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THE JPL ISOLATED APPLICATION EXPERIMENT SERIES

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ABSTRACT

The goal of the Thermal Power System Project's Applications Development element is to establish the technical, operational, and economic readiness of small power systems for a variety of applications in the power range below 10 MWe. Power Systems are being developed and tested to the point where commercialization efforts can lead to successful market penetration. A key element in this strategy is the use of experiments to test hardware and assess operational readiness. The JPL Isolated Application Experiments are described and their objectives discussed.

BACKGROUND

The three successive milestones required in the development of a new technology to the point of commercial readiness are: 1) demonstrating technical feasibility, 2) verifying readiness of the technology, and 3) meeting cost goals required for commercial readiness. The three phases in the evolution of a new technology can be described as creation, development, and commercialization. Participation by both government and the private sector may be necessary, with increasing activity by the latter as the commercial readiness phase is approached. Potential users are involved early in the design phase, and to the maximum extent possible.

A key element of the program strategy is first the identification, and later the penetration, of near-term markets that will provide a stimulus for establishing a manufacturing industry. This, in turn, will lead to cost reductions as a result of improved manufacturing methods, coupled with an increasing volume of production as lower cost markets are penetrated. The importance of this program element lies in the belief that design improvement alone will not result in a sufficiently low price to penetrate the utility market. A combination of mature technologies and mass production, however, offers the potential for economically competitive power systems with a significant environmental advantage.

Potential users will be sought that fall into two broad market categories: 1) the near-to-mid-term market, which is smaller, and for which costs are higher; and 2) the far-term market which largely corresponds to the utility sector for which a mature solar thermal technology is needed before penetration can be expected. Application studies and system analyses are being conducted to develop candidate system configurations best matched to the users in each category. Selected system design concepts will be developed through contracts let to private industry.

THE ISOLATED APPLICATION EXPERIMENTS

The Isolated Applications Experiment Series is the second major activity within the Applications Development area. The Series will be a set of small (approximately 60-150 kWe) solar thermal power experiments, each of which is meant to address a separate isolated load application.

These experiments will employ point focusing distributed receiver technology with emphasis on electric and possibly some thermal power applications. The program will be closely integrated with the Technology Development element of the Thermal Power Systems Project with the objective of utilizing the technologies being developed under that program.

The first experiment in the Series has been initiated and is co-sponsored by the U.S. Navy under the auspices of the Civil Engineering Laboratory (CEL). CEL and JPL have worked together to develop system requirements. The experiment, designated as the Military Module Power Experiment, will be a modular system using a hybrid fired Brayton cycle energy conversion. Subsequent experiments will test different versions of similar hardware in different applications which are now being selected.

Primary considerations in implementing the series are to:

- Test the readiness of suitable solar power technologies at the system level in a number of different applications.
- Economically provide testing of both technologies and markets, thus meeting principal program objectives without large expenditures.
- Involve a large consituency of industrial suppliers and users.
- Address the potential for near-to-mid-term market for small power systems that is needed to provide the initial incentive to manufacture these systems.
- Increase programmatic flexibility by employing a number of small and varied experiments.

Emphasis will be on:

- High reliability and safety.
- Early plant deployment.
- Low program cost.
- Complete test and evaluation.

The engineering experiments will be designed, installed, and operated to permit JPL to better understand solar thermal plant applications and technical feasibility.

The objective of the engineering experimentsd is not to maximize the kWh of energy generated by the solar plant or to lower the electric power costs of the site participants. Rather the objectives are to:

1. Verify that the solar thermal plant can produce power from solar radiation supplemented by fossil fuel to meet energy requirements for this application during designated test periods.

2. Verify that the solar hybrid plant concept can be considered as a firm power resource for this application during designated test periods.

3. Characterize the total performance of the plant (site preparation, components, subsystems, modules, and plant) as a function of load characteristics, insolation, weather, operations and maintenance activities, safety regulations, environmental regulations, seismic factors, and legal and socio-technical factors.

4. Identify and understand plant failure modes.

5. Identify and quantify the impact of solar hybrid plant operations on the daily operations activities of user personnel and on user manning requirements.

6. Identify and quantify the impact of solar hybrid plant installation and operations on the local environment.

7. Identify and quantify the impact of solar hybrid plant installation and operation on the acceptance of solar power plants by local public officials, local power system officials, and the local public.

Schedule

Tentative schedules have been developed for the series. The MMPE will begin operation during FY83 with a test and evaluation period of 2 years duration. Subsequent experiments in the series will begin at approximately 12 month intervals.

THE MILITARY MODULE POWER EXPERIMENT

The hardware to be employed in the MMPE consists of the General Electric Co. Low Cost Concentrator plus engine and receiver design by the Garrett Corp. Control and display systems plus auxilliary equipment will be defined during plant detail design. A brief description of the major components follows.

The Low Cost Concentrator (LCC) currently being designed by the General Electric Company is a twelve meter diameter point focus parabolic reflector which tracks the sun with two-degrees-of-freedom. The reflector is composed of 24 injection molded plastic panels arranged in three concentric rows, supported on twelve radial trusswork ribs located inside the reflector dish.

All panels have the same frontal surface area. The reflective surface is a second surface metallized plastic film which is integrally bonded onto the panel when the panel is injection molded.

The reflector is supported on trunnions at the rim of the reflector to provide motion in elevation, allowing a stowage orientation pointing to the ground. This orientation reduces the wind loads and aids in keeping the reflective surface clean. The pivots are supported on tripods mounted on the base, which provides azimuth rotation about a pintle bearing by six wheels running on a steel circular track. Windless-driven cables are used to provide rotation, the azimuth cable lying in a groove on the circumference of the base and the elevation cable on an arch running from the receiver/engine at the focus to the counterweight at the rear.

The internal radial trusses are precisely positioned by tooling during the reflector buildup. The individual reflective panels are mounted directly on the trusses with no provisions for focusing adjustments. No field welding during LCC site assembly is envisioned.

An ephemeris generated by a central computer provides ±1° coarse solar tracking and each LCC has an active solar tracker for ±1/8° fine solar tracking. Each prototype concentrator, with a clean plastic film surface, is projected to provide 66 kWth into a .283 meter diamter aperture under an insolation of 0.8 kW/m^2.

Glass second surface mirrors as the reflective surface will also be investigated.

The Brayton cycle solar receiver is currently being designed by the AiResearch Manufacturing Company of California. The active cavity is 0.5m in diamter and 0.86m in overall height. The aperture is 0.2m in diamter. The plate fin matrix is 1.3cm in depth and 0.71m long. The matrix and headers are fabricated of Inconel 625. The reflector skirt/aperture assembly is fabricated of silicon carbide as is the cavity back plate. Inside the carbon steel shell is 13cm of Johns-Manville Cerablanket insulation. The entire assembly weighs about 193 kg.

This size receiver is designed to accept about 85 kWth through the aperture. It is designed for use with an open cycle air Brayton power conversion unit. Maximum operating pressure is about 354 kPA (50 psia) when operating with a 815°C (1500°C) outlet temperature and a 565°C (1050°F) inlet temperature. Mass flow is about 0.25 kg/sec of air at these conditions. Pressure drop is about 3% of the inlet pressure. The receiver has been designed for a 30 year lifetime.

Hybridization of the solar-powered hybrid power conversion unit (PCU) that is being evaluated for use with point focus distributed receiver electric power systems permit operation on solar radiation, combustion of liquid fuels or on combinations of both. The PCU consists of:

1. A radial turbine and compressor assembly running on oil bearings which is the power section of AiResearch Model GTP36-engine.

2. A 400 Hz, 8000 rpm generator.

3. A gearbox from an AiResearch production engine to reduce turbine shaft speed to the required range of generation speeds.

4. A high-effectiveness recuperator using plate-fin construction in a pure counterflow arrangement.

5. A liquid fuel combustor designed to be compatible with the PCU's solar thermal configuration and in series with the solar receiver.

6. An engine control system which holds turbine inlet temperature constant at 815°C (1500°F) over a range of thermal energy input to the cycle of 30 to 72.7 KW. Inputs below 30 KW require the unit to run at constant speed and at a reduced turbine inlet temperature to avoid recuperator over-temperature.

The degree of MMPE module self-containment will be driven by both economics and reliability. Each module will contain (at a minimum) concentrator, receiver, hybrid combustor, turbine, recuperator, compressor, alternator, module controls, starter, concentrator drives, tracking devices and sensors, some fuel storage and necessary exhaust hardware. A completely self-contained module is desired with only the true plant functions located centrally. These will be power combination and conditioning equipment, module and plant performance indicators, grid interconnection equipment, computing and data recording facilities, instrumentation, plant safety and control equipment. The normal mode of module operation will be unattended, however each module will be equipped for safety or emergency shutdown, both manual and automatic. Although a fixed installation is expected, individual modules must be transportable, field erectable and field serviceable.

Long term thermal storage will not be included in the plant. No thermal buffering will be provided except by the heat capacity of the installed components and working fluid. The hybrid combustor control system will provide the desired transient response characteristics.

SITE SELECTION

Site selection for MMPE has been a U.S. Navy responsibility. It will be conducted in parallel with the system integration control activities and basically independent of the technical tasks. The Marine Corps Air Station at Yuma, Arizona, has been tentatively selected as the site for the experiment. The plant will be operated by the system integrator for the first three months of its evaluation. The following 21 months will see operation by MCAS Yuma personnel.