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Solar Thermal Power Systems Project
Parabolic Dish Systems Development

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Annual Technical Report

Fiscal Year 1981

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March 15, 1982

Prepared for
U.S. Department of Energy
Through an Agreement with
National Aeronautics and Space Administration
by

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

and

NASA Lewis Research Center
Cleveland, Ohio

(JPL PUBLICATION 82-22)

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ABSTRACT

This report summarizes the activities of the JPL Solar Thermal Power Systems Parabolic Dish Project for FY 1981. Included are discussions on subsystem designs of concentrators, receivers, engines, power converters, and thermal transport. Analyses and test results are also included along with progress on field tests, Small Community System development and the Parabolic Dish Test Site.

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GLOSSARY

DOE	Department of Energy
JPL	Jet Propulsion Laboratory
NASA	National Aeronautics and Space Administration
PDTS	Parabolic Dish Test Site
PCA	Power Conversion Assembly
GE	General Electric Company
TBC	Test Bed Concentrator
ORC	Organic Rankine Cycle
FACC	Ford Aerospace and Communication Corporation
AGT	Advanced Gas Turbine
PRDA	Program Research and Development Announcement
PKI	Power Kinetics, Inc.

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SECTION I

INTRODUCTION

Point-focus parabolic dish technology is being developed for the U.S. Department of Energy (DOE) by the Jet Propulsion Laboratory (JPL) under an interagency agreement with the National Aeronautics and Space Administration (NASA). The status of this work is described below in terms of the major subsystem hardware elements, the integration and test effort, and the field experiment preparation. Testing is done at the Parabolic Dish Test Site (PDTS) to assist in the development of dish subsystems and to verify the performance of a dish module before deploying dish hardware in field experiments in user environments.

Parabolic dishes uniquely combine an ability to develop high temperatures with an inherently modular nature. The temperature of the working fluid depends on its flow rate and, with low flow rates and suitable fluids, temperatures up to 1650°C (3000°F) are possible. Therefore, heat engines can be operated at the highest practical temperatures and thus at maximum efficiencies. Dishes can be used in either thermal or electrical modes and in cogeneration applications, including a wide range of industrial applications at temperatures down to about 315°C (600°F).

Because dishes are modular, a single dish can be used autonomously in remote applications, or a field of dishes can be deployed with their outputs electrically connected. Power can be added incrementally, as required, and individual dishes serviced without disturbing other units in the field. Modularity also offers manufacturing and installation advantages because a large number of identical devices are dealt with.

SECTION II

COMPONENT TECHNOLOGY DEVELOPMENT

The major components of a parabolic dish module are the concentrator (including support structure and sun-tracking systems), receiver, engine, and alternator. The engine and alternator are referred to in this report as the power conversion subsystem. The grouping of receiver, engine, and alternator is termed the power conversion assembly (PCA). A typical dish module is shown in Figure 1.

A. CONCENTRATOR DEVELOPMENT

The concentrator consists of a reflective paraboloidal surface, its supporting structure, and tracking provisions. The measures of performance derive from the geometric accuracy of the reflective surfaces, the specular reflectivity of the surface, and the sun-pointing accuracy. The dish is relatively large, which strongly affects overall cost, so the development effort centers on attaining the lowest cost consistent with the desired performance. Contracts with both General Electric (GE) and Acurex were in effect for concentrator development during the reporting period.

1. General Electric Concentrator

The GE concentrator, designed to provide an output of 80 kilowatts thermal (kWt) at an insolation of 1000 watts per square meter (W/m^2), has the following nominal characteristics:

(1) Diameter	12 m (40 ft)
(2) Rim angle	53 degrees
(3) Tracking accuracy	+ 1/8 degrees
(4) Reflective surface area	113 m ² (1216 ft ²)
(5) Reflectivity (specular)	0.78
(6) Concentration ratio (geometric)	1000 for 38-cm (15-in.) diameter aperture

The detailed design of the concentrator was completed early in FY 81. The paraboloidal dish identified in Figure 1 is composed of 12 radial gores, each comprising an inner, center, and outer panel. The outer panel is 3.05 m (10 ft) wide by 1.06 m (3-1/2 ft) deep. A precision master mold was made for each of the three configurations panel by GE subcontractors. The support panels consist of a fiberglass sandwich with a balsa wood core. The reflective surface is a second surface aluminized mirror on a Llumar film. Three panels making up one gore were fabricated and shipped to JPL at the end of FY 81 for evaluation and optical testing.

Early in FY 82, a complete concentrator will be fabricated, including reflective panels, support structure and articulation subsystem. The complete concentrator with its control system will be shipped to the PDTS for performance evaluation and subsequent systems testing with PCAs attached at the focal plane.

Figure 1. Typical Parabolic Dish Module

2. Acurex Concentrator

In October 1980, work began on an Acurex contract to design an alternate point-focus concentrator. In initial conceptual studies of an advanced concentrator, Acurex developed a triangular concentrator design configuration with triangular panels. The substructure panel material selected was plastic to accommodate the sheet-molding technique used by the subcontractor, the Budd Company. Acurex selected a chemically tempered glass from Glaverbel in Germany for the second surface mirrors. The 0.7-mm (0.028-in.) thick, low iron soda lime glass is used to reduce solar adsorption.

Early in the contract, Acurex determined that a circular planform would be as much as 30% more economical in small numbers of concentrators than the original triangular shape, so this configuration (shown in Figure 2) was selected. For the concentrator support system, the single-pedestal design selected consists of a 43.2-cm (17-in.) diameter pipe extending 3.2 m (10.5 ft) above ground and embedded in a 0.9-m (3-ft) diameter concrete pier 5.5 m (18 ft) deep. The estimated performance for the Acurex dish is 78.6 kWt at an insolation of 1000 W/m² with a 24 cm (9.4 in.) receiver aperture. Other characteristics of the Acurex concentrator are:

(1) Diameter	11 m (36 ft)
(2) Rim angle	45 degrees
(3) Tracking accuracy	+ 1/8 degree
(4) Reflective surface area	95 m ² (1022 ft ²)
(5) Reflectivity (specular)	0.95
(6) Concentration ratio (geometric)	2000 for 24-cm (9.4-in.) diameter aperture

Acurex completed the major portion of the detailed design of its concentrator near the end of FY 81. Developmental panels were fabricated in two configurations: one with a glass-reinforced plastic structure and one with a cellular glass substrate similar to the facets on the two Test Bed Concentrators (TBCs) at the PDTs. Both had bonded second surface glass mirrors. In all, six cellular glass and one glass-reinforced plastic developmental panels were fabricated and optically tested. Initial optical tests of the glass-reinforced plastic panels indicated structural problems requiring additional development, but the cellular glass tests showed excellent optical quality.

The two TBCs have been in operation at the PDTs since October 1979. Although they were designed as test instruments, much of the test experience applies to concentrator operation and maintenance. These two identical dish concentrators (Figure 3) are nominally 11 m (36 ft) in diameter and can produce a maximum of 82 kWt with an insolation input of 1000 W/m². The pointing error with closed loop sun sensor tracking is less than 0.05 degrees.

There are 224 individually adjustable mirror facets on each TBC; these can be adjusted as required to match the power limitations of devices being tested. With the mirror segments set for sharpest focus, a peak flux of 1500 W/cm² is obtained through an aperture 20 cm (7.8 in.) in diameter. For most receiver testing to date, the center mirrors are defocused to reduce peak

Figure 2. Acurex Concentrator

Figure 3. Test Bed Concentrators at the Parabolic Dish Test Site

flux intensity to about 600 W/cm^2 . As mentioned below, a Sanders receiver with a quartz window was tested on a TBC during FY 81 at a sustained temperature of 1425°C (2600°F).

3. Advanced Concentrator Design

a. Thin Film Bonding on Steel Panels (Boeing). Of the many concentrator design concepts examined, one of the more promising approaches, in terms of production economy and adequate performance, is the bonding of thin film on steel panels. This approach is being pursued by the Boeing Engineering and Construction Company in Seattle, Washington. When sample panels were tested at JPL, measured slope errors were only 1.2 mrad, an accuracy approaching the specifications of the TBC, which indicates that, if high reflectivity can be coupled with long life, a concentrator of thin film on steel may be cost effective. This design has sufficiently high potential to warrant further development.

b. Transmittance-Optimized Fresnel Lens Concentrator (E-Systems). A second promising concentrator design concept is being pursued by E-Systems, Incorporated, of Dallas, Texas. Currently under development is a point-focusing Fresnel lens concentrator for high-temperature solar thermal energy system applications. It uses a transmittance-optimized, short focal-length convex, dome-shaped, acrylic Fresnel lens as the optical element combining both excellent optical performance and large error tolerance for manufacturing, deflection and tracking. The completed conceptual design is an 11-m diameter dish with an estimated 70% efficiency at 815°C (1500°F) receiver operating temperature and a 1500x concentration ratio.

The dome consists of ten conical-segmented rings, each flat in the radial direction and curved in the circumferential direction, and the lens has a 45° rim angle. The ultraviolet-stabilized acrylic plastic lens is mounted on a steel space frame structure, and the concentrator is pedestal mounted. An 11-m concentrator is estimated to have a 78% efficiency.

B. RECEIVER DEVELOPMENT

Receivers are identified with the heat engine cycle to which they provide thermal input. They can also be classified by the working fluid used or by phase change materials contained, if any, for buffer storage. Cavity-type receivers under development for the organic Rankine, Brayton and Stirling cycle heat engines are discussed below. Comparative characteristics are presented in Table 1.

1. Organic Rankine Receiver (Ford Aerospace and Communications Corporation)

The receiver for the organic Rankine cycle (ORC) is being developed by Ford Aerospace and Communications Corporation (FACC) to supply toluene vapor at about 400°C (750°F) to the turbine of the Barber-Nichols power conversion subsystem. The receiver and power conversion unit is shown in Figure 4.

Table 1. Receiver Characteristics Summary

Manufacturer		Ford	Airesearch	Airesearch	Sanders	Fairchild
Working Fluid		toluene	steam	air	air	helium
Engine Cycle Usage		Rankine	Rankine	Brayton	Brayton	Stirling
Fluid Outlet °C		400	750 ^a	815	1370	700
Temperature °F		750	1300	1500	2500	1300
Aperture Diameter	cm	38	22.8	22.8	19.7	20.3
	in.	15	9.0	9.0	7.75	8.0
Integral Hybrid Design		no	no	no	no	yes
Efficiency % ^b		92-95	80-92	70-85	up to 90	85 (est)
Maximum Pressure	MPa	3.4	14	0.35	0.7	15
	psi	500	2000	50	100	2200
Material		metal	metal	metal	ceramic	metal
Buffer Storage		yes ^c	no	no	yes	no

^a This is the capability for the receiver; a typical Carter engine, as described in Table 2, would use a lower flux.

^b Temperature-dependent.

^c 135 kg_m (300 lb_m) of copper acts as integral buffer storage.

Figure 4. Cross Section of an Organic Rankine Power Conversion Assembly Showing Receiver, Organic Rankine Engine and Permanent Magnet Alternator

FACC began testing the ORC receiver in February 1981, under steady-state conditions using a test loop to simulate the Rankine heat engine. Runs were made at both sub and super-critical toluene pressures, and the thermal output of the receiver was varied over a range of 25 to 100 kW during qualification testing, which was completed at FACC in June 1981. The engine/alternator subsystem, completed in August 1981, was tested using a fossil-fired boiler. Then it was shipped to FACC for the receiver to be attached in preparation for testing on TBC-1 at the PDTS in November 1981.

2. Steam Receiver (Airesearch Manufacturing Company of California)

A contract was awarded to Garrett Airesearch for the design and fabrication of a steam receiver. The cylindrical cavity is 43.2 cm (17 in.) in diameter by 54.6 cm (21.5 in.) deep and contains a tubular helix wound with Inconel 625 tubing. The aperture plate and back closure plate are water-cooled aluminum and stainless steel, respectively. It is suitable for industrial process heat applications as well as for driving Rankine cycle heat engines. Testing, completed in March 1981 at the PDTS, demonstrated that receiver operation over its full performance range was stable and uniform. No flow instabilities were evident even at very low mass flow rates. The receiver is in frequent use as a steam source for making fuels and chemicals and for testing engines and components. It will be used in the future for developing receiver aperture and cavity designs and for evaluating their resistance to thermal shock.

3. Air Receiver (Airesearch Manufacturing Company of California)

An open-cycle air Brayton engine under development has a rated turbine inlet temperature of 870°C (1600°F). An all-metal receiver for the Brayton engine, shown in Figure 5, was delivered to JPL in December 1980 by the Garrett Airesearch Manufacturing Company, Torrance, California. It was instrumented and installed on TBC-2 with testing completed in May 1981. The maximum operating envelope of the receiver, including temperature, pressure and flow rates, was established. It was concluded that, while all performance goals were met, the high thermal gradients in the Inconel heat exchanger produce stresses that reduce the lifetime of the receiver to an unacceptable level. A number of solutions to this problem have been developed that could be incorporated into any future hardware with the necessary changes.

Garrett Corporation is also under contract to develop a preliminary design for a higher temperature receiver employing latent heat buffer storage. Performance maps for typical insolation conditions at the PDTS were produced from computer simulations. Seven design concepts were screened for performance and cost, and a ceramic slip-cast design was selected for a fabrication feasibility study to be performed by the Norton Company. The slip-cast concept allows the heat exchanger element to serve as the pressure container for the working fluid, thus eliminating the need for a transparent window to seal the aperture. Successful development of this ceramic, second-generation receiver will expand the application of dish technology in all three proposed areas: industrial process heat, electric power generation, and fuels and chemicals production.

Figure 5. Air Receiver for an Open-Cycle Brayton Engine

4. Brayton Receiver (Sanders Associates)

Sanders Associates was awarded a contract in early 1980 to design and fabricate a high-temperature 1370°C (2500°F) air receiver using a ceramic honeycomb designed for a pressure of 2 atmospheres. The receiver, shown in Figure 6, uses a sintered beta silicon carbide honeycomb matrix as the heat exchanger and mullite to provide buffer storage. Because the receiver cavity is pressurized, the aperture is sealed by a quartz window. Fabrication was completed in September 1980, and Sanders conducted in-house testing.

The receiver was then shipped to the PDTS for a series of pre-solar performance tests and interface compatibility tests. The first phase of the Sanders receiver testing at the PDTS indicated air exit temperatures ranging from 870°C to 1425°C (1600°F to 2600°F). Preliminary estimates of efficiency are 60% at 1200°C (2200°F) ranging up to 90% at 870°F (1600°F) when aperture solar beam spillage losses are accounted for. These tests demonstrated the feasibility of this high temperature receiver concept for exit air temperatures exceeding the existing state-of-the-art of metal designs. The temperatures exceed those required to power the automotive advanced gas turbine (AGT) engine currently being developed and will support the solarized version of the AGT now under development.

5. Stirling Cycle Receivers (General Electric and Fairchild Stratos)

Receivers for Stirling cycle engines differ from those previously described because close conductive coupling is required. These receivers were designed and fabricated by the General Electric Company and Fairchild Stratos. The GE hybrid receiver concept utilizes heat pipes to conduct the energy to the engine heater head through encapsulated salts that provide buffer storage. Complete assembly of a test unit was cancelled, however, due to funding reallocations by DOE.

The Fairchild receiver contract, awarded in 1979, was for design, development and fabrication of a metal receiver for the United Stirling (Sweden) engine shown in Figure 7. Its hybrid capability allows thermal augmentation by a gaseous fossil fuel providing continuous power and eliminating the need for energy storage. The heater head and preheater were fabricated from copper and Inconel by Solar Turbines International (STI). The receiver was shipped to JPL in December 1980 for combustor and preheater tests in preparation for a fully integrated test of the power conversion assembly in Sweden.

In June 1981, the receiver was shipped to United Stirling in Sweden and integrated into the power conversion assembly. The receiver, power converter, and control system were shipped from Sweden to the PDTS in July 1981; prior to delivery to the PDTS, the heater heads were repaired at STI. After undergoing a series of initial tests in the fossil-fired combustor mode, the complete PCA was mounted on the TBC for solar testing.

C. ENGINE AND POWER CONVERTER DEVELOPMENT

Brayton, Rankine and Stirling cycle heat engines were investigated for use with dish systems. Two versions of the Rankine cycle, one using steam as

Figure 6. High-Temperature Hybrid Air Receiver for Brayton Engines

Figure 7. United Stirling Engine/Receiver Unit

the working fluid and one using toluene, were previously studied under this program. The principal characteristics of these engines at this stage of their adaptation for dish use are presented in Table 2.

1. Organic Rankine Cycle Power Converter

Organic Rankine cycle (ORC) technology is well understood and considered to be low-risk. In December 1979, Ford Aerospace and Communication Corporation (FACC) received a contract to develop the ORC receiver and to serve as integrating contractor for the power conversion assembly (PCA). FACC subcontracted with Barber-Nichols for the engine, and Barber-Nichols subcontracted with Simmonds Precision for the permanent magnet alternator.

The PCA, consisting of receiver, engine, and alternator is illustrated in Figure 8. In ORC operation, toluene working fluid flows in a closed loop and is expanded through a single-stage axial flow turbine. The exhaust vapor then passes through a regenerator (heat exchanger) to preheat the toluene entering the receiver. From the regenerator, the exhaust vapor flows through a forced air-cooled condenser, constituting the outer annulus of the converter, and thence to the pump.

A high-speed permanent magnet alternator is integral with the engine. The output is rectified for transmission to a central collection station.

Receiver qualification tests were completed in June 1981 at FACC. Barber-Nichols shipped the engine and generator set to FACC where the PCA, with control system, was assembled and will be tested in late October in preparation for shipment to the PDTs in December 1981. The PCA system level tests will be conducted after installation on a TBC. The test will determine operating characteristics of the PCA, including performance, stability, and efficiency in all operating modes, and verify the mutual compatibility of the constituent subsystems.

2. Brayton Cycle Power Converter

A power converter for parabolic dishes is being developed by Garrett Aircor, Phoenix, Arizona, based on their automotive advanced gas turbine (AGT-101) work. The solarized AGT-101 (SAGT), shown in Figure 9, is an open-cycle machine with a 870°C (1600°F) turbine inlet temperature. The solar input to a typical receiver is 85 kW for an insolation of 1000 W/m². The air entering the receiver from the recuperator is at a temperature of 580°C (1075°F) at a pressure of 0.25 MPa (37 psia). The flow rate is 930 kg/hr (2050 lb/hr). At these conditions the turbine inlet temperature is 815°C (1500°F), and the mechanical shaft output power of a production engine is estimated to be 24 kW at an efficiency of about 32%. Growth versions incorporating ceramic parts should be capable of turbine inlet temperatures up to 1370°C (2500°F) for which the shaft power would be 71 kW at an efficiency of 48%.

The schedule for the Brayton effort calls for testing of the initial SAGT engine either late 1981 or early 1982, followed by the delivery to the PDTs in

Table 2. Heat Engine Characteristics Summary

Engine Type		Steam	Organic Rankine	Brayton	Stirling
Manufacturer		Carter	Barber-Nichols	Garrett	United Stirling
Source	°C	565	400	870	700
Temperature	°F	1050	750	1600	1300-1400
Sink	°C	100	45	25	50
Temperature ^c	°F	212	115 ^a	80 ^b	125
Pressure	MPa	17	4.8	0.2	15
(Maximum)	psi	2500	700	30	2200
Engine Efficiency	%	20	25	32	39
Efficiency Speed	rpm	3600	50,000	80,000 to 86,000	1800
Power Conversion Assembly Output	kW _e	20	18 ^d	24 ^e	25 ^e
Mass Flow	kg/hr	91	430	930	NA
	lb/hr	200	945	2050	
Engine Operating Time Between Overhauls	hr	NA	7500	5,000(minor) 50,000(major)	7,000(minor) 10,000(major) ^f
Working Fluid		steam	toluene	air	helium
Engine Weight	kg	275	365	210	205
	lb	600	800	460	450

^aCondenser exit^bAmbient^cHeat exchanger inlet^dWith 94.5% efficient alternator^eWith 94% efficient alternator^fAssumes a metal heater head; a ceramic head would prolong the interval

Figure 8. Organic Rankine Power Cycle Conversion Assembly

Figure 9. Solarized Brayton Engine Power Conversion Module

July 1982 of the engine, gear box, and alternator assembly. This demonstration engine will produce 15-18 kW_e. Either the Garrett or Sanders receiver will be used.

3. Stirling Cycle Power Converter

Like the Brayton engine, the dish Stirling engine is being developed as a "solarized" version of an automotive Stirling engine. The solarized engine (shown in Figure 7) is referred to as the United Stirling 4-95 engine. In December 1980, it was modified to accommodate the attitudes of the engine relative to the ground as the dish tracks the sun and was tested for operation in an inverted position. The four-cylinder kinematic engine was tested at 1500 rpm, with a heater head temperature of 710°C (1310°F), a coolant temperature of 50°C (120°F). It produced a shaft power of 18 kW with a corresponding efficiency of 35% at a mean helium pressure of 11 MPa (110 atm). At 15 MPa (150 atm), a shaft power of 24 kW was developed with an efficiency of 38%. A total of 300 hours of operation has been accumulated on this engine. The PCA was delivered to the PDTS in July 1981.

By the end of September, after three months of component and subsystem assembly, shakedown, and check-out at the PDTS, the Dish Stirling Solar Experiment power conversion assembly was ready for mounting to the TBC. The United Stirling Solar engine had driven the GE induction generator while being powered by the hybrid Fairchild Dish Stirling Solar Receiver. All automatic functions of the electrical utility interface unit, the engine control unit, and the solar receiver combustor unit were exercised by the programmable controller within the Advanco Corporation system control console. All experimental instrumentation was installed, wired, interfaced with the computer, and checked out. Components and subsystems requiring special attention included misprogrammed programmable controller, leaky solar heater head quadrants, an incomplete electric utility power interface unit, a weak combustor air blower, a broken combustor oxygen sensor, and failed engine supports. Those components requiring special attention were reprogrammed, repaired or replaced and all subsystems passed functional ground tests.

Mounting of the PCA, connection of all water, natural gas, electrical, control, and instrumentation will begin in October 1981 followed by functional and performance tests.

SECTION III

THERMAL TRANSPORT

Cost effective thermal transport for parabolic dishes was examined for applications using industrial process heat (IPH). The two major areas of concern are the match between dish characteristics and IPH applications and the thermal piping networks and methods, which will minimize installed costs.

Application studies were conducted by Science Application, Inc. (SAI) and Ford Aerospace under contract to JPL. These studies examined the integration of solar process steam units into four industries: (1) an ore processing plant for U.S. Borax; (2) oil pumping for low production stripper wells; (3) farm production of furfural from agricultural wastes; and (4) drying of gypsum wallboard. Elements such as available space, the processes involved, and user economics were considered.

A computer optimization code was developed to evaluate thermal piping networks and methods and to determine the most cost-effective thermal transport layout. The code incorporates data on collector spacing, operating temperatures, heat losses, fabrication techniques, pumping losses, and costs. Evaluating thermal transport subsystem costs for 510°C (950°F) steam shows a subsystem cost of \$27/m² of collector area and \$7/m² for a factory-fabricated riser and down-comer.

SECTION IV

SMALL COMMUNITY SYSTEM/MODULE DEVELOPMENT

The objective of the Small Community Experiment is to utilize proven dish modules in a user environment to generate a one megawatt grid-connected electric power system. The systems contractor for this experiment is FACC, with JPL serving as technical manager. For the Small Community Experiment, an organic Rankine power converter was chosen over the potentially more efficient Brayton or Stirling cycles because it will be technologically ready before the other two.

U.S. communities interested in solar thermal power were identified through the issuance of a DOE Program Research and Development Announcement (PRDA). This solicitation was aimed at small communities having a peak electric load of less than 20 megawatts and served by a distribution network owned and operated by the local utility. Communities with larger utilities were acceptable if they were remotely located or could demonstrate a need for an alternate energy source based on economic considerations. The response pattern is shown in Figure 10; the communities preferred, based on engineering considerations only, are starred. Final site selection will be made in early FY 82.

Figure 10. Small Communities Solar Experiment Response Map

SECTION V

FIELD TEST AT CAPITOL CONCRETE PRODUCT COMPANY

In December 1980, Applied Concepts Corporation was selected through a PRDA for a field test at Capitol Concrete Products Company in Topeka, Kansas. Applied Concepts Corporation will provide the site, user, system and all equipment and services necessary to design, fabricate, install, operate, maintain, and evaluate for 12 months, an experimental solar plant in a typical industrial environment. The selected test involves operating a slat-type point-focusing concentrator, manufactured by Power Kinetics, Inc., (PKI) in a fuel displacement mode.

The PKI collector is shown in Figure 11 undergoing verification testing at Sandia National Laboratories, Albuquerque. The concentrator has a reflective surface area of 80.3 m^2 (865 ft^2). The curved slats are attached to the support structure by pivot points at their ends and are rotated about their center of mass for elevation tracking. The structure is attached to a circular track that rotates on pier-mounted casters for tracking in azimuth. The receiver consists of an insulated stainless steel housing with enclosed straight-tube boiler. The large aperture, used to increase interceptance of reflected light, is surrounded by a metal skirt to prevent excessive thermal convection losses.

Verification testing of the PKI collector at Sandia Laboratories began in September 1981. Preliminary test results indicate that collector peak efficiency (insolation converted to a net increase in the thermal energy of the working fluid) is about 80%, measured at an insolation level of 0.98 kW/m^2 and a steam receiver exit temperature of 150°C (300°F). At these conditions, the collector produces about 60 kW of thermal energy. Collector operations at Capitol Concrete are expected to begin in November 1981. The experimental plant will provide 77 kg/hr (170/lb/hr) of 150°C process steam at 0.3 to 0.5 Mpa (30 to 60 psig) to two autoclaves for curing masonry blocks. A final report to be submitted by the Applied Concepts Corporation in February 1983 will summarize technical performance and operational feasibility based on operational experience at both the industrial and the test sites.

Figure 11. Power Kinetics, Incorporated Collector

SECTION VI

PARABOLIC DISH TEST SITE SUPPORT TO DISH DEVELOPMENT

The activities at the Parabolic Dish Test Site (PDTS) at Edwards Air Force Base, California, have been implied earlier in much of the text devoted to receiver and power converter development. However, it is appropriate to summarize here the salient activities at the PDTS that support the development of parabolic dish modules:

- (1) Tested the Sanders Associates high-temperature solar receiver to exit air temperatures up to 1425°C (2600°F).
- (2) Completed tests of the Garrett Airesearch air Brayton receiver at air exit temperatures up to 815°C (1500°F).
- (3) Tested the Garrett Airesearch steam receiver at 705°C (1300°F) and 14 MPa (2000 psi) with stable operation verified. Completed testing of the J. Carter Enterprises 1- and 2-cylinder steam engines using steam from the Garrett steam receiver mounted on TBC-1.
- (4) Utilized TBC-1 and the Airesearch steam receiver in the experimental production of furfural from corn cobs.
- (5) Tested the receiver/combustor for the Stirling engine in preparation for fully integrated tests of the Stirling PCA. Refocused the TBC-1 mirrors to meet power requirements of the upcoming test.
- (6) Conducted calibration tests and mirror alignments for each TBC as required to characterize these test concentrators and to satisfy the required power levels of a particular experiment or test usage. A cavity calorimeter and a flux mapper were used.
- (7) Completed flux mapping of the Omnium-G concentrator. Tested the Omnium-G steam engine using TBC-1. Mounted and aligned new concentrator petals.
- (8) Completed test verification of the Omnium-G system for the Southern New England Telephone Company application.