PARABOLIC DISH CONCENTRATOR (PDC-2) DEVELOPMENT

D. Rafinejad
Acurex Corporation
Mountain View, California

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ABSTRACT

Acurex Corporation has completed the design of the point-focus Parabolic Dish Concentrator (PDC-2). The fabrication of the prototype dish has begun.

The PDC-2 is a high-flux, 12.2m-diameter dish with a thermal output of 96.5 kW_t. The concentrator consists of a lightweight space-frame structure and 64 highly accurate reflective panels. The structurally efficient panels are comprised of cellular glass cores sandwiched between thin backsilvered mirror glass on the front and unsilvered glass on the back. The concentrator tracks the sun in elevation and azimuth axes and is mounted on a single embedded pedestal foundation.

This paper describes the concentrator design and status of the development project.

INTRODUCTION

Acurex developed the PDC-2 design as a subcontractor to Ford Aerospace and Communication Corporation, under the sponsorship of the Department of Energy. The objective of the program is to develop a 12.2m parabolic dish concentrator for use in the Small Community Solar Experiment (SCSE No. 1). The program scope includes the design, fabrication, and testing of one concentrator at Sandia test facilities in Albuquerque, New Mexico.

Although PDC-2 development is intended for electrical power generation at a small community, it can be used in a much broader area of application. PDC-2 is a highly accurate concentrator that can be used in a distributed solar system for thermal and electrical power generation. The power conversion unit can be mounted at the focal plane or be centrally located. Its modular nature makes it suitable for applications in all system sizes.

Acurex has designed several generations of parabolic dish concentrators under JPL sponsorship. Extensive conceptual design studies have been performed over several years to optimize the design. The optimized concept has now been successfully carried through the detailed design and component prototyping stage.

The optimization studies were based on the overall installed system life cycle cost and performance and incorporated relevant improvements in related technologies such as heliostats. The PDC-2 design reflects several years of dish development and represents the state of the art in high performance solar dish technology.

The following sections describe the PDC-2 design and update the project status.

PDC-2 DESIGN

The PDC-2 is a single reflection point-focusing, two-axis tracking solar concentrator with a reflective surface aperture of 12.2m in diameter. The focal length to aperture diameter ratio (f/D) of the dish is approximately 0.54. The reflected solar radiation focuses onto a receiver aperture of 10 to 15 in. in diameter, depending upon application. The dish concentration ratio ranges from 1,000 to 2,300. PDC-2 is shown in figure 1.

PDC-2 produces a minimum of 96.5 kW thermal power (100 kW_t nominal) at the receiver aperture at 1,000 W/m^2 insolation and 10 mph wind.

The PDC-2 concentrator is designed for minimum fabrication and installation cost and is adaptable to low cost at high volume production. The concentrator has a design life of 20 years for reliable and safe operation.

The PDC-2 operates safely at winds up to 25 mph. At winds greater than 25 mph the concentrator will move to stow position facing the zenith.

The PDC-2 consists of five subsystems, as shown in figure 1:

- Reflective surface
- Support structure
- Pedestal/foundation
- Drive subsystem
- Electrical and controls

These subsystems are described in the following sections.

REFLECTIVE SURFACE SUBSYSTEM

The concentrator surface consists of two concentric rings of independent reflective elements (panels) which form a physically discontinuous parabaloidal reflective surface with a common focal point. The inside ring is made up of 24 panels, and 40 panels comprise the outside ring. The reflective panel consists of a lightweight cellular glass core bonded to a thin glass mirror in front and a narrow strip of unsilvered thin glass in the back spar. The mirror glass and the spar cap carry the major portion of the bending loads of the composite structure. The reflective panel design is shown in figure 2.

The high quality reflective surface has a slope error of less than 1 mrad rms due to manufacturing tolerances and worst-case operating conditions. Cellular glass is a low-cost, noncritical material with a very high stiffness-to-weight ratio. It is easily machinable to provide the highly accurate optical surface and closely matches the coefficient of thermal expansion of the front and back glass. The panel back is shaped to minimize weight while maintaining the minimum thickness for structural integrity.

Each panel is supported at three points via support pads that are bolted to the ring truss structure. The support pads are made of precipitation

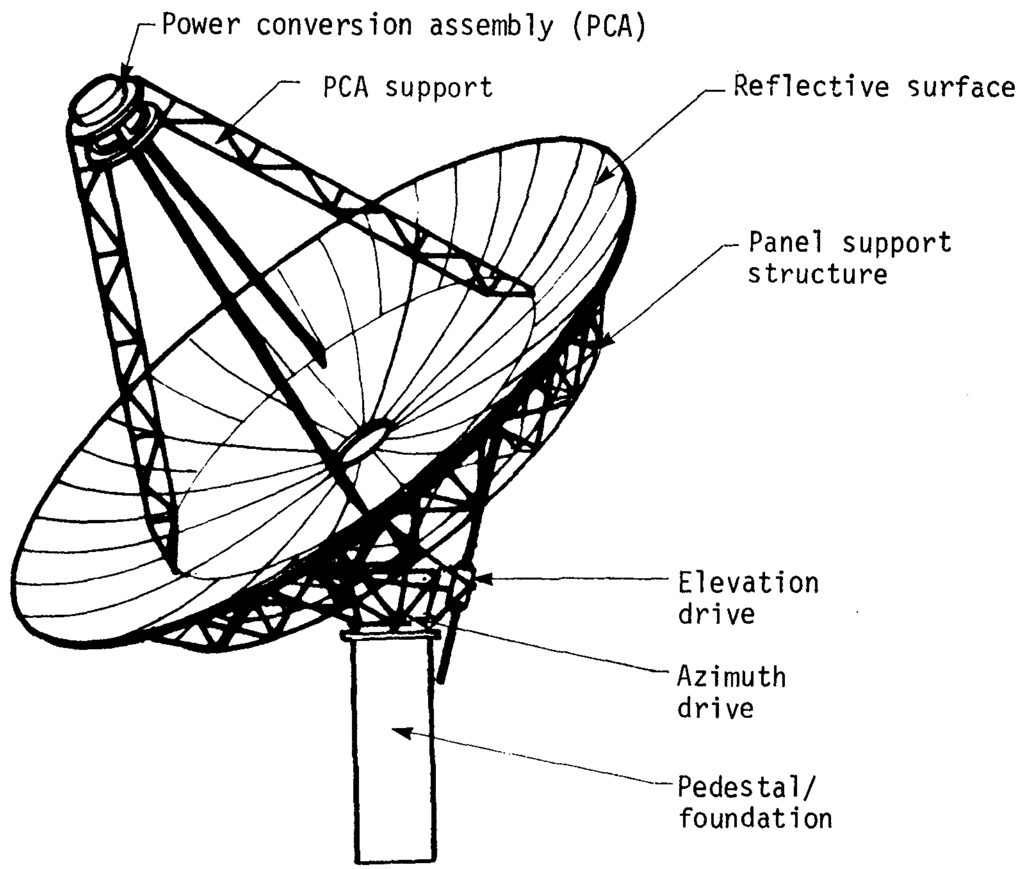


Figure 1. PDC-2

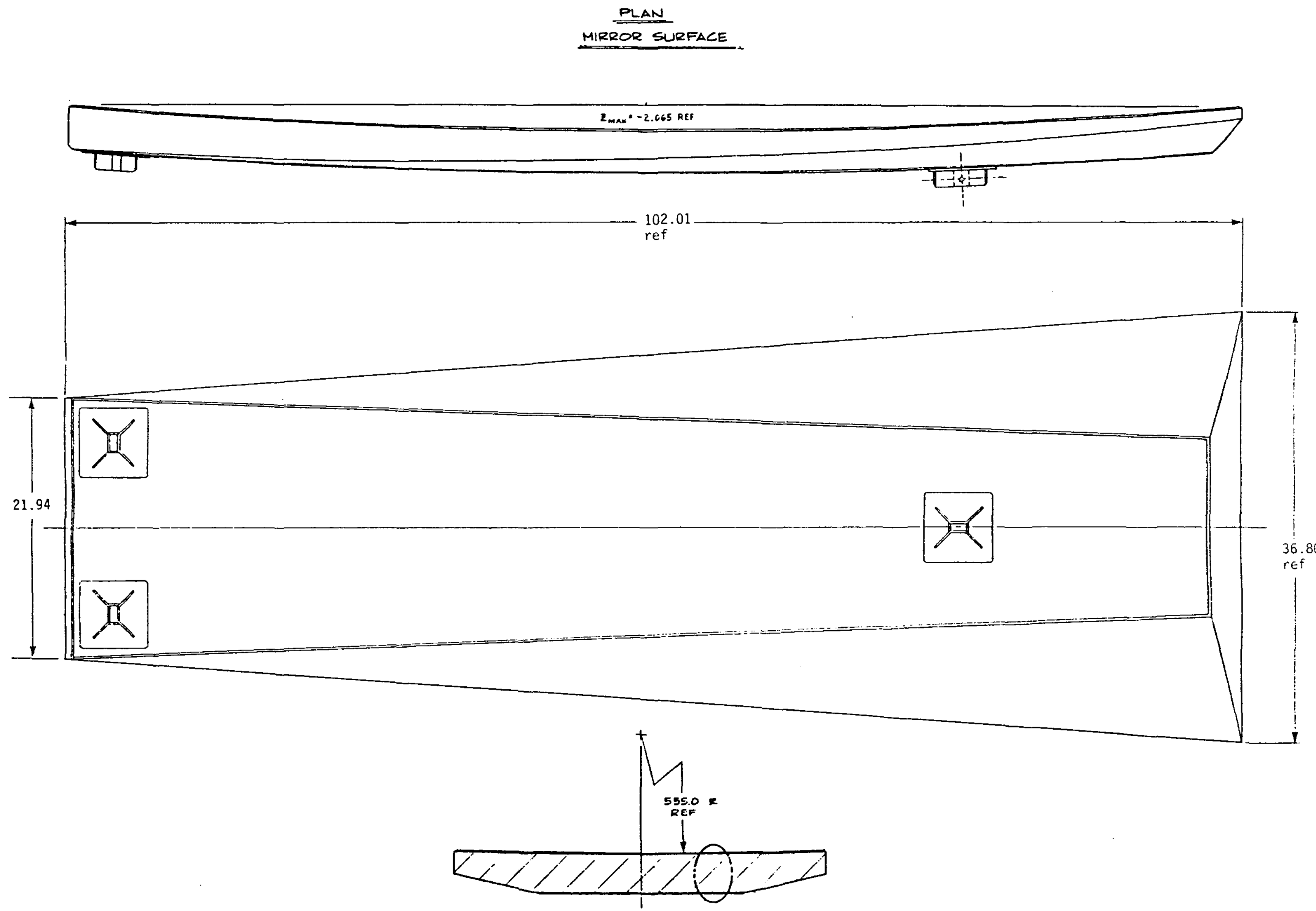


Figure 2. Outer Reflective Panel

hardened steel (ph 15-7 mo) for a good match with coefficient of thermal expansion of the glass.

The reflective surface mirror is a 0.040- to 0.058-in. thick chemically strengthened backsilvered glass. Acurex investigated availability of thin solar mirror glass in the desired length (108 in. for inner panel) from various U.S. and European suppliers.

Although it was determined that mirror in the desired size could be obtained from one European supplier it was deemed prudent early in the project to develop an alternate panel design to minimize program risk. A spliced joint reflective surface configuration was designed. In this design, two shorter (50 in. long) glass mirrors are butted together with a narrow piece (6 in.) of overlapping thin clear glass. The prototype PDC-2 panels will be made of full size (single sheet) corning 0317 glass that is 0.058 in. thick and is currently available in limited quantities.

The standard 24 in. by 18 in. by 5 in. foamglass blocks are currently mass produced by Pittsburgh Corning. The supplier will not manufacture large pieces (full size) of foamglass unless very large quantities are ordered. Therefore, for prototype and low-volume production of PDC-2 panels, 10 standard blocks are bonded together and cut to shape. The foamglass front surface is machined in a sanding operation to the paraboloidal configuration.

SUPPORT STRUCTURE SUBSYSTEM

The support structure subsystem consists of three parts as shown in figure 3:

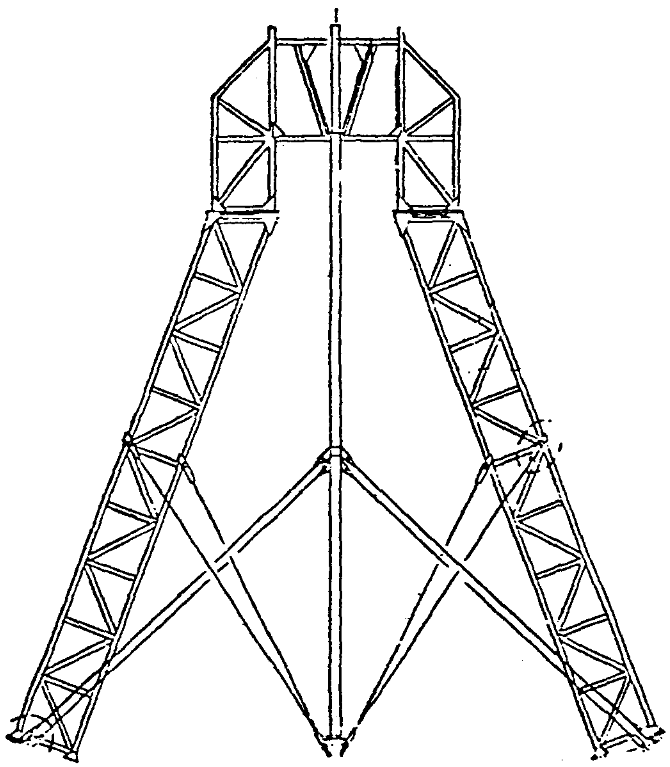
a. Power conversion assembly (PCA) support
b. Panel support
c. Drive support

The overall support structure weight is 8,000 lbs and supports the 1,500-lb PCA, 5,400 lb of reflective panels and 600 lb of cabling and miscellaneous hardware.

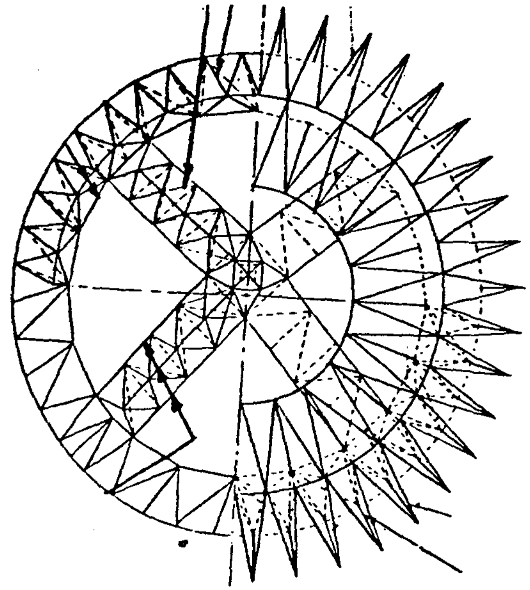
The PCA support is a quadripod structure using laced legs and is of thin-wall steel tubing construction. Sixteen 5/16-in. diameter guy cables contribute to structure stability. The quadripod also provides a means of routing cables and lines to the equipment located at the focal point. The structure has a detachable PCA mounting frame required for installation and removal of the PCA. The quadripod legs are rigidly attached to the panel support structure at four flange mounting points located 45° with respect to the vertical and horizontal dish axis. The PCA support structure is designed for minimum shading or blocking to the incident and reflected insolation.

The panel suport structure is a space frame ring truss made of structural steel tubing. The triangular truss ring has outrigger attachments to support the reflective panels (see figure 3).

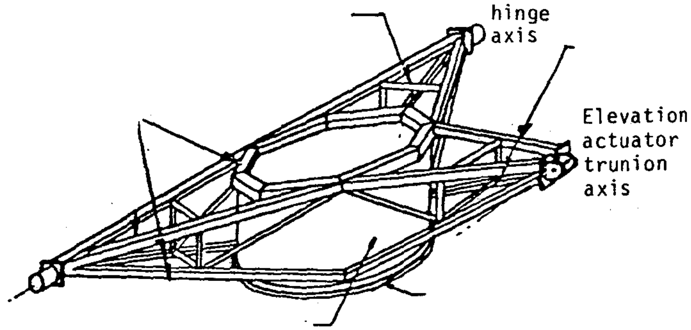
The 64 reflective panels are installed on the ring truss structure with statically determinant three-point attachment. These attachments have



a. PCA support



b. Panel support



c. Drive support

Figure 3. PDC-2 Structure

sufficient degrees of freedom to allow fine tuning of the composite reflective surface for installation and optical alignments and allow for the panel/structure differential thermal displacements.

The panel support structure is fabricated in five detachable segments for shipment; four ring truss segments and one center frame segment. The segments are bolted together in the field.

The drive support structure serves as an intermediate structure between the reflector assembly and the pedestal. The center hub contains the azimuth drive assembly and is pivoted about the azimuth axis at the top of the pedestal. The space frame arms of the drive support structure provide supports for the elevation hinge about which the dish is pivoted. The third arm supports the elevation actuator trunion. The azimuth drive turntable bearing is connected to the mounting flange on the top of the pedestal.

The PDC-2 structure has been analyzed to determine the contribution of the support structure deflection to the dish optical error. It is determined that the contribution due to gravity loading is approximately 1.5 mrad in the worst case when the dish is facing the horizon. The effect of operating wind loads is negligible.

PEDESTAL/FOUNDATION

A single pier foundation of the PDC-2 provides a fixed axis about which the concentrator assembly is pivoted. The pedestal is a 30-in. pipe that is embedded approximately 16 ft in poured-in-place concrete. The mounting flange is field-levelled and welded to the embedded pedestal.

DRIVE SUBSYSTEM

The PDC-2 can be driven independently about the elevation and azimuth axes at two speeds: slew and tracking.

The azimuth rotation is provided by a ring gear/pinion drive mounted at the top of the pedestal. The pinion is driven by a 5-hp DC motor through a 724:1 gear reduction to provide the necessary mechanical advantage. Azimuth travel range is between 0° and 310°.

The elevation rotation is accomplished with a 30-ton inverted ball screw jactuator mounted between the drive support structure and panel support structure. The elevation drive motor is a 15-hp DC motor. The range of elevation travel is between 0° (facing the horizon) and 90° (facing the zenith). It should be noted that the normal concentrator duty cycle requires small fraction of the design rating of the motors and the paresitic energy consumption is small.

DC motors were found to offer clear advantages over AC motors for this application. The advantages of DC motors as they relate to the PDC-2 application include: wider range of speed control, ease of speed, acceleration/decelleration and torque control, higher torque capacity, quick reversing and braking and lower cost in the 5 to 15 hp size range.

The drive control provides dynamic braking to bring the concentrator to a stop. In addition, a mechanical brake is provided for elevation drive to hold the concentrator stationary once it has come to a stop under the stow and operating conditions.

ELECTRICAL AND CONTROL SUBSYSTEMS

The electrical subsystem provides power to the concentrator drives and transmits the output power from the PCA to a rectifier box mounted on a rack near the pedestal.

The concentrator control subsystem consists of:

a. Central controls that provide the plant level control interface with the concentrator
b. Power conversion system interface controls
c. Local concentrator control subsystem

The local concentrator control elements consist of a sun sensor, azimuth and elevation positional feedback devices (encoders), limit switches, drive controller, and the remote control interface assembly (RCIA).

The drive controller consists of the azimuth and elevation motor speed controllers and a manual control station. The controls are set up for two-speed operation from the panel or RCIA. The azimuth and elevation drive speeds in tracking and stow are 0.1°/sec and 1.2°/sec, respectively, with speed control repeatability of $\pm$10 percent. The drive controller also provides independently adjustable acceleration and deceleration controls. It is housed in a NEMA 3 double door cabinet with heat exchanger for high-temperature outdoor operation.

The RCIA contains the control algorithms and logic for sun tracking and interface with the central controls. The sun tracking is a hybrid system. RCIA calculates ephemeris data to provide coarse tracking signals to the concentrator. The sun sensor provides the fine "sun track mode" signal. During intermittent cloud coverage, the concentrator goes into the ephemeris track mode where it follows the sun path. The concentrator can also follow the sun path in the offset track mode where it performs ephemeris track with an angle bias. Other concentrator control modes include acquisition and detrack from sun and stow command. The concentrator control is a fail safe system and causes the concentrator to go to stow if there is a power or software failure. An emergency back-up generator is required at the system level to provide power in case of grid power failure. Limit switches are provided to stop movement of the concentrator beyond certain position in each direction.

PROJECT STATUS

The PDC-2 design development is complete and the detailed design drawings have been prepared. Specifications for procurement of all concentrator components have been prepared and issued for competitive bidding. The subcontracts for delivery of the support structure, reflective surface mirror glass, drive motors and controllers, elevation drive jactuator, azimuth drive speed reducer and the ring gear turret, have been placed and they are currently at various stages of fabrication.

A semi-automated technique for fabrication of the reflective panels has been developed, including the cellular glass sanding and mirror bonding and sealing. Two partial full-scale prototype panels have been fabricated to verify the design and demonstrate the viability of the foamglass sanding technique. The partial full-scale prototype panel was designed as a true section of the full size outer panel to simulate the features of the full panel as closely as possible.

The partial full-scale panels are scheduled for optical, structural, and environmental testing at Sandia. The factory layout and tooling design requirements for production of the reflective panels have been prepared. The long lead factory equipment have been ordered.

The final stage and remaining task in the PDC-2 development will be the completion of fabrication and testing of a prototype module.