MASTER

APEX - Advanced Geothermal Primary Heat Exchanger

Quarterly Progress Report Q-5

Period Covered:

1 January 1977 - 31 March 1977

Contract E(04-3)-1125

Prepared For:

**Energy Research and Development Administration
Washington, D.C.**

**Aerojet
Liquid Rocket
Company**

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APEX
ADVANCED GEOTHERMAL
PRIMARY HEAT EXCHANGER

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1.0 INTRODUCTION

The development of the Advanced Geothermal Primary Heat Exchanger (APEX), will provide a self-cleaning heat exchanger for utilization of geothermal brines with high fouling characteristics. During the Phase I contract (E(04-3)-1125) period, the Aerojet Liquid Rocket Company (ALRC) conducted laboratory research experiments which verified the technical feasibility of the APEX concept. In Phase II APEX evaluation continues with field testing at the ERDA East Mesa Geothermal Component Test Facility.

The APEX approach is intended to minimize or eliminate heat exchanger fouling from geothermal brines and thereby increase the economic usefulness of hydrothermal resources. One of the problems encountered in energy conversion from geothermal brines has been the deposition of solids on process equipment. Fouling of heat exchanger tube walls as the brine cools can greatly reduce the effectiveness of the heat exchanger. The reduction in heat transfer coefficient and the resulting need to frequently clean, replace, or oversize the heat exchanger, makes the use of some geothermal resources economically unattractive. The APEX fluidized bed concept retards fouling by recirculating solids (such as sand) through the heat exchanger with the geothermal brine. The action of the bed material, in mechanically scouring the tube wall and in providing nucleation sites for solids deposition, is intended to keep the tube walls clean.

The fluidized bed approach was evaluated at the Aerojet Research Physics Laboratory during Phase I. The Phase II effort centers on installation and testing of an APEX heat transfer loop at the ERDA East Mesa Component Test Facility. The objectives of Phase II are to verify APEX performance with geothermal brines and to provide long term corrosion and erosion test data. In order to increase testing effectiveness, three heat transfer modules will be operated in parallel. Two sections will have recirculating solids with one circulating solids continuously and the other on an intermittent basis. The third section serves as a scaling baseline and will not have the recirculating bed.

1.0, Introduction (cont.)

Analysis of the comparative fouling, erosion, and corrosion test results of the three sections will permit determination of the feasibility of concept application to geothermal energy recovery using a binary cycle.

The first quarter of the Phase II effort was directed toward design of the field test experiment setup and procurement of required hardware and equipment. This report describes progress during the second quarter of the Phase II APEX development effort under Contract (E(04-3)-1125) for the time period from 1 January 1977 through 31 March 1977.

The current program status relative to the schedule and key mileposts is described in Section 2.0. Each task is identified and described and the progress on that task defined.

Section 2.0 also summarizes the technical progress meetings held between ALRC and Lawrence Berkeley Laboratory (LBL) personnel.

Section 3.0 is a technical discussion covering the experiment design, assembly, and laboratory testing.

Section 4.0 describes the work effort planned for the subsequent report period 1 April 1977 - 23 June 1977.

2.0 PROGRAM STATUS SUMMARY

Phase II of the APEX program is a nine month effort scheduled to be completed 23 June 1977. Phase II has been divided into three major technical tasks and a documentation task as shown in the schedule, Figure 1. Task 1, Well-Site Experiment Design, covers all the efforts required to complete the design of the experimental test rig which will be located at the ERDA East Mesa Geothermal Component Test Facility. This task was completed during this reporting period.

Task 2, System Fabrication, includes procurement of commercially available components, locating and refurbishing the on-hand equipment, and fabrication of special components, as well as assembly and checkout of the system at Aerojet. This task overlaps Task 1 by two months to permit purchase of long lead items as soon as the design is sufficiently firm. The system fabrication task has been completed with the exception of some instrumentation which will be installed in the field when available.

The third major technical task is Well Site Testing. This task has been initiated. The Task 3 effort includes transportation, setup, and check-out of the test rig at East Mesa followed by verification testing, and data analysis. The setup and checkout test is presently in progress. Verification testing is expected to begin 17 April as scheduled.

The documentation task includes two written quarterly progress reports, two program reviews with ERDA and/or designated representatives, and a final report. This is the second of the two quarterly progress reports.

Five key mileposts have been identified which must be completed as scheduled to insure maintaining the program schedule. The first milepost is completion of the design. The second is completion of laboratory durability testing. Milepost three is receipt of all purchased items. The fourth key milepost is completion of the system checkout and the final milepost is initiation of well-site testing. The first four mileposts are considered to have been successfully accomplished. The program is expected to be complete by 23 June 1977 as scheduled.

Figure 1. Program Schedule

2.0 Program Status Summary (cont.)

2.1 TASK 1, WELL-SITE EXPERIMENT DESIGN

The well-site experiment design task was scheduled to be completed by 31 December 1976. This task includes two key mileposts: 1) completion of the process design, and 2) laboratory durability tests for selected components. All subtasks were completed on schedule with the exception of the laboratory durability testing. These tests depend on subcontractor delivery of the two candidate bed recirculation components requiring durability testing, namely, the brine/bed injection eductor and slurry pump. These items were received at Aerojet after the scheduled delivery date. The slurry pump was received on 1 April 1977, tested and found to be satisfactory for the intended service. The slurry pump was selected as the key bed recirculation component over the eductor in February 1977. This formally completed the Task 1 effort.

2.2 TASK 2, SYSTEM FABRICATION

The Task 2 effort, system fabrication, is complete. Slippages were experienced in delivery of some of the instrumentation, and the purchase of the second slurry pump was held up somewhat awaiting component verification testing. This resulted in a delay in completing the equipment procurement subtask and the test rig assembly. Checkout of the test unit was completed at East Mesa to accommodate hardware delivery and maintain the field test schedule.

The system checkout at ALRC could not be conducted as completely as originally planned because one of the three brine flowmeters was delivered damaged and had to be returned and a second meter had not been received when required. The absence of flow data on two of the circuits prevented complete system checkout and calibration. The system was given a complete proof and leak test and the pumps were activated to verify proper functioning. The bed injection and removal system was given a functional checkout, and operated satisfactorily.

2.2, Task 2, System Fabrication (cont.)

The test rig was shipped to East Mesa rather than being retained at ALRC to await final delivery of all components because no further constructive work could be accomplished at ALRC. The field setup, however, could be effectively accomplished at East Mesa while awaiting final component delivery.

2.3 TASK 3, WELL-SITE TESTING

Task 3 was initiated on 31 March 1977 when the test rig was shipped from Sacramento to the East Mesa test site. Setup is now in progress at the site and is presently scheduled for completion by 15 April 1977. This is compatible with the facility scheduled three-shift operation capability which is planned for 11 April 1977 and the original ALRC schedule for test initiation by mid-April. All remaining components have now been received and are being installed. No difficulties in maintaining the 15 April setup completion date are anticipated unless site integration delays develop during startup.

2.4 MEETING SUMMARY

Two meeting were held between ALRC and LBL personnel during this reporting period. The first meeting was with Mr. Jack Angevine at ALRC. The purpose of this meeting was to review the interfaces between the ALRC rig and the facility and to generally determine the suitability of the test rig in reference to the facility capabilities. It was agreed that the test trailer and facility were compatible and the unit could be shipped. Mr. Angevine acquired data needed to initiate the site mechanical and electrical interface activities.

The second meeting was with Jack Addoms and Charles Gracey of ALRC and Kirk Collins of LBL on 24 March 1977 at ALRC. This meeting was held to review the safety aspects of the ALRC test rig and operating procedures. Mr. Collins suggested that a shield be placed over the rotating parts of the pump as an added safety factor. ALRC personnel concurred and work began to complete this action item.

3.0 TECHNICAL DISCUSSION

3.1 TEST RIG ASSEMBLY

The test rig assembly has proceeded substantially as shown schematically in Quarterly Report Q-4. Figures 2, 3 and 4 are photographs of the completed test rig. The entire rig with the exception of the remote recorders is mounted on a flat bed trailer for mobility. Figure 2 shows the trailer from the heat exchanger side. The baseline exchanger is at the top because it requires the least attention. The continuous duty exchanger is immediately below the baseline exchanger. This is the exchanger piped to the outboard slurry pump. The continuous duty pump is designed to be the most accessible. The coolant cooler is mounted below the exchangers.

The left side of Figure 2 shows the sand loader and sand collection pot mounted on a bulkhead; behind the bulkhead are the separators. Below the bulkhead are the slurry pumps. The ports cut in the bulkhead provide for observation of the sight gages for the slurry circuits. The various manifold drains are shown in this view.

Figure 4 shows the rear view of the trailer. The brine and cooling water interfaces are illustrated in this view. The sample collection tubes for the exchangers can be seen at the reversal end of each test heat exchanger. The trailer is equipped with vises to facilitate work on the test rig in the field.

3.2 SLURRY PUMP TESTING

The Phase II testing schematic is similar to that used in Phase I with the exception that a slurry pump is used to reinject the recirculating bed material into the brine rather than the eductor approach used in Phase I. The approach change was recommended because of durability problems encountered with the eductor during Phase I testing.

Figure 2. Test Rig - Side View

Figure 3. Test Rig - Front View

Figure 4. Test Rig - Rear View

3.2, Slurry Pump Testing (cont.)

Duration testing of the slurry pump was required before it could be selected as a viable component for the Phase II field testing effort. The test goals were to (1) establish that the pump will circulate bed material of the particle density, size, and weight % planned, (2) to establish the rate of decay of pressure head developed, and (3) to establish the wear patterns of the pump so that adequate and proper spare parts are on hand at the test site.

The duration testing of the pump was performed using ambient temperature deionized water to which garnet sand bed material was added.

Figure 5 is a photograph of the test setup with the pump disconnected from the suction and discharge pipe. The bed loader and the sampling system from the Phase I program were incorporated into the setup for loading the bed material and to sample the recirculating slurry for determination of weight % solids and particle size degradation. The pump head developed was taken out across an orifice plate.

The pump was run for two 100 hr duration tests. During these tests, no degradation of the developed pump head was observed. Both tests were terminated because of excessive leakage of the mechanical seal. Figure 6 is a photograph of the mechanical seal after the test. The ceramic face is undamaged; however, the carbon face is badly worn. Figure 7 is a photograph of the pump casing and impeller after the first 100 hr test. Some minor erosion of the impeller vanes was experienced.

It was concluded that the slurry pump will be acceptable for the Phase II testing. This conclusion was based on the reasoning that the worst condition which will be experienced is the necessity of replacing the carbon face of the mechanical seal on the continuous duty pump every fourth day.

Figure 5. Slurry Pump Test Setup

Figure 6. Slurry Pump Seal after 60 Hours Operation

Figure 7. Pump Casing and Impeller after First 100 Hour Test

3.2, Slurry Pump Testing (cont.)

This can be accomplished in about one hour at a cost of \$25. The intermittent duty cycle pump seal should last for the duration of the test. There is some evidence that the pressure of the deionized water piped to the mechanical seal cavity could have dropped below the slurry pressure during the durability evaluation test. If this happened, sand could migrate to the seal face and cause the damage observed. If this is the case, the pump seal can be expected to last much longer in the actual test.

Sufficient spare seal parts will be taken to handle the worst case anticipated. One spare impeller will also be included with the spare parts taken to the test site.

3.3 TEST RIG CHECKOUT TESTING

Test Rig Checkout testing officially began on 25 March 1977. During initial testing the pump and system performed as expected -- no problems were encountered. The system was hydro tested to 200 psig.

4.0 WORK PLANNED FOR NEXT REPORTING PERIOD

The remaining program tasks will be completed. This includes the following tasks:

1. Test rig setup and checkout at East Mesa
2. Four week verification testing effort
3. Data analysis
4. Final Report