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Author
Hunt, A.J.

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-SOLAR TEST RESULTS-

Arlon J. Hunt

Applied Science Division, Lawrence Berkeley Laboratory
University of California, Berkeley, California 94720

INTRODUCTION

The Small Particle Heat Exchange Receiver (SPHER) concept is a new approach to solar thermal conversion based on the direct absorption of concentrated sunlight by ultra-fine particles suspended in the working gas. The concept has been under investigation at Lawrence Berkeley Laboratory (LBL) since 1976. The central activity has been the development of the SPHER concept for a high temperature gas receiver. Earlier work analyzed the optical, physical, and thermodynamic processes of using small suspended particles as the solar absorber (Hunt, 1979). Experimental and analytic studies indicated that it was a practical approach and that it possessed significant advantages over conventional solar receivers.

Applications include heating a gas to high temperatures to provide industrial process heat or operate efficient heat engines, and direct solar processing of chemical feedstocks. An underlying goal of the project is to gain a basic understanding of the radiant heat exchange process in two phase, particle-fluid media to facilitate the development of direct radiant receivers for the processing of fuels and chemicals.

The SPHER, Mark I receiver was designed and built at LBL in 1981. It was tested in the summer of 1982 at the Advanced Component Test Facility (ACTF) at the Georgia Institute of Technology. The design and construction of the Mark I were described earlier (Hunt and Evans, 1982) and the solar test results in a recent report (Hunt and Brown, 1983).

PRINCIPLE OF OPERATION

The SPHER operates by injecting a very small mass of absorbing particles into the working gas. The gas-particle mixture passes into the solar receiver that consists of a hollow chamber equipped with a window. Concentrated sunlight enters through the window and passes into the gas-particle suspension. The particles absorb the sunlight and rapidly transfer the heat to the surrounding gas. The particles may react with the gas to form a clear exhaust.

The receiver in the test utilized carbon particles as the absorber and air as the working gas. After providing the heat exchange, the carbon oxidizes at temperatures from approximately 500 to 1000°C depending on the allotrope of carbon. The amount of carbon required is very small, less than 0.1% by mass of particles to air for most applications.

Advantages to this approach include high optical efficiency because of the characteristics of small absorbing particles and low chamber temperatures because the particles are nearly the same temperature as the gas and the absorption takes place within the gas, not on the chamber walls (easing material requirements and reducing radiant heat losses); moreover, the low pressure drop across the receiver improves turbine efficiency. Small-particle receivers can be scaled from the size suitable for a parabolic dish to multimegawatt central receivers.

EXPERIMENTAL SYSTEM

The main components of the experiment are the absorption chamber, particle generator, and air supply system. Ambient air is supplied by a Coanda effect air inducer. The particle generator produces carbon particles by the pyrolysis of acetylene in an argon carrier gas and mixes them with the incoming air. Figure 1 shows the cross section of the Mark I receiver. Concentrated sunlight enters the bottom of the receiver through the window. The gas-particle mixture is routed into the annular manifold. Eighteen nozzles direct the gas flow into the chamber and produce a swirling motion. This motion organizes the flow and reduces the effect of nonuniform flux distribution.

The gas particle mixture circulates to the axis near the window where the quartz exhaust tube is located. The arrangement insures that the mixture passes through the maximum flux density region before exiting.

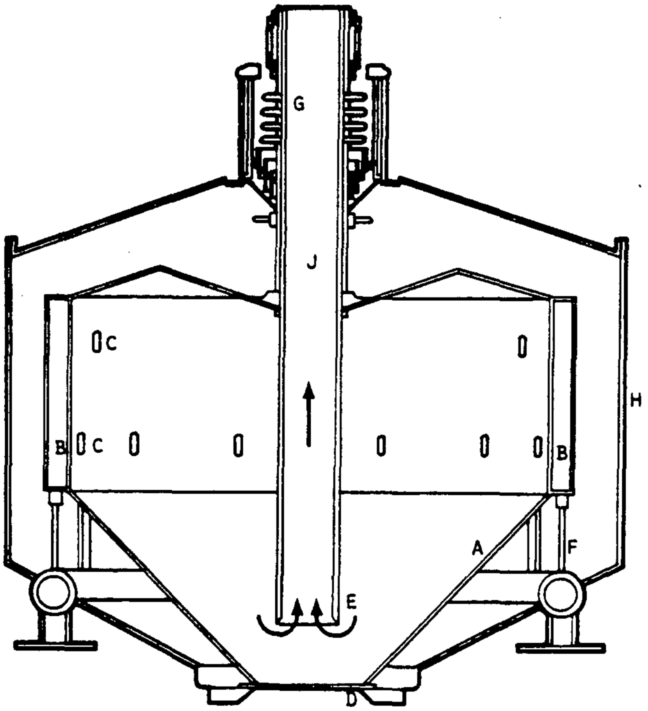

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Fig. 1. Cross section of the Mark I receiver.

Receiver wall temperatures were monitored by 26 thermocouples. A thermocouple with a four-component radiation shield determined the exhaust gas temperature. The output power was determined from the mass flow and the temperature rise. Solar input power was determined with a flux measurement system developed at the Georgia Institute of Technology. Accurate efficiency data is not available because the calorimeters did not survive the intense solar heating at the focus, so the input power had to be estimated from other data.

The components were mounted on the ACTF tower, where 550 mirrors concentrated sunlight onto the receiver. The 20-centimeter-diameter window admitted 30 kW of sunlight with a flux density up to 200 W/cm^2. The receiver operation was monitored with thermocouples, pressure transducers, and laser probes that measured the absorption of light by the particle suspension.

RESULTS OF SOLAR TEST

Solar testing was conducted on 13 days for a total testing time of 35 hours. All major test objectives were met. The maximum output gas temperature was 750^{o}C, and the output power exceeded 30 kW. "Burn out" or oxidation of the particles was achieved. The test established that concentrated sunlight can be absorbed directly within a working gas by small particles. The test also established that a window can be used successfully in a high-temperature environment and that carbon build-up on the window was not a problem.

Fig. 2 illustrates the test results by showing the chamber temperatures for two different particle loadings. The temperature of the output gas is indicated by the dashed line, and the average interior-wall temperature by the solid line. It can be seen that the gas temperature exceeds the wall temperature over the entire run. The increase in density of the particle suspension (from 0.46 to 0.88 gms/m^3) was accompanied by a dramatic rise in the gas temperature with almost no increase in the wall temperature. The large difference in temperatures between the walls and gas indicates that the gas-particle mixture was being heated directly by sunlight and not by the walls. This is an important result for future work because obtaining localized heating in the gas is a key to achieving very high temperature radiant processing of chemicals.

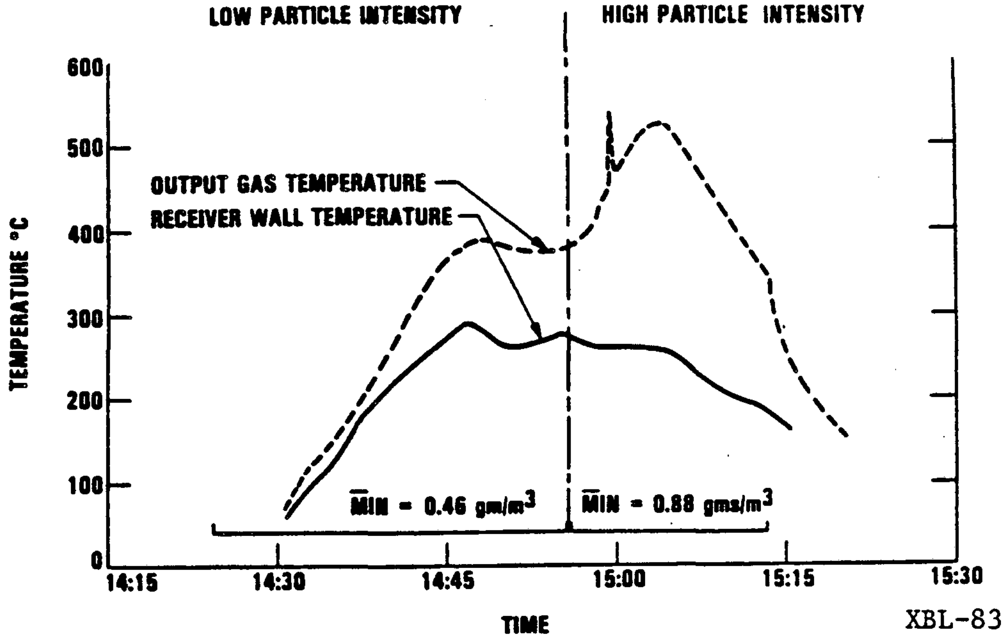

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Fig. 2. Gas and wall temperatures vs. time.

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REFERENCES

Hunt, A. J. (1979). Proc. of the 14th IECEC, Boston, MA Lawrence Berkeley Laboratory Report LBL-8520.

Hunt, A. J. and Brown C. T. (1983). Lawrence Berkeley Laboratory report LBL 15807.

Hunt, A. J. and Evans, D. B. (1982) Report to the STTF Users Association, Lawrence Berkeley Laboratory Report LBL-13755.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720