# World Symposium on Applied Solar Energy

ENS R. E. Gomory
Physical Sciences Division
Office of Naval Research

The solar energy reaching the earth has two main characteristics. There is a lot of it, and it is spread very thin. The first characteristic accounts for the long history of attempts to harness solar energy, while the second has prevented any great successes. The energy provided by the sun amounts to about 2 gram-calories per minute per square centimeter (0.14 watts per square centimeter) on a surface facing the sun and located outside the earth's atmosphere. Due to atmospheric absorption, scattering, and reflection from clouds, less than half of this energy reaches the earth. This supply, although dilute, is still very large. The solar energy falling on the United States each day is nearly 2000 times the daily energy requirement for heat, light, and power.

At the recent World Symposium on Applied Solar Energy, cosponsored by the Office of Naval Research, scientists from many parts of the world gathered in Tucson and Phoenix, Arizona, to discuss advances that may lead to a greater utilization of this energy. Some of the developments discussed at that meeting are described below.

Since solar energy is so widely spread, it is necessary to collect it over a large area to obtain appreciable amounts. This can be done by using either lenses, reflectors, or flat-plate collectors. Large reflectors can be made much more cheaply than large lenses but even reflectors are extremely expensive when it comes to covering large areas of ground. The most widely used system is the flat-plate collector.

A flat-plate collector consists essentially of a large metal plate, blackened for better absorption and placed where the sun can heat it. Water can be run through pipes in contact with the hot absorbing plates, and when heated, can be used as a hot-water supply or for heating a house. The heat can also be used directly to drive heat engines or to obtain electric power through thermocouples. Effectiveness for these last two applications depends largely on the temperature of the flat-plate collector.

The higher the temperature of the plates of the collector, the greater the temperature difference which the heat engine or thermocouple has available for its operation. However, the hotter the plate the larger are the losses to the surroundings due to radiation and convection. To cut down these losses the boxes containing the absorber plates are often glassed in, with one or more glass layers between the absorbing plate and the sun. This cuts down sharply on convection losses and on radiation losses as well, for although glass transmits the short visible wavelengths in which most of the incident solar energy is concentrated, it is a poor transmitter for the longer wavelengths at which the heated black plate emits most of its radiation. Of course the more layers of glass used, the greater are these effects, but the losses due to transmission and reflection of sunlight through the extra glass layers also increase. Two or three glass layers seem to be the best compromise, but of course the use of these layers adds to the cost of the installation.

At the recent meeting in Tucson a new approach to this problem was proposed by Professor Tabor of the National Physical Laboratory of Israel. Professor Tabor has used flat-plate absorbers covered with a thin layer of finely divided metal and has succeeded in producing plates that are good absorbers of sunlight but which re-radiate very little energy. Professor Tabor makes use of the fact that the energy of the incoming sunlight is almost all in wavelengths shorter than 2 microns while the energy re-emitted by the collector plates, even when at temperatures of 300°C, is almost all in longer wavelengths. Professor Tabor's plates are good short-wavelength absorbers and poor long-wavelength emitters, and therefore absorb the sunlight and re-emit very little energy. These desirable absorbing and emitting characteristics are obtained by coating the metal plates with a deposit of smoke or finely divided metal powder, which appears black to the eye.

Professor Tabor has computed the effect of using these selectively absorbing blacks on a flat-plate receiver with one cover glass. The receiver is assumed to be working in the sunlight of the Jerusalem area and the heat is used to drive an ideal Carnot heat engine. Using selectively absorbing blacks an efficiency of 8 percent results as compared to 4-percent efficiency with an ordinary collector. Also, since radiation loss has been reduced, convection loss is now more important, so if the space between the glass cover and the plate is partially evacuated, a 13.9-percent efficiency is obtained as compared to a 5-percent figure for an ordinary collector. Since this efficiency measures the percent of the total incident radiation converted into mechanical work, it is clear that the use of selectively absorbing blacks may represent a considerable advance in methods of using solar energy.

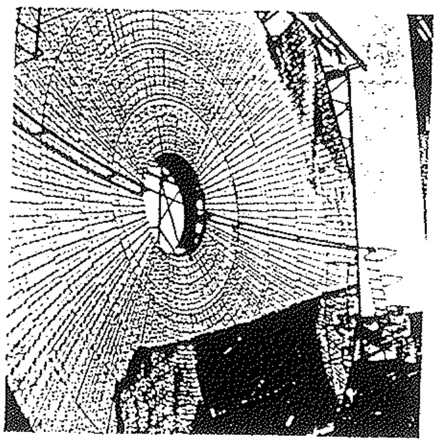

Figure 1 - Solar furnace in France has parabolic reflector made up of 3500 small mirrors. *(Photo by University of Wisconsin Photographic Laboratory)*

A very different application of solar energy is the high-temperature solar furnace. A solar furnace is simply a parabolic reflector which focusses the incoming sunlight into a single point. The largest such furnace in the world today is at the Laboratoire de L'Energie Solaire at Mont-Louis, France. This reflector (Figure 1) is made up of 3500 small, curved mirrors and has a diameter of 10.8 meters, a focal length of 6 meters, and is set on a fixed mounting. A large flat mirror moves with



the sun and reflects sunlight int
trates the energy into a focal spo
charged with material is placed
tion coming through the open e
3000°C can be obtained and quite
be treated.

The stabilization of zirconiu
thing that can be accomplished v
high melting point (2600°C) zircon
as a refractory material because
state accompanied by a change of
of volume has been enough to crac
If 4 percent of quicklime is mix

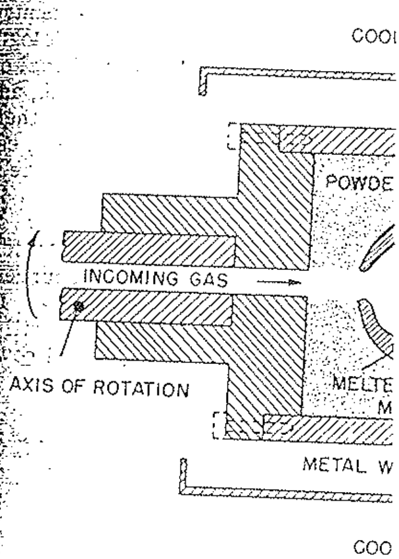


Figure 2 - A typical crucible

mixture is fused at 2600°C in the sola
a cubic structure which remains stab
solar furnace at Mont-Louis is capa
50-kilogram lots, and more than thr
and sold for use as a refractory mate

A further advantage of the solar
be treated without contamination from
Figure 2, where the melted material
unmelted powdered material rather th
ble is usually spun about an axis, as
advantage that centrifugal force keep
any vapor emitted flattened against t

the sun and reflects sunlight into the parabolic mirror which concentrates the energy into a focal spot about 10 cm in diameter. A crucible charged with material is placed at the focal spot with focussed radiation coming through the open end (Figure 2). Temperatures up to 3000°C can be obtained and quite large lots of refractory materials can be treated.

The stabilization of zirconium oxide is an example of the sort of thing that can be accomplished with the solar furnace. In spite of its high melting point (2600°C) zirconium oxide has been of limited utility as a refractory material because it undergoes a crystalline change of state accompanied by a change of volume at about 1100°C. This change of volume has been enough to crack ceramic objects made of the oxide. If 4 percent of quicklime is mixed with the powdered oxide and the

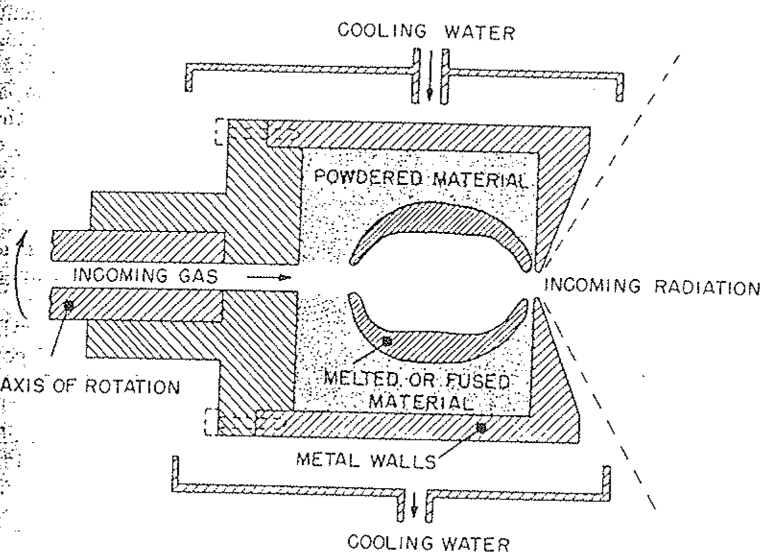


Figure 2 - A typical crucible.

mixture is fused at 2600°C in the solar furnace, a material results with a cubic structure which remains stable at all temperatures. The huge solar furnace at Mont-Louis is capable of preparing this material in 50-kilogram lots, and more than three tons have already been made and sold for use as a refractory material in industry.

A further advantage of the solar furnace is that the material can be treated without contamination from the crucible. This is clear from Figure 2, where the melted material is seen to be in contact with the unmelted powdered material rather than with the crucible. The crucible is usually spun about an axis, as shown in Figure 2. This has the advantage that centrifugal force keeps both the melted material and any vapor emitted flattened against the walls and maintains a cavity approximating a blackbody.* By admitting gas into the cavity through the hollow axis of rotation, materials can be treated in a variety of atmospheres.

One of the more spectacular recent developments in using solar energy has been the development of the solar battery. Modern semiconductor techniques have led to the development of materials (usually germanium or silicon crystals with impurities added) which when illuminated send a small current through a wire connected across the crystal ends. Carefully prepared laboratory cells have been able to convert 10 percent of the incident sunlight into electrical energy, and the theoretical limit to the performance of these cells is thought to be about 22 percent. These cells, which can produce a few milliwatts per square centimeter of sunlit surface, are a convenient source of small amounts of power, but at the present time are too expensive to be used as a major power source.

Along a different line are experiments conducted in this country by Arthur D. Little, and in Japan by the Tokugawa Institute for Biological Research on the growth of algae, especially Chlorella, for fuel or food. The algae require nothing but sun and water for their growth, and when powdered make a nourishing food. If the expense of growing them can be reduced, algae may become an important food supplement, especially in the Orient, since the appearance of the powdered algae is not markedly different from that of some conventional Eastern foods.

There is a variety of other uses for solar energy. Reflectors can be used for cooking, and sunlight is clearly a convenient source of energy for evaporating sea water, for irrigation, or for power for small isolated settlements. However, how widely solar energy will be used will depend on its economics. As compared to conventional power sources, power from solar energy usually requires a large initial investment, then very little further expense. Whether it is competitive with ordinary power sources depends on the sunlight conditions of the region being considered and on the cost of conventional fuels. It is not generally competitive in the United States, but it may be in some of the more arid underdeveloped areas.

Solar energy has the advantage compared with fossil fuels that it conserves the dwindling supply of coal and oil. This is a desirable feature it shares with atomic energy. Compared with atomic energy, however, it has the advantage that it can come in small packages and is not plagued by the problem of disposing of radioactive wastes. One guess as to the future would be that solar energy will be used for smaller units, atomic energy for main power stations. However, it is hard to predict the progress that large-scale research may make in a field that until now has been the preserve of a few isolated solar-energy enthusiasts.

---

*A blackbody is defined as a surface which absorbs all radiation incident upon it. A perfect blackbody does not exist.