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SOLAR PONDS EXTENDED

Unclassified

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July 27, 1973

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July 27, 1973

A. F. Clark

SOLAR PONDS EXTENDED

I. Summary

In the course of a search for practical uses of solar energy, solar ponds have appeared most attractive to us. The largest item of cost in a solar energy system is the collector, and a pond can be made very cheaply compared to mirrors or metal collectors or multilayered glass systems. Moreover, the heat can be transported by, stored in, and extracted from water very readily and relatively inexpensively.

The thrust of our effort has been to find and develop a system to produce electrical power from solar energy. However, hot water from a pond can be used for a variety of purposes, and therefore these studies should prove useful for other heat and energy systems.

The present concepts include the distinctive feature of a shallow pond which is quickly and readily heated and can be emptied at night, thus cutting down on the thermal losses (see Fig. 1). The pond would be filled only when the solar radiation is strong enough to heat the water. The rest of the time the water would be stored in a large insulated reservoir, thus providing as much heat energy storage as desired and certainly enough to last more than a day or so.

Calculations indicate that a thermodynamic cycle using some fluid other than water could be more efficient in extracting power. Perhaps a Freon 11 liquid-vapor system will be the appropriate fluid to run the

turbine and generate electricity. As one possibility, waste heat could be disposed of in a water cooling tower.

II. Rationale

Water is cheap, easily pumped, has a large heat capacity, and can be used easily and efficiently in a heat exchanger. However, temperatures higher than the boiling point of water cannot be maintained without high pressures, and it is unrealistic in terms of expense to pressurize a large area such as a pond.

With adequate design efforts, the thermodynamic efficiency should increase about as fast as the temperature difference between the hot and cold reservoirs; thus, higher temperatures are most worthwhile.

Much attention has been and is being paid by other investigators to focusing schemes to increase the temperature -- but such systems are much more expensive. We expect that our system will produce cheaper power, but we do not yet have adequate estimates.

Our solar pond system should be compared also with the flat plate collectors; many investigators have either estimated or obtained temperatures well in excess of the boiling point of water, and such collectors would therefore have a higher thermal efficiency. Aside from the fact that these collectors are relatively expensive, such temperatures were achieved (or estimated) only during bright sunshine hours. If the heat is stored over a 24 hour period, the heat losses are increased. If power is to be withdrawn continuously, then, from the point of view of cost effectiveness, the optimum flat plate temperatures are apparently

about 100°C. Thus, using water (or brine) should not be a limitation on the maximum desired temperature. For instance, Hottel¹ estimated an optimum temperature of 112°C using 4 surface-treated glass plates tilted toward the south to an optimum angle. Such an installation would be much more expensive than a pond. Also, Weinberger² calculated an optimum working temperature for a salt water pond of less than 100°C.

If somewhat higher temperatures are desired, a brine solution can be used; for instance, the boiling point of a saturated water solution of $MgCl_2$ is 117°C. Other salts and compounds can be found with desirable properties. It would appear that the boiling point of water is not a major problem. In some areas, temperatures below 0°C might be a worry. Again, brines or other chemicals could come to the rescue.

Water emits in the infrared very much as a black body. Metal surfaces coated with special thin black layers can be made so that they absorb sunlight and will get hotter than ordinary black surfaces because they will re-emit less energy in the infrared. Of course, these coatings are relatively expensive and subject to deterioration. Some improvement compared to the optical properties of water may be obtained with a thin layer of oil on the surface, and oil would also decrease the evaporation.

Energy storage is desirable and sometimes necessary, and the solar pond has an inherent and cheap thermal storage ability. Fossil fuel

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1. H. Hottel, Solar Energy Research (Daniels & Duffie, 1955), pg. 85..
 2. H. Weinberger, Solar Energy 8, 45 (1964):

power sources are available any time of the day or night, so there is a built-in human bias and a real disadvantage to sources that are available only at unpredictable times. A simple argument suggests that intermittent power should be worth the price of the fossil fuel it would replace. For a typical power plant, about half of the bus-bar costs are for fuel. Thus one could try to meet that cost with intermittent solar power.

We understand that the one meter deep salt ponds of Tabor had problems with stability against convection. If a vertical column of water gets mixed as to density, then convection currents start and grow³. In contrast, a shallow pond appears more easily maintained and more promising.

III. Present Concept

A current version of our Solar Pond system is sketched in Fig. 1. The individual modules could be 12 ft. wide (the width of good plastic sheets), and as long as 600 ft. If the ponds were wider, fewer headers would be needed to hold the plastic (a cost saving), but the average vertical spacing of the plastic would increase, and thus increase the convective losses. The welding of plastic strips together is a problem, and wider strips would be held less firmly and thus probably not last as long. Individual modules would be repaired without disturbing the rest of the system.

3. F. Edlin, Private communication.

In spite of the ability to stop evaporation with an oil layer, the present suggestion is to use two layers of transparent plastic above the water to decrease the heat losses to the atmosphere. These plastic layers will withstand weathering and are relatively cheap: about 4¢/sq.ft. per mil of thickness. They will be heat barriers to re-radiation, convection and wind.

In many areas of the country, simple stabilization of the subsoil with salt is adequate to form a flat surface for the insulation. The insulation will probably need protection from moisture, for instance by a plastic sheet. A sheet of black plastic or rubber is needed to contain the water and act as an absorber of light. The two transparent plastic layers are shown attached to the header in some undetermined way. An air pump could be used to keep the top layer convex so that rain will drain off, etc.

An effective way to "insulate" a storage tank is to put it underground. Dry ground around the storage tank should be adequate insulation, and could support the walls of the tank in order to make the tank cheaper. Therefore, water is pumped up out of storage into the ponds and flows back into the tank after being heated. The storage tank can contain a heat exchanger and a separate fluid which follows a closed cycle through the heat exchanger, the turbine and cooling tower. The generator supplies electric power on demand.

A shallow pond, emptied at night, will cool off, and its stored heat will be lost. Therefore, the heat capacity of the pond should be minimized. We estimate heat losses of 5% or less due to the heat capacity of the empty

pond structure. The estimated costs for insulating the ponds and storage tank are quite low.

Since hot water used as a thermodynamic fluid, apparently has a poor efficiency (less than 1/2 of the Carnot efficiency), it is probably desirable to use a heat exchanger and another thermodynamic fluid, e.g. Freon 11.

Table 1 shows a breakdown of cost estimates totalling less than \$1. per square foot for the pond, pumps and associated equipment. A research and development program should decrease these costs. It is estimated⁴ that the transparent plastic will last 4 years; the rest of the equipment should last much longer. An independent estimate⁵ indicates that a non-focusing system should be competitive with other power plants at about 75¢ per square foot.

Thermal sensors and perhaps pressure sensors would regulate the pump and valves, and thus the flow of water into and out of the ponds. So far we do not have realistic estimates for the costs of heat exchangers and a turbine, nor of the efficiency of the turbine, but we are optimistic.

This concept is very simple and cheap and uses present day materials. (New technology will be used to improve the components.) Therefore, the estimation of cost and performance should be more reliable. The plans can be implemented on any time scale considered appropriate. Small,

4. F. Edlin, Private communication.

5. C. Backus, Private communication.

easily adjustable units should be constructed to test the details and check for unexpected problems. Then, as many modular units as desired can be designed and constructed. Small units may be useful in certain areas and for various purposes.

The concepts presented here have not been thoroughly explored. This writing is presented only as a preliminary report on the status of our thinking. As a consequence of our investigations the system will be different and improved.

IV. Program

A. We expect to continue improving our understanding of performances of ponds. We will invent and discover ways of making a pond and its power system cheaper and more effective.

B. We will investigate, and/or develop good transparent plastics and black surfaces for the bottom of the pond. In addition, the surface of the water may be subject to improvement (e.g. with an oil layer).

C. Small test ponds should be built soon to check evaluations and discover experimental problems and their solutions. Probably some small output machines such as dynamometers should be attached for testing. Thus, a whole system can be checked for problems and improvements.

D. Because the temperatures are low, the thermal machine components are different from those in normal steam power plants, and there is need for design development and testing.

E. On the basis of the above work, the next step is to design, build, and "de-bug" a larger operational pond system with a finite electrical output.

F. In all areas one must push for cheap, simple solutions with an overall optimization of cost effectiveness. The whole system needs to be optimized as an integrated project; some of the parts will not be optimum when considered as separate components.

G. Communication should be established and maintained with power companies and their suppliers.

TABLE I

	COST PER FT ²
1. INSULATION	\$.06
2. MOISTURE BARRIER	.06
3. CURBING	.17
4. POND LINER	.10
5. PIPE & HARDWARE	.12
6. TRANSPARENT PLASTIC	.24
7. SPECIAL EQUIPMENT & INSTRUMENT	.10
8. PLASTIC SUPPORT SYSTEM	<u>.02</u>
TOTAL	\$.87

SECTION A-A
 SHALLOW SOLAR POND
 SCHEMATIC
 Figure 1

AFC/mm

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