

COO-2631-21

80-100 ~~HP~~ STIRLING ENGINE FEASIBILITY STUDYPROGRESS REPORT NO. 21  
FOR THE QUARTER JANUARY-MARCH, 1977

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Prepared For

THE U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION  
UNDER CONTRACT NO. EY-76-C-02-2631.001M

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80-100 HP STIRLING ENGINE FEASIBILITY STUDY  
QUARTERLY PROGRESS REPORT NO. 21  
FOR THE PERIOD OF JANUARY 2-MARCH 31, 1977  
CONTRACT EY-76-C-02-2631.001M

A. BACKGROUND AND OBJECTIVES

Ford Motor Company has sponsored research and development of a 170 HP swashplate-type of Stirling engine suitable for application to a passenger car having a curb weight in the neighborhood of 4,600 pounds. The success of this program has justified the need for investigating the application of the Stirling engine to passenger vehicles of smaller size and lighter weight. Contract EY-76-C-02-2631.001M (formerly E(11-1)-2631) was awarded with an effective date of June 28, 1975, and has as its objectives two tasks:

Task I provided for preparation of a report containing an evaluation and presentation of the results of Contractor-financed testing of a Torino passenger car powered by a 170 HP Stirling cycle engine.

Task II provides for a feasibility study to evaluate the potential of a Stirling cycle engine for significant improvements in emissions and fuel economy over the present day internal combustion engine, and to develop a concept of an 80-100 HP engine design suitable for use in a passenger car in the 2500-3000 lb. weight class.

The ultimate objective of this and other Ford programs is to develop technology to determine whether it is reasonable to undertake a high volume Stirling engine production program.

B. PROGRESS DURING THE REPORTING PERIOD

1. Task I - 170 HP Stirling Engine Test and Evaluation

a. January Activity

During January, Stirling engine No. 3X (a sliding seal engine) developed several problems which ultimately led to its removal from the dynamometer test cell. Inspection after disassembly revealed oil on the gas side of the sliding seal. The oil was transported past the sliding seals because it was known that the hydrogen/oil separator was functioning well during engine operation.

Stirling engine 1X (a rollsock seal engine) was installed on the dynamometer test stand. During an investigation to determine the cause of engine oscillation, it was found that hydrogen was leaking into the cooling (water) system. Therefore, engine No. 1X was removed from the dynamometer cell.

b. February Activity

Stirling engine No. 5X (rebuilt as a rollsock seal engine) was reinstalled and the check points for the vehicle simulation computer program were run. Subsequent to the accumulation of check point data, a water leak

developed in the combustion part of the engine. A one inch crack was discovered in the No. 3 piston bore.

A new heater head was installed and the check points re-run to verify that the emission and fuel economy data had not been affected by the heater head change.

c. March Activity

Stirling engine 5X was removed from the dynamometer test stand and prepared for vehicle installation. In an attempt to improve engine life, hydrogen filters and a rollsock protection circuit were installed on the engine. A two-position EGR controller valve was also installed on the engine.

After resolution of several problems, both electrical and mechanical, the vehicle was finally driven prior to installation on the chassis rolls for the CVS-CH tests. A CVS hot start test and highway test were conducted but the results were invalid due to the EGR valve hanging closed which did not allow full EGR.

A second CVS-Hot test was stopped because of a cooling water over-temperature reading. The recording instrument was found to be defective. In addition, the EGR valve was still not functioning properly.

Stirling engine No. 3X was installed on the dynamometer test stand. A rollsock seal protection device was also installed.

Test and development on the following components for the 4-215 Stirling engine continued or were completed during the January to March quarter.

• Spool Valve and Linear Solenoid Fuel Control

The complete system was installed on a dynamometer engine for test. Slow response of the fuel measurement feedback device limited accuracy to steady state conditions only. Lean and rich mixtures were noted during accelerating and decelerating conditions respectively. Electrical interference gave higher than actual fuel flow indications.

Shortening of tubing and lines connecting the fuel pump, regulator, metering valve and flow scan unit resulted in more stable system operation. Electronic filtering and shielding reduced interference and reasonable correlation between the control air/fuel ratio and that measured by exhaust analysis is being obtained.

• Multiple Injector Fuel Control System

Burner rig tests on the thermal and acoustic Vortair systems have shown the thermal units to have less frequency variation at any given set point than the acoustic unit. Long term drift runs, up to four hours at a given set point, and repeatability runs have been completed with satisfactory results. The worst deviation from a

constant air-fuel ratio occurs around 0.8g/sec. of fuel flow. This deviation is caused by the non-linear output of the Vortair at this low air flow. A non-linear compensation circuit has been designed and is being incorporated.

• Air Throttle Valve Position

A positioning system has been designed and fabricated using a small D.C. motor and a differential drive circuit. The maximum current draw is 1.2 amps and when the input error signal is nulled out, the motor current draw is zero. This circuit design eliminates the need for springs and reduces the power dissipation in the D.C. motor and drive transistors to a very low value. The average input power to the positioning loop is reduced from 24 watts to 3 watts with the newly designed system.

• Power Control

Layout drawings for a linear power control valve for the 4-215 engine have been completed. Detail drawings will be started in the next quarter.

• Automatic EGR Scheduling

Automatic EGR scheduling hardware has been installed on the engines but are currently scheduled for 2 positions only. The hardware will be recalibrated to a finalized EGR schedule when it has been determined.

2. Task II - Design Study of 80-100 HP Stirling Engine

a. January and February Activity

- Work has continued on the writing of Engineering Notes to document the work previously done during the design and analysis of the 4-98 engine.
- Additional vehicle simulation computer runs have been completed on the baseline 2.3 liter Pinto in preparation for making final comparisons of emissions and fuel economy between the baseline and ERDA vehicles.
- A method has been derived for calculating the estimated CVS-CH fuel economy from the vehicle simulation program steady state points. This method will be used in the final projections for the feasibility study.

b. March Activity

The first typed draft of the final ERDA report has been completed. Retyping as a result of author's reviews has also been completed. Graphic Arts has completed initial art on 98% of the illustrations, most of which have been reviewed and corrected to final form.

c. Engineering Notes Completed During March

Piston Rod Sliding Seals, PEN-127, issued 3/22/77.

d. Communications Applicable to the January 1 to March 31 Reporting Period

- STIR-039 Monthly Progress Report (November 1976) to R. Schulz, ERDA
- STIR-040 Quarterly Progress Report (October-December) to Dana Dixon, ERDA
- STIR-041 Stirling Photographs (3) to R. Schulz, ERDA
- STIR-042 Stirling Photographs (8) to R. Schulz, ERDA
- STIR-043 Stirling Photographs (5) to R. Schulz, ERDA
- STIR-044 Monthly Progress Report (January 1977) to R. Schulz, ERDA
- STIR-045 Stirling Engine Feasibility Study Report to R. Schulz, ERDA
- STIR-046 Monthly Progress Report (February 1977) to R. Schulz, ERDA

e. January-March Quarter Ford/ERDA/NASA Meetings

January 11 G. S. Arendsen, E. W. Kitzner, T. W. McLaughlin, N. D. Postma  
Meeting No. 7 with ERDA/NASA to Negotiate Stirling Engine  
Contract

February 2 G. S. Arendsen, D. Beremand, E. W. Kitzner, N. D. Postma,  
J. T. West to discuss ERDA Statement of Work

f. Financial Status

Contract cost, excluding fee	\$509,250
Cumulative incurred costs, 3-31-77	493,807
Balance as of 3-31-77	<u>\$ 15,443</u>