Spectra-Physics has just introduced sixteen new ion laser models with significantly increased levels of performance. These lasers produce substantially higher output power than previous models while maintaining the highest standards of performance in the critical areas of mode purity, low noise, directional pointing stability, convenience, and reliability. These Spectra-Physics lasers represent the best combination of power, performance, and price available today.

Improved Performance and Reliability

Spectra-Physics has continually increased the performance of its ion lasers through an ongoing program of design improvement.

Refinements in the plasma tube have produced a more reliable laser capable of consistently higher output power. The tube has a unique computer-designed contour to ensure that the profile of the bore matches that of the plasma discharge. This advanced design effectively contains the plasma, and reduces the rate of bore erosion in the BeO tube—there are no sharp edges, no discs to be eroded. Bores are straighter, mode structure is better, and plasma tube reliability is improved.

In the power supply, recent design changes have increased safety margins and have provided additional protection to virtually eliminate unexpected shutdown.

In the laser, tuning elements have been modified for easier wavelength selection. A number of design improvements have ruggedized the resonator to make the laser less susceptible to vibration and shock. Improved mechanical design has reduced drift in optical alignment for better power stability and reduced beam wander. Beam-pointing stability in all models is superb.

Broader Product Line

Laser users will be able to more closely match laser performance and price to application requirements. Selection can now be made from models with 2 to 18 watts all-lines power specifications. And these power levels are conservative. At delivery, output powers are typically 30% higher than specified powers.

Laser Efficiency

Laser efficiency and plasma tube bore diameter are closely related—as the bore diameter is increased, the efficiency of the laser increases. To a point, the increased efficiency produces higher output power with no negative impact on other performance parameters. Beyond that point, however, larger diameters result in decreased optical stability and loss of power in low gain laser lines.

In all of its ion lasers, Spectra-Physics has optimized the bore diameter both for laser efficiency and for performance in the critical areas of stability and output power in the deep blue and ultraviolet.

The new Spectra-Physics models are state-of-the-art in laser design and represent a significant improvement in ion laser performance and reliability. Contact your Spectra-Physics office for additional information on specifications, price and delivery, or circle No. 143 for a complete brochure.

Spectra-Physics Laser Update

AN UP-TO-THE-MINUTE REPORT ON LASER TECHNOLOGY

New Levels of Power and Performance Achieved in Ion Lasers

Models Covering All-Lines Output Power From 2 to 18 Watts

<table>
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<th>Output Power</th>
<th>2 watts</th>
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<th>4 watts</th>
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<td>164-06</td>
<td>164-07</td>
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</tbody>
</table>

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President’s Column

What is physics? This is a question that comes up from time to time.

As a schoolboy, I used to define physics as “organized common sense”. That’s how it seemed to me when the subject dealt with macro-scale, linear, intuitively-understandable phenomena, before I met nuclear physics and quantum mechanics.

Then at university one fell back on defining physics rather negatively, in terms of what it’s not. It’s not chemistry, it’s not engineering, etc.

Another approach was taken by the American professor quoted by Sir Brian Pippard recently, who said, “We define physics as the subjects covered by papers in the Physical Review”.

A few years ago I had a task which involved answering that question for an intelligent layman. I was honorary secretary of the Institute, and the Council had resolved to commission a professional graphic designer to produce a logo for use on all its printed material. In our discussions, we had decided not to use the initials AIP, partly because of confusion with other organizations such as the American Institute of Physics. What we wanted was a logo which symbolized physics itself. Furthermore we wanted something rather abstract, because representational pictures of physics apparatus go out of date in a generation or two. Another important criterion for a logo is that its clarity should be independent of size; it should be suitable on a flag or on the front of a building, and yet not lose detail when reduced on to a business card or the corner of an envelope.

When I put this to the designer, Mr Terry Baker, he naturally enough asked me to explain what physics was. I talked in terms of matter and energy and their relationships, leading on to examples of how the discipline was developed to where it is today. We discussed it for some time, while he tried to distil out of it some concepts which could lead to an abstract symbol for physics.

The final result will be familiar to all readers of this journal as it has appeared on the front cover of every issue since January 1972. I shall quote now the description of the significance of the design as it appears in the AIP General Information booklet, which I wrote following my talks with Mr Baker:

“It is based on the mathematical symbol for infinity, representing the limitless of space and time and the open-endedness of physics as a science. The arrows represent movement, action and continuous development. The interweaving to and fro represents the scientific process by which observations lead to theory and back again to better observations, which lead in turn to better theory.”

James Campbell

Institute Affairs

OFFICE-BEARERS 1977-78

As there were no further nominations made for Office-bearers for 1977-78, the following are duly elected to take office from the conclusion of the 14th Annual General Meeting in 1977 until the conclusion of the 16th Annual General Meeting in 1979.

President — Professor T. M. Sabine
Vice-President — Professor H. C. Bolton
Hon. Treasurer — Dr C. J. Howard
Hon. Registrar — Dr J. G. Collins
Hon. Secretary — Dr J. R. Bird

Returning Officer — B. M. Spicer
Education
Alarm Bells

SIR,

The table below shows the changes in the number of students taking physics as a Higher Schools Certificate (HSC) subject in Victoria over the last ten years.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Candidates taking HSC Physics</th>
<th>Number taking Physics as a % of all HSC Candidates</th>
<th>Number of Candidates taking Physics, Chemistry, Pure and Applied Maths.</th>
</tr>
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<tbody>
<tr>
<td>1965</td>
<td>4714</td>
<td>41</td>
<td>unknown</td>
</tr>
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<td>1970</td>
<td>6336</td>
<td>34</td>
<td>2955</td>
</tr>
<tr>
<td>1975</td>
<td>5550</td>
<td>24</td>
<td>2460</td>
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These statistics are alarming and should be a cause of concern to the physics community. In Victoria, at present, there are approximately 3000 students taking physics at HSC level, spread among about 500 schools. This is averaging at 10 students per school and the Education Department has a ruling that classes will not be conducted for groups of less than 10 students. The averaging technique is not valid, some metropolitan schools have in excess of 30 HSC physics students. It is therefore certain, that for 1977, the study of physics will not be an option open to some students in some schools in Victoria, even when schools combine in order to present matric subjects.

Why students are choosing not to do physics is a question that many people are asking. Some possible explanations that have been put forward are:

Physics is no longer “relevant”
Physics will not provide a “meal ticket”
Physics at matric level is no longer required for entry into tertiary institutions

To most school students it is true that physics is difficult, uninteresting and unrewarding. Hence, it is not studied.

These trends away from physics pose many questions for an organization such as the Australian Institute of Physics.

1. Do we wish to see ourselves as a very elite group? Maybe we do not consider physics to be the sort of area that should be open to the masses—if this is so, the current situation will, very soon, make us unique, if not obsolete.

2. Do we think we should, as a subject area, be alive and growing? If so, then we have got to take a very active interest in the training and inculcation of young people into our subject area.

3. Why are we an institute not attracting physics teachers and physics students as members? Do we wish to increase our membership among this group of physicists? If so, how can we do it?

Physics is reaching a decreasing population. If we are concerned that our discipline be a continuing discipline, then we must take steps to ensure that young people are coming into this area. I believe the Tasmanian Branch initiatives in this area are of vital importance. I hope the Victorian Branch will move actively in this direction. I hope the newly constituted Education Committee of Council will lend its support to, and encourage other states to participate in, this important, neglected area of our profession.

JEAN CLARK, FAIP
Head, Department of Physics,
Melbourne State College, Victoria

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Australian Astronomy

The Minister for Science, has announced the appointment of a committee to review the operations of astronomical observatories which are wholly or partly financed by the Commonwealth Government. The committee will include representatives of the Department of Education, the Treasury and the Public Service Board, it will be assisted by a scientific sub-committee chaired by Professor K. C. Westfold of Monash University. It is to inquire into and report on astronomical research in Australia and to recommend policies to promote the co-ordinated development of the various areas of astronomy together with the rationalised use of astronomical facilities.

The committee is to report within six months and its report will be passed to the Interim Australian Science and Technology Council for comment. The committee’s report and the Council’s comments would then be considered by the Government.

A total of approximately $9 million is currently being spent on astronomical research in Australia each year and the bulk of this is funded by the Commonwealth Government.
The Sunburnt Country

Since ancient times society's elite have urged homage to the sun — as the source of life and much of life's sustaining resources. And so it is today. Admittedly, sacrificial ceremonies are out of fashion but the gathering of sages to observe an eclipse continues to be a familiar occurrence. It is taken for granted that the same sages can predict, with great accuracy, the time and place of an eclipse but not the prevailing weather. Likewise, whilst they have produced an ever-expanding technology for exploiting mineral resources, the direct use of solar energy has all but been priced out of the market. It is not surprising, therefore, that there are continuing vocal claims for renewed efforts to rectify these shortcomings.

Parliamentary Committees are of long standing in Australia but their hearings are not widely recognised as a valuable source of scientific and technical data. This should change. For example if you are interested in information such as:

* Regular weather observations are made at over 8000 locations in and around Australia;
* A solar cell operating under average weather conditions takes 2½ years to generate an amount of electricity equal to that consumed in its manufacture;
* Perth is the only Australian capital city with an annual mean wind velocity as high as 7 m/s;
* 8300 m² of solar absorber surface was produced in Australia in 1973 and 25000 m² in 1975;

then you should consult the Hansard record of Hearings of the Senate Standing Committee on National Resources.

Although you will have to wade through thousands of pages you will find such pearls of wisdom as:

* We use a great deal more energy to make beer cans than we do to recycle bottles;
* The law in Australia does not forbid building in such a way as to prevent light reaching a neighbour's windows — the 'right to light' could therefore be an important factor in the development of solar energy;
* Policy for settlement in Australia must, inter alia, have a very long time horizon;
* It is important to realise that much of the currently available consumer literature quotes the hot water availability on the best days of the best month — the yearly mean being usually about two thirds of this.

You will also find flashes of human interest such as seldom illuminate scientific reports:

* "This we know
  The earth does not belong to man, man belongs to the earth . . .
  Whatever befalls the earth befalls the sons of the earth
  Man did not weave the web of life, he is merely a strand in it
  Whatever he does to the web he does to himself."
  (Chief Seattle, 1854);
* "Being in favour of solar energy is like being in favour of motherhood and against sin".
  (Surely this scientist was not quoting the latest trends in the time reversal of patterns of behaviour);

So where do we stand, in this sunburnt country, with progress in the use of solar energy? Away from the coal deposits of the East coast, electricity is expensive and flat plate collectors for hot water production are attractive, with CSIRO ground work and Australian commercial designs being well known in this field. Telecom Australia has 100 wind-driven generators and 20 small solar cell systems in use for powering microwave stations in remote areas. Many projects are in progress to develop other applications of solar energy and some are described in this issue of the Australian Physicist. Additional information is also contained in Solar Energy Progress in Australia and New Zealand which has just been published by the International Solar Energy Society.

It is not clear that we can be self-sufficient in energy from the sun without digging coal or uranium. Evidence submitted to the Senate Standing Committee on Natural Resources suggests that widespread use of solar heaters could lead to higher electricity tariffs because of unfavourable peak load conditions when the weather turns bad. There are considerable doubts that enough suitable land could be available for growing crops such as sugar cane, cassava or timber to make a major contribution to power requirements by the end of the century. Although the use of solar energy may appear to be pollution free, the production processes for materials for solar energy systems must be considered as well as possible conflicts in land use.

The questions are challenges and many people in Australia want to get on with the development of new systems and their applications. The only way to obtain answers is to begin and the AJP has added its voice to those calling for an increase in funds for research and development work on solar energy.

— R. Bird
The Case for Solar Energy

D. Haneman, School of Physics, University of N.S.W., P.O.B. I

Australia has large coal reserves, usually quoted as adequate for hundreds of years. It is important to note that if oil supplies diminish and much oil production from our coal is initiated, then supplies will run down much more rapidly.

Current Australian oil usage is 610,000 barrels per day (1/3 is imported). In 10 years we shall be using say 800,000 b/d (1 barrel = 159 litre). If local oil is by then depleted, which appears likely, and imported oil too expensive, we shall need to produce say 700,000 b/d from coal. This will require (at 2 barrels/tonne), 130 million tonnes/year in addition to normal coal requirements (by then) of about 70 million tonnes/year (currently about 60 million tonnes/year). This rate of about 200 million tonnes/year will deplete our known first category reserves of about 14,000 million tonnes of black coal and about 12,000 million tonnes brown coal (has one quarter heat value of black coal weight for weight) in about 85 years for a constant use rate. If the use rate continues to increase, the time will be even less. There are considerable second category recoverable reserves but these will be more expensive to utilise. The result is that our coal supply situation is far from secure over even 100 years. Furthermore the value of coal for chemicals production makes it undesirable to continue burning away these reserves when alternative energy sources are available. An additional point is that although our coal and oil is mostly of low sulphur content, the pollution arising from this fossil fuel combustion in cities is nevertheless a problem of increasing importance.

With regard to fission reactors, the problems of radioactive waste disposal have not been demonstrably solved, particularly with regard to ensuring encasement safety for time periods comparable with relevant radioactive half lives. Minor mishaps have already occurred. Hence solar energy, with its abundant supply and relatively minor side effects, is an attractive proposition and this has been realised in many places. The US expenditure on solar energy research and development for fiscal 1977 is approximately A$1.11 per head of population, totalling approximately A$240 million. (Australian expenditure in 1975/76 was about A$1 million, or A30,064 per capita, about one seventeenth of the 1977 US rate per capita).

Considerable concern has been expressed in many quarters about the scale of the Australian effort. Years ago this country was in a leading position in the field of flat plate collectors for converting solar energy to low grade (60-70°C) heat for domestic and industrial purposes. The present Australian market is 30-50 thousand such units per annum, mostly in country areas where electricity is not available or more expensive than in cities. Solar heaters for swimming pools are also on the market and are economically competitive with other systems. However, conversion of solar energy to higher temperature heat forms, or to stored fuel such as hydrogen or decomposed ammonia or methanol, is still in the development stage.

A very important field is conversion to electricity using silicon, cadmium sulphide-cuprous sulphide, gallium arsenide or other photovoltaic cells. An intense and expensive research effort to reduce the relatively high costs of these devices is under way, mostly overseas. Also of great interest is the power tower concept where large fields of tracking mirrors focus sunlight onto a fairly conventional boiler-turbine generator system sited on top of a tall central tower. Projected cost estimates for such systems, which would supply electricity on a large scale (order 10^6 MWH), are in the region of 2.8 cents (US current cents) by AD 2000 which would be economically competitive with other methods (source: Report of the Solar Resource Group Committee on Nuclear and Alternative Energy Systems, Oct., 1976, USA). An experimental power tower is currently under construction in Arizona, to test the predictions.

Bio-conversion of solar energy by using suitable crops as fuel is also of interest, particularly if waste products can be utilized. A recent interesting suggestion (M. Calvin) is the cultivation of plants of the genus euphorbia, from which hydrocarbons can be obtained directly (latex) rather than having first to convert carbohydrates e.g. from sugar. The field of direct production of hydrogen at illuminated semiconductor interfaces or certain recently discovered organic layers (rutheinum complexes) is also of interest as being potentially economically competitive.

While Australia cannot hope to be actively involved in all types of solar energy research and development, there are several new fields as well as older ones in which work is being successfully done in this country. It is certainly in the national interest to maintain a solid effort both to obtain the benefit of any developments produced here, and to have a body of experts able to appreciate and capitalise on developments from elsewhere. The abundance of solar energy in this country together with cheap land for large scale utilisation, make it one of the world's favoured regions for solar energy usage. It may well be that these aspects of Australia will eventually equal or out-rank in importance the abundance of minerals which currently contribute to our prosperity (while supplies last!).

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The sun whose rays
Are all ablaze
With ever-burning glory.
Does not deny
His majesty
He scorns to tell a story.

He don't exclaim
"I blush for shame
so kindly be indulgent"
But fierce and bold
In fiery gold
He glories all effulgent!

The Mikado

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The work in this group is directed towards the development of solar concentrating devices. Projects are under way which can provide useful output temperatures covering the range 100°C to 250°C.

Three of these projects are discussed below:

Linear Refracting Concentrators

W. Szulmayer.

The aim of this project is an inexpensive stationary concentrator intended for industrial as well as domestic heating. It should be capable of boiling water and super-heating steam to temperatures of 120-130°C, without tracking or seasonal re-adjustment. Other equally important requirements are: low production costs, easy assembly and mounting and flexibility of geometrical arrangements to permit operation in several modes, adapted to high or low temperature outputs as demanded by industrial or domestic users.

A concentrator design which meets these requirements is a considerable degree incorporates refracting and reflecting elements. A transparent plastic strip with an extruded pattern of prismatic ridges acts similarly to a cylindrical Fresnel lens so that radiation incident perpendicularly on the strip is focussed on a receiver pipe. Obliquely incident radiation converges on the pipe after reflection from a suitable cylindrical collector. Several reflector profiles can be designed to match the refraction pattern of the strip for a required tolerance to oblique incidence (±3°). Figure 1 shows focusing of radiation deviating by ±3° and ±2° respectively from normal incidence.

Such a concentrator with the longitudinal axis oriented East-West is suitable for semi-stationary operation, requiring seasonal altitude adjustment, i.e. changing the tilt angle from 30° to 45° and 60° (to the horizontal) for optimum winter, equinox and summer collection of solar heat respectively. However, replacement of the planar side walls shown in Figure 1 by suitable curvatures can increase the tolerance to oblique incidence up to ±30° or even ±35°. Thus a permanently fixed mounting at a tilt angle of ~45° and fully stationary operation all year round can be achieved. In Sydney, the zenith angle during the summer solstice is 79° and the heat supplied when the sun is at low altitudes (10°-18°) is hardly worthwhile collecting. Heating experiments conducted with experimental refractor profiles (15cm and 25cm wide) and varied reflector configurations confirmed theoretical predictions. Stagnation temperatures of 180°C were reached in Sydney in May-July, and 150°C in Los Angeles (August) and Montreal (September) with a relatively crude concentrator assembly 25cm by 60cm heating a pipe of 1/2" diameter.

It is worth stressing that despite the smoggy atmosphere in Los Angeles producing highly diffuse radiation (the sun was barely visible and casting no shade before 9:30 a.m.), the absorber pipes maintained temperatures above 100°C for 5% to 6% hours daily during the whole week of operation as an exhibit during the ISES congress 1975. The temperature recordings from Los Angeles are considered to be valuable evidence contradicting the often repeated claims, that focusing collectors cannot operate in such conditions.

Asymmetrical Non-Imaging Concentrators

D. R. Mills & J. E. Guittionich

Work is also proceeding on a new family of asymmetrical concentrators which are related to the Winston-type non-imaging concentrators, but which unlike the latter, are not symmetrical around the optic axis. Both parabolic and non-parabolic designs have been developed. Practical non-imaging concentrators, both asymmetrical and symmetrical, do not require tracking mechanisms and can be built with lower manufacturing tolerances than imaging systems. They require 'bi-weekly tracking at most, and low concentration configurations may remain stationary throughout the entire year. They occupy the heat production ranges characterized by concentrations up to about 10, a very useful range for potential solar energy utilization, and can be used in conjunction with solar cells.

Asymmetrical non-imaging concentrators can be designed to bias the direction of maximum concentration anywhere within their angle of acceptance. Different configurations have different advantages, but some possible relative advantages over non-imaging symmetrical systems are:

i. the possibility of increased concentration, and hence, energy collection per unit of mirror area for receivers which can make use of large daily variations of energy input.

ii. greater operational flexibility for accommodating unexpected fluctuations in demand.

iii. the possibility of compensation in design for:
   (a) projected solar area fall-off in early morning and afternoon in high concentration versions
   (b) seasonal fluctuations in demand in low concentration versions.

The asymmetrical non-parabolic concentrator in Figure 2 is of a type which could be used in either medium or higher concentration versions to give either a flat or highly sinusoidal daily output at solstice, depending upon orientation. A unit of this general type having an acceptance angle of 12° and a maximum concentration of about 10 is near completion at the time of printing. The examples shown in Figure 3 would be suitable for domestic space and/or water heating. They are of similar performance, give a concentration of about 1.6 in the winter and 1 in the summer, are completely stationary the entire year, and accept a significant amount of diffuse radiation. If only two adjustments were allowed in a year, much higher concentration units could be devised. In both Figure 2 and Figure 3, the angle of acceptance is bounded by the extreme ray directions K1 and K2.

For high concentration non-imaging systems economic comparisons must be made between the extra mirror required (as compared to tracking systems) and the cost and complexity of a tracking mechanism. On this basis, non-imaging systems may prove attrac-
tive in many situations. In under-developed areas the simplicity and ease of construction of non-imaging systems, which could be fabricated largely of local materials, must prove doubly appealing.

Fig. 2. A Non-Parabolic Concentrator. $k_1$ and $k_2$ are the extreme ray directions defining the angle of acceptance.

Fig. 3. Two of many possible stationary reflector profiles which could give a concentration varying from 1.0 in summer to 1.6 in winter.

Linear Tracking Concentrator
J. E. Guitronich and D. R. Mills

A third project is designed to determine the temperatures and efficiencies obtainable using a larger (5m²) cylindrical parabolic collector. The size chosen is probably near the upper limit of the unit size which may be used in any future practical application. The collector is continuously trackable about one axis.

Possibly the most difficult problems in a concentrator of this type are associated with the reflector. It is necessary to economically produce accurately curved mirrors of good reflectivity and of long life expectancy. These requirements indicate the use of glass with a reflecting coating on the second surface.

A technique has been developed and used to heat-sag glass components (500mm x 500mm) to an accuracy of ±0.002 radians. The method involved the cutting and hard-filing of a steel template to an accuracy of ±0.001 radians and then machining a casting to copy the shape of the template. The glass components were saged three at a time onto the casting at a temperature of ~520°C. As two different shapes of mirror components were required for this project, two templates and castings were made. The mirrors were commercially silvered using the standard process and are protected from the elements by a layer of 1/64 inch lead which is sealed at the edges using a silicone sealant. It is expected that these mirrors will have a life comparable with those used in non-humid indoor situations.

It is intended to use various absorber pipe assemblies and to measure collection efficiencies as a function of temperature in each case. Variations in design will include the use of selective surfaces, vacuum and subsidiary reflectors adjacent to the pipe.

Hydrogen Production from Water using Solar Energy

D. Haneman, E. R. McCartney, I. Bedwell and F. Steenbeeke, School of Physics and Dept. of Ceramic Engineering, University of N.S.W.

This project commenced in 1975 with ARGC assistance. The aim is to produce a useful storable form of energy from solar input at a reasonable efficiency and cost. The method under development appears promising on all these counts. It involves photolysis of water at a semiconductor interface under illumination. The method is illustrated in Figure 1. Electron hole pairs created in the surface barrier region by the illumination are separated by the field. The electrons flow round to a metal electrode and neutralise $\text{H}^+$ entities to produce molecular hydrogen, a storable fuel. The valence band holes extract electrons from $\text{O}_2^-$ entities in the solution, leading eventually to molecular oxygen production. This can be collected for use e.g. in fuel cells, or it can be abandoned to the atmosphere. Further details and a current bibliography are available (Chemical Methods of Solar Energy Conversion, D. Haneman, Proc. RACI Jan. 1977).

Suitable semiconductors so far investigated include $\text{TiO}_2$ and $\text{SrTiO}_3$ which are chemically stable and have a high quantum efficiency. However, their bandgap is about 3 eV so that only about 3% of the solar spectrum has sufficient energy to bridge the bandgap and thus be effective. Various other semiconductors are being studied.

We have found that $\text{TiO}_2$ works well not only as a single crystal but also in the form of thermally oxidised Ti sheet, anodised sheet, and also sintered pellets. Hence material costs for large area application can be kept low. We have found that iron oxide has a photoresponse to 570nm which is very suitable, but with a lower quantum efficiency for gas production than $\text{TiO}_2$. These aspects are currently being investigated. We have also obtained responses from a range of other oxides and titinates. Current studies include in addition, the effects of doping treatments, and measurements of semiconductor surface barrier height in solution, in order to optimise the various parameters.

Fig. 1
The Development of Metal-Insulator-Semiconductor Solar Cells

Martin A. Green, R. B. Godfrey and L.W. Davies
Department of Solid-State Engineering, School of Electrical Engineering, UNSW.

The most important commercial solar cells today are silicon p-n junction devices. These are generally fabricated by diffusing a thin layer of phosphorous n-type dopants into a p-type boron doped silicon substrate. [Novel 1975]. Not only does this diffusion process account for about a quarter of the total cost of the cell but it also causes minority carrier lifetimes throughout the entire cell to degrade to about a third of their starting values. The aim of our present research is to produce cells of comparable efficiency without using this diffusion process. This would not only lower cell costs by simplifying the cell fabrication, but it would also enhance the prospect of materials such as polycrystalline silicon, where p-n junctions are difficult to form.

Figure 1 is a sketch of the current-voltage characteristics of a solar cell both in the dark and when illuminated. It is the purpose to lump the factors determining the overall cell efficiency under specified illumination conditions into three parameters. These are the open-circuit voltage, $V_{OC}$, the short circuit current, $I_{SC}$, and the fill factor, FF, which is the ratio of the maximum power obtainable from the cell to the product of $V_{OC}$ and $I_{SC}$. For silicon p-n junction devices, $V_{OC}$ depends primarily upon the resistivity of the silicon substrate. $I_{SC}$ depends on two factors: the efficiency of light into the cell, and the proportion of minority carriers generated by this coupled light which is collected by the junction. Optical anti-reflection coatings are used to increase the first factor, while the second is determined by the cell geometry and the lifetimes within the cell. The fill factor is generally restricted to the range 0.7-0.8, but it can be drastically reduced if the parasitic series resistance of the cell is an appreciable fraction of the quantity $V_{OC}/I_{SC}$. For a cell as large as the experimental devices we are fabricating (10cm$^2$) where we are aiming at a $V_{OC}$ of 600mV and an $I_{SC}$ of 300mA under solar illumination, this means that the cell resistance has to be a lot less than $2\Omega$, say about 0.1$\Omega$.

One way of making silicon solar cells without diffusions is to use a rectifying metal-semiconductor contact (Schottky contact) instead of the p-n junction. However, it can be shown that these cells will always have a $V_{OC}$ value smaller than a p-n junction diode. [Green, Godfrey 1976]. Typically it is about half the value, and the overall cell efficiency is reduced by this factor. However, inserting a very thin insulating layer (<15 Å) between the metal and semiconductor can change this situation dramatically. The resulting Metal-Insulator-Semiconductor (MIS) structure allows current flow through the insulator by tunneling processes. With this structure it is possible to control whether carrier transport occurs predominately between the metal and the minority carrier energy band in the semiconductor or the majority carrier band. If the minority carrier band is chosen it is possible to produce contacts with properties exactly the same as p-n junction diodes. [Green, King, Schewachen 1974]. One of the major achievements of our group to date has been to show that solar cells based on this structure display open circuit voltages comparable to the best p-n junction devices yet produced. [Green, Godfrey 1976 – Green, Godfrey, Davies, 1976]. The MIS structure therefore completely eliminates the disadvantages of the Schottky cell.

If the MIS contact is designed so that transport in the metal and the majority carrier band is favoured, it acts essentially as a low resistance contact. This type of property can be combined with the previous type to produce the very simple MISIM solar cell of Figure 2. For a p-type substrate, the contact is a low work function metal to induce the minority carrier mode, while the back contact is a high work function metal to induce the majority carrier mode. A similar device can be made on n-type silicon by interchanging the location of the high and low work function metals.

The devices are fabricated by thermally oxidising the silicon substrate in a furnace at temperatures in the range 400-600°C to produce a nominal 12 Å oxide. The respective metals are then evaporated and to either side. We are using Al and Au for our low and high work function metals respectively.

In the dark, the MISIM cells have current voltage characteristics identical to p-n junction diodes. They show similar saturation current densities, temperature variations and dependences upon the substrate resistivity. When illuminated the devices have open circuit voltages comparable to the best p-n junction diodes. This is demonstrated in Figure 3 where experimental $V_{OC}$'s and fill factors are plotted as a function of the short-circuit current density for device No. 15. At current-densities typical of solar cell operation (30mA cm$^{-2}$), the device has a $V_{OC}$ of 618mV. The fall-off of the fill factor at high current levels is due to parasitic resistance.

![Figure 1: Schematic of the dark and illuminated characteristics of a solar cell.](image1)

![Figure 2: Schematic of the MISIM solar cell.](image2)
effects. Figure 4 compares the maximum Voc's we have observed for our cells with different resistivity substrates to a similar curve for devices produced at NASA Lewis at the end of 1975. [Green, Godfrey, Davies 1976]. This demonstrates that we have our open circuit voltages well under control.

We are currently working on improving I2C and FF for our cells. Once the light is coupled into the cell, our devices collect generated carriers marginally better than p-n junction devices, and the current lifetimes in the MISIM cells are not degraded during fabrication. Coupling the light into the cell presents a different problem from the p-n junction case, since light must pass through the top contact of the MISIM cell. We are experimenting with two different approaches to accomplish this. [Green, Godfrey, Davies 1976]. The first is a "grating" approach shown in Figure 5. The top contact is not continuous but consists of very fine lines, close together. They have to be less than a diffusion length apart (~100μm for our devices), to allow a high proportion of generated carriers to be collected. Using photolithography, we have made MISIM cells with grating lines 5μm wide spaced 50μm apart. Even though this structure allows a high proportion of incident light to be coupled into the cell, our experimental "grating" structures do not collect these very efficiently due to high recombination velocities at the bare silicon surface between the grating lines. We aim to overcome this problem by using an anti-reflection coating material which simultaneously "passes" these vulnerable areas.

The second approach is the "transparent" metal approach shown in Figure 6. In this case the top metal layer is continuous but very thin (<100 Å). A metal grid structure is placed on top of it to reduce the series resistance contribution of the thin layer. The aim is to produce layers which are transparent but do not have a high sheet resistivity. Using slowly evaporated (~5Å/sec) Al layers without an antireflection coating, we obtain layers that are virtually transparent, coupling more than 80% as much light into the silicon as would a bare surface, for sheet resistivities of the order of 100Ω/sq.

Our best MISIM cells to date have had a conversion efficiency of 7% compared to 15% for a "good" p-n junction device with an anti-reflection (AR) coating. An AR coating would increase the efficiency of our devices by 30-40%. Our short term aim is to increase the efficiency of our devices to 10% (no AR coating) primarily by improving the design of the grid used to reduce series resistance. By adding an AR coating, MISIM efficiencies of over 13% should be obtainable. The smaller production spreads which are likely to result from their simpler processing effectively will reduce the difference between the p-n junction and MISIM devices further.

To date our research has shown that the MISIM solar cell has the potential for high efficiencies while having the advantage of being a less expensive cell to fabricate. After producing an experimental device which fulfills this potential with single crystal silicon, our aim is to investigate the MIS structure as applied to less expensive polycrystalline material.

Figure 3: The open circuit voltage and fill factor of an experimental device (# 15).

Figure 4: Comparison of the maximum open circuit voltages observed for MISIM and p-n junction cells.

Figure 5: Schematic of a "grating" MISIM solar cell.

GRATING STRUCTURE MISIM SOLAR CELL

Page 178 The Australian Physicist, November 1976
Solar Thermoelectric Devices
L. B. Harris, T. Durst, G. Vella and H. J. Goldsmid, School of Physics, UNSW

We are looking into the possibility of using thermoelectric generators and refrigerators in conjunction with solar energy. Thermoelectric generators operate at less than one-quarter of the ideal thermodynamic efficiency for a given temperature difference between the heat source and sink, but they are exceptionally versatile in their requirements of temperature and power. Most thermocouple materials have been selected either for refrigeration (i.e., below room temperature) or high temperature generation. We are aiming to improve the materials for use at temperatures of up to about 200°C. To this end we are preparing alloys based on Bi₂Te₃ by powder metallurgy techniques and evaluating their properties. Thermocouples made from these materials will be built into a solar thermoelectric generator.

Thermoelectric energy converters are exceptionally simple to build if the number of couples is kept to a minimum. We are, therefore, investigating ways of converting power from very low voltage-high current sources into high voltage-low current. In particular, we are looking at switches and oscillators based on the Hall effect and the magnetoresistance effect.

A combination that can be constructed using very few thermocouples is a thermoelectric refrigerator powered by a thermoelectric generator. In some circumstances this may consist of no more than two couples. We have, in fact, made a device consisting of four generating couples and one refrigerating couple that has produced ice from the sun. The illustration shows the four flat plate collectors that are attached to the generating couples; the refrigerating couple on which the ice was formed is shown by the arrow.

*This work was supported by the Radio Research Board and the Australian Research Grants Committee.
The Energy Research Centre of the University of Sydney, under the chairmanship of Professor C. Watson-Munro, has initiated a number of interdisciplinary studies in the utilisation of solar energy in the Australian context. The work divides into two basic streams—the first, centred in the Biochemistry and Chemical Engineering Departments, is involved with the bioproduction of liquid and gaseous fuels from organic matter, i.e., photosynthetic conversion of solar energy. The second, centred in the Physics and Mechanical Engineering schools, is concerned with physics-based methods of conversion, concentrating on the photo-thermal utilisation of solar energy.

The Biochemistry group, headed by Professor J. L. Still and Dr. B. S. Deol, has developed a process for the fermentation of rice hulls and wheat straw into methane gas, a convenient energy source, and a residue which is potentially just as important, a protein-rich cattle feed. Blue Metal Industries, a company with extensive timber interests, has supported the work. Following the successful development by the group of a fermentation process for turning sawmill wastes into methane and protein residue, BMI are building a large scale process on a site at a sawmill, in consultation with the University group. The fermentation of wood is a difficult process, requiring the breakdown of the ligno-cellulose. However, by the development of suitable organisms, even such durable timber as Blackbutt has been processed. The Biochemistry group is now looking at the even more difficult problem of urban waste processing, a problem in which a local Sydney council has a keen interest. Two patents have been taken out on aspects of the group's work.

The Chemical Engineering group, headed by Professor R. G. H. Prince and Dr. D. J. McCann, is studying agri-industrial complexes for the production of chemical fuels and food. A detailed study of fuel crops for the production of ethanol, in conjunction with Dr. H. Saddler of the Botany Department, has now been completed and has shown that such large scale complexes would become economic if the oil-derived product were merely to double in price. The support of the Bushells Trust has enabled the setting up on an experimental basis of another type of agro-industrial complex. A piggery at Berrima, south west of Sydney is being adapted to produce methane fuel by fermentation of pig wastes.

The liquid fuel crisis promises to be more pronounced in Australia than elsewhere and contributions from all sources will be important in minimising the impact on our life styles.

The Physics group, comprising Dr. B. Window, Dr. D. McKenzie, Dr. G. Harding and Dr. L. Wilbow is concerned with the efficient conversion of solar radiation to heat at high temperatures for domestic and industrial applications. The most economic way to utilise solar energy is to convert it to heat and use it as heat, because then the collector extraction efficiency can exceed 50%. Conventional flat plate collectors operate with this efficiency at temperatures up to 60°C, adequate for domestic hot water applications, but improved collectors are necessary to increase the efficiency of extraction at temperatures in the vicinity of 100°C. To reduce the convective loss, evacuated modules must be used; to reduce the radiative loss, selective surfaces which absorb strongly for the solar spectrum but emit weakly for the thermal spectrum, must be developed.

The group in the Physics School has developed all glass collecting modules, incorporating a selective surface produced using reactive sputtering. The sputtering technique was adopted because of its suitability for coating long tubes, the excellent adhesion and the possibility of producing very stable compounds reactively. An excellent surface, based on iron carbides on copper, with a solar absorptance of 85%, a thermal emittance of 4% at 300°C, and a projected lifetime in excess of 20 years at 300°C has been patented.

The absorbing properties of such films are often enhanced by incorpating small metal particles in the matrix, a situation which is often treated theoretically using Maxwell Garnett theory. This theory is only valid as a limiting case, and experimental and theoretical work is in progress to extend the theory to other situations. Another way of improving the solar absorptance of an absorbing interference layer is to grade the refractive index through the layer. Theoretical calculations have confirmed the usefulness of this approach, and the fabrication of such graded films using sputtering is under way.

The behaviour of holographically produced grids and other geometric situations has been experimentally determined by C. M. Horwitz, a graduate student, and the results correlated with work being done in the Theoretical Physics Department on the calculation of the properties of metal gratings and grids. The performance, both theoretically and experimentally, of such grids and structures does not look promising and it is unlikely that practical surfaces of this type will ever be used.

The evaluation of selective surfaces produced by the group and other groups for suitability for advanced vacuum insulated collectors requires careful ageing in various pressures and at various temperatures to predict the lifetimes of the surfaces. Such experiments are being carried out.

The development of the coating technique to the production stage to mass vacuum insulated all glass collectors is being pursued through a number of prototypes. Ultimately a continuous coater will be made.

Non concentrating collectors have been manufactured and stagnation temperatures (i.e., no energy extraction) in excess of 300°C have been achieved. Such collectors will efficiently deliver energy at 200°C. In collaboration with the Department of Mechanical Engineering, studies of methods of extracting the heat at these temperatures are being carried out.
Solar Energy Conversion using Photo-Electrochemical Cells

D.H. Bradhurst, A.A.E.C. Research Establishment, Lucas Heights, N.S.W.

Although the most efficient applications of solar energy are those in which the heat is used directly, there is a growing interest in other methods of solar energy conversion, such as the generation of electricity using the photovoltaic effect in semiconducting materials. The maximum efficiency of conversion of solar energy to electrical energy is about 18%, using pure single crystals of silicon. [Energy Alternatives]. Commercially available photovoltaic units operate at about 10% efficiency but are too expensive for general use ($20000-$50000 per kilowatt).

A relatively new concept in the conversion of solar energy which holds promise for the production of cheap electrical power, and also for the storage of solar energy, is the photo-electrochemical cell. In this type of cell chemical reactions occur at the electrodes when they are exposed to light of a suitable wavelength. In principle, all semiconducting materials can be used as electrodes, but in practice the range of materials which have the right combination of semiconducting and chemical properties is severely limited. In 1972 Fujishima and Honda described a photoelectrochemical cell in which water could be electrolysed into hydrogen and oxygen when irradiated with UV light from a xenon lamp. [Fujishima, Honda 1972].

The photo-sensitive anode consisted of a single crystal of titanium dioxide.

This work provided the initial stimulus for similar experiments at the A.A.E.C. Research Establishment, where previous experience had been obtained with the electrochemical properties of oxide films on metals used in nuclear reactors. Photo-electrochemical cells were made in which hydrogen was produced using various oxidised metals as the photosensitive anodes instead of the relatively expensive single crystals of titanium oxide used in the Japanese work. [Bradhurst, Stolarski 1975].

Principle of Operation

A cell consisting of an oxidised titanium anode and a platinum cathode is shown schematically in the diagram. When light of energy exceeding that of the band gap in titanium oxide (3.1 eV) strikes the surface, an electron-hole pair is formed:

$$\text{TiO}_2 + 2\text{hv} \rightarrow 2\text{Ti}^+ + 2\text{e}^- + \text{O}_2$$

The bending of the energy bands within the space-charge region of the titanium dioxide near the oxide-electrolyte interface causes the electrons and holes to separate rather than recombine. The electrons flow through the external circuit to the cathode where hydrogen is produced:

$$2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$$

The holes react at the semiconductor surface to produce oxygen:

$$2\text{p}^+ + \text{H}_2\text{O} \rightarrow \text{O}_2 + 2\text{H}^+$$

The overall reaction, therefore, is the decomposition of water into hydrogen and oxygen. Useful electrical work is obtained from the current flow through the load, while the hydrogen can be stored for conversion to electrical energy in a fuel cell, or burned as a non-polluting fuel.

Results Obtained Using Oxide Films

A variety of metals including titanium, zirconium, various zirconium alloys, tungsten, molybdenum and iron were oxidised either anodically or in air, and their photovoltaic response was tested in various electrolytes. The more promising oxides were tested as anodes in photo-electrolytic cells in either sunlight, or UV light from a mercury lamp. The polarisation behaviour of the electrodes was measured using a potentialmeter method. The overall efficiencies of energy conversion were measured by using a thermopile wattmeter to monitor the power input, and an electrometer and gas burette to measure the power output, and volume of hydrogen gas produced. Measurements of the spectral response of the oxidised titanium anodes have shown that all of the photocurrent was produced by light of wavelength less than 500 nm. Quantum efficiencies of up to 36 per cent were obtained for the best anodes, with overall efficiencies of 2.5 per cent using the mercury lamp source, and 1.3 per cent using sunlight.

It was more efficient to operate the cells at maximum current rather than maximum electrical power. Hydrogen has a heat of combustion of 58 Kcal per mole and the power which is recoverable by burning it is between seven and ten times the power obtainable in the resistive load. The efficiencies obtained are already sufficiently high for these cells to be economically competitive with silicon cells, but further improvements are needed in order to reduce the area of solar collectors which would be necessary to produce useful amounts of power in a practical device. Further experiments aimed at improving the efficiency of these cells are in progress.

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Selective Surfaces for Solar Energy Utilisation

K.J. Cathro & A.F. Reid, Division of Mineral Chemistry, CSIRO.

Work on solar energy utilisation at the Division of Mineral Chemistry has to date largely been directed to the development of improved selective surfaces for use on solar collectors working in the range 50° to 150°C. Two main approaches to the problem have been employed, the first being improvement of the copper black [Christie 1970] used on commercial solar panels, and the second the evaluation as selective surfaces of a number of electro-deposited blacks, originally suggested for use as decorative finishes.

The black surface formed on copper by treatment in alkaline chlorite solution [Christie 1970] shows considerable selectivity between adsorption of solar radiation in the infra red. However, it is not entirely satisfactory, and shows both thermal and humidity degradation over long periods. Work in the Division [Reid, Wilson 1974] showed this surface to consist mainly of cuprous oxide, and reaction systems were therefore sought which would convert this to a stable copper compound such as copper chromite or chromate. It was found [Reid 1976] that simple immersion of the surface in warm ammonium chromate solution gave a marked change in appearance, with typical values for solar adsorption and infra-red emittance, $\varepsilon_{s}$ and $\varepsilon_{i}$, of 0.93 and 0.07 as compared with initial values of 0.88 and 0.09. Resistance to corrosion by high humidity or water condensation was greatly improved, and thermal degradation was significantly reduced, although still not prevented. Tests on a collector panel of 0.75 m$^2$ gave efficiencies as shown in Figure 1, significantly improved as compared with standard copper black panels.

Subsequent work on the nature of the chromate reaction product has shown it to be a thermally stable basic ammonium cupric chromate, which forms an insoluble protective coating over the individual cuprous oxide crystallites of the copper black surface. Similar compounds are known in catalyst technology [Sandilya, Roy, Gosh 1970; Tsareva, Guynner 1968].

Studies on electro deposited surfaces were begun with nickel black, originally suggested for use as a selective surface by Tabor [Cathro, Christie, Reid 1975]. This black is a complex mixed deposit of nickel and zinc sulphide and oxides, plated from a bath containing nickel and zinc salts, together with ammonium and thiocyanate ions. A somewhat similar surface deposit is formed without electrolysis when a zinc surface is treated with a solution containing nickel sulphate and ammonium thiocyanate.

A range of nickel blacks were deposited both on copper and on nickel-plated steel substrates, and it was confirmed that surfaces having $\varepsilon_{s}$ in the range of 0.85 to 0.90 and $\varepsilon_{i}$ values of 0.10 to 0.12 could be prepared [Cathro, Christie, Reid 1975]. The chloride bath of Wesley and Knapp gave more uniform results than did the usual sulphate bath but the $\varepsilon_{s}$ and $\varepsilon_{i}$ values could not be improved. [Wesley, Knapp 1958].

A series of electrophotochemically deposited chromate coatings were next examined, among them black chrome. This surface, a mixture of chrome metal and chrome oxide deposited from a bath containing chromic acid and a suitable catalyst such as fluorosilicic, was shown by MacDonald to be spectrally selective and proved to be the most promising of the surfaces studied. [MacDonald, 1975]. A number of test deposits were therefore made, mainly on nickel-plated mild steel, using commercially available formulations such as Duramir BK from Diamond Shamrock Chemicals and also a number of the bath compositions listed. [Shinno, Gowrie 1973]. It was possible by optimizing current density and deposit thickness to achieve deposits on nickel plated steel having $\varepsilon_{s}$ values of 0.96 to 0.97 and with $\varepsilon_{i}$ from 0.10 to 0.15, there being little difference between the optimal deposits obtained from the various plating baths.

Black chrome surfaces were deposited on a number of full size solar panels, to enable evaluation under normal collector operating conditions. The results obtained are shown in Figure 1 in the form of a graph of collector efficiency vs (temperature rise/radiation input), and it can be seen that the chrome black surface offers higher performance than any of the other surfaces up to $\Delta T/G$ ratio of 0.05, typical of hot water systems, the black chrome surface shows a collector efficiency of 60% as compared with 48% for currently used copper black surfaces. In a typical domestic system this corresponds to one less collector, which should lead to appreciable cost savings.

The black coating formed on zinc when it is electrolysised with alternating current in a sodium nitrate-sodium hydroxide bath [Encheva, al. 1972] has also been examined. This coating was found to be strongly selective, and values of $\varepsilon_{s}$ of 0.94 to 0.95 and $\varepsilon_{i}$ of 0.09 to 0.11 were fairly readily attained. The treatment should be of low cost, as zinc plated steel is relatively inexpensive, and a-c electrolysise has the advantages of not requiring rectifier systems and of allowing two panels to be simultaneously electrolysed.
To be useful in practice a selective coating must be stable at the highest temperature at which the collector is likely to operate, and should not be subject to corrosion or other deterioration. Black chrome is similar to bright chrome in its corrosion resistance [Branciaroli, Stutzman 1967] but black nickel can deteriorate in the presence of moisture. It is possible that black zinc may also deteriorate at the moisture levels than can occur in collector operation, although tests to establish this are not yet complete.

Samples of all the selective surfaces described have been held at elevated temperatures, in air, for periods up to six months. The upper temperature limits at which there was no significant decrease in $\alpha$ or increase in $\epsilon_f$ for the surfaces tested were, for standard copper black 75°C, for chromated copper black 100°C, for black nickel 125°C, and for black zinc 125°C. For black chrome on nickel plated steel there was no change in performance at the highest temperature tested namely 200°C, and this material has also withstood 300°C in vacuum for four weeks without change. Its stability is thus outstanding, although all of the surfaces described can be used with hot-water systems, and the least stable – standard copper black – has been used successfully in this application for some years.

In other work concerned with solar energy utilisation – much of it in cooperation with the CSIRO Division of Mechanical Engineering – relatively large evacuated tubular collectors are being designed and manufactured in order that the performance of such devices can be assessed. Additionally, since the measurement of thermal emittance is of prime importance in the quality control of selective surfaces, the relatively inexpensive Land Surface Thermometer is being evaluated as an emissivity measuring device. Preliminary measurements show that it is sufficiently sensitive for emissivity measurements down to temperatures of about 50°C, well below its usual operating range.

Acknowledgement

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Use of Solar Energy in Remote Telecommunications Equipment

R.E. Collins, AWA Research Laboratory, N.S.W.

While the full potential of solar energy clearly remains to be realised in the future, there are today a few areas in which solar energy can be utilised economically. One of these is direct conversion of sunlight to electricity. This is usually done with a solar cell – a surface p-n junction on the semiconductor, silicon.

Solar cells are widely used for satellite power generation. Although the cost/reliability requirements for such an application are very different from those for terrestrial power generation, solar cells are finding increasing use in the latter situation.

The dramatic and continuing reduction in solar cell prices is increasing the scope for terrestrial power generation in areas where conventional power sources are absent.

At present, encapsulated silicon solar cells capable of generating a few watts can be purchased for approximately AS20-30 per peak watt, and for somewhat less in very large quantities. The required power generating capacity in any particular installation is determined from the anticipated demand and from statistics of available sunlight. In addition, a battery storage system is needed to provide continuity of power at night and over extended cloudy periods. A safety margin in both generating and storage capacity is always included. This is related to the tolerable level of system failure during extended periods of low solar flux. These additional requirements result in an electricity cost per continuous watt at least an order of magnitude higher than the cost per peak watt of the solar cell. The actual figure depends critically on system size. In large installations, for example, significant savings can be achieved by rotation of the solar cells and by concentration, by up to a factor of 2, of the incident radiation.

The cost of electrical power generated by direct conversion of solar energy is clearly very high at present, compared with the cost of conventionally generated power. Even so, there are many practical situations where remoteness or inaccessibility makes the utilisation of solar power economic. One such application in Australia is remote telephony repeaters. AWA Engineering Products Division has designed and manufactured a number of such repeaters which are totally dependent on solar energy for their electrical power. A typical unit requires an electrical power equivalent to 5 watts continuous. This is supplied by commercially available solar cells – typically 7 separate units, each capable of generating 7 watts at peak sunlight. A lead-acid battery energy storage system with a capacity of approximately 800 watt-hours is used.

Several systems of this type have been installed. When user confidence is established in such solar powered systems, a very large market is expected to develop for this and similar equipment.
The Institute for Energy Conversion  
Flinders University of South Australia

INTRODUCTION

This University has encouraged the organisation of related disciplines into working groups with clearly defined, society-oriented research goals. The Institute for Energy Studies is one of several such groups, in which staff and students participate in the search for alternative energy sources. It was formally constituted in 1973.

Investigations have not been confined to solar energy conversion alone, but they include also the development of natural gas fuel cells, catalytic coal gasification, plasma physics, energy storage, utilisation of arid lands, architectural design, and a strong emphasis on public education to encourage energy conservation and preparation for the eventual introduction of energy alternatives.

Recently the University acquired almost 500 hectares of semi arid land at Caroona 200 km north of Adelaide. It is hoped to establish there a field station for the testing of energy storage and conservation devices.

Study of primary energy input (P. Schwertfeger)

A specially attractive aspect of the Flinders solar and wind energy conversion research is the participation in the Institute's activities by meteorologists and the close collaboration with the Institute for Atmospheric and Marine Sciences.

Detailed solar radiation data is important both in the elucidation of purely scientific questions on the solar constant and atmospheric attenuation processes as well as in the provision of irradiational data required in planning locations and methods for energy conversion.

Although such data is available for a very limited number of fixed locations in Australia, little is known about detailed spatial and temporal variations in solar irradiation for any major Australian city. The Flinders Institute for Atmospheric and Marine Sciences has, however, in its study of the climate of the Adelaide region, discovered the general nature of the variations which may be encountered. While the mean fluxes over the near southern suburbs of Adelaide range from a maximum of \( (26.2 \pm 3.6) \times 10^6 \text{ Journe} \text{ m}^{-2} \text{ day}^{-1} \) \( (7.28 \text{ kWh m}^{-2} \text{ day}^{-1}) \) in summer and \( (7.2 \pm 3.6) \times 10^6 \text{ J m}^{-2} \text{ day}^{-1} \) \( (2.00 \text{ kWh m}^{-2} \text{ day}^{-1}) \) in winter, almost an order of magnitude can separate readings taken at Port Adelaide and Mt. Lofty respectively at certain times. The main features of the solar radiation regime are related to cloud cover, once atmospheric geometrical factors have been accounted for. In the Adelaide region, the Mt. Lofty Ranges generate substantial orographic cloud even when clear skis may extend over most of the city.

Potential users require access to reliable irradiational data applicable to their particular location rather than average estimates for a whole city or region in order to be able to compare the relative economies of competing power sources. At the present time, most Australian users of solar energy conversion devices have made decisions based more on enthusiasm than on precise facts. Similarly, such data is required in the technical refinement of existing devices and in their responsible marketing. Most important, though, is the need for information on the magnitude of the potential national resource available in solar energy, irrespective of current conversion technology.

Parabolic cylinder solar collectors

(H. A. Blevin, E. L. Murray)

An evacuated tubular collector at the focus of a parabolic cylindrical trough has been designed and is presently being constructed. Associated with this collector, a standard flat plate collector and isolation measurement system serves as a performance reference. Facilities for digital recording of flow rates, isolation and temperature differential will be provided. The tubular collector system contains a closed packed array of seven troughs, each being one metre in length with an overall array area of approximately one square metre. Comparative tests of selective surface absorbers can be readily achieved in this manner since each trough has an independent monitoring system.

Much of the work carried out so far has been concerned with methods of heat transfer from the collector to storage. It appears that a simple wickless heat pipe will adequately cope with the heat fluxes encountered and this leads to a simplification in the collector tube design.

Fig. 1. Photo electrochemical cell for the direct production of hydrogen.
Photo electrochemical hydrogen production. (J. O'M. Bockris).

Conventional hydrogen production requires photovoltaic converters and electrolyzers. In a different approach solar light is split into two equal beams, directed respectively onto semiconductor electrodes.

When the p-type electrode receives a photon, an electron is activated into a conduction band and can emit to neutralize protons in solution. When an n-type semiconductor absorbs photons, holes are made available in the valency band and these can receive electrons.

If matching conditions are met, the combination of n- and p-type semiconductor electrodes in an electrolysis cell, could make the production of hydrogen photo-driven. The new method gives prospects of cheaper hydrogen than with previous methods.

Combining the capital costs would be less in one system situation and the degree of purity of semiconductor electrodes may be less important because the path from the excitation site inside the material to the point at which an electron is accepted in the double layer is smaller than the mean free path in, e.g. silicon photovoltaics. The development of new photo-cathodes such as cadmium telluride have realised the concept discussed above. (Figure 1). On the other hand, the concept is not yet commercial; thus the achieved efficiency is about 2%, whereas the minimum efficiency to make the device worth using would be about 8%.

Among the paths ahead are the synthesis of new semiconducting materials with suitable energy gaps and electron affinities; and the development of techniques which allow efficient light absorption but reduce anodic dissolution and corrosion.

Fig. 2. Demonstration models for high power wind generators. Left, the Mullett generator for generators in excess of 10 MW. Right, a Danish design of the vertical non directional wind collector.

Development of wind generators (H. J. de Bruin, L. F. Mullett, in association with Davey Dunsite and Chloride Batteries Australia Ltd.) Using a 2 kW wind generator of conventional design a larger version for domestic applications has been developed. Special features of this 5 kW generator are the propellor blade design, feathering mechanisms, and energy storage facilities. This newly developed equipment will now be used in the production, storage and direct conversion of electrolytic hydrogen.

The size restrictions on conventional mast-born generators limits its usefulness to domestic applications. Alternative designs in excess of 1 MW are being considered of which the most promising is the Mullett Generator of which a working model is shown in Figure 2, along with the prototype vertical wind collector.

Urged on by considerable public support a research laboratory self sufficient in domestic energy is being planned under the name SOLAB. Besides the research centre for the Institute, it will provide a service to industry for the testing of new solar energy conversion devices, as well as being a display and public education centre. This project cannot proceed without Government support.

Solar Energy Developments at SAIT
R. W. Smyth, Head of School of Mechanical Engineering

A number of small investigational projects related to solar energy utilization have been undertaken within the undergraduate student programme in Mechanical Engineering at the South Australian Institute of Technology. In the main, these have involved the performance testing of flat plate collectors in an collaborative development ongoing programme with local industrial manufacturers. This has highlighted the scarcity of insulation data in a form suitable for the design of industrial solar installations, and prompted commissioning of an installation measuring station. Whilst initially conceived to provide an absolute basis for collector efficiency determinations, the measured variables are being extended to include the 15 minute averages of diffuse and global radiation, wet and dry bulb temperatures, and wind run and direction. Although not yet finally commissioned it is hoped that the station will be recognised by the Bureau of Meteorology as providing insolation data relevant to the Northern enivrons of Adelaide.

Complementary long term performance testing of a domestic/industrial water heating system using bulk water storage is also in hand.

Evaluation tests of ethanol as an internal combustion engine fuel are also being conducted to extend the range of ethanol concentrations with commercial petroleum for which performance characteristics and engine settings are currently available.

A more useful project concerns a total system design for the utilisation of methane produced from piggery wastes for fuelling farm transport and building heating.
The work of this division has been reported recently in the latest edition of Solar Energy Progress in Australia and New Zealand and there is a wide range of work being undertaken.

Optimization of Solar Energy Systems — M. Kovarik

Utilization of solar energy has reached a state where it is possible to construct models of cost and performance as a function of design and operation features of simple collection systems. By analysis of such models, it is possible to select features corresponding to the best possible value of some chosen index of performance, such as the cost of heat collected.

Perimeter Air Conditioner with Solar Space Heating — C. Y. L. Chan

A low energy consumption air conditioning system with solar space heating was described by Chan. At present the prototype system is in the last year of a 3-year test programme, aimed partly to obtain values of solar contribution towards space heating.


The technology for the design and construction of many of the components which are used in producing a solar heat generating system is known, but a more fundamental understanding of the performance of the system as a whole is required. There is a need in the future to establish simplified guidelines for designing economically viable solar heating systems for space heating and cooling and industrial processes.

In recognition of the need to understand system performance as an aid to system design, the CSIRO Division of Mechanical Engineering has embarked on a programme of work on solar systems which will involve a combination of analysis, mathematical and experimental modeling and data collection.

One of the main experimental tools in this work is a recently completed high temperature solar water heating facility constructed at Hightett.

The research facility has been designed as a powerful, versatile experiment to aid in validating system mathematical models and to provide experimental information on particular system components and configurations.

Heat Loss from Solar Collectors — J. G. Symons

An experimental testing procedure has been developed to enable heat loss from solar collectors to be measured. The test is conducted in a controlled environment where a range of ambient conditions can be simulated.

During the test, hot water passes through the absorber plate of the collector, at controlled inlet temperatures and flow rates. Heat loss from the water is measured to enable the collector heat loss coefficient to be calculated. The tests are conducted under steady state conditions, and for two wind velocities, 0 and 3 m/s.

The accuracy of the testing method has been checked by comparing results with other external heat loss experiments, and found to be satisfactory.

The experimental testing of heat loss from solar collectors has proven useful as a development tool. Along with results from external efficiency tests, new collector designs can be evaluated.

Perhaps the most exciting collector development in the world today is the evacuated glass cylinder. The stated output of these is substantially higher than the flat-plate type due to the low collector heat loss. However, the manufactured cost is extremely high and even projected costs, assuming complete automation, would appear to make them non-competitive at this stage.

Justification can therefore be taken for the future development of the cheaper flat-plate collector and for systems which employ collectors integrated into the building structure, thereby reducing the overall costs and improving the appearance.

The market for solar water heaters is expanding both in the low temperature application and also for higher temperature industrial use. Industry's requirements vary greatly. For instance some processes utilize water in large quantities as low as 45°C whilst in other 95°C is mandatory. Heat recovery by exchange is not always practicable and it is expected that solar water heating will become a popular heat source for these applications when its potential is more fully appreciated.

Swimming pool heating is another area where a significant contribution could be made. Because of the low temperature difference — mean plate temperature to ambient — it is usual to use an uninsulated collector plate and there is a large market for this application alone.

If the same collector plate can be insulated and glazed for higher temperature applications it then becomes more universally acceptable and the usual and manufacturing costs can be amortized over a much larger output.

Copper plates and tubes are being used in this context along with aluminium plates and copper tubes. There have also been recent developments in the use of plastics some of which appear to offer prospects for the multiple applications mentioned above.

Performance Characteristic of Flat-Plate Solar Collectors — P. I. Cooper, P. Pott, R. V. Dunkle

Two experimental facilities have been constructed for testing flat-plated solar water heaters outdoors.

Solar Swimming Pool Heating — J. T. Czarnecki

There are two basic methods of increasing the temperature of the swimming pool water by solar energy, namely:

1. Utilize the solar radiation incident on the swimming pool to a better advantage by reducing the heat loss from the water by means of transparent covers or enclosures.

2. Using solar collectors for heating the water.

Swimming pool covers made of clear plastic film in the form of an inflated mattress were developed and tested by the CSIRO Division of Mechanical Engineering some years ago.

It is estimated that when using the cover, the swimming season of an open swimming pool can be increased by six weeks on each end.

Several such covers are in use in home swimming pools. The expected useful life of the cover is about five years, though experience shows that with careful handling they last much longer.

Transparent swimming pool enclosures offer an alternative to the covers, but they are rather expensive and, therefore, their use can only be justified if year round swimming is required. In such cases heating of the air inside is also desirable. The combined heating system must be carefully designed making the best possible use of the available solar energy.
The Indirect Use of Solar Energy

Wof N. Garwoli, Department of Communication and Electronic Engineering, RMIT.

INTRODUCTION

The conventional utilization of solar energy is handicapped by capital cost in terms of money and energy required in production. The storage of solar energy is also a problem. Fuel derived from fossil processing is generally non-flexible and unsuitable for transport, peaking power stations, etc.

The research to be described avoids the above difficulties. It can be divided into the following areas: Wind energy (urban residences, rural residences, multistorey buildings). Methane (farm units: large and small area unit, anaerobic digestion of city garbage). Collection of wind energy at sea (in places such as Bass Strait), and conversion to hydrogen for storage.

The Wind Turbine

It is well known that the energy derived from a wind collector is proportional to its area i.e., linear dimension squared (D^2) while the approximate cost, stress etc. is proportional to (D^3). Hence there is a severe penalty to be paid for increase in size. The turbine in the system is a relatively small unit with a large wind concentrator. This enables a much greater wind speed range to be utilized than is possible with a conventional wind mill. The upper wind speed limit can be determined passively by selecting the appropriate aperture in the wind concentrator so that air flow becomes turbulent at the desired wind speed. This enables a static structure to take the excess wind loads. The other significant advantage from the conventional system is that the system is adaptive i.e., the wind spectral density with respect to time is monitored. This data, combined with system parameters such as inertia, friction, drag, load etc. is used to determine the optimal impulsive response of the system required to extract maximum energy from wind.

The response of the wind system is then adjusted by mechanical alteration of the turbine (slow) and by altering the dynamic load and excitation (fast) of the reluctance generator. Fig. 1. This enables maximum extraction of energy from wind gusts and is significantly superior in energy collection to a regulated AC or DC generator.

Storage of Energy

The energy is stored in two modes, heat bank and/or compressed air. In an urban residence a high temperature heat bank is used. This type of storage is used because more than three quarters of the energy consumed in a house is in the form of heat and it is logical to generate and store it as heat. Heat piles are used for cooking hot plates and the heat loss from the heat bank is utilized to heat hot water for the house. Fig. 2.

Methane

In Australia we anaerobically digested all the organic waste emanating from livestock manure, domestic bird manure, and organic waste from cereal, vegetable and other crops, we would produce more than 2.2 x 10^18 Joules pa of methane. City garbage treatment is also a proposition. Taking Melbourne as an example, the equivalent of 4% of the Gas and Fuel Corporation of Victoria sales could be obtained from recyclable material and carbon dioxide. The energy gain is approximately 2.6 to 1 if the system is self-contained. If the garbage system can be sited in conjunction with a power station such as Newport so that waste heat can be utilized, an energy gain of approximately 30 to 1 becomes possible. Work is being done on optimization of two stage digestors. Based on this, work models with a capacity of from 50Kg to 1000 tonnes per day are being studied and designed. The end result of this work could make the Australian farming community and rural residences independent of the world oil situation and present power utilities. There is also hope that some of this work will be implemented in the urban sector.
New Chief for CSIRO's Textile Physics Division

A leading Australian wool textile scientist, Mr. Robert Haly, has been appointed Chief of CSIRO's Division of Textile Physics at Ryde, NSW. He joined CSIRO's former Wool Textile Research Laboratory in 1951 as a technical officer, became a research officer six years later, and was appointed as a Senior Principal Research Scientist in 1970. Scientists at his Division are working on many aspects of one of Australia's major exports — wool. They have developed the objective measurement techniques now used in wool marketing and testing and are continuing studies of other techniques to aid marketing and manufacturing.

Success For Woman Physicist

Ms Kristine Graham, a graduate in Science from the University of Queensland with first class honours in physics was awarded a Zonta International Fellowship, in 1973, for research in Ionospheric Physics. She worked under Professor Feyer, University of California and was awarded a Doctorate of Philosophy in April this year. University News, Queensland, November 75, September 1976.

The Personalized System of Instruction (PSI)

American physicist, Professor Donald DeGraaf of the Department of Physics and Astronomy, University of Michigan at Flint, Michigan, recently completed a six months research visit to Murdoch University. Since 1966, Professor DeGraaf has been developing study guides in physics which allow an undergraduate to study in the style and pace best suited to his individual needs.

The PSI system is said to offer substantial benefits for students who welcome individualised opportunities for study and who desire continual assurance that they are making satisfactory progress in their course. The system has developed from the work of the psychologist Keller.

The Flint Introductory Physics Sequence Curriculum Project, University of Michigan — Flint, Flint, Michigan 48303, USA, distributes the study guides to other teachers of physics. Gazette, Volume 9, Number 3, August 1976.

Ian Clunies Ross Memorial Foundation — Two Appointments

Mr. Harold Melouney has been appointed Executive Officer of the Ian Clunies Ross Memorial Foundation. He was until his early retirement in June, General Manager and Director of Mary Kathleen Uranium Ltd. He had previously held various executive positions with CRA.

Mr. Melouney is a fellow of the Royal Australian Chemical Institute, Australasian Institute of Mining and Metallurgy and the Institution of Chemical Engineers.

Mr. Raymond Archer has been appointed as from 17th August 1976, Administrative Officer of the Ian Clunies Ross Memorial Foundation.

He has had a wide range of experience during his 22 years service with the Broken Hill Proprietary Company Limited and has held various senior positions within the Company at Port Kembla, NSW, Cockatoo Island, WA, and most recently at Head Office Melbourne.

USSR Lecture Tour

Professor K. D. Cole, Head of the Division of Theoretical and Space Physics and Chairman of the Department of Physics, La Trobe University, has been invited by the Institute of Physics of the Earth of the Academy of Science of USSR to lecture in USSR on his recent research in the area of solar-terrestrial physics. Professor Cole will be the guest of the Academy for fourteen days in December 1976. He will lecture on the interaction of the earth with the interplanetary medium, electromagnetics of the ionosphere and sun-weather relationships.

Zonta International Grants

Zonta International Grants valued at $4000 — these will be made available to women for graduate work in aerospace related science and engineering. A first degree is required together with evidence of exceptional ability and potential. The closing date for application is 1 January, 1977. University News, Queensland, Number 75, September 1976.

The Cadmium Content of Rural Tank Water in Western Australia

A stable isotope dilution technique has been used by de Laeter, Ware, Taylor and Rosman of WAIT to measure the cadmium content in rural drinking water tanks in WA. Cadmium present due to its presence in the zinc used for galvanizing the tanks. A level of 3.6 ppb was the highest recorded which is certainly below that of a maximum of 10 ppb in drinking water recommended by the World Health Organization. When water was obtained from newer tanks, much lower results were found, indicating that at least this respect, drinking tank water is quite safe. Search, Vol. 7, Number 10, 1976.

Frontiers of Theoretical Physics

The Indian National Science Academy is organizing an international conference on "Frontiers of Theoretical Physics" to be held in New Delhi on 6-12 January, 1977. The conference will be followed by a winter school for ten days in which a series of lectures by distinguished physicists will be given in the fields of statistical physics and high energy physics. Further information can be obtained from: Professor F. C. Auluck, Department of Physics and Astrophysics, University of Delhi, Delhi 110007, India.

Infrared Technology

A conference on Industrial and Civil Applications of Infrared Technology will be held in London, March 15-16, 1977. Further information can be obtained from: G. B. Dunn, Sira Institute Ltd., South Hill, Chislehurst, Kent BR7 5EH.

Computer Learning

A symposium on computer assisted learning in the biological, medical and physical sciences and engineering is to be held on 30 March - 1 April 1977, at the University of Surrey. Further details may be obtained from: K. R. Knight, Department of Physics, University of Surrey, Guildford, Surrey.
AUSTRALIAN INSTITUTE OF PHYSICS
SOLID STATE PHYSICS MEETING – WAGGA WAGGA, 9-11 FEBRUARY 1977

A residential solid state physics meeting will be held at the Riverina Agricultural College, Wagga Wagga, NSW, from Wednesday, 9th February to Friday, 11th February 1977. The meeting is being sponsored by the Council of the Institute with assistance from the CSIRO National Measurement Laboratory, Sydney.

General
This is an opportunity for solid state physicists to get together in the informal atmosphere of a residential college to discuss their research work and facilities.

The meeting will include:
(a) invited review papers on selected fields of work
(b) invited reviews on programmes and facilities at major centres of solid state research in Australia
(c) contributed papers and research reports.

The meeting will cover a wide range of topics including magnetic, thermal, transport, resonance, optical, mechanical and structural properties of solids. (It should be noted that the topics Defects, Channeling and Ion Implantation will be included in the programme of the Nuclear and Particle Physics Summer School at Jindabyne, 7th to 11th February 1977).

Contributed papers (15 minutes) may cover completed work, progress reports on incomplete or controversial topics, or even “cries for help”. There will be no parallel sessions; this may necessitate the use of “verbal abstracts” or “poster sessions”.

Dates and Times
Applications to attend close on Monday, 13th December 1976.
Abstracts of contributed papers must be submitted by Monday, 10th January 1977.
Conference registration commences on the evening of Tuesday, 9th February 1977.
Conference sessions commence at 9 a.m. Wednesday, 9th February 1977.
Conference ends at midday Friday, 11th February 1977.

Annual General Meeting of the Institute
The Annual General Meeting of the AIP will be held in conjunction with the meeting (the exact date and time is still to be decided).

Costs
The cost (including board, meals and teas) will be $15-$18 per day. Student members of the Australian Institute of Physics may apply to the Hon. Secretary of their local Branch for financial assistance to attend this meeting.

Registration Fee
There will be no registration fee.

Information and Application Forms
These may be obtained from the conference secretary—
Dr R. K. Day,
CSIRO National Measurement Laboratory,
University Grounds,
CHIPPENDALE, NSW, 2008. [Telephone (02) 660 0566].

IOP Elections
Honorary Officers and Members of Council
The following Honorary Officers and Members of Council of The Institute of Physics took office on 1 October 1976:

President – Dr B. J. Mason FInstP FRS
(Meteorological Office, Bracknell)
Vice President – Dr G. H. Stafford FInstP
(Rutherford Laboratory, Chilton)
Honorary Treasurer – Dr H. Rose FInstP (re-elected)
Honorary Secretary – Professor E. R. Dobbs FInstP
(Bedford College, University of London)
Ordinary Members of Council – Professor K. Hesselitz FInstP (Mullard Research Laboratories, Redhill)
Dr E. R. Pike FInstP (RSRE, Malvern)

The 2nd International Conference on the Nucleon-Nucleon Interaction will be held at the University of British Columbia, Vancouver, Canada from 27-30 June 1977. Nuclear and particle physics aspects will be included. Further information from D. F. Mead, Physics Department, University of British Columbia, Vancouver, BC, Canada, V6T 1W5.
Subscription Equalization

From time to time there have been suggestions that the subscription for all corporate members be the same with perhaps some differential based on age. Such proposals have not met with much enthusiasm, mainly because it was felt that there should be some additional payment for the status accorded by a higher grade; this opinion has gained some support from those who wish to promote the formal legal recognition of grades for the purposes of establishing status and pay rates in the community at large.

There have also been suggestions that the present set of membership grades is cumbersome and that it should be replaced by something simpler. These proposals too have not met with much support mainly because of the existing subscription structure.

I believe that these matters of subscription structure, multiplicity of membership grades, and their possible legal recognition should be considered together. In order to initiate the debate on these matters I propose below a tentative scheme of subscription equalization spread over a number of years.

A sample survey of the corporate membership suggests that there are roughly equal numbers of members above and below the age of 35 years and this has been taken as the break point for a differential rate. The effective numbers of members used are roughly correct and have been rounded so as to keep the calculations simple. While this affects the magnitude of the total subscription it has little effect on the relative magnitudes which increase by about 10%. The basic idea is that a Fellows subscription should remain fixed at about $55 and members under 35 at $35. Other subscriptions are increased by $5 each year until under 35 graduates reach $35 and members over 35 reach $55 in 1981. I do not believe that Graduates over 35 should get away with reduced subscriptions and so their rate has been set equal to that for members over 35.

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J. K. MACKENZIE
Honorary Treasurer

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conferences, Australian meetings, Institute Affairs, etc. They
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Deadline—1st of month prior to month of issue.

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authors such as covers, special headings, etc.
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- Power Output Variation: <2% /°C
- Storage Temperature: Range -40°C to 90°C
- Humidity: 95% Relative Operating
- Power Requirements: 115VAC (10%) 160W, 50-400 Hertz
- 220VAC (10%) 160W, 50-400 Hertz
- 12VDC

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