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LOW COST CONCENTRATOR

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ABSTRACT

The Acurex Corporation is under contract to the Jet Propulsion Laboratory to design, fabricate, install, and test a cost-effective point focus solar concentrator. The key to concentrator cost effectiveness is the proper design of the reflector surface panels. The low cost concentrator reflective surface design is based on the use of a thin, backsilvered mirror glass reflector bonded to a molded structural plastic substrate. This combination of reflective panel material offers excellent optical performance at low cost. This paper briefly describes the design approach, rationale for the selected configuration, and the development status. Reflective panel development and demonstration results are also presented.

INTRODUCTION

The overall objective of the low cost concentrator project is to develop and demonstrate a state-of-the-art technology concentrator which is cost effective in high volume production and has a 30-year life under wide environmental extremes. The development project is structured into a three-phase effort. Phase I, completed in March 1979, encompassed the concept selection, preliminary design and cost assessment, and demonstration of the mass production reflective panel fabrication approach. The Phase II efforts, which began in September 1980 and are currently underway, encompass detailed design and analysis and demonstration of the prototype reflective panel fabrication approach. Phase III includes fabrication, installation, and testing of three prototype concentrators and is scheduled for completion in May of 1982.

DESIGN SUMMARY

The design of the 11 meter diameter (95 m^2 gross aperture area) Low Cost Concentrator is shown in Figure 1. The concentrator is a two-axis tracking system designed to interface with a 1,500 lb thermal receiver/power conversion unit package. Predicted performance of the concentrator is 63 kWt at the receiver aperture based on the following design conditions:

- 800 W/m^2 insolation
- 1,700°F receiver operating temperature
- 95 percent reflectance
- 30 mph operating wind

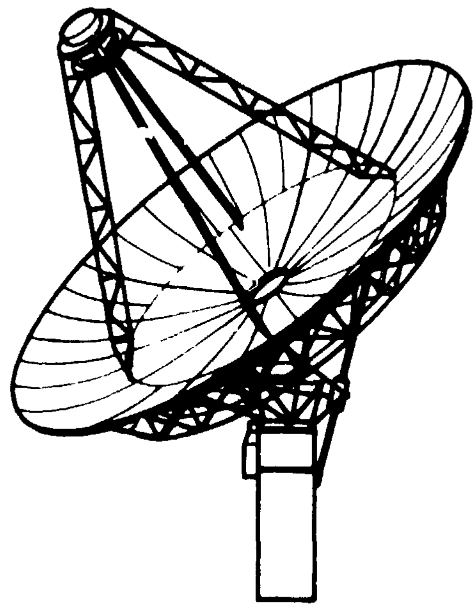
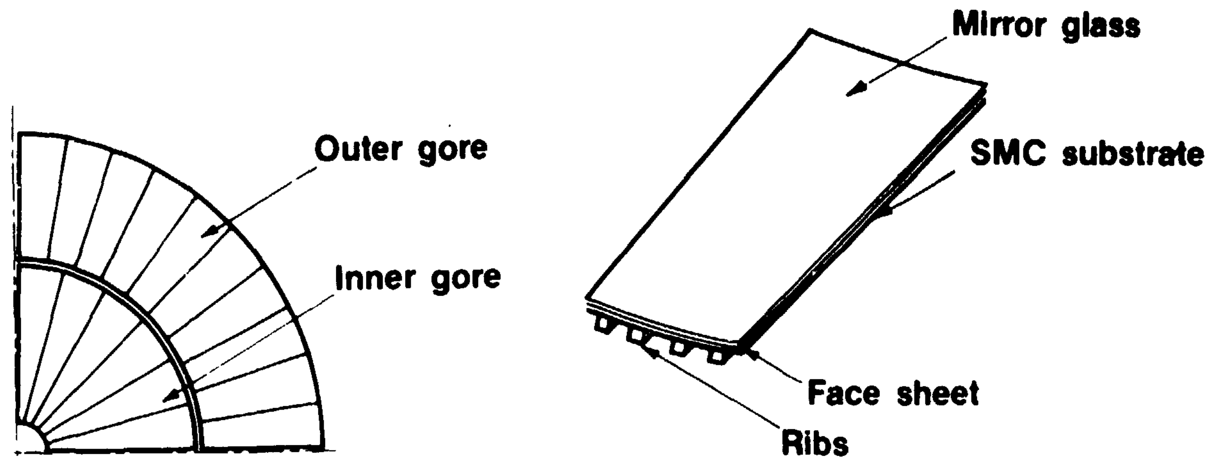


Figure 1. Design Description

The major design features of each of the subassemblies of the mass production concentrator are discussed in the following paragraphs. Prototype-specific modifications for the reflective panel subassembly are also presented.

Reflective Panel Subassembly

The reflective panel subassembly consists of inner and outer groups of reflector gores forming a complete but physically discontinuous reflective surface. As shown in Figure 2, a concentrator consists of 40 outer and 24 inner gores. The reflective gores are a composite construction of thin (0.028 in), backsilvered mirror glass with a sheet molding compound (SMC) supporting substrate. A thin glass reflector was chosen because of high performance and long life characteristics. In terms of performance, backsilvered mirror glass provides the highest practical solar hemispherical reflectance (0.95) and has excellent specularity. Glass is highly abrasion resistant and environmentally durable. The reflective panel substrate is a compression molded material generically referred to as SMC. SMC is a ready-to-mold polyester resin material with chipped fiberglass reinforcement processed in continuous sheet form. Parts of SMC are typically molded at 300^{o}F and 1,000 psi in 3 to 5 min cycle times. SMC molding is a high volume production process and offers the potential for low cost reflective panel substrates. The reflective panel substrate design consists of a thin (0.15 in) face sheet with an intergrally molded rib structure. The glass mirror is bonded to the SMC substrate.



a. Reflective Surface Configuration

b. Typical Gore Configuration

Figure 2. Reflective Panel Design

Support Structure Subassemblies

The three support structure subassemblies are:

- Panel support structure
- Receiver support structure
- Intermediate support structure

The lightweight space frame subassemblies feature welded steel shop subassembly construction using standard size, commercially available steel tubing. Finite element analysis techniques were used to optimize the support structure for minimum weight.

Foundation and Drive Subassemblies

The foundation design features simple installation and adaptability to sloping or rough terrains. The foundation consists of a single cast-in-place, reinforced concrete pier with an azimuth turret mount. The single pier foundation was selected in order to minimize site preparation and foundation installation labor costs. It does result in a slightly higher weight concentrator than would result with a wide base foundation. However, because of reduced installation labor, total installed cost is minimized. Hydraulic power units were selected for both azimuth and elevation drive systems. The azimuth drive is a hydraulically-powered gear drive. The elevation drive is a single stage, double-acting hydraulic cylinder actuator. Emergency power is provided by a pressurized gas accumulator.

Tracking and Control System

A hybrid, two-axis, sun tracking control system based on microprocessor technology, has been selected. Coarse synthetic tracking is achieved through a microcomputer based control system to calculate sun position for transient periods of cloud cover as well as sundown and sunup positioning. Accurate active tracking is achieved by two-axis sun sensors.

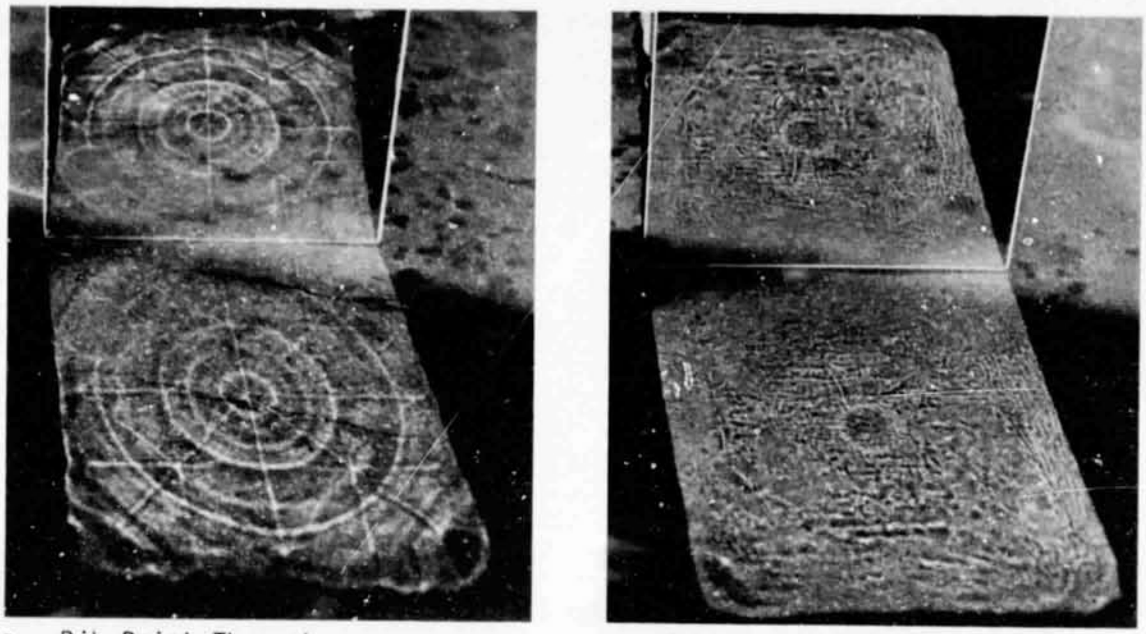
Reflective Panel Prototype Modifications

Prototype-specific modifications to the mass producible reflective panel design are being made to reduce prototyping cost. The most significant modification is in the area of the compression molded SMC substrate. The cost of a full-size mold is prohibitive for prototyping purposes. The prototype panels will be fabricated by hand layup of glass-reinforced polyester (GRP) on a contoured epoxy tool. The panel face sheet will be fabricated on this tool in a similar manner as boat hulls. The ribs will be cut from GRP sheet stock, assembled, and bonded to the face sheet. The mirror glass will be bonded to the assembled substrate.

Reflective Panel Development and Demonstration

Two-foot square compression molded SMC-Mirror Glass panels were fabricated and tested in the Phase I effort. Compliance with the requirements of the low cost concentrator has been successfully demonstrated. Both subsize and full-size hand layup GRP-Mirror Glass prototype panels will be fabricated and tested in Phase II of this project. Panel testing will consist of dimensional verification, slope error, hail impact, thermal cycling, and structural deflection tests.

The primary objective of the Phase I compression molded SMC-Mirror Glass test panels was to demonstrate the optical surface quality attainable with present state of the art. Test panels were fabricated with both a single-step molding process and a two-step, molding-bonding approach. The single-step process integrally molded the SMC-Mirror Glass panel in one molding cycle. The two-step process involved molding of the SMC integral face sheet-ribbed substrate followed by adhesively bonding the mirror glass using the female portion of the mold as the bonding fixture. Qualitative and quantitative evaluation of test panel optical quality was performed. Representative panels produced with each manufacturing method are shown in Figure 3. The reflected light patterns from each panel provide a very sensitive qualitative evaluation of mirror surface topography. The single-step molded panel exhibited discernible rib print-through (the diagonal line patterns crisscrossing the mirror surface). This effect is related to material shrinkage at the rib/face sheet junction during molding and curing. A second observable feature in the single-step molded panel is a system of concentric ripples progressing outward from the center of the panel. This pattern was traced to a system of concentric ripples in the tool. The patterns were impressed into the glass sheet by the high molding pressure of the compression molded



a. Rib Print-Through
Circular Tool Pattern

b. No Rib Print-Through
Subtle Circular Pattern
0.95 mrad Slope Error

Figure 3. Compression Molded SMC-Mirror Glass Test Panels

process. The two-step, molded-bonded panel was visually superior to the single-step molded panel, showing no trace of rib print-through and only subtle traces of the concentric tool markings. Reflected light patterns from these panels revealed a relatively featureless surface, with a low amplitude, random oriented ripple uniformly covering the surface. This ripple is believed to be caused by variations in the bond joint thickness. The two-step molded-bonded panel was then tested at the Sandia Laboratory ray trace facility. The resulting slope error standard deviations for the surveyed area was 0.95 mrad, well below the target value of 2.4 assumed for initial performance estimates. From these experimental results, it can be concluded that composite reflective panels of SMC-Mirror Glass can be manufactured with required precision using current state-of-the-art methods. Bonding of the mirror glass to a premolded SMC substrate would be used for initial panel production. The impact of the additional processing time is small. In the long term, further developments in single-step molding will allow panels of comparable quality to be produced.

KEY RESULTS

The key results of this development project to date are:

- A state-of-the-art point focus solar concentrator based on SMC-Mirror Glass reflective panels has been shown to be highly cost effective in mass production
- SMC-Mirror Glass reflective panels manufactured with required precision using current state-of-the-art methods have been demonstrated