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## UTILISATION OF SOLAR ENERGY

AS our resources of fossil fuel are being rapidly exhausted, the search for other sources of energy has become an important problem in recent years. Among the new sources, atomic energy and solar energy appear to be the most promising. Thanks to the rapid developments which took place during the last war, many of the problems connected with the practical utilisation of atomic energy have been solved during the last few years. It appears that even the energy of thermonuclear reactions may be regulated and made use of. An interesting article on this appears elsewhere in this journal.

With the object of encouraging and accelerating the pace of solar energy research, the University of Arizona and Stanford Research Institute sponsored the First World Symposium on Applied Solar Energy and the associated Conference on Solar Energy a few months ago. A fairly extensive report has appeared in *Science* (1956, 123, 826).

The World Symposium was attended by nearly a thousand scientists and engineers from thirty-two nations, and a permanent International Association for Applied Solar Energy has been organised. The first issue of the Association's news letter, *The Sun at Work*, has appeared in March while it is also planned to issue a *Journal of Solar Energy Research*, to report advances in solar sciences and engineering. The subjects of the papers at both meetings covered a wide range such as solar energy measurements, increasing the world's supply of energy (mechanical, electric and chemical) and increasing the world's supply of food (for both animal and human consumption).

### CONVERSION OF SOLAR ENERGY

Although many radiation-measuring stations exist in many countries, it is apparent that data about insolation are not readily available for large areas. The problems considered in the World Symposium included the type of

additional information that is most needed—the degree of measurement accuracy that is sufficient for most uses and the instruments that are required to perform these measurements correctly and simply enough to permit their widespread use throughout the world.

The conversion of solar energy into mechanical, electric, or even chemical energy was the main problem that engaged the attention of nearly everyone at the symposium. Physicists, physical chemists, engineers, and economists attacked the problem according to their own disciplines, and the industrialists and businessmen who had joined them attempted to evaluate and correlate the various approaches. The conversion processes considered were: (i) thermal conversion processes; (ii) electrical conversion processes, and (iii) photochemical processes.

#### THERMAL CONVERSION PROCESSES

In the solar energy field there are two schools of thought devoted respectively to the so-called flat-plate collectors and concentrators. The flat-plate collectors make use of the hot-house effect, absorbing the radiation on a dark surface and inhibiting reradiation loss by appropriate insulation and usually one or more parts of glass cover plates. So far, this has been used in hot-water installations, space-heating installations, and in mechanical pumps. The types of installations built in England, Japan and Israel were described during the Conference. These consist usually of a flat-plate collector (area from 30 to 60 square feet, depending on climate and consumption) connected to an insulated storage tank (50 to 100 gallons) that is located about 2 feet above the collector to permit thermosiphon flow of the heated water. These installations were described as economical and efficient. It appears that solar collectors with auxiliary conventional heat sources can supply all space-heating requirements of dwellings with adequate roof area in regions with average or better-than-average climates.

Another interesting use of flat-plate collectors is in mechanical pumps. The hundreds of Arizona farmers who visited the solar exhibit in Phoenix observed a simple Italian solar pump in action. Such was their interest that 50 of these pumps, manufactured by the Somor Company in Lecco, Italy, could have been sold on the spot if they had been available. This pump utilizes an ordinary flat-plate collector to vaporize sulfur dioxide which drives a sim-

ple, one-cylinder motor that is cooled by the pumped water. The pump converts solar energy into mechanical energy at about 4% efficiency.

In his paper on the "Economics of Solar Energy", J. Hobson estimated the cost of solar power to be, in optimum circumstances, between 4 and 8 annas per kilowatt hour. This figure reflects the high initial price of these devices and the low load factor under which they must operate with intermittent solar energy. However, even this is not expensive power where other fuels are not available and where man must depend on animal power or even his own power for his daily bread.

It may be possible to reduce the cost of flat-plate collectors appreciably in the near future, by using selective surfaces to obtain substantially high temperatures, than at present. These would strongly absorb the visible spectrum of sun's radiation, but at the same time emit very little of heat.

The term 'concentrator' is used to denote installations in which solar energy is concentrated in a small area by means of suitable reflectors. They have been used in many different ways. Small parabolic reflectors with an area of about one square metre have been shaped into solar cookers; large accurate parabolic reflectors are used as solar furnaces; cylindro-parabolic collectors have been used in steam-boiler installations, and finally, arrays of flat mirrors aimed at a single target can be used for many purposes.

Depending on the concentration ratio, temperatures can be reached all the way up to 3,500° C. If reasonable efficiencies are desired, it can be shown that flat-plate collectors are best used for temperatures up to 70° C. or 80° C., selective surface collectors up to 175° C., and concentrators from 100° C. to 3,500° C. The main disadvantage of concentrators is that the collector or an auxiliary mirror must track the sun, and the mechanism that is required to do this is usually expensive.

Much interest was shown in solar furnaces at the symposium. F. Trombe of the French National Centre for Scientific Research, reported on the work at the Mont Louis Laboratory in the Pyrenees, where a 35-foot furnace—the largest in the world—has been in operation for several years. There is no doubt that the solar furnace is a well-established high temperature research tool that permits operation free from contamination by flames, magnetic fields, and the like, at temperatures as high as 3,000° C. to 3,500° C. The French Centre also announced



that construction was beginning on a 1,000-kilowatt furnace (10 times larger than the one at Mont Louis) to be located in the Pyrenees not far from existing installations. This furnace will be used for the production of ceramic and metallurgical materials.

The most interesting report on steam generation was prepared by V. A. Baum of the heliotechnical laboratory of the U.S.S.R. Academy of Science. In his paper, Baum described the plans for a centralized 1,000-kilowatt solar power plant now on the drafting boards of his laboratory. This plant will be able to generate steam at 350° C. and 16 atmospheres pressure. It would consist of a central black body boiler on a 40-metre tower at the focus of 23 concentric rail-road tracks on which rail-road cars with flat mirrors would focus the sun's rays to the unique target. The mirrors would follow the apparent path of the sun by travelling during the day around the track. The target would also rotate slowly during the day to follow the sun. This plant would then produce steam for electric power generation and use low pressure steam to heat homes in winter and to cool them in summer with a refrigeration unit.

Interesting work with concentrators has also been done in India by K. N. Mathur and K. L. Khanna at the National Physical Laboratory, and by A. L. Gardner of the INSDOC. This centred mostly round hot-air engines, and Gardner has developed very simple and cheap concentrators consisting of arrays of flat mirrors aimed at a single target. Mention must also be made of the pioneering work in U.S.A. of Charles Abbott of the Smithsonian Institution, who has built, and is still building, small solar engines with specially designed flash boilers to permit rapid steam generation.

#### ELECTRIC CONVERSION PROCESSES

Much attention was devoted at the symposium to recent developments with photovoltaic cells for converting sunlight directly into electric energy. The Bell Telephone Laboratories have developed a converter which consists essentially of a silicon crystal with a small amount of arsenic impurity covered with a very thin layer of boron impurities (about  $10^{-4}$  in. deep). The crystal so prepared is about 1 in. in diameter and 0.04 in. thick. A number of such small crystals or wafers may be connected in series and assembled on a common backing; they convert solar energy into electricity at convenient direct-current voltages. These

cells are now being tested in operating telephone repeaters near Americus, Ga. A conversion efficiency of about 10% has been achieved.

A whole session of the symposium was devoted to thermocouples and thermoelectric generators. T. Momota (Tokyo) reported experiments with reduced titanium dioxide semiconductors in which efficiencies slightly in excess of 1% at 550° K. were obtained. From his results, he predicted that lead telluride might permit efficiencies as high as 16%. Further research in this field may ultimately yield a much cheaper collecting surface with, perhaps, lower efficiencies than the silicon converter mentioned above.

One paper by K. M. Sancier of Stanford Research Institute described the various types of photo-galvanic cells that have been known for years. His experience with certain of these cells indicated a conversion efficiency not far different from those attainable with thermocouples. It appears that further research in this field may prove profitable.

#### PHOTOCHEMICAL CONVERSION PROCESSES

Probably one of the two most promising attempts at converting solar energy to power is through the production of hydrogen by the photochemical breakdown of water under exposure to sunlight. Various organic and inorganic photocatalysts that will absorb sunlight and transmit the absorbed energy to a second reactant that will initiate the decomposition of water are used in most reactions. In the decomposition reaction, the photocatalyst and all other reagents are regenerated so that only water is consumed. From the papers presented it emerges that it is still too early to know whether such experiments will be completely successful; but if they are fairly high maximum efficiencies of the order of 30% to 40% could be expected.

#### INCREASING THE WORLD'S FOOD SUPPLY

The interest of the biologists and engineers centred round the problems of (i) increasing the world supply of fresh-water with solar stills to convert saline or brackish waters into fresh-water for domestic or agricultural uses, (ii) finding more efficient plant cultures to increase the world supply of food directly, and (iii) increasing the rate of growth of certain crops by using reflectors or other auxiliary heat collectors.



New developments in the field of solar stills were reported by American and Algerian researchers. They indicate that although solar stills cannot produce fresh-water at prices acceptable to large-scale consumers such as farms and large cities, there is no doubt that small stills can provide drinking water at reasonable prices in areas where none is available.

One of the most efficient plant cultures that has received considerable study in recent years is the algæ, *Chlorella*. Many papers were therefore devoted to its characteristics. While no one exactly agrees on the energy conversion efficiency of *Chlorella*, it appears that under favourable conditions, *Chlorella* will do better than most higher plants. *Chlorella* therefore may provide a technique for increasing the world's food supply and possibly even for producing fuels for use in conventional boilers. Unfortunately, to date no strain of *Chlorella* has been found that will grow profusely without somewhat complicated and costly equipment.

Papers by N W Pirie (Harpenden, England) and P. C Mangelsdorf (Harvard University) stressed the merits of higher plants as storers of solar energy. Their contention was that if as much time, attention, and care were devoted

to certain higher plants as have been devoted to *Chlorella*, there is little doubt that increased growth efficiencies close to those demonstrated by some *Chlorella* strains would be obtained. Mangelsdorf pointed out that of approximately one-third million species of plants in the world, the world's people obtain the larger proportion of their food from approximately 12 species (potatoes, sweet potatoes, cassava, cane, beets, rice, wheat, corn, soya beans, common beans, coconuts, and banana). The various types of plants mentioned (root plants, sugar plants, grains, beans, and trees) appeared to him a promising field for the study of hybridization.

It is probable that in the years to come the emphasis of research will be directed toward attempts at modifying the genetics of higher plants to increase, among other things, their protein productivity.

The symposium revealed that there are immense possibilities in the utilisation of solar energy, provided suitable converters are evolved. It also brought out the fact that the fundamental aspects of the techniques or such a conversion have been fairly well studied and that a concerted effort should now be made by scientists, engineers and industrialists to carry out research into the practical application of these methods.

### DIAMOND AS A PINPOINT RADIATION COUNTER

SINCE van Heerden reported that silver chloride at low temperature would detect  $\beta$ -particles, several other crystals have been found which possess this property, and diamond is one of the most useful of them. Cotty (*Nature*, 1956, 177, 1075) has observed that certain types of diamond will act as ideal radiation counters at room temperature for  $\alpha$ - and  $\beta$ -sources usually used in the laboratory, and are as efficient as the Geiger counter.

Diamond has physical and chemical properties which makes it an attractive material for use in a practical counter. Physically, its density is such that diamond has a stopping power nearly three thousand times greater than that of air, and electronically, the density (and the  $\gamma$ -ray absorption) of carbon is of the same order as that of human tissue. Thus a high-speed particle would penetrate both diamond and tissue to about the same degree. Consequently, if the diamond counter were to be used to measure the dose-rate on patients receiving deep therapy or similar

treatment, one would expect to get more accurate measurements than could be obtained with more conventional instruments. Furthermore, because of its chemical composition, diamond can be autoclaved and sterilized satisfactorily for use internally.

The only drawback against the use of every diamond for the purpose appears to be polarization due to space charges built up inside which oppose the externally applied field and reduces its counting efficiency. This is due to current carriers being captured by the trapping sites in the crystal. But Cotty has been able to sort 100,000 diamonds (by ultraviolet fluorescence tests), which are electronically perfect enough not to be seriously affected by polarization. These diamonds, it is claimed, make really efficient counters and maintain a reasonably steady counting rate for periods of several hours, perhaps indefinitely. Such diamonds have been in use for the past five years and hold out possibilities of ultimately being developed into a useful pinpoint counter suitable for specialised—probably medical applications.