SOLAR POWER

MAKES FOR A QUIET LIFE . . . SAYS JOHN CAMPBELL

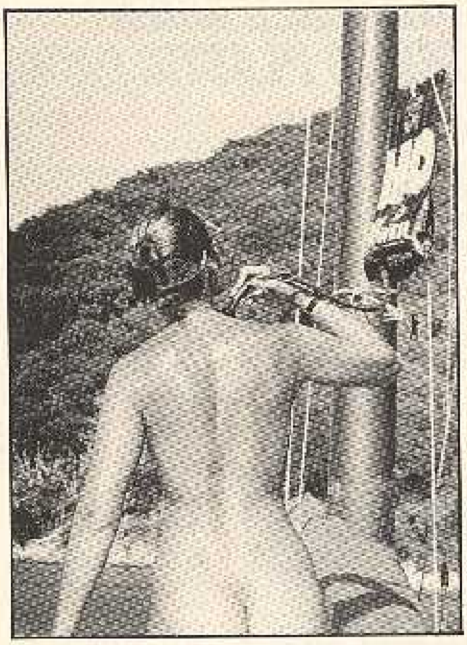
I AM SURE most people have left a bucket of water in the sun to warm at some time, ready for washing themselves or the dishes. Recently a variation on this theme has been marketed from California called the Sun Shower. It is simply a plastic bag, one side black, one side clear, with a spout at the bottom. The bag is filled with about two gallons of water, and laid in the sun, black side down. The black absorbs the sun's heat and, in a surprisingly short time, warms the water. It can then be hung in the rigging to provide a hot shower, or the water can be used for other washing purposes. (Because of the toxicity of the plastic,however, the water should not be used for drinking.)

What has caught the imagination of the boating fraternity more than the use of solar *heat* though, in recent years, is the use of solar *light* — which can be quite easily converted into electrical energy and stored in a battery. It is almost ironic, really, that most of this stored energy is then turned back into light energy — either to illuminate the cabin or power the navigation lights.

Something that turns light into electrical energy is termed a photovoltaic cell. Such cells can work in various ways and can take many forms. They can be tiny enough to fit inside the light meter of a camera, or they can be arranged as rows of discs in panels, which are becoming especially prevalent on short-handed, long distance racing boats.

The black discs are actually very thin slices of silicon. Purified sand is heated to a very high temperature until it is molten, and a single crystal of nearly pure silicon is grown from the molton mixture. A little impurity is added as the crystal forms to enable it to conduct negatively-charged electrons in the finished cell.

The crystal is cut to the desired shape and sliced into the thin discs that form the cells. Now part of the wafer is



treated to enable it to carry positive charges — which, strange as it may seem, are called holes. This is usually done by subjecting one surface of the crystal slice to Boron gas at very high temperature.

The layer that can carry electrons is termed the *n* (for negative) layer, and the one which can carry the positively charged holes the *p* (for positive) layer. The manufacturing process varies, and in some the *n* layer will be over the *p* layer, while in other the *p* layer will be on top. However, the manner in which the cells work is similar in all cases. The secret lies in the junction between the two layers — the *p/n* junction.

Sunlight, for our purposes, consists of a stream of photons being emitted by the sun. When a photon reaches the *p/n* junction, it can separate into its constituent hole and electron. The hole, being positively charged, migrates to the *p* layer.

The movement of these electrons and holes results in the *p* layer becoming positively charged in relation to the *n* layer. Whenever there is a voltage difference, an electric current will try to flow. If a wire is connected to each layer, a curent will flow in that wire, and can do work so long as there is a stream of photons reaching the *p/n* junction to maintain the voltage difference.

For the photons to reach the *p/n* junction, the cell must be very thin. The contacts on the top layer must not obscure too much of the surface from the approaching photons, yet the cells work best when the electrons or holes have a short distance to travel. The contact for the top layer is usually composed of a network of metallic strands spread over the surface to collect the charge, and conduct it to a heavier contact.

All cells of this general type will generate a voltage of about .45 volts. To obtain a higher voltage, a number of cells can be arranged in series. For effective charging of a lead-acid battery of nominally 12 volts, a voltage of around 16 volts is best. Most solar panels designed for charging a 12 volt battery consist of 35 or 36 cells in series to potentially give around 16 volts when operating.

The current generated by a cell is largely dependent upon the number of photons reaching the *p/n* junction. For a cell of a given thickness, in constant sunlight, the number of photons reaching the *p/n* junction will be proportional to the surface area of the cell. With the present generation of photovoltaic cells, a cell of 100mm diameter (78.54cm² surface area) should be able to give up to about 2¼ amps in good bright sunlight. A cell of half the diameter (50mm) has a quarter of the surface area (19.633cm²) and so will generate just a little over half an amp.

From this we can see that a panel of 35 or 36 cells in series, 100mm in diameter, should be capable of giving about 2¼ amps of current at around 15 or 16 volts. The expected output of smaller cells are calculated pro-rata, 75mm cells giving about 1¼ amps, and as we have seen, 50mm cells a little over half an amp. These figures are about the best we can expect in bright sunlight shining directly onto the panel. Claims for higher outputs with cells of this type would be misleading.

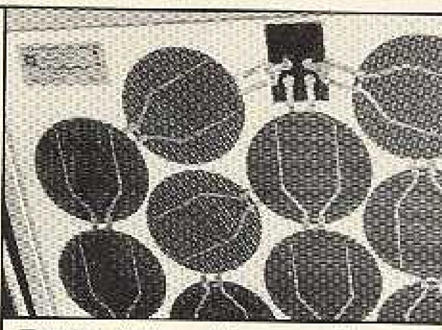
If a higher voltage is required, then more cells must be connected in series. For 24 volts it is usual to connect two 12 volt panels in series, to give in effect 70 or 72 cells in series. If more current is required, either bigger cells must be used, or two or more panels giving the required voltage must be used in parallel. By varying the number and arrangement of panels, any voltage and virtually any current can be produced, cost and space usually being the limiting factors.

For our own use on board, *Papilio Ruĝa*, we have a single panel of 36 cells, 100mm in diameter. It is 44" x 17", and weighs about 20 pounds. In bright direct sunlight it produces over 2 amps into a 12 volt lead-acid battery of 100 amp hours. In the tropics this averages out to around 20 ampere hours per day. (This is equivalent to the battery receiving a charge of 20 amps from an engine-driven alternator for an hour.) This is plenty for our needs. We live on the boat, use cabin lights without trying to conserve, run a cassette player and radio off the ship's battery, electric fan in the galley, and make moderate use of the VHF. At the time of writing, the panel is the sole means of charging the battery, and has proved entirely adequate.

These panels work best if they are cool. Their efficiency falls off rapidly as the temperature rises. If a panel is to be placed in a vulnerable position, and it is desired to cover it with a sheet of Lexan or similar, then it is of paramount importance to leave adequate ventilation for the panel. The greenhouse effect of a closely fitting sheet of Lexan will at best reduce the efficiency of the panel, but extremely high temperatures could destroy the panel completely. Some panels designed for boats have a finned heat sink built into the back. This will help cool the panel provided there is a flow of air over it. In any event, it is better to allow air to flow freely over both sides to help cool it.

What does one look for when choosing a panel? There are two major considerations — output and durability. Output we have already discussed, so what constitutes a durable panel? Discounting accidental mechanical damage, there appear to be two main causes of failure.

The most common failure we have seen has been a cracking of the cells. If cells crack, the output will be reduced perhaps to zero. Each panel we have seen with cracked cells, excluding those suffering mechanical damage, share one common characteristic. The panel has not had a glass face. These panels are made by taking a metal or plastic tray and laying the cells onto a layer of liquid silicone rubber. The cells are then covered with a further layer of silicone rubber, and in some cases with a further layer of a harder resin. At first glance, this would look perfect for a marine environment. However, and here we have to speculate a little, what appears to happen is that air bubbles get trapped beneath the cells. These air bubbles expand in the heat of the sun and eventually the cell cracks.

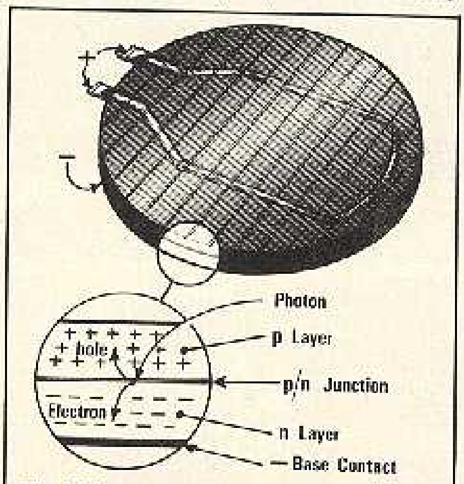


Further information regarding cost and dealer locations can be obtained from:
Solar Power Limited, 220 Grand Buildings, Trafalgar Square, London WC2N 5HB, England. Telex: 21221. Telephone: 01-930 0873/4

A glass-covered panel can be built rather differently. Our panel, built by Solar Power Corporation, was assembled 'dry', without any sealant. A vacuum pump then draws all the air out from between the glass and the bottom of the panel. Once the air is removed, the silicone sealant is drawn in by the vacuum, reducing the risk of air bubbles being trapped. So far we have not ourselves seen a panel of this type fail.

The second source of problems is a break occurring in the chain of cells. It only takes a break in contact between two cells to shut the whole panel down. On our panel there are double interconnects between each cell, which supposedly halves the chance of a break occurring.

We have seen panels with such a break successfully repaired. On many panels it is possible to either push a pin in through the back of the panel, or to drill a little hole so contact can be made with the conductor between cells. A voltmeter can be used to isolate the break, by placing one probe on the cell at one end of the series and moving the other probe from cell to cell. Provided light is falling on the panel, a voltage will show, increasing as the number of cells between the probes increase. The break will be found when the voltmeter shows no reading.



The 'p' layer carries positive charges called 'holes', the 'n' layer negative charges, or 'electrons'. Sunlight, consisting of a stream of photons, reaches the p/n junction and each photon separates into its constituent hole and electron. The migration of these to their appropriate layers creates a voltage difference between layers and thereby an electric current.

By cutting into the panel, often easiest through the back, it should be possible to re-solder the connection. All the holes must then be well re-sealed to keep moisture out. This sort of repair should be done as a last ditch effort, on a panel whose warranty has expired, and when every other part of the system has been tested.

Some panels come equipped with a blocking diode. The theory here is that when the panel is generating, the current can flow into the battery. When there is not enough light for the panel to generate, the diode will prevent current flowing back to the panel to be radiated. In practice, we have found that our panel operated better without a diode. Using a diode, there is a significant voltage drop across the diode which reduces the charging efficiency of the panel. Our panel only uses 12 milliamps when it is radiating at night. It can radiate for 8½ hours of total darkness, and only take 1/10 of an ampere hour from the battery. We felt, using a diode, that the losses were greater than 1/10 ampere hour in charging current.

I have already stated that our panel can give about 2¼ amps under optimum conditions. Light cloud or haze reduce the output by around a half. Heavy overcast or open shadow cut it again in half, to give about ½ amp output. Complete shadow reduces the output to milliamps. Now, Catch 22 is that the light density controlling the output of a series of cells, appears to be the light falling on the darkest cell. In other words, one cell in complete shadow will, to all intents and purposes, shut down the panel. Indeed, the shadow of a rope falling across just part of one cell will drastically reduce the output. A point to bear in mind.

What does the future hold? It is generally accepted that the type of cells we have discussed are running at around 10% efficiency. A second generation of cells is being developed right now which will perhaps become twice as efficient. Ways have recently been discovered to make cells from molten silicon of a multi-crystal matrix. If the costly crystal growing stage can be eliminated, manufacturing costs could come down. Meanwhile, it is so nice to have unlimited cabin lights, without ever having a generator shatter the peace of an idyllic anchorage. I wish the yacht sharing our anchorage was also solar powered! ●