Quarterly Progress Report Q-1 Contract E(04-3)-1125

ADVANCED GEOTHERMAL PRIMARY HEAT EXCHANGER (APEX)

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DISCLAIMER

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1.0 INTRODUCTION AND SUMMARY

This Quarterly Report covers the progress on the Advanced Geothermal Primary Heat Exchanger (APEX) Contract E(04-3)-1125 for the period from 1 July through 30 September 1975. The progress made during the reporting period is described as well as the work anticipated for the subsequent reporting period. A program schedule marked to indicate work progress is included. This report is organized to coincide with the tasks described in the schedule.

2.0 TECHNICAL STATUS

Figure 1 is the program schedule. Each major task and subtask which make up the total program are listed on this figure. The time period during which the performance of the tasks has been scheduled is indicated by the open bars. These bars will be filled in as work progresses to indicate the time period over which the task was actually conducted.

Referring to Figure 1, Task 1 has been completed in its entirety. Task 2.1, Heat Transfer Loop and Test Section Setup has been initiated.

3.0 ACCOMPLISHMENTS

The major effort during this reporting period was directed toward performing the analytical design task and initiating the laboratory setup.

3.1 ANALYTICAL DESIGN

Task 1, Analytical Design, includes the selection of a suitable demonstration site, water chemistry and temperature, and thermodynamic power cycle, Task 1.1; and parametric design and sensitivity analysis of a heat exchanger suitable for a 10MW electric "proof of concept" plant, Tasks 1.2 and 1.3. The purpose of Task 1 is to define the design and operating parameters in sufficient detail to allow meaningful laboratory experimentation in Task 2.

MAJOR MILESTONE SCHEDULE

AGCS 0130-67

PROGRAM SCHEDULE

MILESTONES	8/1	9/1	10/1	11/1	12/1	1/1	2/1	3/1	4/1	5/1	6/1	7/1
TASK I ANALYTICAL DESIGN												
1.1 DEMO SITE SELECTION				complete								
1.2 PARAMETRIC ANALYSIS			(1)	complete								
1.3 SENSITIVITY ANALYSIS				complete								
TASK 2 LABORATORY EXP.												
2.1 HEAT TRANS. LOOP & TEST SECTION SETUP				(2)								
2.2 ENTRAINMENT & SEPARATION COLD FLOW EXP												
2.3 BASELINE HEAT TRANSFER					(3)							
2.4 BASELINE FOULING												
2.5 FLUIDIZED BED CHARACTERIZATION									(4)			
2.6 HEAT TRANSFER & FOULING TESTS											(5)	
TASK 3 CONCEPT RE-EVALUATING & UPDATE												
TASK 4 DOCUMENTATION												
4.1 PROGRESS REPORTS												
4.2 ERDA PROG. REVIEW												
4.3 FINAL REPORT DRAFT												

PROGRAM KEY MILEPOSTS

(1) COMPLETE ANALYTICAL DESIGN

(2) COMPLETE CHECKOUT OF RECIRCULATING BED FACILITIES

(3) DEMONSTRATE FOULING CAPACITY OF GEOTHERMAL FLUID SIMULANT

(4) ESTABLISH HEAT TRANSFER & FOULING PARAMETERS

(5) ESTABLISH EXCHANGER PRELIMINARY DESIGN CRITERIA

WEEKS

MONTHS

FISCAL YEAR

CALENDAR YEAR

Figure 1

3.1, Analytical Design (cont.)

Task 1 was initiated and completed during this reporting period in accordance with the program schedule. The following paragraphs summarize the analytical design findings.

3.1.1 Demonstration Site and Plant Thermodynamic Power Cycle Selection

Well sites were reviewed as candidate geothermal water sources suitable for the demonstration of the APEX self-cleaning heat exchanger concept. The worst geothermal brines in the western United States are found in the Imperial Valley of California and the worst of these is at the Niland field. This site has been selected because of its high water temperature and solids concentration. The high solids concentration offers a worst case test for the APEX concept while the high temperatures offer capabilities for higher cycle efficiencies, hence lower power operation costs.

The power cycle selected is the Binary Rankine cycle using an organic media as the working fluid. A super critical cycle employing isobutane as the working fluid was selected as being the most representative of current cycle study recommendations.

3.1.2 Primary Heat Exchanger Parametric and Sensitivity Analysis and Preliminary Design

The design analysis for the heat exchanger is based on standard log mean temperature difference methods accounting for forced convection film resistances for flows internal and external to the tubes, tube wall resistance and standard fouling factor for the organic fluid side. Continuous recirculation of the particulate material has been assumed to maintain a fouling free condition on the brine side. Assumptions concerning particulate flow rate, supply temperature, heat capacity and carrier fluid at injection have been made to complete the heat balance.

3.1, Analytical Design (cont.)

The exchanger design selected is based on the use of a single pass counter flow design with the brine-solid mixture flowing within the tubes. The design variables considered in the parametric analysis were tube diameter, brine velocity and isobutane velocity. Results of this parametric analysis indicate optimum tube side velocities in the 5 ft/sec range, 1/2 inch tube diameters preferred and shellside velocities in the 5-10 ft/sec region.

Optimized designs are dependent on the relative importance of minimum heat exchanger surface vs minimum pump power. Table I summarizes the general characteristics of a minimum surface and a minimum pumping power design.

Analysis of conditions required for the solids transport, separation, and injection indicate a bed particle size of 0.002 to 0.005-inch diameter will be sufficiently small to avoid saltation within the exchanger at the anticipated tube velocities and still be readily separated in a horizontal separator. A jet pump was selected as the recommended technique for reintroducing the solids into the brine.

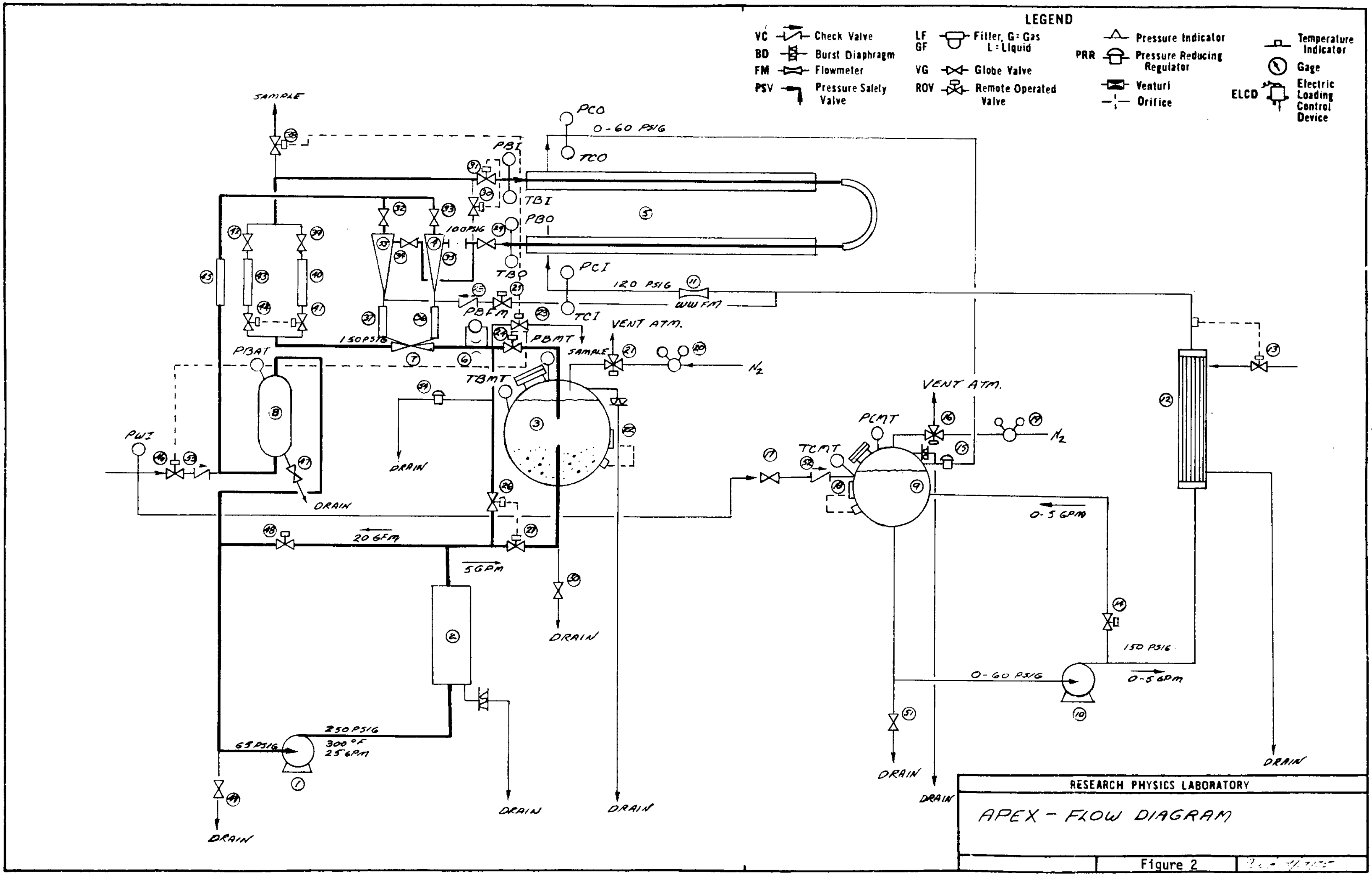
3.2 LABORATORY EXPERIMENTS

Preparation for laboratory experimentation was initiated as soon as sufficient analytical data from Task 1 were available to productively proceed. The initial effort was directed toward finalizing the process flow schematic which would provide reasonable simulation of the operating and design conditions developed in Task 1 within the program cost and schedule. Figure 2 is the flow diagram selected. The most significant departures from the flow diagram presented in the initial concept result from a change in heat exchanger test sections from a short vertical tube to a relatively long,

<u>TABLE I</u>

SUMMARY OF OPTIMIZED DESIGNS

	MINIMUM SURFACE	MINIMUM PUMP POWER
Surface required (ft^2)	40,000	67,000
Tube dia (in.)	1/2 in.	1/2 in.
Number	1132	1132
Tube Material	24 gage/316 stainless steel	24 gage/316 stainless steel
Total length (ft)	260	450
Shell dia ID/OD (ft)	2.4/2.6	3.0/3.25
Modules	5 @ 52 each	9 @ 50 ft each
Shell material	Carbon steel	Carbon steel
Shell side Dp (psi)	50	8
Tube side Dp (psi)	31	55
Total pump power (Mw)	0.22	0.097


LEGEND
VC Check Valve
BD Burst Diaphragm
FM Flowmeter
PSV Pressure Safety Valve
LF GF Filter, G = Gas L = Liquid
VG Globe Valve
ROV Remote Operated Valve
Pressure Indicator
PRR Pressure Reducing Regulator
Venturi
Orifice
Temperature Indicator
Gage
ELCD Electric Loading Control Device
SAMPLE
PCO
0-60 PSIG
TCO
PBI
TBI
PBO
TBO
100 PSIG
PCI
120 PSIG
WW FM
TCI
PBFM
PBMT
150 PSIG
PBAT
TBMT
SAMPLE
VENT ATM.
N2
PWI
DRAIN
20 GPM
5 GPM
VENT ATM.
PCMT
TCMT
N2
0-5 GPM
150 PSIG
0-60 PSIG
0-5 GPM
65 PSIG
250 PSIG
300 °F
25 GPM
RESEARCH PHYSICS LABORATORY
APEX - FLOW DIAGRAM
Figure 2

horizontal, 1/2-inch diameter brine tube which more closely approximates the probable tube selection for the primary heat exchanger. This test section change, when coupled with provision for evaluation over a range of flow velocities, necessitates an appreciable increase in pump ΔP, a change in separator mechanism and in the technique for reinjecting the bed material and an increase in the size of the heater.

The selected heat exchanger test section design, shown in the upper center of the flow diagram, consists of a tube within a tube arrangement. The center tube which handles the brine-solid mixture is 1/2-inch stainless steel. The outer tube is 3/4-inch stainless steel. The annulus between the tubes provides the cooling jacket. Two 10-foot sections will be used. These sections will be joined at one end by a transparent 180 degree return bend.

The brine-solids mix exits the heat exchanger and enters the separators. Two uniclone separators in parallel will be used to provide the capability for handling both high and low flow rates effectively. The liquid leaves the separators at the top and is routed to the suction of the pump via a sight glass and a separator tank to remove any solids carried over. The solids exit from the bottom of the separators through a sight glass to the suction of a water eductor.

The pump discharges into a 40 Kw electrical heater. Excess flow is bypassed to the suction of the pump. The desired flowrate is routed to the mineral tank. A bypass around the mineral tank is provided in the event that no additional salt is required in the brine solution. The clear brine solution is then used as the operating fluid in the eductor.

The brine-solids mixture leaving the eductor passes through a sample system which permits locking in an instantaneous sample in a sight glass and observing the solids concentration and makeup. From this point the mixture enters the heat exchanger and the brine loop is completed. A bypass is provided around the heat exchanger to permit the system to come to steady state before the exchanger is brought on-stream.

The cooling loop which is used to simulate the working fluid has been modified from that proposed to provide greater control and flexibility. A pressurized system will be used so that coolant temperatures in excess of 212°F are possible. A heat exchanger will be used instead of flashing the coolant water to remove the heat. The heat exchanger is cooled by plant water. A control valve on the plant water permits regulation of the desired water temperature to the test section. A bypass from the pump discharge to the suction provides for regulation of the flowrate.

All of the process equipment has been located, purchased, or designed preparatory to local fabrication. Considerable effort was required in purchasing process equipment which would perform satisfactorily and still had an acceptable cost and delivery schedule. This difficulty necessitated some flow schematic revisions and compromises. The equipment ultimately selected should perform satisfactorily and is within the program budget. Delivery schedules are tight. If all suppliers make their deliveries on schedule, and no problems are encountered during installation, the 11-1-75 milepost for completion of system checkout can be made.

The following table lists the major process equipment, the manufacturer and status. Other components such as valves, actuators, loaders and electrical equipment are on order. Delivery promises range up to 15 October.

3.2, Laboratory Experiments (cont.)

	Supplier/ Manufacturer	Delivery Promise
Mineral Tank	Aerojet	on hand
Eductor No. 1	S&K	10-1
Eductor Backup	Aerojet	design complete
Separators	Aerojet	on hand
Test Section	Aerojet	design complete
Brine Pump	Pacific Pump	10-1
40 Kw Heater	Montgomery Bros.	10-15
Coolant Tank	Aerojet	on hand
Coolant Pump	Aurora	10-1
Coolant Heat Exchanger	Aerojet	on hand

4.0 WORK PLANNED FOR NEXT REPORTING PERIOD

The work planned for the next reporting period will be concentrated on collecting the baseline test data required in Task 2 of the program prior to initiation of the APEX concept testing.

The test loop setup for Task 2.1 will be completed.

The cold flow solids entrainment and separation experiments which check out the performance of the eductor and separators and establish the entrainment velocity limits will be completed. This is Task 2.2.

The baseline heat transfer tests, Task 2.3, will be completed. These tests, which are conducted without bed using clean water, provide a reference condition.

The baseline fouling tests will be completed, Task 2.4. These tests, conducted without bed material, provide the baseline fouling data on the geothermal fluid simulant.

4.0, Work Planned for Next Reporting Period (cont.)

The bed characterization tests, Task 2.5, will be initiated. These tests, conducted with clear water plus solids, permit establishing baseline heat transfer data and transport characteristics of candidate solid materials.