16 "Prospects for the Application of Solar Energy in the USSR," by V. A. Baum, Proceedings of the Phoenix Symposium on Applied Solar Energy, 1955, p. 289.
17 "Electricity from the Sun," by G. L. Pierson, Proceedings of the Phoenix Symposium on Applied Solar Energy, 1955, p. 281.
18 "Wind-Generated Electricity," anonymous, *Engineering*, vol. 178, March 25, 1955, p. 371.
19 "Direct Conversion of Solar Energy," by P. W. Erlandson, Proceedings of the Phoenix Symposium on Applied Solar Energy, 1955, p. 261.
20 "High Temperature Furnaces," by Felix Trombe, Proceedings of the Phoenix Symposium on Applied Solar Energy, 1955, p. 63.

Discussion

FARRINGTON DANIELS.[6] This paper gives an excellent historical summary of the field and points out well the potentialities and the limitations in the direct use of solar energy. The data on solar radiation and energy collectors are important.

It is hoped that discussions of this paper will be directed toward challenges for the mechanical engineers in the utilization of solar energy.

At least for the present solar engines will have to be limited to small sizes of a few horsepower because the collecting areas have to be so large that they create structural problems, particularly if they have to track the sun. Fifty to one hundred square feet of solar radiation are required for a 1-hp engine. New materials of plastics introduce possibilities for solar collectors. Large reflectors may be cheaper than heat-absorbing water heaters. There is a lively difference in opinion regarding the relative merits of flat-plate collectors and concentrators. It may turn out that the focusing-collector type will be better for climates with much direct sunshine because of the higher boiler temperatures available and the smaller boiler surfaces with smaller heat losses. The flat-plate collectors on the other hand probably will be better in cloudy climates which render focusing impossible for much of the time. There is a good chance for improving both types of heaters through research to minimize radiation losses from the boilers.

Research on hot-air engines should be encouraged as suggested by the author.

The economic challenge is great, not for use in the United States now, but for the nonindustrialized countries where electricity, fuel oil, and coal are expensive and difficult to transport. Small units for irrigation, lighting, and village industry are needed in such areas. A 1-hp gasoline engine costs less than $50 but a 1-hp steam engine costs five times as much. Is this difference chiefly a matter of mass production—or is there not a chance that someone can invent a simple, perhaps inefficient but rugged 1-hp steam engine of new type which can sell for $50?

E. A. FARBER,[7] J. D. BENNETT,[8] AND J. C. REED.[9] We wish to congratulate the author for his excellent presention of many of the problems underlying the practical utilization of solar energy. It is especially gratifying to see that the Society, which has just formed a Committee on Solar Energy Application, is sponsoring papers on this very important subject.

Also we wish to add a few comments covering some of our experiences and results relating to a number of the points discussed in the paper.

We have found that the curves presented in Fig. 8 of the paper can be shifted considerably with surface condition and composition of the paint (pigment material, pigment grain size, binder, and so on) and hope soon to be in a position to extend the data given here.

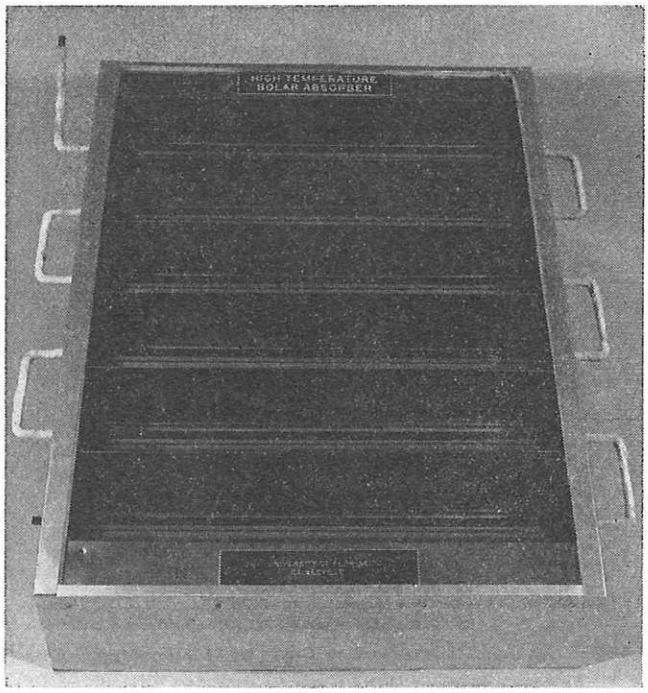

FIG. 15

In attempting to improve the flat-plate absorber for solar water heating we experimented with tubeless designs, operated at atmospheric pressure. These absorbers consisted of two thin metal sheets fastened together along the edges forming a thin space for the liquid to pass through while picking up the heat. This design exhibits two very important advantages in addition to a slight increase in conversion efficiency. The operation at atmospheric pressure allows a very light and inexpensive construction. The heat exchanger necessary to transfer the absorbed heat from the atmospheric closed cycle to the hot-water storage tank (at city water pressure) consists of a thin sheet-metal shell partially around the tank. The use of antifreeze solution in the absorber circuit prevents damage that might be caused by freezing temperatures. This damage caused by freezing is one of the reasons why ordinary solar hot-water systems are not very popular in Northern Florida. They have to be drained during cold nights.

We also have attempted to combine some of the advantages of the flat-plate absorber with those of the concentration absorber. The result of our efforts is the high-temperature absorber, Fig. 15, which consists of small glass-covered tubes at the focus of small parabolic troughs under a single sheet of glass. This arrangement, having about the same dimensions as a flat-plate absorber, is set up at the proper angle, facing south and with the troughs running east-west. It is stationary, thus much simpler and less expensive and gives temperatures higher than those obtainable with the ordinary flat-plate absorbers. The actual temperature obtained is a function of the trough as well as pipe size and can be designed for use in steam generation or solar refrigeration.

In closing we again thank the author and the Society for bringing this material to the attention of our membership.

AUTHOR'S CLOSURE

Dr. Daniels' comments are particularly appreciated since it was his thought-provoking analysis of the solar energy situation which first turned the author's thoughts to this challenging subject. A report has just come to his attention in which reference is made to a district in India where 700 villages exist with no

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electricity, refrigeration, water supply, or sanitary facilities for more than 21,000 inhabitants. Such conditions, utterly unknown in the United States, can be ameliorated materially by small solar power plants for water pumping and generation of electricity. It is toward this goal, rather than large central stations, that solar power research should be directed today.

Dr. Farber and his colleagues have called attention to several useful improvements in flat-plate collectors which have resulted from their wide experience in the development of water-heating equipment. The high-temperature absorber shown in their illustration should be particularly useful as a source of heat for solar refrigeration.

Since the preparation of the paper, a new cover material for flat-plate collectors has become available in the form of thin, extruded films of completely fluorinated hydrocarbons. This material has the same optical properties as glass in that it transmits the short solar radiation, but is virtually opaque to the long rays emitted from low-temperature surfaces. It is also unaffected by ultra-violet and does not deteriorate when exposed to the elements for periods of at least ten years.