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INITIAL TEST BED CONCENTRATOR CHARACTERIZATION*

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ABSTRACT

This paper reports on the operational characterization of the Test Bed Concentrator (TBC). The control system responsible for tracking and safe operation of the TBC is discussed in detail. The techniques used for mirror alignment and verification are also described. Finally, the paper briefly addresses the plans for future tests using the TBC.

INTRODUCTION

Two TBCs were designed, fabricated, and assembled by E-Systems, Inc. at the Parabolic Dish Test Site (located near Lancaster, California) operated by the Jet Propulsion Laboratory (JPL). (See Figure 1.) JPL retained responsibility for the optical design and mirror alignment of the TBC. Electrospace, Inc., the control system subcontractor to E-Systems, Inc., instructed JPL test personnel in the operation, circuitry, maintenance, and trouble-shooting of the control unit.

This paper is limited to three areas concerning the initial characterization of the TBCs. First, the operational characteristics of the control system will be discussed. Next, the alignment technique and results, including verification tests using the moon as the light source, will be presented. Lastly, the near-term testing which is planned to characterize the thermal performance of the TBCs will be outlined.

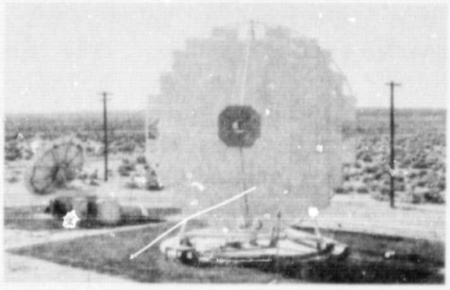

FIGURE 1. TEST BED CONCENTRATOR

*The research described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the U.S. Department of Energy through an agreement with NASA.

CONTROL SYSTEM OPERATIONAL CHARACTERISTICS

The final design of the TBC control system provided one axis of fast slew capability so that either the sun acquisition or emergency off-sun mode could be obtained in a minimum time. Due to differences in the mechanical design, the azimuth axis has the higher rate capability. The azimuth drive is a wheel and track system driven through a two-stage gear box by a three-horsepower, DC electric motor. The elevation axis drive is a low efficiency jack screw which would require a very large electric motor to accomplish the same drive rate as the azimuth drive. Since this drive system is based on a modified antenna design, it was not cost-effective for E-Systems, Inc. to increase the slew rates of both axes. The slew velocities of the two axes are 2028°/hr (0.56°/sec) for the azimuth and 168°/hr (.05°/sec) for the elevation. These rates are achieved with 48 km/hr (30 mph) wind loadings; calm day velocities are slightly higher.

The procedure for getting on and off sun is to run the elevation axis up to the approximate elevation of the sun for the particular time of acquisition and then slew the concentrator on sun in azimuth. This prevents the sun spot from crossing the bipods or guy rods. The sun spot, defocused slightly, does cross the receiver ring structure. A preliminary, worst-case thermal analysis showed that ring temperatures could enter the 1093°C+ (2000°F+) range in seconds. The results of this thermal analysis led to the installation of 5-cm (2-in.) thick Fiberfrax insulation material on the ring structure and over the bipod joints. The remaining upper half of the bipods and guy rods was covered with 3-mm (1/8-in.) thick Fiberfrax.

The TBC base, or alidade, has the capability of rotating 178° from south due to its wheel and track design. Therefore, during maintenance or malfunctions the concentrator dish can be pointed towards north. The dish can be moved about the elevation axis between the zenith position and the horizon, or 0°-90°.

The automatic sun-acquisition system is controlled by two sun sensors, one for each axis. Each of the sun sensors has a ±2° acquisition cone angle within which the concentrators are programmed to point. Pointing within ±2° is accomplished through a memory track system. The memory track consists of a computer memory bank device which stores ephemeris data from the prior tracking period; the data can also be updated by keyboard or by an external computer to provide the sun's ephemeris data for the day of interest. The stored data is used to point the concentrator close to the sun's position. The sun sensors then take over and point the concentrator dish to within a few hundredths of a degree of the sun.

As the sun sensor system views the edge of the sun disk it reduces the slew velocity rate of the drive motor. This in turn makes the sun spot track across the receiver ring support structure at a very slow rate. The early slow slew speed can be changed by a keyboard input from the control unit to insert a time lag between the first acquired sun signal and the speed reduction in the motor. This time lag allows the sun spot to track at full speed across the ring and not slow down until it reaches the receiver.

The concentrator control units have the capability of correcting for gravitational deflections as a function of elevation angle. The sensitivity of the sun sensors can also be changed to compensate for seasonally variable insolation levels or for atmospheric conditions. This feature allows the sensors to pick up less than optimum sun intensities and diminishes their tendency to track bright spots at the edge of clouds.

The control unit can also be used to roughly determine the sun sensor mechanical misalignment through the use of the sensor sun presence signal (sun intensity) and the axis angle readout dial. If the sensor mechanical misalignment is 1° or less it can be corrected electrically by inputting data through the keyboard.

MIRROR ALIGNMENT

Light sources considered for mirror alignment were moon, sun and an incandescent lamp. The technique chosen utilized a semi-distant incandescent light source which produced a reflected image on the focal point target. The target surface is composed of a series of concentric rings 2.54 cm (1 in.) apart. The moon was not selected because of its cyclic appearance and potential occlusion by clouds. The sun was not used due to weather and safety considerations. Both of these discarded methods would have required the TBCs to track which would have introduced a tracking error into the mirror alignment.

Only one TBC mirror facet could be aligned at a time. This necessitated the development of individual mirror covers which could be removed and reinstalled easily. (See Figure 1.) Opaque plastic covers with Velcro fasteners were chosen. The alignment of one entire concentrator (224 mirrors) took about two weeks of night work.

The light source was located at a NASA facility atop a hill 5.8 km (3.6 miles) southwest of the test site. This allowed protection for the equipment and provided convenient electrical power, even though the equipment was designed to be weather resistant and portable. The light was attached securely to the roof of the building and the rest of the equipment was placed indoors. The light was aimed towards the concentrators until a maximum brightness could be observed at the TBC site.

Once the light source was aimed, the TBC was boresighted to it. This was done using two sets of cross hairs and two disks which were replaced by a series of disks with successively smaller apertures. The cross hairs were placed at the front (outer end) of the receiver mounting ring and at the rear of the concentrator dish structural hub on the geometrical center. The disks with variable size circular apertures were placed at the mirror surface plane and at the focal plane of the receiver. By moving the concentrator while sighting along the cross hairs and through the apertures in the disks to the light source, the concentrator was boresighted to the light. The final aperture size in the two disks was 1.27 cm (0.5 in.) in diameter, resulting in the maximum pointing error being within $\theta = \tan^{-1} 0.5 \div 259.8$ or 0.11^{o}. The cross hairs used in conjunction with the dish apertures and the light reduced the boresighting error by half, or $\theta = .05^{o}$. The control system position repeatability for the concentrator system was designed to be $\pm .01^{o}$. When it was programmed to move the concentrator to the boresighted position of the light source, a visual alignment check was performed several times by physically sighting the light source along the cross hairs and through the two disks. This verified that the image was geometrically centered at the focal plane target location.

The mirror alignment is implemented by using a three point adjustment system (see Figure 2). Each mirror facet is attached to the concentrator structure with three flexures (see Figure 3). The three flexure halves bonded to the mirror facet are bolted to a matching bracket on the concentrator structure. Both halves of the joint have slotted holes to allow for adjustment or movement. One at a time, each of the 224 mirror facets was loosened at the flexure joint and adjusted to center its image on the focal target. When the image was centered the three flexure joints were tightened in place (see Figure 4).

FIGURE 2. MIRROR FACETS WITH FLEXURE ATTACHMENT HARDWARE

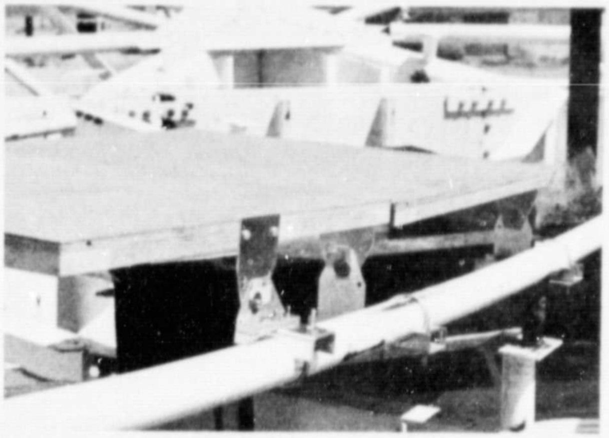

FIGURE 3. MOCK-UP MIRRORS WITH FLEXURE ASSEMBLY

Additional alignment verification checks were made periodically by removing a cover from a previously aligned mirror and re-verifying its light image position. No displacement was evident in these checks. After all mirrors were aligned, the opaque target at the focal plane was replaced with a translucent target and a picture was taken of each individual mirror image. All mirror covers were then removed and the resulting image was recorded on film (see Figure 5). A further alignment check was made by pointing the concentrator at the moon and imaging the moon on the target; this image was also recorded on film (see Figure 6). The moon's image was approximately 20 cm (8 in.) in diameter. This matched the predicted image size and further verified that the mirrors were aligned satisfactorily. On several occasions one edge mirror was uncovered while the concentrator was pointing at the sun.

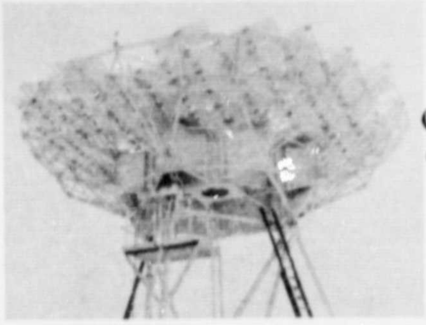

FIGURE 4. REAR VIEW OF TBC WITH MIRRORS ALIGNED

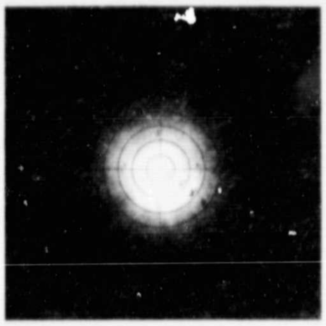

FIGURE 5. LIGHT SOURCE IMAGE

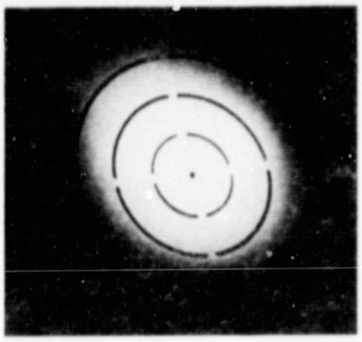

FIGURE 6. MOON IMAGE

This provided increased confidence in the mirror alignment because the sun produced an elliptical image from these edge mirrors of approximately 20 cm (8 in.) maximum dimension, as determined by eye observation from the ground. The edge mirrors produce the maximum elliptical image size because they are the furthest off axis.

FUTURE TESTING

Test preparations are underway to install a solar flux mapper to characterize the solar spot. It will measure the size, shape and intensity of the sun's image.

Upon completion of flux mapper testing, cavity cold water calorimeter testing will be initiated. This will provide information on the thermal characteristics of the TBCs. Both test sequences will be done using three regions of mirrors individually and then all mirrors at once. Testing will be done with both clean and soiled mirrors. The reflectivity of sample mirrors will be measured as necessary to coordinate the reflectance with the solar test results.

Upon completion of the characterization tests, the TBCs will be ready for the various receivers and engines scheduled to be tested.