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OMNIUM-G CONCENTRATOR TEST RESULTS*

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ABSTRACT

The Jet Propulsion Laboratory Solar Thermal Power Systems Project, Module Development, conducted a performance evaluation on a commercially available point-focus solar concentrator manufactured by the Omnium-G Company. Thermal power test results indicate that slightly more than six kilowatts of thermal energy is available from a system of this configuration using a 10 cm aperture under the conditions outlined in this paper.

INTRODUCTION

Preliminary results of evaluation testing conducted to determine the thermal performance of a Heliodyne^{TM} model HTC-25s tracker/concentrator manufactured by the the Omnium-G Company of Anaheim, California are summarized in this paper. The concentrator is part of the OG-7500 module purchased by JPL in 1978.

This system consists of a two-axis, sun-tracking parabolic dish concentrator six meters in diameter with a four meter focal length. The dish structure has 18 pie-shaped elements, or petals, surfaced with anodized aluminum (Alzak^{R}).

All tests were conducted with petals that were new, clean, and in an "as received" condition. Sun-tracking was done in the manual override mode, i.e., automatic sun-tracking was not employed. More detailed results of these tests will appear in an external report.

TESTING

The chronological order of the tests performed on the system is shown in Table 1. These thermal power tests are part of a more extended series.

A concentrator retrofit is indicated in Table 1. Within that time interval the Omnium-G Company recovered the original "A"-mold petals and replaced them with "C"-mold petals; only results for the latter are presented here.

The system checkout testing was conducted to determine an operational ready-state and to establish remote control capability of the system on the Parabolic Dish Test Site (PDTS) at the JPL Edwards Test Station.

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Table 1. Chronological Order of Significant Tests
Performed on the Omnium-G System

12-21-78	System Checkout
01-27-79	Reflectivity Tests
02-06-79	Alignment
02-06-79	Calorimeter
02-22-79	Alignment
02-27-79	Calorimeter
03-12-79	Moonlight Focal Plane Evaluation Plane Evaluation
03-13-79	"Stop Testing" Memo
04-12-79	Convertor (Cold)
04-20-79	Fluxmapper
04-23-79 thru 05-10-79	Concentrator Retrofit
05-15-79	Alignment
05-25-79	Fluxmapper
06-06-79	Calorimeter
06-22-79	Convertor (Cold)
08-20-79	Convertor (Hot)

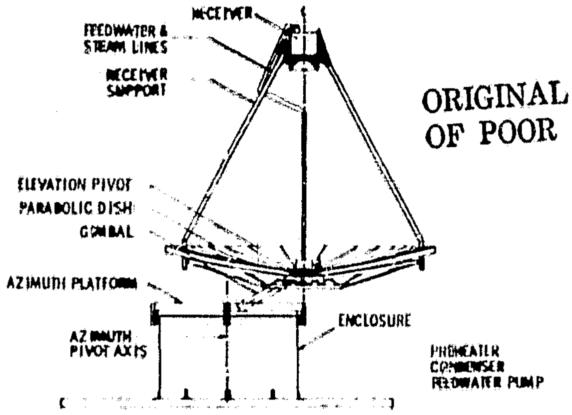
The concentrator is positioned in the azimuth and elevation axes by a null-seeking sun-tracker system consisting of a sun-sensor photocell box and tracker electronics module. The sun-sensor photocell determines the error and the tracker electronics module controls the tracker DC drive motors. The diagram shown in Figure 1 illustrates the concentrator with the convertor (receiver) mounted at the focal point. A hemispherical reflectivity test series was performed before the first set of concentrator petals was installed. In this test a light source was used to illuminate a small area of a concentrator petal and the reflected light intensity was measured. Twenty-two concentrator petals were measured at nine locations and the average reflectivity was eighty-four percent.

The concentrator petals were aligned at night to assure that all reflected images were superimposed at the focal plane. Three different alignment methods were used. Figure 2 illustrates the method used for the "C"-type petal concentrator installation. After positioning the concentrator toward the light source, an observer views the reflecting surface through the wire hoop eyepiece. Technicians then adjusted each individual petal manually until full illumination of the reflective surface was observed. The manufacturer selected the mirror elements for installation prior to delivery, and no further provision was made to refocus the petals after delivery to the test site.

Boresighting, the final alignment operation, requires the manual repositioning of the sun-sensor photocell box relative to the concentrator support structure. Repositioning assures that the aggregate group of solar images is centered on the receiver aperture. This operation, or its verification, must take place following each changeout of an experiment to compensate for mass changes at the focal-point end of the support structure.

EXPERIMENTAL APPARATUS AND METHODS

The thermal performance output of the concentrator was determined by three different tests. The flat-plate cold-water calorimeter, the fluxmapper, and the Omnium-G receiver were the devices used in testing. The flat-plate calorimeter and the fluxmapper yield data as a function of aperture diameter. There was special interest in the results of the 10 cm (4 inch) dimension because it was the cavity entrance diameter for the receiver supplied by Omnium-G.



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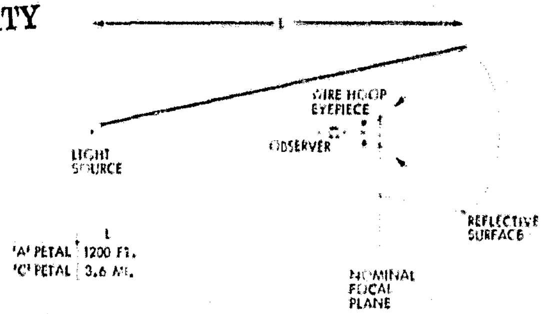


Figure 1. Omnium-G Heliodyne tracking concentrator/collector

Figure 2. Nighttime alignment technique

The flat-plate calorimeter was fabricated from two 36 cm by 36 cm square copper plates. The plates were furnace-brazed together after cooling water passages were machined into one of them. These parallel passages were connected to inlet and outlet passages forming manifolds. The calorimeter was designed to permit a low water temperature rise and a hot-side surface temperature of less than 38°C. The front surface of the calorimeter was painted with 3M Velvet Black spray paint providing a 0.97 solar absorptivity.

The water temperature rise across the calorimeter was controlled in the range 3°C to 6°C by adjusting flow rate. If the temperature rise is too low there will be a high degree of uncertainty in the measurement results and if the temperature rise is too high it will cause an excessive calorimeter operating temperature.

The calorimeter water flow rate was measured using a turbine- type flow meter. The absolute inlet temperature of the feed water was measured with a thermocouple probe near the flow meter. The rise in water temperature was measured with thermocouples arranged in series (a thermopile) so that a larger output voltage for the small temperature difference could be measured. Nominal water flow rate was 38 liter/min.

The calorimeter was mounted approximately 10 cm behind the focal plane location supplied by the Omnium-G Company. Separate aperture plates (with various size apertures) were mounted at the focal plane. These plates were fabricated from 1.9 cm-thick sheets of transite (asbestos), and had a lifetime of about two hours, sufficient to acquire test information. Aperture size (diameter) was varied in the range of approximately 8 to 18 cm.

Initial calorimetric data indicated that a problem existed in the original concentrator petals. As a result of this data, the concentrator system was realigned so that thermal performance could be improved. Some improvement was noted but further information was required to evaluate the optical image near the focal plane.

Visual evaluation of focal length and focusing quality of each concentrator petal was accomplished by using the moon as a light source and viewing the reflected lunar image on a moveable target located at, and near, the focal plane. Representatives of Omnium-G Company were present for these tests and they determined that the concentrator petals were not properly focused individually or collectively. The recommendation of the manufacturer was to terminate the evaluation on the original "A" type petals and replace them with the "C" type. After the concentrator petals were replaced, the final alignment was performed by Omnium-G personnel.

The fluxmapper was then installed and the first thermal performance data obtained for the "C"-type concentrator assembly. The fluxmapper is a device that utilizes a water cooled probe that moves in an X-Y plane perpendicular to the focal axis, or Z-axis. Motion on the Z-axis, ahead and behind of the focal plane, facilitates a three-dimensional mapping of the vicinity of the focal plane. (See paper by W. Owen in these Proceedings.) Figure 3 illustrates the mounting of the open ring support structure and electronics package.

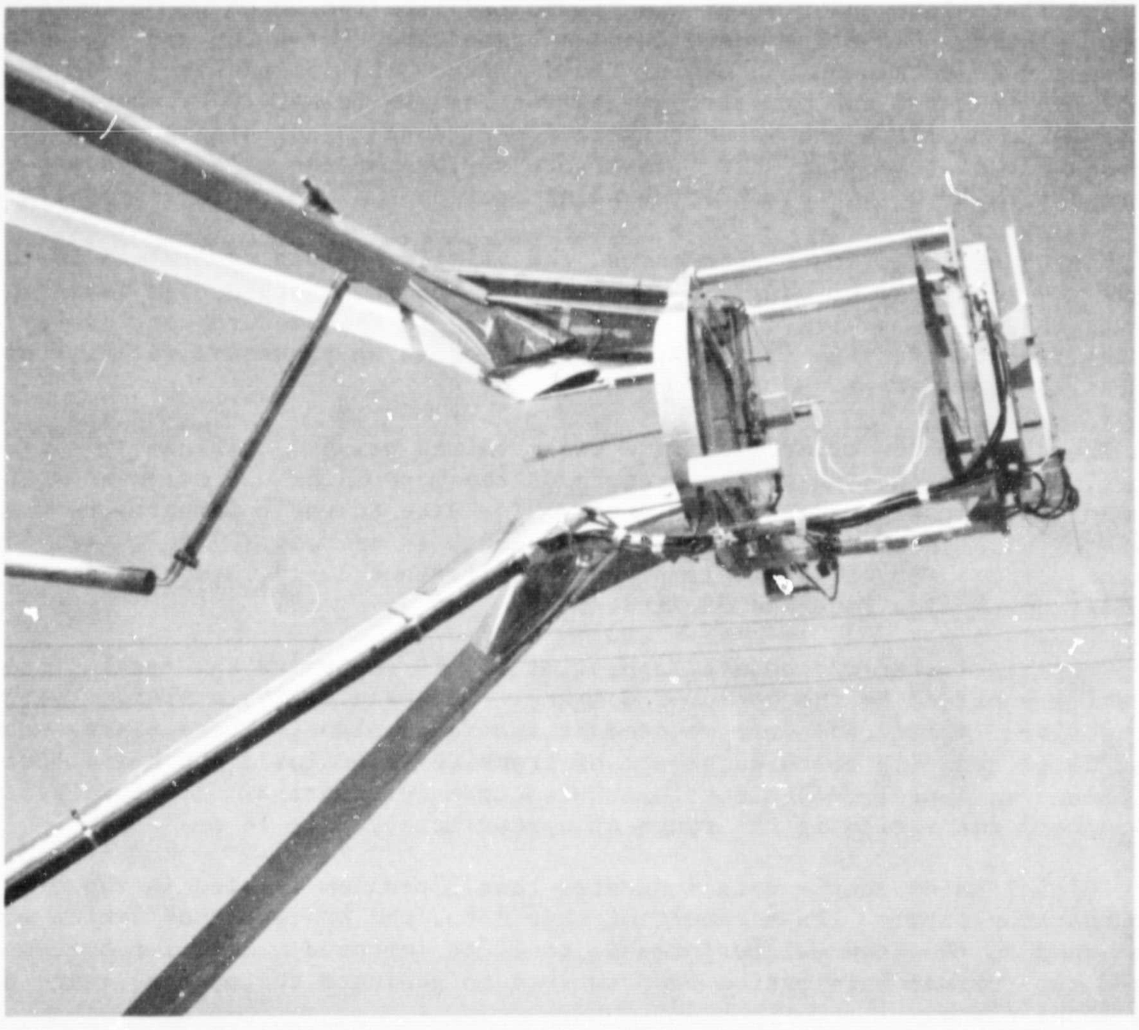


Figure 3. Fluxmapper mounted at the nominal focal plane

All controls for the fluxmapper were programmed into a microprocessor that was also used to gather, store, and process the data acquired by the probe. Output from the processor was displayed on an X-Y plotter or line printer for real-time evaluation of concentrator focal plane shape, and flux intensity.

The third device used to determine thermal performance of the concentrator was the convertor (receiver) manufactured by the Omnium-G Company. This receiver, an early design, incorporated a 10 cm diameter aperture and a steam coil buried in an aluminum block. Originally this aluminum was to have been heated to a molten state, but present design limits the aluminum mass temperature to 638°C (1180°F).

The receiver was tested at two temperature levels: 93°C (200°F), called a "cold" test, and at 204°C (400°F), called a "hot" test. In the first test series facility tap water was used and no steam was produced. The second series utilized the arrangement shown in Figure 4; sufficient back pressure was applied to maintain a saturated water condition at the receiver exit. Steam formed across the expansion valve was condensed and returned to the feed-water reservoir. During this test, the receiver outlet water temperature was maintained for an hour to allow the receiver to achieve thermal equilibrium.

TESTING CONDITIONS

The flatplate calorimeter data and the fluxmapper data were obtained with new, clean petals. Some of the receiver data were obtained with petals that were dirty. In all cases, a manual override tracking mode was employed to assure a continuous on-sun condition, and automatic tracking was not utilized because of occasional tracker drift.

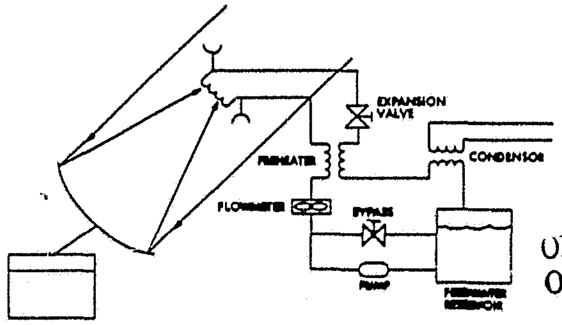
Data was recovered continuously for each test run but only data taken at insolation levels greater than 800 W/M^2 was analyzed. All data was normalized to a solar insolation value of 1000 W/M^2. Solar insolation data was acquired by using three Kendell Mark III, and one Eppley, Pyroheliometers. Wind speed and direction also were recorded.

Omnium-G personnel were invited and encouraged to observe all tests at the PDTS. In addition, JPL furnished the Omnium-G Company with various test data and other results.

THERMAL PERFORMANCE TEST RESULTS

A typical flux contour plot obtained for the "C"-type petals is shown in Figure 5. Superimposed is a hypothetical aperture diameter of 10 cm (4 inches). The peak flux near the center of 700 W/in^2 corresponds approximately to 110 W/cm^2. Fluxmapper data corresponding to various aperture sizes as well as flatplate, coldwater calorimeter data is shown in Figure 6.

Flatplate and coldwater calorimeter data had an uncertainty of $\pm$400 watts, which is indicated by bound-bars in Figure 6. Agreement between fluxmapper data and calorimetric data is excellent.



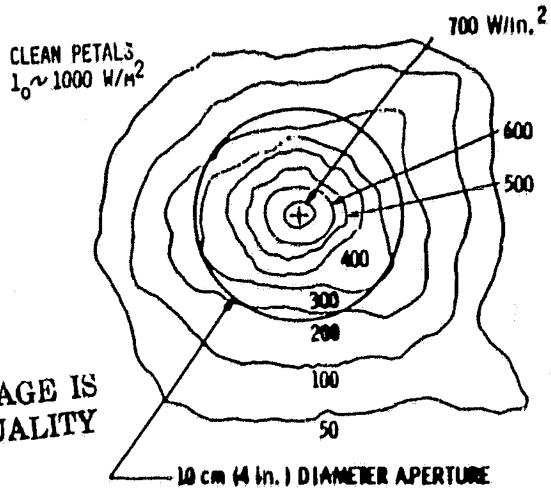


Figure 4. Receiver Thermal Performance Test Schematic Diagram

Figure 5. Typical flux map at the focal plane

"Cold" and "hot" receiver test data are shown in Figure 7 relative to the previous data, which is represented in Figure 7 by the cross-hatched region. Of course, the receiver test results apply only for a 10 cm aperture. The cold receiver test data agrees well with the previous data.

For the cold receiver tests, the receiver outlet temperature was maintained at less than 93°C (200°F) to prevent two-phase flow. A comparison series of tests was performed during the cold water receiver series to determine the effect of dirt and dust accumulation on the concentrator. A 16% improvement in thermal performance was obtained following a mirror cleaning operation recommended by Omnium-G.

The data plotted for the hot receiver test series was obtained while the petals were dirty, but assuming the same 16% improvement could be achieved, thermal performance very close to the calorimetric, fluxmapper, and cold convertor data might be expected. However, the difference in the cold and hot

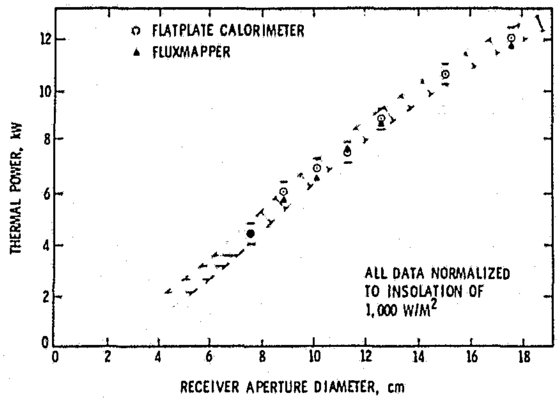


Figure 6. Preliminary thermal power test results

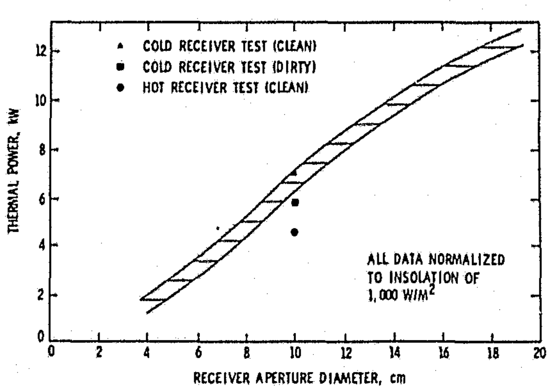


Figure 7. Receiver (converter) test results

receiver data (Figure 7, dirty petals) cannot be explained solely on the basis of differences in thermal reradiation.

Uncertainty in data, including the statistical variation of calorimetric data of $\pm$400 watts (approximately 6% of the energy through a 10 cm diameter aperture), has been estimated. Thermal reradiation received by the flatplate calorimeter from the heated aperture plates was estimated to be about 420 watts for an aperture plate temperature of $325^{\circ}C$. This effect, now being investigated experimentally, is expected to decrease with increasing aperture size. Estimates of thermal losses from forced convection, due to winds of the magnitude seen during test data acquisition (20 mph), indicate about 1 to 2% wind effect.

CONCLUSIONS

Thermal power test results on an Omnium-G tracking concentrator, purchased by JPL in the fall of 1978, have been presented. This includes coldwater calorimeter and fluxmapper data, and some preliminary data using the early Omnium-G receiver design. The measured thermal power was in the range 6 to 7 thermal kilowatts for new, clean petals, and a 10 cm aperture. Design changes to increase the receiver aperture diameter to 20 cm have been completed by the Omnium-G Company in accordance with their continuing development program. A new receiver design has been delivered to JPL and plans are to test it by the summer of 1980.

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