly reduces the opportunity for air movement.

Dr Jeff Symons from the Division of Mechanical Engineering and Mr Bob Gani from the Department of Mechanical Engineering at Monash University recently carried out a simulation study to examine the performance of this type of collector. They used mathematical models to predict how much heat collectors would supply to the fluid passing through them if exposed to a known amount of solar energy.

This type of study depends on detailed knowledge of the properties of all portions of the collectors — the absorber surface, the glass cover, and so on. Materials tests at the Division have produced a great deal of information of this kind.

The study showed that much better results could be expected from a collector with a single high-transmittance cover than from a device with two or three covers. Reductions in solar energy input due to the additional covers greatly outweighed the expected reductions in heat losses.

The only cover materials that gave satisfactory results were low-iron glass and a plastic material called FEP Teflon. Performance of the glass was significantly improved by a process, known as anti-reflection etching, that involves treatment with fluorosilicic acid. This reduces the amount of solar energy reflected from the glass and hence increases the amount reaching the absorber.

Selective surface

The results showed clearly that an efficient selective absorber surface is essential. The best available at present is chrome black, made up of particles of chrome metal in a chrome oxide matrix.

The properties assigned to the convection-suppressing honeycomb in the simulation were based on the results of experiments conducted by American scientists. The type of structure envisaged is a mesh, with sections about 10 mm by 10 mm, of low-iron glass or FEP Teflon. The study suggests that best results would be obtained by a structure 60–90 mm tall fitted between the collector's absorber and cover.

The scientists concluded that a collector with all the heat-saving features described, heating fluid to 150°C under typical operating conditions, should transfer energy from solar radiation to the fluid with an efficiency of about 50%. This is a much better result than appeared possible for flat plate collectors until recently.

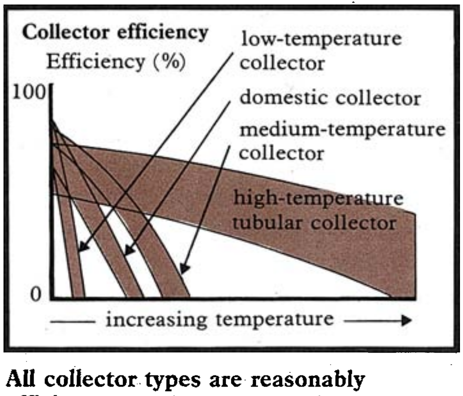
They compared the results of the simulation with the measured performance of the most effective high-temperature collector currently available — the Owens Illinois evacuated tubular model. The relative efficiencies of operation, averaged over a year, were assessed for devices located in Melbourne and Brisbane. The results were most encouraging.

For both locations, the flat plate collector gave better results at temperatures up to 110°C. At higher temperatures the evacuated collector had the edge. But in the whole range, from 100°C to 150°C, the performances of the two types were comparable.

The next step will be to build some high-temperature flat plate collectors and check that their performance lives up to expectations. As a first stage, the Division is designing and constructing convection-suppressing honeycombs. Dr Symons and his colleagues are looking for the best way to produce structures that are effective and durable but not too expensive to build. The main advantage of flat plate high-temperature collectors is that they should cost less than their tubular competitors.

Heat for industry

Meanwhile, the Division's Solar Engineering Unit, led by Mr Wal Read, is undertaking a program aimed at giving engineering consultants and industry experience of the practical problems involved in designing, installing, and operating industrial solar heating systems. It involves installing systems to provide heat for selected factory processes, and then closely monitoring their performance. The processes chosen are ones that operate within the temperature range of the flat plate collectors now available.



All collector types are reasonably efficient at producing small rises in water temperature. But maintaining efficiency during bigger rises requires more-complex collectors.

The collectors heat the water used in this milking shed.

The program was initiated by the CSIRO Solar Energy Studies Unit, set up in 1974 with Mr Roger Morse as Director. That Unit became part of the Division of Mechanical Engineering in 1978, and its name was changed to the Solar Engineering Unit.

The Coca Cola bottling plant at Queanbeyan, N.S.W., was the first factory to participate in the program. Its solar system was commissioned in January 1977, after 77 sq m of double-glazed collectors had been installed on the roof and a large storage tank and the necessary plumbing provided. A further 17 sq m of collectors were installed in March 1978 to meet increased demand for heat.

The collectors provide water at 50–60°C to warm soft drink cans from 3°C to a temperature high enough to prevent moisture condensing on them before packaging. A back-up oil-fired system provides the additional heat needed when the solar contribution is not sufficient to maintain the water temperature needed.

The CSIRO team monitored the system's performance for 2 years, and found that the annual heat output of the collectors closely matched predictions made before the experiment. However, heat losses between the collectors and the can-warmer were considerably greater than expected, and demonstrated a need for better-insulated storage and plumbing.

The installation cost $35 000 (including consulting fees and instrumentation). A calculation made in early 1978 put the resulting saving of boiler fuel at 4·95 tonnes per year. The value of the saving, at the fuel prices then applying, was $713. This gave a gross return on investment for the system of 2·05% per year.

That is a much lower return than any industrialist would expect from an investment, but then nobody expected that the Queanbeyan installation would be an economic proposition. It has done what it was intended to do — demonstrated that a solar system can be successfully integrated with an industrial process and provided operating experience with such a system. The installation is still in use, having been bought by the company from CSIRO for a price based on estimated oil cost savings over 8 years.

With oil prices rising inexorably, the economics of industrial solar heating systems seem certain to become more attractive. Improvements in the design of the systems will hasten the process. One significant feature of the Queanbeyan installation was that the collectors and storage tank accounted for a surprisingly small proportion of its cost — only 53%. The Solar Engineering Unit officers think there should be room for substantial savings in other areas, particularly in the costs of piping, valves, pumps, and so on.

Making solar collectors — a rapidly growing industry.

Heating beer

The group's second experimental installation is at the South Australian Brewing Company's Southwark brewery in Adelaide. Three arrays of high-performance collectors — with low-iron glass covers and chrome black selective surfaces — have been installed over a roof area of 178 sq m.

So that the performances of single- and double-glazed collectors can be compared, both types are in use.

The system provides a small proportion (about 4%) of the heat needed to maintain the water temperature in a section of the brewery's beer-pasteurizing plant at about 65°C. A gas-fired boiler provides the rest of the heat.

The installation came into full operation in September 1978, and its performance will be monitored closely for 2 years. So far it has worked well, providing somewhat more heat than predicted. Including consulting fees and instrumentation, it cost about $71 000. A considerably larger proportion of the cost went into the collectors and a smaller proportion into plumbing than in the Queanbeyan solar system.

A third installation, at an abattoir at Forbes, N.S.W., is now coming into service. It has a 750 sq m collector array that also serves as the roof of a car park. The 'integrated' type of collector used, developed at the Division, can be built and installed over large areas much more cheaply than conventional collectors. Corrugated acrylic material acts as both the roof and the collector cover.

The Energy Authority of New South Wales and the Lachlan Valley County Council, which operates the abattoir, are collaborating with CSIRO in the project. The collectors will heat about 120 000 litres of cold water by up to 20°C every day. Existing oil furnaces will do the additional heating needed to provide the hot water and steam required in the abattoir.

Better economics

Largely because of the inexpensive collector type used and the low operating temperature, the economics of this installation are expected to be much more favourable than those of the earlier industrial units. The cost, which includes the cost of the structures that are to be used as car-parking facilities, has been estimated at $130 000; CSIRO and the New South Wales Energy Authority will each provide $47 500, and the County Council $35 000. Savings of fuel oil are expected to amount to about 75 tonnes, worth more than $10 000 a year. On these figures, the annual return on investment of the solar system will be about 10%.

In collaboration with the Solar Energy Research Institute of Western Australia, another industrial system is being installed at the Solo Kool soft drink factory in Perth. This one includes a heat exchanger, to transfer heat from solar-heated water to the caustic solution used for bottle-washing. The collector area is about 140 sq m.

The Solar Engineering Unit has also collaborated with the Victorian Solar Energy Research Committee on the installation of demonstration systems for milk pasteurizing and swimming-pool heating.

In an exercise for which NERDDC provided funds, engineering consultants from New South Wales, Victoria, South Australia, and Western Australia recently spent a few weeks at the Division examining various aspects of industrial solar water heating. Each then prepared a feasibility study for a possible installation. If the results are satisfactory and funds are available, the installations will go ahead, providing more of the information that will be needed when industry starts making large-scale use of solar technology.

Industry usually needs hotter water than the collectors developed for domestic use can supply.

Robert Lehane

More about the topic

Australian programme for solar heating and cooling. W. R. W. Read. *Proceedings, International Solar Energy Society Silver Jubilee International Congress, Atlanta, Georgia, 1979* (in press).

Materials for flat-plate solar collectors. J. G. Symons. *Metals Australasia*, May 1979, 8–11.

Cover systems for high-temperature flat-plate solar collectors. R. Gani and J. G. Symons. *Journal of Solar Energy*, 1979, 22, 555–61.

Solar heat generation for industrial process heating applications. W. R. W. Read. *Proceedings, International Solar Energy Society Silver Jubilee International Congress, Atlanta, Georgia, 1979* (in press).

Solar industrial process heating for can warming at Queanbeyan, New South Wales, Australia. R. N. Morse. *Solar Energy Studies Unit Report* No. 10, 1978.

Soft energy for food processing. R. N. Morse and D. Proctor. *Chemtech*, 1978, 8, 478–83.

CSIRO collector test facilities. D. Proctor and M. K. Peck. *Proceedings, International Solar Energy Society Silver Jubilee International Congress, Atlanta, Georgia, 1979* (in press).

Better surfaces for solar collectors. *Ecos* No. 17, 1978, 17–21.

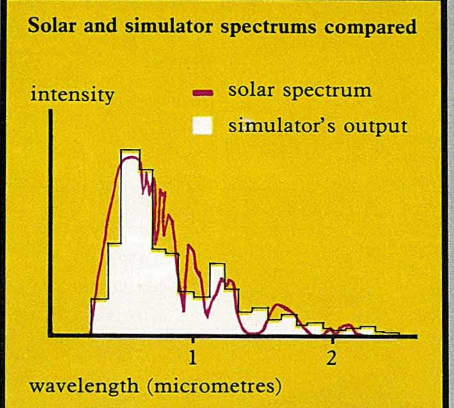
Testing collectors' capabilities

The Division of Mechanical Engineering recently built a solar simulator — an artificial sun — to increase its capacity to test the performance of solar collectors. The simulator is an array of fourteen 1000-watt mercury iodide lamps, which give out light with virtually the same wavelength distribution as solar energy. The lamps are arranged to provide an almost even light distribution over the collector being tested, and the whole array can be raised, lowered, and tilted as required.

Dr David Proctor designed the simulator, which enables collectors to be tested more quickly than they can be outdoors — untroubled by changes in light intensity during the day and by vagaries of the weather. Testing is an essential part of collector development. It also enables manufacturers to give precise descriptions of the capabilities of their products and enables other people to check the claims of the manufacturers. It provides detailed information on the heat output, at different operating temperatures, of collectors exposed to varying amounts of solar energy.

The bulk of collector testing in Australia is carried out at the Division; work for manufacturers is done on a fee-for-service basis. Part of the current testing program aims at validating a method for rating domestic solar water heaters as proposed by the Standards Association of Australia.

The method, designed for outdoor test rigs, involves comparing the performance of heaters with that of reference solar units. Much of the work involved in devising it was performed by Dr Peter Cooper of the Division.



The simulator's mercury iodide lamps produce radiation with a wavelength distribution similar to that of solar radiation at ground level.

The need for standards relating to solar water heaters has become urgent with the enormous expansion of heater production in recent years. So has the need for testing facilities. Outdoor facilities have now been, or are being, established in all States, and a solar simulator somewhat similar to the Division's device has been built at the University of Sydney. The Division intends in future to put more of its testing effort into research and less into tests of commercial collectors.

Much of this work will be on high-temperature collectors. The solar-simulator test rig is being given the capacity to test collectors working at temperatures above 100°C. And a new outdoor rig — one of a number at the Division — has been specially designed for high-temperature work.

This rig automatically tracks the sun's movement through the sky, and can be used to test a number of collectors simultaneously. High-temperature flat plate collectors built at the Division will be tested on it. So will other types of collectors, including tubular ones, built by manufacturers and research groups working towards the goal of a commercially viable high-temperature collector.