for the solar houses erected near Washington, D. C., by Harry Thomason.

Interest in solar-activated absorption refrigeration continues at the University of Florida, as illustrated by Fig. 6, which shows the collector-generator used by G. L. Moore and E. A. Farber at the University of Florida Solar Energy Laboratory near Gainesville. Unfortunately, only limited financial support is available for work of this type, and so the results have been correspondingly meager.

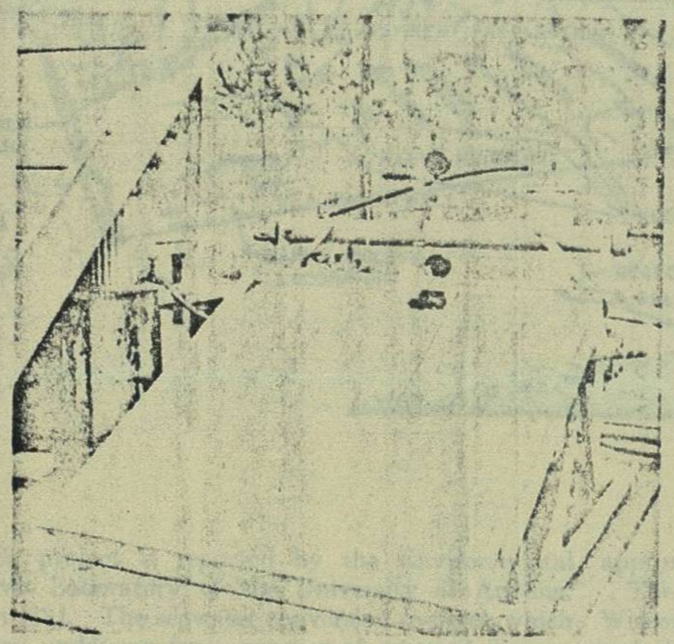

Fig. 6 Collector-generator used with solar refrigeration system at the University of Florida's Solar Energy Laboratory in Gainesville (photo courtesy of Dr. Gordon Moore).

Solar Power

As the need for larger power sources becomes apparent in the space program, interest has turned again to fluid cycles which can receive their heat from large solar concentrators and reject the heat which they cannot use to outer space by radiation. NASA is currently testing a closed-loop Brayton cycle [28] which uses a mixture of inert gases (helium and xenon) as the working fluid, with a high-effectiveness regenerator to transfer a large portion of the exhaust heat into the compressed gas. A 10-kw power plant using this system would be expected to weigh 3500 to 4000 lb, which is well within the capability of today's boosters. For energy storage when the spacecraft is in the dark, lithium fluoride would be used. For planetary probes traveling away from the sun, an isotope heat source is proposed. The closed-loop Brayton system is also though to be suitable for use under water and in remote Arctic regions.

For use in the much more distant future, Dr. Peter Glaser has proposed a novel space system in which two satellites, orbiting the earth in an east-west direction at an altitude of 22,300 miles would continuously convert solar radiation into electrical power and transmit this back by microwaves to receivers on the earth. For this purpose the solar concentrator would be approximately four miles in diameter, and a two-mile-wide antenna would be required on the earth [29].

In his paper Dr. Glaser gives forecasts of the energy requirements of the world for the year 2000, and he notes that these will strain the capacity of all of the conventional energy sources, as well as the nuclear power which is likely to be replacing fossil fuels.

Heat Transfer

No new developments in fundamental heat storage technology are reported, but ingenious new applications of well-known materials continue to be developed. Dr. Maria Telkes reports [30] the development of temperature-control systems for use in the long-range weather forecasting balloons which will be employed in the Worldwide Weather Watch. The balloons will circle the earth at 30,000 ft or higher for periods up to six months, and they will have an electronic communication system powered by solar cells and a storage battery. The information which they obtain will be transmitted to a satellite circumnavigating the earth nearly 16 times per day. Some thousands of such balloon stations will be in use continuously. At the altitude at which the balloons will travel, temperatures will range from −30 C in the sun to −60 C at night. The electric power output of the nickel-cadmium batteries in the power system will drop to zero at such low temperatures, and so the radiation from the sun must be used to warm the batteries.

The difficult problem of keeping the daytime temperature of the battery below 80 F, while the nighttime temperature remains above −8 F, was solved by using one of Dr. Telkes' heat storage materials, which has its melting point at −8 F and, during the daytime, can absorb enough solar heat to keep the battery temperature below the 80 F limit. To minimize heat loss by radiation at night, the battery tubes are surrounded by a spiral shield containing eight layers of Teflon FEP type-A film. The transmittance of this heat shield for solar radiation is nearly 0.70, as compared with 0.50 for eight layers of clear window glass, and 0.35 for eight films of 0.005-in. Mylar.

Since the balloons will travel at the altitude which is currently used by jet aircraft, they must be extremely fragile so that they will not damage aircraft windows or engines. The combination developed by Dr. Telkes is reported to meet that requirement, as well as the very stringent temperature limitations demanded by its components.

Basic Developments

No radically new solar developments have been reported in the past several years, but significant studies have been made of earlier discoveries. The honeycomb heat absorbers first proposed by Francia [31] have been subjected to intensive analysis with encouraging results. It has been found [32] that cellular structures, particularly of elongated rectangular shape, can perform three useful functions: (1) Suppress natural convection and thus form good insulators, (2) transmit thermal radiation which is directed down the axis of the cell, and (3) block much of the radiation which is emitted from the heated surface.

A significant change in direction of a major solar

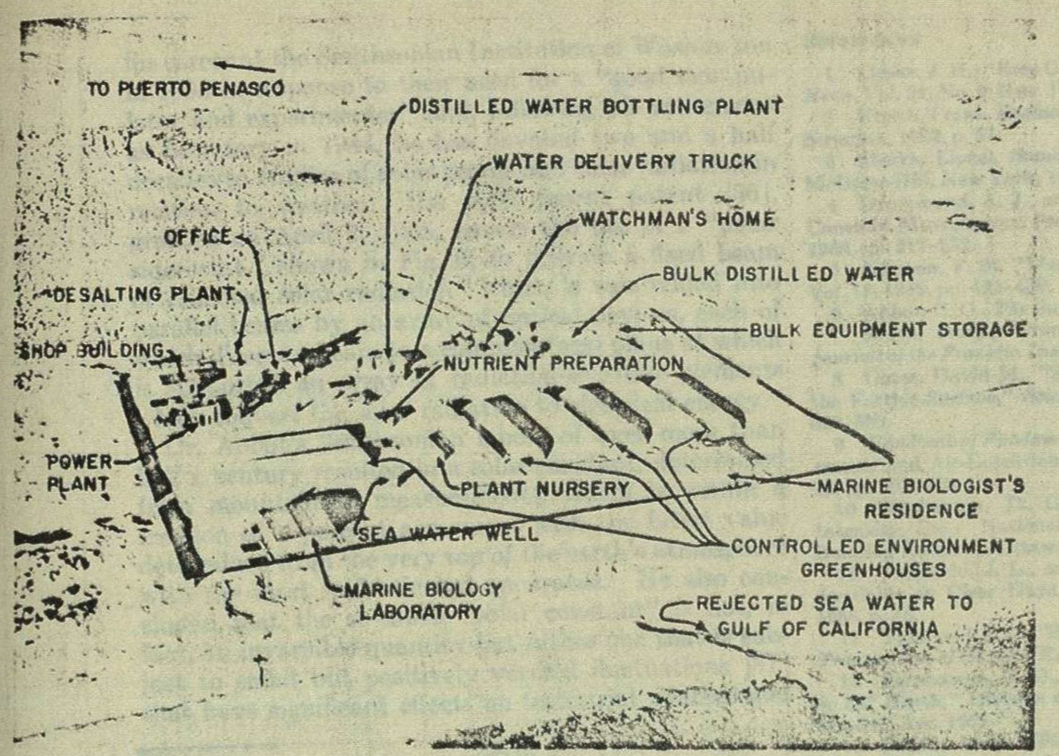

Fig. 7 Integrated plant at Puerto Peñasco, Mexico, produces fresh water, vegetables, and power, using seawater, solar radiation, and a diesel engine (University of Arizona photo).

research project is reported by the Environmental Research Laboratory of the University of Arizona, Tucson [33]. The seawater conversion research which has been underway for a number of years at Tucson and Puerto Penasco, Mexico, has been turned to a study of the growth of vegetables within controlled-environment greenhouses made of air-inflated plastic, Fig. 7. The sun's radiation makes the vegetables grow and energizes the solar distillation process by which the water which is transpired by the plants is condensed on the under surfaces of the greenhouse cover to be returned to the plant roots. Much of the heat required to produce fresh water from the available ocean water comes from the Diesel engine which is required to pump the seawater. In addition, the exhaust gases from the engine, after being cleaned in seawater scrubbers, can be used to enrich the atmosphere within the structures with carbon dioxide, thus greatly accelerating growth of the plants inside.

This program, under the direction of C. N. Hodges and sponsored by the Rockefeller Foundation, gives promise of producing both food and water for isolated desert areas where the only present water supplies are either brackish or saline. A large installation is now being planned for erection at Abu Dhabi, a Trucial State on the Arabian Peninsula, 500 miles southeast of Kuwait. A grant of $3.16 million has been made by the ruler of this state to the University of Arizona to plan and construct an integrated power-water-food facility in his state. One of the goals of this program is to reduce the price of vegetables, which now cost $1.50/lb at Abu Dhabi, to something like 10 cents/lb, and to produce perhaps 2 million lb of high-quality food annually to supply the 40,000 people who live in Abu Dhabi. The complex to be erected in Arabia will be approximately ten times as large as that shown in Fig. 7.

The Solar Energy Laboratory at the University of Wisconsin, under the direction of Prof. J. A. Duffie and the leadership of Professor Emeritus Farrington Daniels, has been active for more than a decade in the field of solar energy utilization. The major financial support for this work has come from the Rockefeller Foundation and the Wisconsin Alumni Research Foundation. Their work has been devoted toward the classic objectives of meeting human needs for drinking water, cooking, house heating and cooling, refrigeration, and production of electric power for the operation of pumps. In a detailed report to the sponsors of this work [34], it has been pointed out that the difficulties which still confront workers in this field are both sociological and technological. Apparatus which appears simple to a competent American technician may pose formidable problems to those in foreign lands who have never confronted anything remotely technical. Customs which have evolved through millenia are not altered quickly and tradition stands in the way of change in any aspect of life in primitive cultures.

The philosophy of the work at Wisconsin has shifted [35] in response to increasing knowledge of the problems which confront the solar researcher and in recognition of the fact that solar devices will only gain acceptance if they do a necessary job cheaper and better than competitive apparatus. Messrs Löf, Close, and Duffie conclude [35, p. 250]: "With the exception of salt factories, water heaters, stills, and solar cells, solar processes and devices are not yet sufficiently economical, reliable, or convenient to meet real needs."

The dean of the solar energy movement throughout the entire world is undoubtedly Dr. C. G. Abbot who is, at this writing, in his 98th year. Dr. Abbot began his career at the Smithsonian Institution of Washington in 1895 in response to their need for a "good manipulator and experimenter" and, following his retirement as Secretary in 1944, he has devoted two and a half decades to studies of solar power and solar radiation in relation to weather. His most recent patent [36], granted on April 2, 1968, covers the use of a "polar siderostat," shown in Fig. 8, to provide a fixed beam of reflected solar radiation "which is subdivided into parallel beams by an array of optical devices, each of which directs a beam to a common focal plane at which is supported an array of radiation-sensitive elements which convert the solar radiation to electrical energy."

Dr. Abbot's Smithsonian labors of over more than half a century resulted in a solar constant, determined from mountaintop measurements, which is within a fraction of a percent agreement with the latest value determined from the very top of the earth's atmosphere with the most sophisticated apparatus. He also concluded that the so-called "solar constant" is not, in fact, an invariable quantity but rather one that is subject to small but positively verified fluctuations [37] that have significant effects on terrestrial weather and

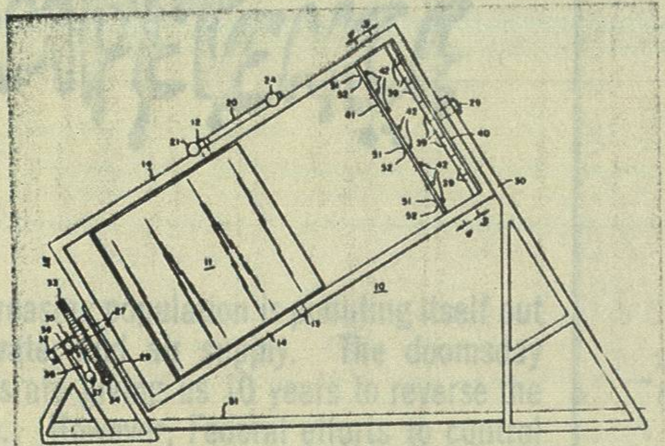

Fig. 8 Polar siderostat used in 1968 by Dr. C. G. Abbot to reflect solar rays throughout the entire year upon a battery of helio-electric generators

temperatures. Unfortunately his series of solar-constant determinations was terminated upon his retirement and it is to be hoped that a major objective of any permanent manned satellite will be the resumption of absolute measurements of our one basic source of energy and life, the radiation from the sun.

The Solar Energy Society, with headquarters on the campus of Arizona State University, Tempe, continues to search for uses of solar energy utilization by publishing its quarterly scientific journal, "Solar Energy," under the editorship of Dr. A. J. Drummond of the Eppley Laboratories. The 1968 meeting of the Society, held at Palo Alto in October, was well attended by representatives of a dozen countries. The 1970 meeting was held, appropriately, March 2–6, at Melbourne, Australia, which is the location of much of the most significant work currently being done in solar energy utilization. The president of the Society for the past two years has been Dr. P. E. Glaser, Mem. ASME, of Arthur D. Little, Inc., Cambridge, Mass., and president for 1970–72 is Roger Morse, head of the Mechanical Engineering Division, CSIRO.

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