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NON-HEAT PIPE/P-40 STIRLING ENGINE

R. A. Haglund, Senior Project Engineer
Fairchild Stratos Division
Manhattan Beach, California

ABSTRACT

This project will demonstrate the technology for a full-up Hybrid Point-Focus Distributed Dish Stirling Solar Thermal Power system by the fall of 1980 at JPL's Desert Solar Test Facility near Lancaster, California. Hybrid operation is provided by fossil fuel combustion augmentation, which enables the Stirling engine to operate continuously at constant speed and power, regardless of insolation level, thus providing the capability to operate on cloudy days and at night.

The Non-Heat-Pipe Receiver/P-40 Stirling Engine system will be installed and operated on the JPL Test Bed Concentrator. A 25-kW direct-driven induction-type alternator will be mounted directly to the P-40 engine to produce to a 60-Hz, 115/230-volt output.

NON-HEAT PIPE RECEIVER DESIGN

The Non-Heat-Pipe Receiver design is a cavity-type receiver, as illustrated in Figure 1. The primary receiver surface is a conical plate with integral passages for the helium working fluid. The passages are formed by Inconel 617 tubes imbedded in a copper matrix, which in turn in incapsulated in an Inconel 617 sheet. The cone is heated by solar insolation on the exposed surface and by combustion gas on the back surface and the regenerator tubes. The receiver is attached directly to the Stirling engine cylinders and regenerator housings. Simplicity in design has been emphasized, along with extensive use of parts and assemblies proven in other applications but under similar operating conditions, such as normally found in industrial boilers and gas turbines. Where expensive cobalt alloys are required, their use has been minimized.

The combustion system design is based on heavy duty industrial burner technology, scaled to the size and configuration required to assure reliable cold start, stable combustion over the full operating range and uniform heating of the heater tubes extending from the underside of the cone to the engine regenerator manifolds. The combustion air, provided by an electric-motor-driven constant speed blower, is directed through a preheater into the combustion chamber, which contains eight integrally cast venturies, oriented to produce a swirling flow field inside the

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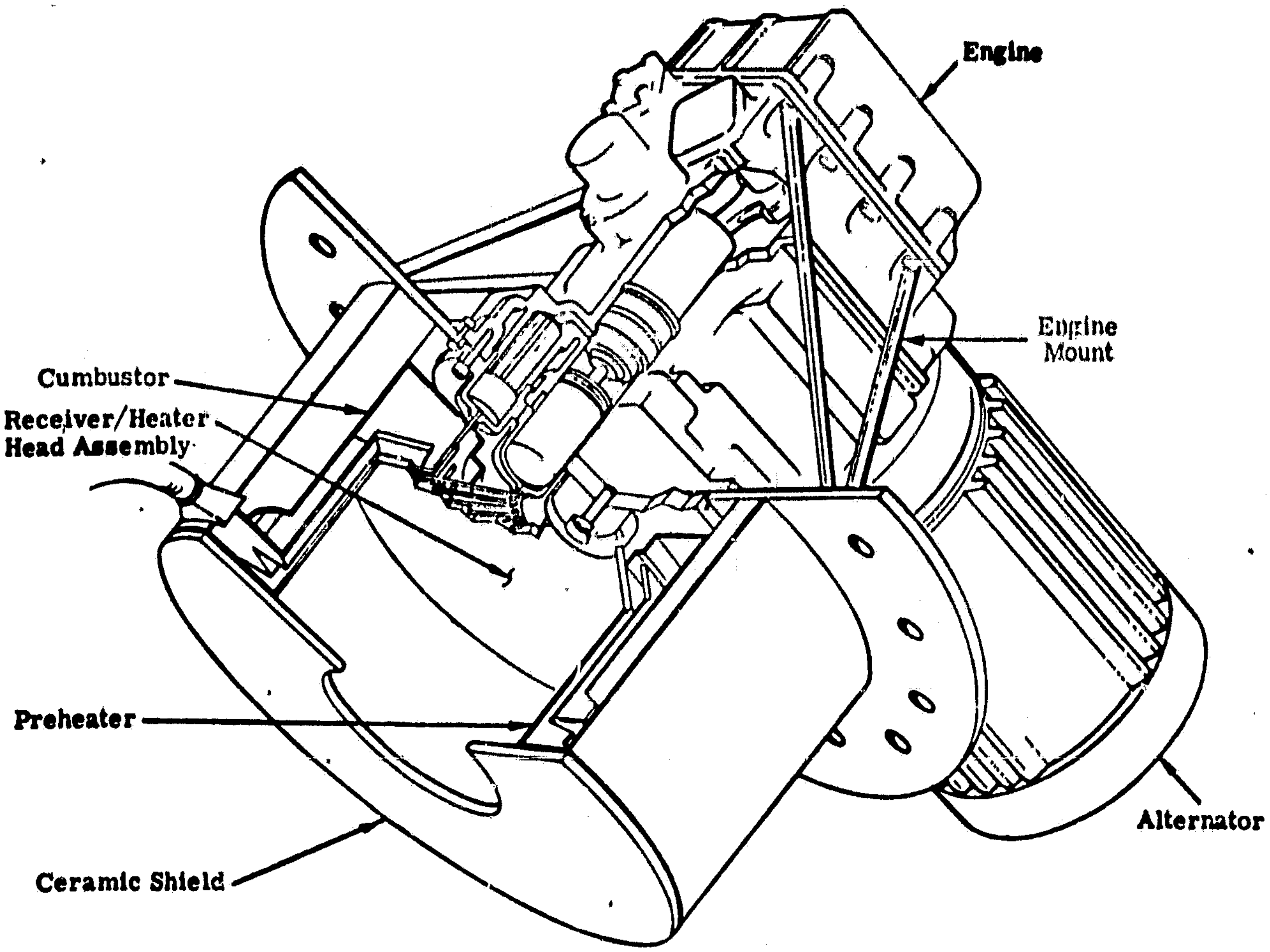

FIGURE 1. NON-HEAT PIPE/P-40 STIRLING ENGINE

combustion chamber. Fuel is introduced through a jet located inside each venture. Electric spark igniters are provided directly in front of two of the venturies; the igniters also provide flame sensing, so that the main fuel valve closes automatically in the event of flame-out. Automatic restart is provided.

Performance Goals

The following performance goals have been identified by JPL for the Non-Heat-Pipe Receiver design:

Concentrator diameter (active)	10 m
Geometric concentration ratio	2000
Peak insolation (1 kW.m^2)	76.5 kW
Concentrator efficiency (clean)	0.83
Total error (slope plus pointing)	3 mr
Fossil fuel combustor peak input to helium	70.0 kW$_t$
Combustor turndown ratio	10:1
Working fluid temperature (helium)	1200° to 1500°F
Peak engine pressure (helium)	2500 to 3000 psi

Expected Receiver Performance (24-cm Aperture Diameter)

Losses (kW)		
Radiation	2.8	5.2
Reflectance	0.9	0.7
Convection	3.6	4.4
Efficiency (%)	0.875	0.827
Maximum Cavity Temperature (°F)		
Center Plug	1966	2053
Cone	1561	1836

Program Status

The receiver design effort has been completed and a Detailed Design Review was held on September 27, 1979. As shown by the schedule in Figure 2, combustion and heat transfer tests are being conducted at Fairchild Stratos Division in Manhattan Beach, California and are carried out jointly by JPL, Fairchild and the Institute of Gas Technology. Test objectives include evaluation and demonstration of cold start, combustion stability and energy release at various power levels, combustion air preheat, pressure drop, fuel/air ratios and heat transfer. Reliable cold start performance, full design output power and turndown capability have been demonstrated. The general arrangement of the combustion test rig is illustrated in Figure 3.

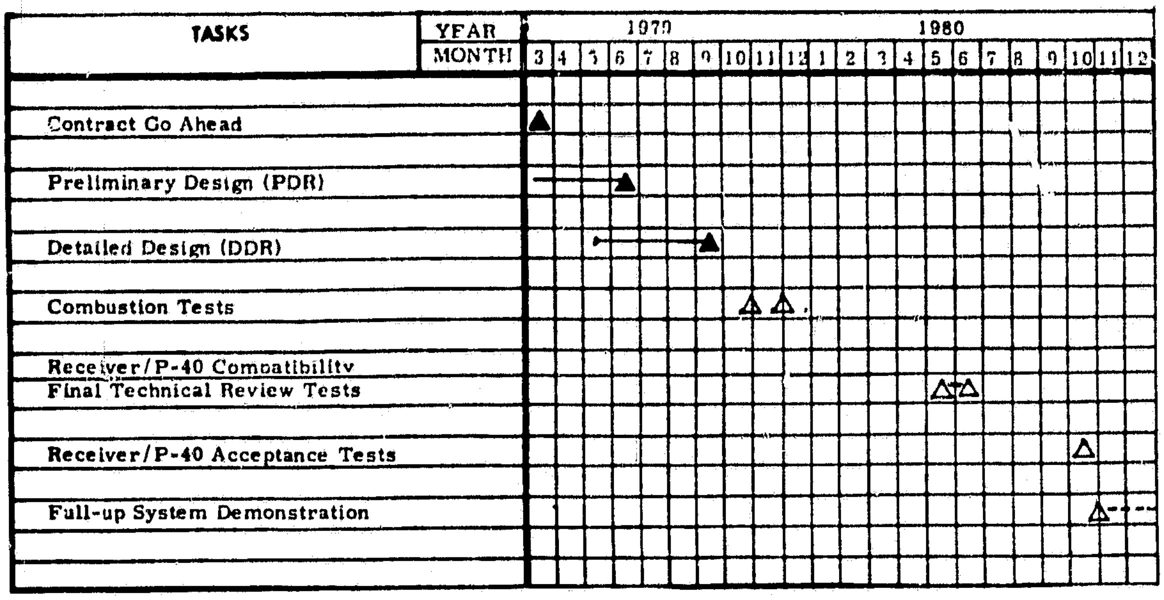

FIGURE 2. MAJOR TECHNICAL MILESTONES CONTRACT 955400
30 November 1979

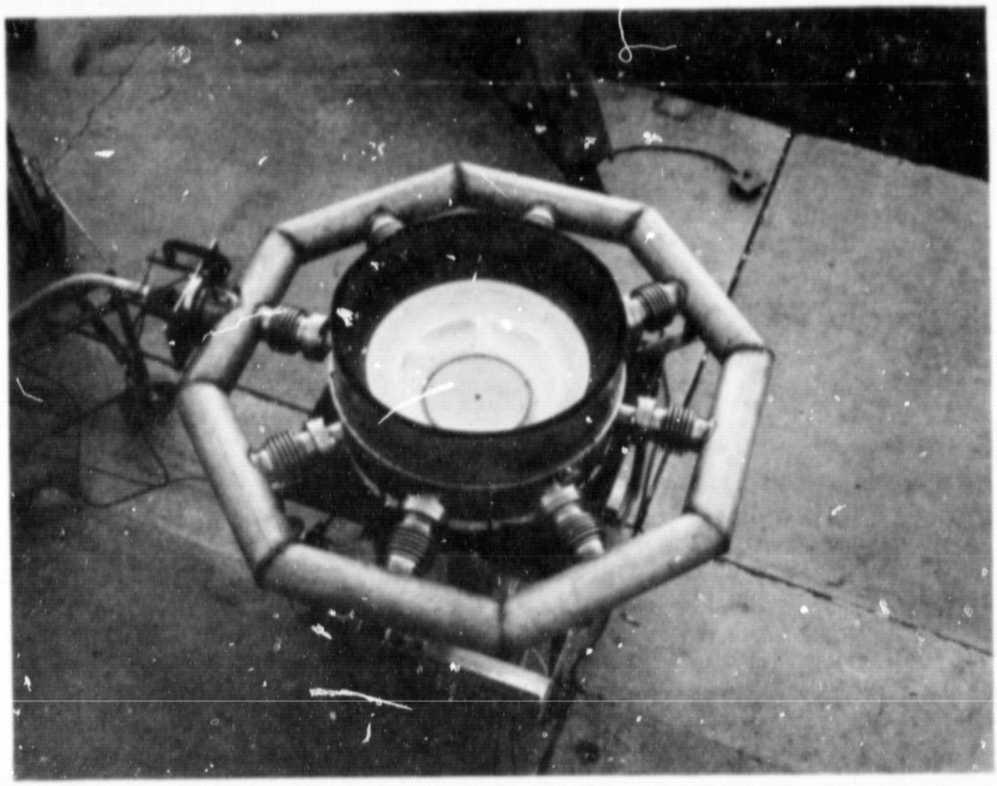

FIGURE 3. PHOTO OF TEST RIG