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JPL'S PARABOLIC DISH TEST SITE*

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ABSTRACT

A Parabolic Dish Test Site (PDTS) has been established at the Jet Propulsion Laboratory (JPL) California Institute of Technology's Edwards Test Station (ETS) in the California Mojave Desert to carry out Department of Energy (DOE) sponsored work in testing solar point focusing concentrator systems and related hardware. The site was chosen because of its high solar insolation level and year around clear sky conditions. A description of the Parabolic Dish Test Site objectives and capabilities is contained herein. Also described are the various facilities and equipment at the PDTS, and the concentrator experiments being performed.

INTRODUCTION

The PDTS is located approximately seventy airline miles north of Los Angeles, in the California high desert (elevation of 2300 feet) with an average rainfall of four inches per year. The site occupies approximately ten acres of the 600 acre Edwards Test Station. Ample adjoining acreage has been set aside for future growth. The primary purpose of the PDTS is to provide a site for the testing and evaluation of:

1. Concentrator-receiver-power conversion systems
2. Concentrators
3. High flux density receivers
4. Thermal transport
5. Power conversion systems
6. Hybrid systems using point focusing solar concentrators and fossil fuels

OBJECTIVES

The objectives of this task are threefold. First, the PDTS will be utilized to support solar thermal development activities, primarily to test and evaluate DOE developed hardware. Second, acceptance testing of prototype solar thermal power systems will be accomplished at the PDTS before committing to fullscale production. Third, test and evaluation of industry developed point-focusing systems will be accomplished at the PDTS as time and funding permit and feedback will be provided to industry on the integrity of these systems.

CAPABILITIES

The JPL ETS was selected as a prime location to perform testing and evaluation of Point-Focusing Distributed Receivers, at the subsystem and system level, at temperatures between 600 F and 3,000 F for the following reasons:

* Sponsored by DOE through an agreement with NASA

1. ETS based personnel have a large amount of experience in working with high temperature, high pressure fluids, since ETS is JPL's rocket engine test facility. This experience is directly applicable to thermal power system (TPS) projects.
2. A high insolation level exists at ETS which is considered one of the best in the United States.
3. Excellent meteorological conditions exist at ETS - thus minimal down time because of bad weather.
4. Supporting services include: instrumentation and calibration laboratories; electric, machine, and weld shops with personnel; office space; and a cafeteria.
5. All required utilities are readily available.
6. Security as well as easy access for visitors is provided at all times.
7. An Emergency Rescue Crew and Vehicle is available to provide emergency medical treatment at ETS.

SAFETY

Safety is a first order consideration at the PDTS. As testing progressed from Precursor Concentrator to the Test Bed Concentrator test phase, the safety aspects for the PDTS became more involved. Initially, fairly simple safety requirements were needed, but as solar flux densities increased, stricter safety requirements were required. The key point of the PDTS safety practices are:

1. Written test procedures are required prior to the start of any testing activity.
2. Safe operating limits of critical parameters (temperature, pressure, etc.) are remotely monitored during subsystem and system testing, and displayed in the Control Room. Upper and Lower limits are predetermined and set into the Data Logger so that an alarm will alert the operator in the control room.
3. An emergency override procedure is implemented should a safe operating limit be exceeded or anticipated.
4. Safety glasses (gas welding goggles) and hard hats are required for operating personnel in the test area during "on sun" operation of solar concentrators.
5. Operating personnel are not permitted to work closer than two focal lengths from the concentrator while tracking the sun.
6. The "buddy system" is used by personnel in the test area during operation of the solar concentrators.

DATA ACQUISITION AND REDUCTION

To obtain the required data formatted for efficient analysis, during performance testing of the subsystem and system tests, a computer automated Data Gathering and Processing (DGAP) system was designed and implemented at the PDTS. DGAP equipment is required to periodically make parametric measurements, display the data in real time, monitor and record data on mass storage. The necessity of a computer processor system is dictated by the large volume of data to be processed, the need for real-time analysis of critical parameters, the requirement for graphical representation and off-line data analysis with higher mathematical functions, and the requirement for efficient system flexibility to support a wide range of testing. Operational experience to date has pointed up the value of real-time printout of data as well as real-time displays of critical paramcters.

The computerized data acquisition system at the PDTS includes a Digital Equipment Corporation PDP 11/10 minicomputer with two RK05 disk drives, one half inch, nine track magnetic tape transport, high-speed multiplexers, A/D converters, three Acurex autodata nine data loggers, CRT terminals, alphanumeric and graphic video monitor, and a printer-plotter. The interface between the computer and its peripherals is provided by RS 232-C serial data lines.

Each of the three data loggers has the capability of accepting up to 1,000 channels of data. Input cards are provided for type "K" and "T" thermocouples, voltages up to 120V DC, 4-10 ma and 10-50 ma current transmitters and RTD's. Programming of the data loggers may be accomplished manually or by the computer. The data loggers scan up to 24 channels per second with resolution to 0.01 percent of full scale. Resolution to 0.001 percent is available at reduced scan rates. The high speed multiplexers and A/D converter can scan low levels (10mV-500mV full scale) at rates up to 200 channels or samples per second. A data logger with high common mode rejection is essential because signals being measured are in the millivolt range.

All data is stored on one half inch magnetic tape for retrieval. Final data reduction is performed at the JPL Pasadena facility using a Digital Equipment Corporation PDP 1134A computer. This Pasadena facility also develops the software used at the PDTS.

WEATHER STATION

Insolation measurements were begun in October 1977 at ETS, Building E-22. This facility is approximately 500 feet from the PDTS. The following measurements are being taken and recorded:

1. Direct component of radiation, using two pyrheliometers
2. Total sky radiation, using a pyranometer
3. Wind speed and direction
4. Temperature and dew point
5. Barometric pressure
6. Circumsolar telescope data

The pyrheliometers and the pyranometer, Kendall model Mark III and Kendall model Mark VII, respectively, were developed by JPL utilizing the absolute radiometer concept. These instruments have a range of 0 to well over 1000 watts/m^2.

The wind speed instrument, model 1022S, was manufactured by Meteorology Research, Incorporated. This instrument has a range of 0 to 75 MPH.

The wind direction instrument, model 1022D, was manufactured by Meteorology Research, Incorporated. This instrument has a range of 0 to 540°.

The ambient temperature and dew point measuring instruments are each designated as model 892-1, manufactured by Meteorology Research, Incorporated. These instruments each have a range of -30 to +50° C. Humidity is derived from these measurements.

The barometric pressure measuring instrument, model 751, was manufactured by Meteorology Research, Incorporated. This instrument has a range of 24.6 to 31.5 in Hg.

The circumsolar telescope was developed by Lawrence Berkeley Laboratory to obtain solar radiation measurements for accurate prediction of performance of solar thermal systems utilizing focusing collectors. The instrument measures the effects of atmospheric conditions on the direct and circumsolar components of solar flux. In operation the solar guider aligns the instrument platform at the center of the sun. The telescope body scans back and forth across the image of the sun and circumsolar region to an angle of ± 3 (the solar diameter is about 32 minutes of arc).

A small aperture located in the image plane restricts the angular view of the telescope to solar disc. The light passing through this aperture is chopped, filtered, detected, digitized and written on a magnetic tape as a function of the angular position.

Weather Station data is taken at 1 minute intervals, 24 hours a day. One month's worth of data can be acquired on a single reel of magnetic tape. A small uninterruptible power system is included to prevent data drop-outs during commercial power outages.

CONCENTRATORS

Concentrators constructed at the PDTS for the Point-Focusing Distributed Receiver Technology (PFDRT) Project are described briefly below.

Precursor Concentrator

The precursor concentrator consists of a backing structure simulating a portion of a parabolic concentrator together with an hour angle declination mount. Six mirror facets, (24" x 28") such as used on the Test Bed Concentrator, are mounted on the structure. The Precursor was used primarily as a tool to measure mirror performance and to evaluate alignment techniques.

Omnium-G Module

An Omnium-G (Heliodyne Model MTC-25) solar powered electric generating plant, an early product of industry, was purchased from the Omnium-G Company and installed at the PDTS. The Omnium-G characteristics are as follows:

CONCENTRATOR

6 meter diameter (19.7')
18 petals (mirrors)
25.9 square meter useable reflective area
Electro polished aluminum mirror surface; Trade name is ALZAC, made by ALCOA
Reflectivity is 81-85%
4 meter focal length (13.1')

TRACKER

2 axes sun tracker
1.9° /sec. slew rate (down to up) at 24 volts
0.45°/sec. slew rate in azimuth at 24 volts

Test Bed Concentrator (TBC)

Two eleven meter parabolic TBCs supplied by E-Systems, Incorporated, Dallas, Texas, are installed at the PDTS. The mirror facets, based on a JPL development effort, for these TBC's are made by bonding a second surface mirror to a spherically contoured block of Foamglas (Pittsburgh Corning Corporation) and coating the substrate with a protective sealer and painting it white. Supports for the facets are bonded to the edges. The TBC characteristics are as follows:

NOMINAL 11M DIA REFLECTOR
70 kWth @ 800 W/M^2 INSOLATION
228 FACETS
- 2ND SURFACE SILVERED GLASS
- 24" x 28" NOMINAL SIZE
- 3 REGIONS OF NOMINALLY DIFFERENT RADII OF CURVATURE 520", 620", 634"
- INITIAL REFLECTIVITY 95% MAX
- SLOPE ERROR 1 MR

6.6 M FOCAL LENGTH
PARABOLOIDAL MOUNTING STRUCTURE f/d = 0.6
DESIGN WT AT FOCUS = 1100#

(STUDYING CONSTRAINTS ON OPERATION TO
ACCEPT 3000F)
TRACKING ERROR 1 MR
SLEW RATES
- AZIMUTH 2,000° /Hr.
- ELEVATION 200° /Hr.
8" DIAMETER CONCENTRATED BEAM
1,000 W/CM² peak flux
3,600° K PEAK EQUILIBRIUM TEMPERATURE

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EXPERIMENTS AND EXPERIMENTATION EQUIPMENT

Types of Tests

The test and evaluation phase of systems and subsystems at the PDTS includes, but is not limited to, the following tests:

TRACKER MECHANICAL CHECKOUT
CONCENTRATOR MECHANICAL CHECKOUT
MIRROR SEGMENT ALIGNMENT
SOLAR TRACKING ERROR
REFLECTIVITY (18 PANELS)
MOONLIGHT FOCAL POINT LOCATION
FLUX MAPPER
COLD WATER CALORIMETER TESTS
RECEIVER THERMAL PERFORMANCE
SYSTEM PROOF AND LEAK TEST
POWER CONVERSION PERFORMANCE

A dish-Stirling solar experiment is being planned on one TBC to test the feasibility of the advanced receiver and Stirling engine-alternator subsystem designed by Fairchild Stratos Division of Fairchild Industries, Inc., and United Stirling of Sweden. When mounted on the TBC the test module will be capable of generating 20 kilowatts of electricity. Testing will begin in early 1981.

Test Equipment

Three different cold water calorimeters have been designed and built by JPL:

1. Coil tubing calorimeter
2. Flat plate calorimeter
3. Cavity calorimeter

The calorimeters are used to measure the integrated thermal flux at the concentrator's focal point. The coil tubing calorimeter used on the precursor concentrator is for thermal flux loads up to 2KWth. The flat plate calorimeter used on the Omnium-G is for thermal flux loads up to 25KWth. The Cavity calorimeter which will be used on the TBC's is for thermal flux loads up thru 95 KWth.

A flux mapper was fabricated for use in characterizing concentrator flux pattern and intensity. The flux mapper is a three-axis scan system for measurement of high radiant flux levels as might be expected near the focal plane of a high concentration ratio solar concentrator.

The flux mapper has three modes of operation: 1) pin diode relative, 2) cone radiometer relative, and 3) cone radiometer absolute. In the pin diode relative mode, a pin diode probe scans through the concentrated sun beam while a reference diode is pointed at the sun. The two readings are combined to arrive at a concentration ratio. Similarly, a cone radiometer probe can be used in conjunction with the reference diode for a concentration ratio. The cone radiometer probe may also be used alone to measure flux by calibrating the probe with a small eletrical resistive type heater which is built into the probe.