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MASTER

GEOHERMAL LOOP EXPERIMENTAL FACILITY

ERDA CONTRACT NO. E (04-3)-1137

~~AC03-76ET28443~~

**MAY 1977
BI-MONTHLY REPORT**

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SDG&E - ERDA GEOTHERMAL LOOP EXPERIMENTAL FACILITY

March, 1977-April, 1977

CONTRACT NO. E(04-3) - 1137

H.K. Bishop

J.R. Bricarello

F.L. Enos

N.C. Hodgdon

W.O. Jacobson

K.K. Li

C.R. Swanson

May, 1977

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SUMMARY

The Geothermal Loop Experimental Facility was shut down in March, 1977, for the refurbishment of the facility and the injection well. Heavy scaling, which occurred in the facility brine systems as well as in the injection well, necessitated periodic plant shutdowns and cleanings. Various means of scale cleaning and controls were accomplished and evaluated for cost effectiveness. Initial indications showed that operations were satisfactory.

Initial operational stability, and heat and mass balance testing of the Geothermal Loop Experimental Facility (GLEF) were accomplished in April. Operational stability was demonstrated but heat and mass balance test data was not satisfactory primarily due to off design facility operation. Testing was also hampered by pump failures, injection strainer cleaning difficulties and instrumentation problems.

Initial testing showed negligible heat transfer in one of the two first stage heat exchangers. Other heat exchangers also showed poor performance. Numerous attempts to modify plant operating conditions to eliminate problem and/or achieve heat transfer were accomplished. It appears that off design (low geothermal steam rate and water in the binary loop) conditions were primarily responsible for the observed conditions.

Pump failures were apparently caused by vapor at the pump section compounded by scale erosion, corrosion and bearing wear problems. Remedial actions included: (1) Venting vapors back to pump suction supply vessel ullage space, (2) adding additional bearing surface area (condensate pump only), (3) adding purge water supply (condensate pump only), (4) changing to a cleaner source of purge water, and (5) preparation for changing to more corrosion/erosion resistant pump materials.

Brine injection strainer cleaning was originally intended to consist of back-flushing. Initial operation indicated good success with this cleaning method. Toward the end of April, back-flushing was not able to achieve an acceptable decrease in pressure drop. Strainer was removed and laboriously hand-cleaned. After several days of operation, the strainer again required hand cleaning. Imperial Magma is in the process of investigating more efficient cleaning methods, such as chemicals or water blast techniques.

Instrumentation problems included a combination of electronic failures and scale build-up which affected the transducers. Remedial actions included: (1) Replacement of faulty electronics, (2) periodic cleaning of some accessible instrumentation, (3) trial condensate purging of other instrumentation, and (4) preparation for replacement transducers (such as ultrasonic flowmeters) and modified electronics (such as scanning capability for the data logger).

In summary, the facility operated on one well, a total of 420 hours, during April, during which valuable data was gathered. Some growing pains on the newer systems (strainer on injection line and the data logger) along with pump failures were corrected. Completion of initial test series is expected during May.

1.0. INTRODUCTION

This bi-monthly report summarizes the geothermal activities for the SDG&E/ERDA Geothermal Loop Experimental Facility (GLEF) during March and April, 1977. The objectives and results of tests and operation are discussed in Section 2. The chemistry of plant fluids and scale is reviewed and compared to prior analysis presented in previous bi-monthly reports in Section 3.0. Special problems during operations, their analyses, as well as possible corrective actions are discussed in Section 4.0. A section on the data management of the GLEF is also included.

2.0 OPERATION AND TESTING

2.1 Introduction

Operation of the Geothermal Loop Experimental Facility was resumed in April 1977 after a month's shut down for inspection and maintenance work on the plant and injection well, Magmamax No. 3. Following this shut down the plant was operated for 420 hours using Woolsey No. 1 as a production well and Magmamax No. 3 as the injection well.

Several major aspects of the GLEF operation were investigated. These were:

- a. Single Well Baseline Operation
- b. Heat Exchanger Characteristics
- c. Evaluation of the new production well

(Woolsey No. 1)

Results of these activities are presented. Major problems and interruptions are discussed. Conclusions and recommendations are drawn from these results and observations.

2.2 Single Well Baseline Operations - April, 1977

As reported in the last bi-monthly report, attempts to evaluate long term baseline plant performance operation and maintenance problems, as well as steam, brine and scaling chemistry were hampered by the loss of injectivity of the injection well, Magmamax No. 3. Therefore, after the completion of remedial actions of the injection well by Imperial Magma, (Section 4-6), these attempts were resumed.

Concurrent with this work, approximately 1,000 feet of the injection line before the injection well was cleaned by high pressure jets (hydroblasting). Details are presented in Section 4.3.

Commencement of brine flow from Woolsey No. 1 was successful on April 5, 1977. For these tests, Woolsey No. 1 was the production well and Magmamax No. 3 the injection well. Initial pressure and temperature of the incoming brine at the plant boundary were 150 psia and 380°F respectively. The initial flow was estimated at about 200 gpm which eventually increased to approximately 500-550 gpm (approximately two thirds of the design flow). Average temperature and pressure of Woolsey at the plant boundary during the month were 385°F and 190 psia respectively (standard deviations about 8% and 4% of the mean respectively).

Table 2-1 shows the average operating data in the month of April. Pressure and temperature data was within acceptable accuracies (in most cases within 5%). Difficulties were still encountered in measurement of flows due to scaling of the flow measuring devices and fluctuation caused by control valve operation. Therefore, most flow measurements reported here were only estimates.

On April 7, 1977, one of the condensate pumps, P-10, was out of service due to worn bearings and wear rings. Attempts to maintain condensate flow from the condensate tank by using the other condensate pump P-9 were unsuccessful due to what seemed to be vapor binding. With reduced condensate pumping capacity, brine flow to the plant had to be lowered. On April 12, the plant was shut down to repair both pumps.

TABLE 2-1

START UP OPERATING CONDITIONS* Woolsey No. 1

Test No:

Date: April, 1977

<u>Parameter</u>	<u>Units</u>	<u>Average</u>	<u>Std. Dev.</u>
Inlet Conditions			
	T °F	399.6	0.75
	P psig	194.5	1.91
1st Stage	T °F	322	1.78
	P psig	162.1	2.69
	LF M#/hr	---	---
	SF M#/hr	35.4	1.27
2nd Stage	T °F	305.4	2.87
	P psig	62	2.73
	LF M#/h	----	----
	SF M#/hr	63.6	5.87
3rd Stage	T °F	248.4	4.76
	P psig	17.0	1.923
	LF M#/hr	----	----
	SF M#/hr	13.2	1.76
4th Stage	T °F	194.5	2.0
	P psia	3.4	1.46
	LF M#/hr	----	----
	SF M#/hr	4.9	1.37
Reinjection	T °F	250.9	3.66
	P psig	372.2	23.69
	LF #/hr	----	----

LF = Liquid Flow

SF = Steam Flow

M = 1000

* Data recorded are those obtained after stable plant conditions were maintained. Therefore, start-up and shut-down data are excluded from this table.

These pump failures apparently were caused by a combination of chemical and mechanical factors: scale deposition, vapor at the pump suction, corrosion and bearing wear. Remedial actions included (1) utilizing a better source of purge water for the bearings, e.g., from the first stage condensate; (2) Extending the bearing lengths and journals. Upon completion of these corrective actions on April 15, pump operation seemed satisfactory.

2.3 Heat Exchanger Performance

The heat exchanger surface requirement represents a major consideration in the design of the GLEF. Therefore, evaluation of heat transfer coefficient will be carried out whenever possible. Such efforts were attempted in April but results were inconclusive due to the accuracies of the instrumentations used. Preliminary results of calculations for 2nd, 3rd and 4th stage heat exchangers show approximately $150 \text{ BTU/Ft}^2\text{.-Hr.-}^\circ\text{F}$ while the expected coefficients from other data indicated that the value of HTC should be in the range of 300 to 500. The 1st stage condensate cooler indicates standard deviations ranged as high as $178.4 \text{ BTU/Ft.-Hr.-}^\circ\text{F}$.

Six possible causes exist to explain this performance. These are: 1) the over-surface of the heat exchangers under the present one-well operating conditions, 2) exchangers are operating partially flooded with condensate. 3) exchangers are blanketed with non-condensable gas. 4) mechanical difficulties with the exchanger. 5) heat transfer surfaces are

fouled; and 6) Maldistribution of water due to low flow is distorting temperature profile.

The magnitudes of standard deviations indicate uncertainties in the data. The uncertainties may be attributed to several factors, for example: (1) fluctuations and instabilities of heat exchanger operations, (i.e., in flows, temperatures and pressures), (2) inaccuracies of instrumentation used, and (3) human Factors involved in obtaining the data.

Corrective actions include the inspection and cleaning of the heat exchangers, recalibration of instrumentation, and cross-checking of raw data, inspection and maintenance of control equipment in the heat exchanger operation. Also, modifications to the operating conditions are being evaluated in a hope to avoid possible flooding and gas blanketing. These efforts will be carried out in May, and calculations of heat exchanger performance will be resumed.

The plant was shut down on April 25 for inspection and maintenance. A detailed report on vessel inspections is presented in Appendices A and B.

3.0 CHEMISTRY

This section discusses the GLEF chemistry. Chemical properties of the steam, brine, scale and noncondensable gas and cooling water are described. During this period, the facility was operated for 420 hours using fluid from Woolsey No. 1. In general, the monitored parameters varied little from those observed when Magmamax No. 1 brine was being used.

3.1 Steam System

Tables 3-1 lists the several weekly and daily monitored constituents of the GLEF steam system. The steam line sample locations and sampling techniques have been described in previous bi-monthly reports. As before, the values given are those of compounds in condensed steam samples analyzed at standard pressure and temperature.

The properties of the condensed steam from Woolsey No. 1 brine exhibit the same trends as steam condensate properties from Magmamax No. 1 brine. Characteristic of the first stage is its low pH, high conductivity, high ammonia level, low carryover (sodium) and high iron content. This consistently high iron content is attributed to corrosion caused by the low pH and the relatively large quantities of dissolved gases (CO_2 , H_2S) in the first stage steam. Currently, the steam is being sampled at the well. Since the steel wall of the steam line is also the probable iron source, it is possible the steam sample may be biased. To provide a

Woolsey #1

Condensed Steam Analysis

Table: 3-1
Date: 3/1/77

Sample	pH	ORP mv	Cond umho/cm	Na mg/lit	Ca mg/lit	Fe mg/lit	Cl mg/lit	NH ₄ -N mg/lit	Boron mg/lit
1st stage in	6.30	-180	2300	5.3	3.0	32	20	240	7.7
1st stage out	6.40	-210	2300	1.4	0.7	6.8	5	285	0.6
2nd stage in	7.55	-125	1580	13	7.8	2.0	45	210	6.4
2nd stage out	8.25	- 95	1450	2.8	2.1	1.0	12	210	5.3
3rd stage in	9.40	-115	580	36	20	1.1	115	130	8.4
3rd stage out	9.45	-130	195	2.2	1.2	0.4	10	135	3.4
4th stage in	6.25	-145	1650	95	46	5.0	280	90	1.4
4th stage out	7.05	- 40	1670	2.8	1.0	1.0	5	230	0.2

ORP: Oxidation Reduction Potential

Steam in: Condensed steam from flash vessel to scrubber

Steam out: Condensed steam from scrubber to heat exchanger

Woolsey #1
Condensed Steam Analysis

Table 3-1
Date: 3/2/77

Sample	pH	ORP mv	Cond umho/cm	Na mg/lit	Ca mg/lit	Fe mg/lit	Cl mg/lit	NH ₄ -N mg/lit	Silica mg/lit
1st stage in	6.45	-155	2200	5.7	2.1	13	20	250	1.08
1st stage out	6.40	-160	2700	2.5	0.6	11	7	320	1.70
2nd stage in	7.95	-105	1540	17	8.9	1.5	5	210	0.20
2nd stage out	7.80	- 55	1430	2.3	1.8	3.4	7	205	0.20
3rd stage in	9.90	- 90	390	26	14	0.2	104	125	0.20
3rd stage out	9.75	- 85	180	1.6	0.8	0.2	5	130	0.50
4th stage in	6.25	-144	670	13	8.2	1.0	40	80	0.26
4th stage out	7.10	-131	1910	2.2	1.0	0.7	5	265	0.14

ORP: Oxidation Reduction Potential
Steam in: Condensed steam from flash vessel to scrubber
Steam out: Condensed steam from scrubber to heat exchanger

Woolsey #1
Condensed Steam Analysis

Table: 3-1
Date: 4/6/77

Sample	pH	ORP mv	Cond umho/cm	Na mg/lit	Ca mg/lit	Fe mg/lit	Cl mg/lit	NH ₄ -N mg/lit
1st stage in	6.60	-195	2200	2.0	1.0	13	10	290
1st stage out	6.55	-195	1790	4.8	2.1	13	20	225
2nd stage in	7.30	-140	1410	8.9	4.9	4.3	30	180
2nd stage out	8.55	-185	1130	1.9	1.7	1.6	5	185
3rd stage in	9.60	-205	340	16.5	8.1	0.3	50	125
3rd stage out	9.65	-200	165	2.5	1.3	0.8	5	125
4th stage in	6.55	-130	850	33	16	2.6	80	80
4th stage out	8.55	-205	1160	2.2	1.0	0.4	5	200

ORP: Oxidation Reduction Potential
Steam in: Condensed steam from flash vessel to scrubber
Steam out: Condensed steam from scrubber to heat exchanger

Woolsey #1
Condensed Steam Analysis

Table: 3-1
Date: 4/7/77

Sample	pH	ORP mv	Cond umho/cm	Na mg/lit	Ca mg/lit	Fe mg/lit	Cl mg/lit	NH ₄ -N mg/lit	Boron mg/lit
1st stage in	6.80	-175	2200	4.7	2.1	18	20	245	3.0
1st stage out	6.90	-185	2500	1.6	0.6	19	5	300	1.7
2nd stage in	8.95	-240	1280	14	7.5	0.5	10	200	5.2
2nd stage out	9.00	-230	1150	1.4	0.9	0.5	5	200	2.2
3rd stage in	9.85	-245	260	9.5	4.9	0.3	20	130	6.2
3rd stage out	9.90	-240	155	2.2	0.9	0.4	5	140	5.9
4th stage in	6.80	-185	1160	7.6	3.0	1.6	20	85	1.3
4th stage out	8.90	-215	690	1.6	0.6	0.3	5	205	0.3

ORP: Oxidation Reduction Potential
Steam in: Condensed steam from flash vessel to scrubber
Steam out: Condensed steam from scrubber to heat exchanger

Woolsey #1
Condensed Steam Analysis

Table: 3-1
Date: 4/8/77

Sample	pH	ORP mv	Cond umho/cm	Na mg/lit	Ca mg/lit	Fe mg/lit	Cl mg/lit	NH ₄ -N mg/lit	Silica mg/lit	Sulfide mg/lit
1st stage in	7.05	-255	1700	4.0	2.1	0.6	10	220	0.16	27
1st stage out	7.00	-230	1870	1.8	0.5	0.6	5	270	0.26	-
2nd stage in	9.25	-225	920	3.0	2.1	0.5	15	180	0.12	2.2
2nd stage out	9.25	-240	910	1.5	1.2	0.5	10	185	0.16	-
3rd stage in	10.10	-230	220	9.0	4.3	0.5	20	125	0.20	0.2
3rd stage out	10.05	-225	150	2.1	0.9	0.7	5	135	0.22	-
4th stage in	6.55	- 80	980	8.8	4.1	1.0	30	90	0.12	0.2
4th stage out*										

ORP: Oxidation Reduction Potential

Steam in: Condensed steam from flash vessel to scrubber

Steam out: Condensed steam from scrubber to heat exchanger

*Pump supplying sampling point out of commission.

Woolsey #1
Condensed Steam Analysis

Table: 3-1
Date: 4/19/77

Sample	pH	ORP mv	Cond umho/cm	Na mg/lit	Ca mg/lit	Fe mg/lit	Cl mg/lit	NH ₄ -N mg/lit	Silica mg/lit	Sulfide mg/lit	Boron mg/lit
1st stage in	6.80	-170	2100	4.6	1.8	13	20	300	0.20	3.1	3.2
1st stage out	6.75	-115	2000	3.1	0.5	11	10	310	0.44	4.4	7.0
2nd stage in	9.00	-270	1160	8.8	3.9	0.4	20	235	0.14	2.0	3.2
2nd stage out	9.00	-225	1040	1.5	2.1	0.5	5	235	0.10	1.3	3.5
3rd stage in	10.10	-225	310	19	10.6	0.8	30	125	0.24	0.2	6.9
3rd stage out	10.15	-230	140	1.4	0.7	0.3	5	150	0.28	0.2	3.5
4th stage in	6.85	-115	1390	104	4.9	2.6	300	88	0.30	2.6	2.4
4th stage out	9.25	-200	680	21	6.4	0.3	100	135	0.32	1.6	2.3

ORP: Oxidation Reduction Potential
Steam in: Condensed steam from flash vessel to scrubber
Steam out: Condensed steam from scrubber to heat exchanger

more representative steam sample the steam sample ports are being modified to provide representative sampling in accordance with ASTM D1066.

In comparison to the first stage, the second stage steam possesses a higher pH, lower conductivity, lower ammonia content, and generally a little more carryover (sodium). The third stage steam parameters are essentially duplicates of the second stage showing a slightly higher pH, a slightly lower conductivity and ammonia level, and a little more carryover. In the fourth stage, the measured pH decreases due to injection of CO₂ saturated scrubber water into the separator. Carryover in the fourth stage is also consistently higher than the other stages.

Boron and silica concentration in the steam condensate do not exhibit any determinable trends. Boron's concentration fluctuates from stage to stage throughout the facility. In this respect, it differs from previous experience with Magmamax steam, where the boron concentration decreased steadily through the successive stages. This gradual decrease was attributed to the lower temperature and therefore lower vapor pressure of boron in each succeeding stage. The reason for this difference is unclear. Measurements of Woolsey steam indicate the boron carryover may also be influenced by the amount of salt carryover (entrainment). This would explain the higher boron level observed in the third stage steam which also has a higher salt content.

Silica concentration in the steam condensate also exhibits little change, remaining at 0.2 mg/lit or less throughout the facility.

3.2 Brine System

After 420 hours of Woolsey operation, the fluid chemistry of the Woolsey brine appears to be stabilizing. Table 3-2 summarizes the composition of the Woolsey fluid during the past four months. The lower values measured on March 11 are attributed to sampling of the fluid shortly after well startup before stabilized flow was achieved.

Evidenced in this table is a lower concentration of silicon which may imply a lower scaling rate with Woolsey fluids. The silica concentration in the Magmamax brine declined as it passed through the facility, indicating silica precipitation as the brine cooled. No such decrease in silica concentration was observed with the Woolsey brine, Table 3-3. Thus, more of the silica appears to remain in solution as the Woolsey fluid flows through the GLEF. This does not imply there will be no scale, since inspection of the injection pump on April 25 did show significant scaling. However, less scale deposition was observed in the fourth stage separator (Appendix B).

In general, the ratio of the mineral species in the Woolsey fluid is the same as Magmamax No. 1 fluid. Only the total mineral concentration is less. Exceptions are silicon, noted above, and barium which exhibit the same concentrations in both Woolsey and Magmamax brine.

TABLE 3-2
Woolsey #1 Wellhead Brine

Date Element	2/15/77 mg/l	2/24/77 mg/l	3/1/77 mg/l	4/5/77 mg/l	4/21/77 mg/l
Na	43,300	9,000	39,300	36,100	42,100
K	9,000	8,100	8,200	6,900	10,000
Ca	15,900	18,900	20,400	16,800	20,000
Cl	114,800	112,000	116,000	112,000	117,500
Fe	145	245	165	70	210
Mn	435	535	500	335	565
Zn	78	110	110	100	115
Cu	1.2	1.0	1.2	0.6	1.6
Pb	29	38	34	21	36
Ba	145	135	135	150	120
Si	150	165	130	145	160
Mg	170	150	150	220	135
Li	120	140	145	140	130
Sr	355	300	340	325	295
Al	1.0	1.0	0.7	1	-
B	270	240	240	230	-
SO ₄	106	80	80	85	70
NH ₄ -N	305	305	325	275	330
pH	6.05	5.85	6.20	6.00	5.60

TABLE 3-3
Woolsey Brine Composition
in the G.L.E.F.

Date 4/18/77 Element	Wellhead mg/l	1st Brine Out mg/l	3rd Brine Out mg/l	4th Brine Out mg/l
Na	41,700	43,600	46,800	49,300
K	9,800	10,500	11,200	12,000
Ca	20,300	21,300	23,300	24,600
Cl	116,200	121,200	135,000	140,000
Fe	215	225	255	255
Mn	560	600	650	675
Zn	130	135	130	135
Cu	0.8	0.8	1.2	1.5
Pb	36	43	44	50
Ba	145	145	145	145
Si	160	170	190	190
Mg	150	160	170	175

A high sulfate level (70 to 106 ppm) has been observed in the Woolsey brine. This does not appear possible considering the high barium level in the brine. The solubility of barium sulfate is far less than the sulfate level exhibited in this brine. Two possible explanations are: 1) some other species interferes with the kinetics of the barium sulfate equilibrium. 2) since Woolsey now produces from several levels of porous rock, a low barium, high sulfate water, probably from a high strata, may be mixing with the fluid as it comes up the well casing. LLL has been asked to confirm this high sulfate level and its probable cause.

3.3 Injection Line Scale

During this period cleanout access points were installed in the injection line. Scale deposits at these points were sampled and the composition reported in Table 3-4. As observed in Table 3-4, deposits A, B, and C contain significant amounts of carbonates. These scale deposits were the result of both Magmamax and Woolsey operation and the carbonate level in the scale is attributed to condensate addition to the injection brine. Sample D, Table 3-4 illustrates the results of directing the condensate to the cooling pond. Without condensate addition, no carbonate scale is formed and the silicon concentration in the scale is relatively high. Deposits with similar composition were observed during operation with Magmamax fluids without condensate addition.

TABLE 3-4
Injection Line Scale

Sample	A	B	C	D
Date	3/10/77	3/11/77	3/14/77	4/13/77
Thickness	50 mm	10 mm	10 mm	1-2 mm
Color-general appearance	green-gray multilayered semi-hard	black-gray multilayered	brown gray-white black multilayered	gray single layer
Element	% by wgt	% by wgt	% by wgt	% by wgt
Fe	3.10	3.15	2.90	2.05
Cu	0.08	0.08	0.04	0.14
Zn	0.50	0.40	0.40	0.12
Mn	2.11	2.05	2.00	0.11
Pb	0.17	0.18	0.17	0.04
Ca	5.80	4.40	4.20	0.60
Al	ND	ND	ND	0.28
Si	25.20	25.20	23.55	35.70
Ba	2.80	4.70	4.45	2.10
Mg	0.03	0.03	0.03	0.14
Na	2.45	1.90	1.85	0.46
CO ₃	9.80	7.30	4.75	-
S	0.90	1.15	1.40	-

ND - nondetected

Legend:

- A Injection line: first clean-out access point (1030 feet from plant)
- B Injection line: third clean-out access point (1800 feet from plant)
- C Injection line: second expansion loop along north-south road (2415 feet from plant)
- D Injection line: orifice plate, Woolsey flow only (in plant)

3.4 Woolsey Scale

Table 3-5 gives analyses of the scale in the third and fourth stage separators. The high iron content of the third stage scale is attributed to corrosion of the vessel walls. Normally a high silica scale is found in this location. The fourth stage separator contains scale with lower iron concentration representing either a lower corrosion rate or a lower adherence of the corrosion product to the scale. A major difference between the scales in these two vessels is the barium concentration. This probably occurs because the brine loses its ability to keep the barium sulfate in solution at this point in the system.

Scale deposited on the injection pump is also high in silica, similar to the fourth stage scale. (Table 3-6.) However, probably due to dynamic conditions in the pump, less iron is attached to the scale. The barium concentration in the pump scale is also similar to that found in the fourth stage scale.

3.5 Injection Line Strainer

Table 3-7 shows the type of scale found in the newly installed injection line strainers which are located at the injection well (Magmamax No. 3). The material trapped by the strainers appears to be a mixture of scale deposited in the plant and in the injection line (Table 3-7, A&B). Sealing has also been observed on these strainers. The properties of this scale, as shown in Table 3-7(C), appear

TABLE 3-5
Third and Fourth Stage
Separator Scale
(Woolsey Brine)

Sample	A	B	C	D
Date	4/28/77	4/28/77	4/25/77	4/25/77
Thickness	5 mm	5-7 mm	15 mm	12 mm
Color-general appearance	black olive green	black	black, gray, olive green	black, olive-green multilayered
Element	% by wgt	% by wgt	% by wgt	% by wgt
Fe	17.85	17.85	4.70	9.25
Cu	0.17	0.27	0.20	0.12
Zn	0.29	0.15	0.16	0.34
Mn	1.10	1.53	0.25	1.16
Pb	0.16	0.30	0.31	0.84
Ca	1.30	1.35	1.50	1.40
Al	0.60	0.74	0.65	0.06
Si	18.20	18.20	26.35	19.50
Ba	1.00	1.25	7.10	2.95
Mg	0.23	0.30	0.20	0.16
Na	1.90	2.65	1.30	1.85

Legend:

- A 3rd stage separator: below waterline
- B 3rd stage separator: floor debris
- C 4th stage separator: below waterline
- D 4th stage separator: just above waterline

TABLE 3-6
Injection Pump Scale
(Woolsey Brine)

Sample	A	B
Date	4/25/77	4/26/77
Thickness	10-15 mm	10 mm
color-general appearance	black base layer, white layer, olive layer	olive high moisture content
Element	% by wgt	% by wgt
Fe	1.00	1.20
Cu	0.10	0.40
Zn	0.11	0.12
Mn	0.20	1.74
Pb	0.10	3.25
Ca	3.80	1.50
Al	0.28	0.22
Si	30.80	30.00
Ba	2.95	4.00
Mg	0.10	0.10
Na	4.65	2.25

Legend:

A Pump suction

B Scale on pump body

TABLE 3-7
Injection Line Strainer Scale
(Woolsey Brine)

Sample	A	B	C
Date	4/20/77	4/25/77	4/22/77
Thickness	varied	2-3 mm	less than 1 mm
color-general appearance	olive, black chunks	olive black chunks	greenish yellow
Element	% by wgt	% by wgt	% by wgt
Fe	5.90	5.90	1.95
Cu	0.13	0.08	0.84
Zn	0.45	0.50	0.12
Mn	2.39	2.54	0.45
Pb	0.56	0.35	0.50
Ca	6.60	6.20	4.60
Al	0.12	0.09	0.28
Si	19.20	19.65	27.85
Ba	2.60	3.05	3.50
Mg	0.08	0.10	0.11
Na	2.60	3.65	-

Legend:

- A Debris trapped by east strainer
- B Debris trapped by west strainer
- C Scale built up on strainer

similar to the high silica scale deposited in the injection line.

3.6 Magmamax Supply Line

During a recent inspection, a scale sample was collected from the supply line of Magmamax No. 1. An analysis of the scale (Table 3-8) shows it to be a high lead scale, most probably as lead sulfide. Of interest is the thickness of the scale which is only 1 to 2 mm after approximately 2000 hours of operation.

3.7 Injection Well Scale

When Magmamax No. 3, the injection well, was cleaned by scraping, various samples were taken from several different depths. These are described in Table 3-9 where they are compared with scale found in the injection line.

It can be seen that the first 500 feet is different from the remainder of the casing scale in that it contains very little carbonate scale. Carbonate level of this scale is similar to the injection line scale formed when the plant steam condensate is not added to the spent brine which occurred during the last 934 hours of plant operation. Thus, it is possible that scaling of the upper 500 feet of the injection well occurred during this period. The carbonate content of scale in the remainder of the well is similar in composition to injection line scale found when condensate is added to the spent brine. The GLEF was operated in this mode for 700 hours. Since more scale was deposited during this 700 hour period operating with condensate addition may cause more rapid scaling of the injection well.

TABLE 3-8
Magma Max #1
Supply Line Scale
(Magmamax Brine)

Date	4/29/77
Thickness	1-2 mm
color-general appearance	hard black metallic
Element	% by wgt
Fe	7.45
Cu	0.02
Zn	0.54
Mn	0.19
Pb	60.75
Ca	0.33
Al	0.46
Si	4.90
Ba	0.35
Mg	0.88

TABLE 3-9
Injection Line and Magmamax #3
Well Casing Scale

Sample	A	B	C	D	E
Location	Line	Well	Well	Well	Well
Element	% by wgt	% by wgt	% by wgt	% by wgt	% by wgt
Fe	0.78	5.80	6.90	6.65	7.70
Cu	0.14	1.07	0.08	0.04	0.04
Zn	0.10	0.73	0.16	0.38	0.35
Mn	0.20	3.76	0.37	1.74	1.48
Pb	0.33	0.59	0.10	0.14	0.11
Ca	3.25	11.25	2.55	4.77	5.14
Al	0.20	*ND	0.17	0.34	0.22
Si	27.15	15.90	25.35	22.10	22.10
Ba	0.63	0.48	2.40	2.90	2.90
Mg	0.04	0.04	0.24	0.30	0.30
Na	5.50	3.38	2.57	0.49	1.73
CO ₃	0.30	17.10	*ND	7.95	8.05
S	0.20	0.30	1.55	1.80	1.65

*ND-Nondetected

Legend:

- A Injection line no condensate addition
- B Injection line mixture of scale with & without condensate addition
- C Injection well (Magmamax # 3), top 500 feet
- D Injection well (Magmamax # 3), 500 to 2830 feet
- E Injection well (Magmamax # 3), 2830 feet

Such a simplistic hypothesis may not completely describe the actual mechanism. For example, the scale sample from 500-2830 feet contained more silicon than normally found in a carbonate type scale formed during condensate injection. What may be happening is that a high silicon scale associated with no condensate injection is building upon the carbonate scale deposited earlier.

Other unique aspects of the well scale are its high barium, iron and sulfur contents. The sulfur probably comes from the injection of canal water which contains 300 to 350 mg/lit of sulfate. Laboratory studies have demonstrated that the sulfate in the canal water will react with the barium in the brine to form a precipitate of barium sulfate. The iron in the samples is quite likely corrosion products.

3.8 Noncondensable Gases

The composition of noncondensable gas from Woolsey No. 1 is similar to Magmamax No. 1. The predominate specie is carbon dioxide followed by methane, hydrogen and hydrogen sulfide (Table 3-10). No oxygen, within the detectable limits of the gas chromatograph, was observed.

3.9 Cooling Water System

No change in the cooling pond has been noted except the continual increase of dissolved gases caused by the use of plant condensate as cooling water makeup. During the next scheduled shutdown, tests will be run on the

TABLE 3-10
*Woolsey Gas Analysis

Date	3/2/77	4/7/77	4/19/77
Compound	% by volume	% by volume	% by volume
CO ₂	98.45	98.60	98.37
CH ₂	0.80	0.71	0.92
N ₂	0.11	0.06	0.10
O ₂ **	NDL0.03	NDL0.03	NDL0.03
H ₂	0.60	0.64	0.61
H ₂ S	600 ppm	1000 ppm	850 ppm

*Samples taken from first stage separator

**Detection limits are 0.03%

Note: Numbers normalized to 100%

pond to determine an optimum chlorination procedure to combat algae growth that may occur during the summer months. Also, a comprehensive corrosion protection procedure will be worked out for the condensers.

4.0 SPECIAL PROBLEMS

4.1 Brine Injection Pump

4.1.1 Introduction

This section of the report summarizes the operation and maintenance of the brine injection pump at the GLEF during March and April, 1977. A loss of discharge pressure and corrosion/ erosion were noted during this period.

4.1.2 Loss of Discharge Pressure

The brine injection pump, P-2, operated for an additional 480 hours since last overhaul. On April 25, 1977 at 5:20 A.M., a loss in discharge pressure was observed. Operation prior to the loss was under reduced flow because of poor injection pump performance. Operators opened an irrigation water supply to the pump inlet which brought the discharge pressure slowly back to normal. When irrigation water supply was terminated, reduced brine operation continued. A second loss in discharge pressure followed. Therefore, operation was terminated for inspection of the pump.

4.1.3 Analysis

Several possible causes were investigated. Pump inlet line and 4th Stage separator drain were visually inspected to determine whether blockage of the pump suction existed. No blockage was observed. 4th Stage separator level control and scale buildup in the separator was inspected to determine if vapor was being drawn into suction lines. Both level control and scale level appeared normal. Wellhead pressure charts were reviewed to verify that loss was caused

by pump rather than well drawdown. Results were not conclusive but lack of wellhead anomalies prior to loss with no observable pressure loss in the injection line indicated that the problem was not related to the injection well.

Electrical checks did not indicate any motor problems. The injection pump was removed and visually inspected for blockage at the first stage. No blockage was found but significant wear was noted on bearings and wear rings which may have contributed to the poor pump performance.

4.1.4 Conclusions

The top of the injection pump cavity showed a different scale consistency than below the suction pipe entrance. This fact combined with evidence of air in the 4th Stage vacuum exhaust and return of pump performance and a new supply of cold fluid (irrigation water) indicates significant vapor might have been present in the brine suction.

4.1.4 Corrective Actions

The injection pump was sent to the SDG&E machine shop for complete disassembly, bearing and wear ring refurbishment. Some erosion/corrosion on the impellers and bowls and pitting on the shaft was noted upon disassembly. A wear ring was also found to have broken. Bearings and wear ring clearances were brought to within specification.

Representatives from Peerless Pump were notified and observed the condition of the components. They concurred that

vapor was the probable cause of the original anomaly. A vent line from the pump cavity to the 4th Stage separator was installed. This will provide suction to remove accumulated vapor in the pump cavity from whatever the source to the separator.

Wear in the bearings and wear rings were ascribed to scale accumulation and broken wear ring which created off balance loads in addition to expected wear. Broken wear ring was replaced, and labyrinth seals are being investigated to assure adequate purge water flow to each bearing. Peerless has a labyrinth seal design which will be evaluated.

4.2 Scaling

4.2.1 Introduction

This section of the report summarizes the amount and type of the scale found in the brine system. A reduced amount of scale was observed in the 4th Stage separator, injection pump and injection line, but the scale may be more difficult to removed. Most of this scale was deposited during operation with Woolsey fluids.

4.2.2 Summary

Appendix B details the scale found in the 4th Stage separator and associated hardware. Differences between this scale and previously recorded scale were:

- 1) increased barium in the composition
- 2) reduced total thickness
- 3) increased adherence (difficulty in removal)

The first two items are quantitatively discussed in sections 3 and appendix B. Only qualitative data can be presented for hardness. Generally, scale was removed manually with greater difficulty. Injection pump components, which were previously cleaned by sand blasting and acid treatment, showed some residual scale which required a second sand blast. A test section of 3rd to 4th Stage piping was chemically cleaned by Southwest Chemical Company. Southwest Chemical observed that scale was less porous (harder) than that in the past.

4.2.3 Analysis

The parameters controlling scale deposition are poorly understood, but temperature, velocity and brine composition are expected to be significant variables. Temperatures do not appear to have been significantly different from previous conditions. Velocities were generally less than prior conditions, due to Woolsey supply and the injection well difficulties. The differences in brine composition are detailed in section 3. These differences in brine composition appear to be a major factor in the observed scale differences.

4.2.4 Corrective Actions

No immediate corrective actions are planned. The ability to successfully operate is being demonstrated regardless of cause. Ability to clean the lines and vessels is expected to be demonstrated during May.

4.3 Scale Cleaning

4.3.1 Introduction

Approximately 1,000 feet of the injection line was cleaned for the first time during this period. The injection pump was also cleaned in conjunction with bearing refurbishment. Economics of cleaning is discussed. Additional access and provisions for venting and draining the lines were installed.

4.3.2 Summary

Because of high pressure drop in the injection line in conjunction with injection well difficulties, an additional approximately 1,000 feet of injection line was cleaned using high pressure water jets (hydroblasting). Southwest Chemical Company accomplished the cleaning in five days at an approximate cost of \$7,000 plus disposal. Initial scale thickness was approximately two to three inches. During cleaning, a wooden 4x4 was found in the injection line and removed. The injection pump was also cleaned and 3rd and 4th stage separators inspected. Some limited cleaning tests were accomplished for the scales in the 3rd Stage drain lines.

4.3.3 Analysis

Cleaning of facility lines affects the economical operation of the plant in two ways, downtime and cost. Five days to clean 1,000 feet of pipeline is undesirable since total length of the injection pipeline is approximately one mile. Although scale rate is not constant along the entire

length of injection line, frequent cleaning may still be required. Frequency has not been established but is estimated to be once every one to three months.

If frequency of cleaning is assumed at once every two months, the annual injection line cleaning would exceed \$200,000, with the existing cost estimates. This cost would not be proportionally larger for a commercial power plant because line sizes and lengths would vary due to slant drilling and common lines, but cost to clean would remain significant.

Previous cleaning of the plant indicated a lack of sufficient access, venting and drainage provisions to clean the facility. These items were subsequently installed.

Inspection and some laboratory cleaning tests were accomplished for the scales in the 3rd Stage separator, 3rd Stage drain line, and 4th Stage separator. Test results indicated that scale was more difficult to chemically treat than in the past. Revised chemical cleaning techniques were only partially successful on a laboratory scale.

4.3.4 Future Actions

The use of pigs to clean the injection line will be attempted during May. Initial cost is expected to be in the order of \$3,000 plus disposal fees to clean the injection line from the pump discharge to just upstream of one of the injection wells. If successful, the entire injection line annual cleaning costs could be reduced in the order of \$10,000 plus effluent disposal costs. Time required to pig

the entire injection line is estimated to require less than one day (initial tests are expected to take several days). In addition, frequent periodic cleaning of the injection line could be accomplished without plant shutdown if scale is not allowed to build up significantly and some piping modifications are accomplished.

If pigging is successful, cleaning other portions of the facility piping will be attempted. Although revised chemical cleaning techniques by Southwest Chemical Company were not totally successful, further work is expected to improve on the chemical cleaning reported in the previous bimonthly report. Other mechanical removal techniques are also being investigated.

4.4 Scale Prevention

4.4.1 Introduction and Summary

The source of purge water was changed to the first Stage condensate to provide a lower pH and oxygen free purge water supply. Although operating data is not conclusive, no dramatic improvement has been observed in the pump bearing area.

Lawrence Livermore Laboratory (LLL) is expected to begin construction of a brine effluent treatment facility during the coming period. This facility will evaluate scale prevention techniques on a side stream drawn from the injection line.

A baffle arrangement was installed in the 4th stage separator steam outlet. Baffle is expected to reduce the observed carryover in the separator outlet and hopefully reduce scale formation in condensate pumps.

4.4.2 Operation

Purge water supply piping was modified to allow lower pH 1st Stage condensate to be used in place of the fourth Stage condensate. The condensate cooler outlet line was tapped to supply the source of 1st stage condensate. Operation with this source of purge water was expected to reduce scale formation in the injection pump bearings and other locations where purge water is used. Inspection of the injection pump bearings showed scale formation still occurring.

Appendix C is a proposed scope of work to be accomplished by LLL in implementing a brine effluent treatment facility. Construction is expected to begin during the next reporting period.

A simple box baffle was installed at the 4th Stage separator steam outlet. Baffle forces steam flow to turn and accelerate prior to exit which should tend to throw out entrained liquids and solids. A slosh baffle was also installed at a high liquid level.

4.4.3 Analysis

Although observed scale formation on the pump bearings is not conclusive (bearing clearances were large and some operation with 4th Stage condensate occurred), shifting of purge water supply does not appear to significantly reduce scale formation. Other areas where purge water is used will be observed during major cleaning in May. However, scale formation was also noted on a pressure transducer

which was being purged, further indicating that reduced pH, at least to the level of the 1st stage condensate, is not effective in preventing scale.

The effectiveness of baffles on scale in the 4th Stage steam outlet will be evaluated during the next shutdown.

4.4.4 Future Actions

Test plans will incorporate treatment of condensate and brine in the facility. Type, quantity, mixing, instrumentation and control of the treatment method will depend upon LLL inputs based upon side stream testing being carried out or planned by LLL. LLL inputs are expected within the next few months.

The injection pump bearings will be protected, where feasible, by labyrinth seals. Installation of seals is expected during the next reporting period.

Injection strainer operation has indicated that draining of the brine pond promotes plugging of the strainers. Replacement of the brine pond by a tank (limited residence time and minimizing silt mixing with brine) and pump is planned.

4.5 Component Optimization

4.5.1 Introduction and Summary

More butterfly valves were replaced with gate valves which appear to be better able to stand the environment. Experience with modified ball valves continued to be promising, but some bindings in the Fisher valves were noted. Corrosion/erosion was observed on injection pump components.

4.5.2 Operation

Butterfly valves on the steam outlet lines of the first stage flash vessels were replaced with gate valves. Maintenance on the non-operational 1st Stage vessel was not possible with a closed butterfly valve while operating the other first stage flash vessel due to leakage. Gate valves were used as replacements.

During disassembly of the injection pump, some corrosion/erosion at the impeller entrance and bearing retainer points was noted. Some pitting of the shaft was also observed.

4.5.3 Analysis

Gate valves which are used for shut offs, appear to be more satisfactory to withstand the environment when compared with butterfly valves. Butterfly valves continue to be satisfactory in the steam/water system for throttling control.

Corrosion/erosion in the injection pump appears to be related to the materials of construction, which is stainless steel. Both LLL and Bureau of Mines report that some intergranular corrosion has been observed with certain types of stainless steel when it was subjected to brines. Thus, corrosion combined with the high velocities and suspended particles is suspected as the cause of pitting of the shaft and impeller and bowl attack.

4.5.4 Corrective Actions

Peerless Pump has offered to supply test impellers to alleviate the problem. Impeller is made of glass lined cast iron material. These impellers are expected to be less subject to corrosion and more resistant to erosion. Installation, if available, is expected during May. Concurrently with these efforts, a different type of pump is being ordered for draining the brine tank which will replace the brine pond. A progressive cavity pump (with a rubber liner and low fluid velocities) will be evaluated. Installation, due to long pump lead time, is not expected until September.

Evaluation of pinch and diaphragm control valves is in process. These types of valves offer the potential of sloughing off scale on the moving component (flexible elastomer) of the valve. However, temperature and pressure limitations may prevent its application at the facility.

4.6 Injection Well

4.6.1 Introduction

The loss of capability of Magmamax No. 3 well to receive spent brine from the GLEF was briefly described in the previous bimonthly report. Preliminary corrective actions (hydrofracture and back flush) in February 1977 resulted in partial improvement in well flow. Therefore, continued efforts were undertaken by Imperial Magma during March to improve flow rates. (The March operations proved temporarily effective).

4.6.2 Analysis

Several possible theories for the increased flow resistance at the injection well were proposed: (1) reaction of the Woolsey fluid with the existing fluid in the injection well, (2) solidification of materials in the injection well during the February 29 shutdown, (3) residual scale from the GLEF cleaning which migrated to the injection well, which might have caused (4) plugging of the permeable zones of the reservoir near the well forcing the brine flow into other less permeable zones, (5) plugging of well slots, and (6) changes in the reservoir characteristics.

Because of the lack of complete injection data (temperatures, pressures and flow rates), no firm conclusions were drawn. However, during the hydrofracture and back-flushing operations in February, a significant amount of solids were observed in the well casing which could have contributed to the increased flow resistance. Based on this observation a well cleaning was accomplished in March.

4.6.3 Remedial Actions

Remedial actions undertaken by Imperial Magma in March included (1) running a sawtooth bit to cleaning out the entire injection well; (2) pressure washing the perforations with a four cup pressure washer; (3) flushing the perforations with a 5% solution of caustic in fresh water; (4) running an injection test to 1600 gpm; (5) installation of strainers on the reinjection line with backflush provisions.

4.6.4 Operation

After cleaning, the initial operation of the injection well seemed satisfactory. Well head pressure was about 180 psig at a brine flow of about 340 gpm. This gradually increased to 225 psig at the same flow rate. Injection brine chemistry is presented in Section 3.

During the startup of GLEF, the discharge brine was routed to a storage tank. A significant amount of residual solids from the GLEF clean-up was collected in the tanks. After the start-up, brine flow was directed through the strainers before it was injected into the well. Two strainers were installed so that when differential pressure across one strainer became too great, flow was switched to the second strainer and the first strainer back flushed. Initial operations of the strainer system seemed to be satisfactory. However, toward the end of April, flushing could not provide an acceptable reduction in the pressure differential across the strainers. Repeated laborious hand-scraping of the strainers was necessary to remove the accumulated scale deposit.

5.0 DATA MANAGEMENT

5.1.1 Introduction

Accuracy of plant flow, pressure and temperature measurements has been poor. Causes included: 1) scale and corrosion in the brine, 2) slug flow of brine at the entrance to the plant, 3) difficult external environment, and 4) debugging of a new data handling system (data logger).

5.1.2 Operation

The most troublesome parameter has been flowrate. Pitot tubes, orifice meters and venturi devices have been used with little success. Scale formation on sensing elements and surrounding surfaces quickly destroyed any accuracy. Purge of sensing elements did not seem to help. Best results to date have been with a removable orifice plate flowmeter with periodic cleaning. However, plugging of sensing ports and scaling in pipelines (which were not accessible for cleaning during plant operation) still affect accuracy.

Pressure sensors in the brine were also plugged with scale frequently. Purging with condensate water did not seem to prevent scale deposition and plugging at the brine interface. Occurrence of this plugging did not seem to follow a predictable pattern.

Temperature wells are also easily scaled. Insulation properties of the scale could reduce response time and affect accuracy.

Slug flow into the plant apparently generated significant oscillations in the first stage brine and steam

flows. These oscillations were transmitted to the binary fluid and succeeding flash vessels. Cause of slug flow is uncertain.

Control of the first stage flash vessel pressure is accomplished by venting noncondensable gases from the heat exchanger drain. This venting has not been steady which makes measurement of flowrate difficult. Cause of unsteady flow is uncertain. Maintenance of instrumentation is also difficult.

Environmental conditions in the Imperial Valley are not ideal. Extreme heat, high winds, some salt spray from infrequent discharge into the brine pond, and voracious insects all combine to make a sensitive data acquisition system difficult to maintain. In addition, the data logger is still relatively new and operational experience of operating personnel limited.

Ability of the system to monitor oscillating data is limited. Single point digital readings is the typical application. Variations especially in flows, cause inconsistent data to be generated.

5.1.3 Analysis

Real parameter variations combined with instrumentation difficulties, and scale in brine system make data acquisition difficult. In many instances accurate determination of significant parameters at each data point cannot be achieved.

In addition, slug flow of the brine at the plant precludes accurate measurements.

5.1.4 Corrective Actions

An ultrasonic flowmeter, made by Controlotron will be demonstrated on brine at the facility. If the demonstration is successful, procurement will follow. The ability to measure flowrate without contacting or disturbing the brine promises to improve flow data significantly.

Pressure tap routing out tools are being investigated by SDG&E. Tools may allow cleaning of taps while the GLEF is in operation.

Different types of temperature sensors are being investigated. Thermistor may be tested during the next report period.

Slug flow into the plant appears to be related to alternating vertical and horizontal run of pipe from the supply wells. One of these lines will be leveled and turbulence generating devices installed. It is hoped that this will reduce the separation of liquid and vapor and thus slug flow.

Flow variation in the noncondensable vent gas line appears to be related to the size of the control valve and draining of the heat exchangers. Draining will be improved during the next report period and a smaller control valve installed, if available.

No corrective action is planned for the protection against the severity of Imperial Valley's environment. However, a careful maintenance and calibration of instruments

is planned.

LLL & SDG&E are jointly investigating modifications to the data logger to allow oscillating data to be properly recorded. Resolution is expected during the next report period.

APPENDICES

APPENDIX A

SAN DIEGO GAS & ELECTRIC COMPANY

INTERNAL CORRESPONDENCE

FORM 115-6143C

FROM A. R. Gonzalez

DATE May 2, 1977

TO W. O. Jacobson/H. K. Bishop

FILE NUMBER

SUBJECT 1. Inspection of Third Stage Flash Vessel
April 28, 1977
2. Inspection of Fourth Stage Flash Vessel
Baffel Installation April 28, 1977

The purpose of these inspections was to determine the operating level in the third stage flash vessel and to inspect the condition of the new baffels and vessel prior to start up.

A. R. Gonzalez

ARG:kw

cc: K. K. Li (Original) ✓
Roland Quong
N. Hodgdon
F. Delamarter

THIRD STAGE FLASH VESSEL INSPECTION
APRIL 28, 1977 AFTER 611 HOURS OF OPERATION
BRINE SOURCE - WOOLSEY NO. 1

Entry into the vessel was made three days after shut down. The vessel was cooled down to atmospheric pressure. The purpose of entry was to ascertain the operating level in the third stage flash vessel with the possibilities being that a low level in this vessel would allow the passage of live steam into the fourth stage flash vessel, thus contributing to the brine carryover into the steam line from the fourth stage flash vessel.

1. As the main purpose of the inspection was the water line, the following was noted. The water level appears from all indications to have been at approximately 70 cm (2'4"). This seems to preclude the possibility of steam flow into the fourth stage flash vessel.
2. The debris on the floor of this vessel formed a pile approximately 12 cm deep. It was made up of varying sized pieces of scale, 5-7 mm thick and 1-15 cm across. The debris itself was black in color and contained a piece of rust scale (presumably from the ceiling) as its center. It appears that the continuing fall of rust from the ceiling forms the base for this scale which forms on both sides after the rust falls into the brine. This in itself indicates that the rusting and falling of rust is an ever continuing process, especially since the debris indicates through the varying thicknesses many degrees of scale formation.
3. Scale on vessel wall below the water line was black in color, hard and porous. It was removed without much difficulty but did not indicate any large degree of breaking away during plant operation. Its thickness was fairly uniform, approximately 5 mm.
4. The ceiling of the vessel is undergoing a continuous rusting process. Rust is building up to approximately a 2 mm thickness, then falling in slabs into the brine below where it contributes to the formation of the debris scale.

5. The steam outlet line shows an increase in rust pitting. An x-ray of this area to determine the extent of pitting might be advisable.
6. The brine outlet vortex breaker showed a buildup of scale of about 5 mm in thickness. However, on the inside there was an area where scale had not been removed in the previous cleaning of the brine system. This reduced the diameter of the brine outlet line to 6.5 inches.

CONCLUSIONS:

1. The water level in this vessel does not contribute to the brine carryover in the fourth stage flash vessel.
2. Rusting of this vessel is increasing and x-rays might be advisable.
3. A more thorough inspection after cleaning of brine systems may be in order.

INSPECTION OF INSTALLATION OF BAFFELS IN
FOURTH STAGE FLASH VESSEL APRIL 28, 1977

The purpose of this inspection was to note the condition of the vessel with the new baffels installed prior to start up.

The vessel had been cleaned of all loose and semi-loose scale. All scale which could be removed from the vessel above the water line had been removed. The baffels were in place.

1. The box baffel, open on one side only, was in place around the steam outlet.
2. A large plate baffel was in place across the end of the vessel and extended to just short of the steam outlet.

CONCLUSIONS: None. Hopeful.

Respectfully,

A. R. Gonzalez
A. R. Gonzalez

APPENDIX B

SAN DIEGO GAS & ELECTRIC COMPANY

INTERNAL CORRESPONDENCE

FORM 115-6143C

FROM A. R. Gonzalez DATE April 26, 1977

TO W. O. Jacobson/H. K. Bishop FILE NUMBER CNB 300

SUBJECT

1. Inspection of 4th Stage Flash Vessel 4-25-77
Operating Time 611 Hours Since Last Cleaning
2. Inspection of 4th Stage Steam Scrubber

This unscheduled inspection was brought about by the malfunction of P-2 reinjection pump. The inspection was made to determine whether conditions within the vessel were the prime cause of malfunction, i.e. (loss of pump suction) or a cause leading to the problem.

A. R. Gonzalez
A. R. Gonzalez

ARG:kw

cc: K.K. Li, SDG&E (Original Copy)
Roland Quong, ILL
N. Hodgdon

FOURTH STAGE FLASH VESSEL INSPECTION

APRIL 25, 1977 AFTER 611 HOURS OPERATION

BRINE SOURCE - WOOLSEY NO. 1

The vessel was entered approximately eight hours after shut down. Temperature within vessel at inspection was approximately 130 degrees Fahrenheit with the humidity extremely high. The vessel had not been cooled to the point where scale had begun to dry. Therefore, some new and possibly significant observations were noted.

1. The water line appears to have normally run at about one meter. The scale itself was in two separate layers. There was no mushy scale this time. The outer layer actually was two bonded layers, one the bottom black and the outer grey to olive. This layer was very porous but firm and approximately 7-9 mm thick. This double layer was based on a second layer. This bottom or base layer is rust, 2-3 mm thick, which was not easily removed from the vessel. This had to be pried loose. The outer layer of scale was loosely bonded to the rust layer. It was breaking away and falling free to form a layer of debris on the vessel floor. The rust layer remained in place and new scale was forming upon this. The rust seemed to have reached a point where it was arrested. There were only a very few points where rust layer had fallen away with the outer layer of scale. Also, the rate of scale falling away seems to have decreased over previous runs.

2. The brine outlet vortex breaker was the prime concern in this inspection. There was a degree of scale buildup in excess of the normal wall scale. The scale here was about 2.0-2.5 cm thick. The opening was between 80-85% open. There does not appear to be any reason why this could have caused loss of pump suction.

3. The wall and ceiling above the water line contain two distinct types of scale. The area from the water line extending approximately 40 cm up was covered by a two layer black and olive scale that was breaking away. One section which I removed as a sample was 40 cm long by 25 cm wide and about 1 cm thick. It broke away easily and there was no point where there was any rust brought away with the scale.

The scale from the above noted area was pure black, 0.5-1 cm thick and extended over the entire ceiling area. Normally, I first attempt to remove samples without the aid of mechanical devices. In doing this I have always been able to remove sections of the rust which form the base layer on the vessel ceiling and walls. This time, however, I was unable without the aid of tools to penetrate the scale to obtain the rust. The ceiling scale was in fact falling away but this time there had formed a hard black scale over the rust. Then more black scale formed over this and it is the second black layer which is peeling away and falling. From the samples which I gathered, it appears that the base rust layer is not falling away and is in fact remaining intact.

4. In the steam outlet pipe there is a layer of black scale, same type as on ceiling. This scale was primarily located in the elbow

of the outlet pipe and its thickness was approximately 2 mm thick. This indicates some brine carryover.

CONCLUSIONS:

This run period using Woolsey No. 1 and under the plant conditions of this period have led to a new set of internal scaling conditions within the 4th stage. The rust seems to have been arrested and scale changes as have been noted. For example, the below water line scale has changed from a mushy, soupy type to a more solid porous scale. The ceiling has become more stable with less falling scale and falling rust seems to be nonexistent. Possibly a previous entry of air into the vessel has been eliminated.

No further conclusions can be drawn at this time due to inavailability of information from the other vessels.

INSPECTION OF FOURTH STAGE STEAM SCRUBBER

APRIL 27, 1977

The interior of the scrubber was covered with a white carbonate scale. The scale below the water line was powdery and porous. It was approximately 1 cm thick. Above the water line the scale was a hard multi-layered scale which varied in thickness from 1-2.5 cm. This is also carbonate scale.

The floor of the vessel is covered with a carbonate scale debris, olive in color which is to a depth of about 15 cm.

Only the lower level of the vessel was inspected. Rust did not appear to be a problem here.

Respectfully,

A. R. Gonzalez
A. R. Gonzalez

ARG:kw

APPENDIX C

Interdepartmental letterhead

Mail Station L 220

Ext 3946

June 1, 1977

TO: Distribution

FROM: A. L. Austin/R. Quong

SUBJECT: Revised Plan for Solids and Scale Control

As you know, we have been in the process of revising the GLEF experimental plan. Because of the importance of injection viability, Dr. Lou Werner of ERDA/DGE has requested that we attempt to finalize plans for near and long-term approaches to the injection problem by June 20. The plan is to include input by SDGE, Magma, Bechtel, and consultants. Enclosed is a proposed plan for your review and comment. We hope to finalize agreements on the schedule and approaches at a meeting June 9 (10:30 a.m.-3:00 p.m.) in the SDGE auditorium. Please refer any advanced questions to Roland Quong (415-447-1100, X-7798) who will discuss the plan on June 9. Your attendance will be most helpful.

A. L. Austin

ALA:jej

ISP-7

A PROPOSED PLAN FOR SCALE AND
SOLIDS CONTROL AND/OR REMOVAL

G. E. Tardiff

R. Quong

J. Grens

May 31, 1977

Lawrence Livermore Laboratory

Livermore, California

Attachment (1)

Enclosure (1)

Distribution:

A. Austin
B. Jacobson
T. Hinrichs
B. Holt
A. Rogers
T. Fick
H. Bishop
C. R. Swanson
J. Featherstone
M. Scheve
A. Follett
O. Vetter
J. Nugent
D. Baker
A. Holzer

PREFACE

Because of continuing problems with scaling and injection well plugging, LLL initiated a program emphasizing solids control and removal. The first plan was formulated late November 1976. This led to a revised GLEF plan on April 14, 1977 (see Bechtel Dwg. #12094-001, Rev. 2) and definition of a field program to be carried out by LLL and the Bechtel Corp. (April 15, 1977). The enclosed plan is a further revision emphasizing actions needed for attempts at near term solutions to the injection problem. It should be recognized that any near term solution should have the potential for long term application. At this time, however, there are no assurances that even short term solutions will work.

SUBJECTS

- I. Summary of Action Items
- II. Proposed Updated GLEF Plan for Scale Control, 5/19/77
- III. Status of Flash Tank Tests
- IV. Status of Solids Control Tasks

I. Summary of Action Items

Smooth, trouble-free operation of the GLEF has not been possible because of control, scaling, and injection well plugging problems. Before reviewing the status of the above subject materials, we are listing the actions which we believe must be taken now to increase the probability of success of the GLEF project. Actions are as follows:

- A. Use of a large contact surface device (see Sec. IV) coupled with settling is a proposed method for solids removal from the GLEF output. This is viewed as a possible short term solution to allow GLEF operation to continue. LLL will conduct small scale optimization tests as discussed in Section IV (a). In parallel, SDGE should begin design, procurement and construction of the full scale contact removal system. This will also involve use of the existing brine holding pond as an interim settling basin.
- B. Start immediately to design, fabricate, procure, and install hardware necessary to acidify the GLEF brine flow and combined condensate streams. Target pH is 5.0 which would require 80 ppm HCl for the brine and 500 ppm HCl for the combined condensate stream.

Based on information developed during our field test program over the last six months, we believe that scale and solids production can be reduced by a factor of 30 and that the rate of corrosion will not be a limiting factor for at least six months. In addition, we believe that acidification is an alternate solution to the injection problem for the short term, and quite possibly for the long term. As shown in Figure 1, LLL feasibility tests will be conducted with sufficient lead time to define an early GLEF acid brine test.

However, plant preparations must begin immediately to meet the projected 5 months start-up date.

- C. Take action to improve the stability of GLEF operation (i.e., Ben Holt's and Bechtel's suggestions). This is critical to performance assessment and pH control for acidification.
- D. Initiate early two well operation to identify additional problems which may require long lead time corrective action to insure later successful two well operation.

II. Updated GLEF Plan for Scale Control, 5/19/77

The last operational plan for both performance evaluations (Bechtel) and scale control (LLL/SDG&E) is documented in Bechtel Drawing No. 12094-001, Revision 2, 4/14/77. The scale control related operations are listed in Figure 2 for reference. In view of slips in the GLEF schedule, new technical data, and comments from various parties since that plan was devised it is desirable to consider a schedule revision. A meeting was held at LLL with Messrs. Rogers and Fick of Bechtel and

OPERATIONAL MODE.

1. Magmamax Only, No Cond Inject.
2. Two Well, Cond Inject.
3. Woolsey Only, Cond Inject.
4. Woolsey Only, Treated Cond Inject.
5. Two Well, 4 Alt. for Inject:
a)cond inject., b)treated cond inject.
c)processed water inject., d)no cond inject.
6. 1 or 2 Well, Scale Control Mode, 2 Alt:
a)acidified brine, b) seeding, if
feasible estab. in LLL tests.

MILESTONES:

- Scale Rem Cost, Model 1, Estab.
- Feas. Two Well Opr., Estab.
- Prelim. Scale Rem Cost Mode 2, Estab.
- Scale Rem Cost, Mode 3, Estab.
- Scale Rem Cost, Mode 4, Estab.
- Scale Rem Cost, Mode 5, Estab.
- Cost of Scale Control, Mode 6, Estab.
- Optimum GLEF Process, Defined

DECISION POINTS:

- Decide GLEF and Well Alterations Required
for Extended 2 Well Operation
- Go/No Go Periodic Scale Rem Approach; Revise Plan
- Decide if Cond Inject. Feas., Go/No Go to 4; Revise Plan
- Go/No Go to 5, Decide Inject. Mode for 5; Revise Plan
- Go/No Go to 6; Revise Plan
- Decide Optimum GLEF Mode
- Go/No Go to 50 MW Demo.

Figure 1. GLEF Plan for Scale Control, 5/19/77 Revision.

SCHEDULE FOR SCALE CONTROL PROGRAM AT GLEF

<u>ACTIVITY</u>	<u>TIME FRAME</u>
NO CONDENSATE RECOMBINATION - MAGMAX #1	COMPLETE (1.3 MONTHS)
FULL CONDENSATE RECOMBINATION - WOOLSEY 1	APRIL 7, '77-MAY 23, '77 (TWO WEEKS)
NO CONDENSATE RECOMBINATIONS - WOOLSEY 1	JUNE 15-JULY 15 (ONE MONTH)
CONDENSATE TREATMENT - WOOLSEY 1	JULY 23-AUGUST 23 (ONE MONTH)
NO CONDENSATE RECOMBINATION - TWO WELL	OCT 15-NOV 15 (ONE MONTH)
CONDENSATE TREATMENT - TWO WELL	DEC 15, '77, JAN 25, '78 (ONE MONTH)
NO CONDENSATE RECOMBINATION, CONDENSATE TREATMENT, OR PROCESSED WATER FOR INJECTION MAKEUP - TWO WELL	APRIL 1-JUNE 2 (TWO MONTHS)
BRINE ACIDIFICATION - TWO WELL	AUGUST 1-OCTOBER 2 (TWO MONTHS)

FIGURE 2. OLD GLEF PLAN FOR SCALE CONTROL (SEE BECHTEL DWG. NO 12094-001, REVISION 2, 4/14/77).

Quong and Tardiff of LLL to devise a new plan. The revised plan for scale control together with milestones and decision points is given in Figure 1. The dates shown for each operational mode approximate the Bechtel plan, and may change slightly. The plan outlined in Figure 1 is offered for comment from cognizant parties. A discussion of the reasons for each operational mode are as follows:

Mode 1: Completed January 31, 1977 - Magmamax 1, No Condensate Injection

This operational mode was carried out by SDG&E after a short duration test in which the condensate cascade mode of operation resulted in severe scaling at locations where high pH condensates were mixed with brine. Operation without condensate cascade or recombination was conducted to determine scale and solids production rates (LLL) and costs of scale removal (SDG&E). Scale production rates (~3/4-inch/mo) and solids production (~140 ppm at the injection wellhead) were found to be significant. Preliminary analysis, by SDG&E, however, indicates that the cost of scale removal in this mode of operation is within acceptable limits.

Mode 2: Two-Well, Condensate Injection

An early GLEF test in the two-well mode was not part of the previous plan (see Figure 1). Tom Hinrichs (Imperial Magna) points out that an early test is desirable to identify possible problems associated with two-well operation so that corrective action could be taken early enough to insure later successful two-well operation. This is the primary reason for inclusion of an early two-well test in the new plan. In the event that two-well operation is possible, we would recommend one month of operation to obtain baseline scale

and solids production data and cleaning and removal costs associated with this mode. We recommend elimination of the cascade mode of operation for this and later tests. This removes the scaling potential associated with combining the high pH condensates from the 2nd, 3rd, and 4th stages with brine flows. However, we recommend that all condensate streams be combined and injected with the brine discharge from the 4th stage separator. Recent LLL tests show that the pH of the combined condensate streams is much lower (~6.7) than the individual streams due to low pH (6.3) and buffering capacity ($\text{OH}^- + \text{HCO}_3^- = \text{H}_2\text{O} + \text{CO}_3^{2-}$) of the first stage condensate.

Combination of the condensate streams prior to injection will, therefore, produce minimal scale and solids production and maintain the desirability of condensate (or processed water) for injection makeup to prevent subsequent salting out following mass break-through at the production wells, and to reduce the possibility of subsidence.

Mode 3: Woolsey #1 Only, Condensate Injection

The present test is planned to obtain baseline scale and solids production data during a one-month operation. As discussed above, the condensate streams should be combined and injected downstream of the fourth stage separator. The results of this test will provide a process comparison between Magmamax 1 (Mode 1) and Woolsey #1 fluids and also allow evaluation of scale removal costs (SDG&E) for Woolsey #1 operation. It is also possible that the two-well, Mode 2 test discussed above will be terminated early due to GLEF or well problems which are two-well in origin. Mode 3 would then be the logical test to follow.

Mode 4: Woolsey #1 Only, Treated Condensate Injection

It is possible that injection of the combined condensate streams at pH ~6.7 (Mode 3) may cause aggravated scale and solids production in the injection piping. Mode 4 test addresses the problem by adding HCl to the combined condensate stream to reduce pH to ~5.5, thereby removing the condition which enhances scale and solids production. The results of this test will not only be used to evaluate the cost benefits resulting from injection of treated condensate, but also to provide early experience in handling of HCl prior to the planned brine acidification tests (Mode 6).

Mode 5: Two-Well, 4 Alternatives for Injection

Having established the optimum condensate injection process and having completed the necessary actions to insure viability of prolonged two-well operation (from Mode 2), Mode 5 should be carried out to develop baseline scaling and solids production data for the optimum (unmodified brine) process. Cost of scale removal derived from this test would be used as a basis for estimating costs for a 50 MW demonstration plant. In this and the above tests, a short term interim solids removal method should be utilized and its cost effectiveness evaluated.

Mode 6: 1 or 2 Well, Scale Control Mode (Acidification or possibly seeding)

This mode of operation provides a backup to the periodic removal approach for scale control and solids removal which may not be cost effective. The actions which must be taken now to insure the possibility of an early test (~Dec. 1, 1977) were discussed in Section IB. Feasibility will be determined in LLL tests by mid-September 1977 (see Figure 1).

LAWRENCE LIVERMORE LABORATORY
GEO THERMAL TEST PROGRAM
FLASH TANK ARRANGEMENT

FIGURE 3. SCHEMATIC OF LLL FLASH TANK SYSTEM FOR FEASIBILITY TEST OF BRINE ACIDIFICATION.

5-26-77

III. Status of Flash Tank Tests

Figure 3 shows a schematic of a brine flashing system which is now being installed at the LLL test station. Startup is scheduled for July, 1977.

Objectives of the test are:

1. Prove feasibility of scale and solids control by brine acidification in brine flashing system.
2. Carry out corrosion analysis (general, pitting, weld, etc.) of tested system to determine maximum length of time GLEF can be operated with acidified brine without unacceptable corrosion.
3. Determine corrosion resistance of candidate liner materials for possible future refurbishment of GLEF for long-time operation with acidified brine.
4. Assess injectability of acid effluents by means of core flushing experiments.

Tentative plans for the brine flashing system tests are:

1. Operate stages at temperature corresponding to GLEF stage temperatures (~200°C, ~153°C, 128°C, and 106°C).
2. HCl additions between 1st and 2nd, and 2nd and 3rd stages.
3. Control pH between 4.8 and 5.2 (see Section IB).
4. Two-hour prescaling before acid addition after each startup to inhibit corrosion.
5. Core flushing experiments: acidified, 106°C effluent to determine permeability versus time.
6. In-situ electrochemical corrosion rate monitoring of carbon steel in all stages to provide data for process adjustments to maintain corrosion rate below .030 inch/month.

7. Nitrogen cover during shutdowns.
8. Total operating time 700-1000 hours.

Tests are scheduled to be completed by September 15, Preliminary analysis of results and specifications for GLEF acidified brine operation are scheduled to be available by October 15.

IV. Status of Solids Control

a) Short Term Interim Methods for Solids Removal

Settling - The use of settling for solids removal to help insure successful injection was previously suggested in a task force report.¹ This was included as a recommended desirable task² (Item C.7) and was estimated to cost 30K and require 10 weeks for implementation. This recommendation was not implemented. Settling still remains one of the very few options for a short term solution to the solids removal problem. LLL tests have shown that the large portion of solids can be settled in 1-2 hours.

Sludge production rates are estimated to be 50,000 gal/day. Thus, disposal would be a significant problem. We recommend that SDG&E consider settling using the emergency holding pond and/or large settling tanks as one short term method of effluent cleanup. The attendant problem of disposal must also be addressed. Dewatering by vacuum filtration is one possible method for reducing the volume of sludge. The later, however, requires small scale testing to specify equipment design. In the interim, frequent sludge disposal by trucking or other means will have to be carried out until dewatering equipment can be purchased and installed. LLL plans to conduct tests to define dewatering equipment requirements for this purpose.

Contact Removal - A method for solids removal based on contacting the effluent brine with a large surface area consisting of steel plates was suggested as a short term possible solution to the solids removal problem (at meeting in Niland on May 18, 1977). A schematic of such a device based on use of Baker tanks is attached in Figure 4. The plates could be periodically cleaned and solid residues disposed of. Optimization of plate spacing, number, and size, should be determined by testing. We recommend the contact removal device be given first priority for implementation by SDG&E. The design of the equipment in Figure 4 was based on actual scaling characteristics of the injection pipe and the results of suspended solids studies.

We recommend installation of the contact equipment between the 4th stage and injection pump within the plant compound. This location is in the vicinity of the brine holding pond which, as mentioned above, is required as an interim settling pond, and is also upstream of approximately 4000 ft of injection piping which normally scales heavily from suspended solids in the injected brine. B. Jacobson has suggested an alternative location at the injection well to include removal of solids which may precipitate from the brine while flowing through the injection pipe. This latter location would require an additional injection pump and settling basin, and would not impact on the massive amount of scaling in the injection pipe. Jacobson also suggested that measures to minimize oxidation of the brine should be incorporated in the contact and settling equipment.

SUBJECT			SKETCH LAWRENCE LIVERMORE LABORATORY UNIVERSITY OF CALIFORNIA		JOB NO.		TAB NO.
DRAWN BY					SERIAL NO.		NO. RECD.
DATE			APPROVED BY		DATE	DATE ISSUED	DATE REQD.
BUILDING NO.			ROOM NO.		DELIVER TO		

TANK TO PROVIDE $4000 \pm \text{FT}^2$ SURFACE AREA

SOLIDS COLLECTION TANK

FIGURE 4: CONTACT REMOVAL EQUIPMENT FOR GLEF (400,000 lb/hr)

b) Summary of LLL Effluent Treatment and Solid Handling Task

To date LLL has emphasize studies designed to lead to long-term, permanent solutions to the solids handling problem. A list of solids related activities that LLL has engaged in include:

1. Solids precipitation versus pH in brine expanded to 100°C. Test results obtained for both separated brine and remixed brine (steam liquid).
2. Long-term stability of acidified brine held at 85°C.
3. Quantitative measurements on the amount and rate of solids precipitation in brine due to pH elevation and additions at FeCl_3 and NaOCl . These kinds of tests will be expanded and will be an integral part of the tests to determine methods for solids handling and removal.
4. Sampling and measurement of the concentration and chemical composition of suspended solids as the brine is successively flashed in the GLEF.
5. Sampling and measurement of the concentration and chemical composition of suspended solids at the injection well, and upstream and downstream of the strainers.
6. Evaluation of the effectiveness of the strainers installed at Magmamax #3.
7. Sampling and measurement of scale and deposited solids in the injection line (and also in-process equipment and lines).
8. Evaluated data to determine possible causes of injection well plugging problems and assist in finding solutions or defining alternate methods of operation.
9. Physical and chemical characterization of brine solids.

Most results of the above activities have been reported in highlight reports. Currently, a test pad at the Magmamax #3 injection well is being prepared for testing of solids removal methods which may provide a long term, permanent solution to the problem. The planned scope of work for this site was described in Enclosure 2 to a letter (Tardiff to Featherstone, dated 4/25/77). This letter and enclosures is appended to the present report as Attachment 1. In addition, a contract with Bechtel Corporation has been initiated to augment the LLL program. The Bechtel scope of work is also included in Attachment 1 (see Enclosure 1 to letter).

c) Schedule of Activities for LLL Effluent Treatment and Solids Handling Task

An updated and revised schedule of LLL activities in solids related work is given in Figure 5. Timing of these activities depends on the availability of the GLEF and/or the injection well.

-
1. Chemistry and Materials Task Group Report to A. Follett and J. Nugent, dated 1/28/76, G. Tardiff, et al.
 2. Niland Test Facility Start Up Evaluation TAsk Force, Recommendations, dated February, 1976, J. M. Nugent, L. B. Werner

Figure 5. Updated LLL Schedule for Solids Handling Task.

LAWRENCE LIVERMORE LABORATORY

April 25, 1977

Mr. John L. Featherstone
Program Manager
Hydrothermal Branch
Division of Geothermal Energy
20 Massachusetts Avenue N.W.
Washington, D. C. 20545

Dear John:

The scope of work we have agreed to with Bechtel is attached as Enclosure 1. LLL is preparing to purchase approximately 2.5 man-years of personnel services from Bechtel Corporation to carry out the work over a one-year time frame. The solids removal and water treatment task relates to our LPAD task 5, and the materials application task relates to our LPAD task 4. FY77 expenditures are expected to be 42 and 33 K, respectively. We will decrease expenditures at LLL for these tasks accordingly (130 to 88 K for task 5 and 270 to 237 K for task 4). The expected results for task 5, as described in our LPAD, will remain the same. Bechtel will provide personnel which would otherwise be provided by LLL. The scope of work in task 4 (mainly the polymeric materials subtask) will be decreased to provide the 33 K necessary for the Bechtel materials application task.

A brief description of the scope of work and site preparation for solids removal and effluent treatment studies is attached as Enclosure 2. This work is within the scope described in our LPAD task 5.

Please call me if you have any questions or comments on the enclosed information.

Sincerely,

George E. Tardiff
Project Chemist
Geothermal Energy Development

GET:lm

Enclosures: (2)

cc: A. Austin/A. Lundberg, LLL, w/o encl.
A. G. Follett, ERDA, w/encl.

File

Interdepartmental letterhead

Mail Station L 220

Ext 3946

M E M O R A N D U M - April 15, 1977**TO: J. P. Harris****FROM: G. E. Tardiff****SUBJECT: Exceptional Procurement Action for Purchase of Personnel Services from Bechtel Corporation****Background and Purpose**

The development of chemistry and materials technology for utilization of hypersaline Salton Sea Geothermal Field (SSGF) geothermal brines is a major goal of the LLL Geothermal Energy Program. Advances during the past year in brine chemistry, scale and solids control, and materials technology have greatly increased the probability that the SSGF resource can be economically exploited for power production. Several key developments have particular relevance to the joint ERDA/SDG&E Geothermal Loop Experimental Facility (GLEF) project in the SSGF for which LLL provides technical support. They are: 1) acidification for scale and solids control shows promise for application in the GLEF, 2) prescaling, use of low alloy steels and corrosion resistant linings for GLEF show promise as methods to reduce the corrosion associated with use of acidified brines to acceptable limits, 3) injection of solids laden effluents should be avoided to prevent damage to injection wells, and 4) avoidance of recombination of high pH condensate with brine flows will reduce the rate of scaling or the quantity of acid needed to eliminate scaling altogether.

The technical plan for GLEF operation calls for determination of baseline scaling rate data and costs of periodic scale removal, and for assessment of the technical and economic feasibility of solids removal from the brine effluent prior to injection. In parallel with this, LLL will demonstrate feasibility of brine acidification for GLEF application on a small scale and establish optimum procedures. On the assumption of success, a 2-month test of acidification for scale control in the GLEF is planned to begin on or before July 1, 1978. Also, exploratory studies of other methods of scale control for GLEF application will be carried out by LLL.

Because the LLL chemistry and materials effort is beginning to move from the development stage to the applications stage, it is appropriate to broaden industry involvement in the LLL program ~~to encourage technology transfer and~~ to employ the applications oriented experience of industry to most rapidly bring the SSGF to the point of commercial exploitation. We are requesting an agreement for personnel services from Bechtel Corporation to accomplish these objectives.

University of California

LAWRENCE LIVERMORE LABORATORY

Scope of Work

Bechtel personnel in several areas of specialization will work together with LLL personnel on applications oriented problems associated with utilization of SSGF brine, especially in connection with the GLEF project. LLL personnel will emphasize technology development related aspects and Bechtel personnel will emphasize applications oriented aspects. Naturally, there will exist a degree of overlap in these two areas. At present, the scope of work will involve two technical areas: 1) solids removal and water treatment, and 2) materials applications for geothermal brine handling. A brief discussion of the Bechtel scope of work in each of these areas follow:

1. Solids Removal and Water Treatment

The assessment of technical and economic feasibility of removal of precipitated solids from effluent brine must be carried out as part of a feasibility assessment for a 50MW plant and the GLEF for operations with unmodified brine. LLL has already initiated a solids removal program. Bechtel tasks associated with the solids removal program will include:

- a. participation on task team to help define and test chemical methods to enhance separation.
- b. participation on task team to help define and test small scale solids removal equipment.
- c. analysis of costs associated with scale up and use of solids removal methods for GLEF and 50MW plant. Both capital and operating costs will be assessed.
- d. definition of the most technically and economically viable means of solids removal (with LLL personnel).

The technical and economic feasibility of utilization of plant condensate for non-geothermal uses and use of Salton Sea water or irrigation water as make-up for injection will also be addressed within this area. Bechtel tasks will include:

- a. assessment of the technical feasibility and cost benefits associated with use of condensate for non-geothermal applications.
- b. participation on task team to identify and test methods of treating Salton Sea water and irrigation water for use as makeup for injection.
- c. assessment of costs for and treatment of makeup water.

Memo to J. P. Harris
April 15, 1977
Page 3.

Bechtel will make available a specialist in water treatment and a cost engineer totaling 1.4 man years of effort over the next year for this task.

2. Materials Applications for Geothermal Brine Handling

The cost of materials for handling of brine acidified to control scaling and solids must be assessed to fully establish the feasibility of brine acidification for geothermal plant applications.

In particular, the costs of refurbishment of the GLEF to allow long time operation with acidified brine must be determined. Candidate materials for linings and replacements are now being tested by LLL. These studies will also provide the basis for estimating the material and fabrication costs for a flash binary plant operating with acidified brine. Bechtel tasks in this area include:

- a. collaboration with LLL on selection and testing of materials for acidified geothermal brine.
- b. cost analysis for refurbishment of GLEF for acidified brines using linings and/or replacement. Candidate materials to be selected on basis of LLL tests.
- c. cost analysis of materials for 50MW plant vs. method of application and type of material.

Bechtel will make available a materials application specialist, a piping and fabrication specialist, and cost engineer at a total of 1.1 man-years to carry out the above tasks.

Bechtel will make available a primary contact in both the solids removal and water treatment and materials applications area. Primary LLL contacts will be Roland Quong and Hank Weiss, respectively. The term of the agreement shall be one year. Modification to the scope of work will be made depending on new results and priorities upon agreement between the cognizant LLL and Bechtel Project Managers (George Tardiff and Al Roger, respectively).

George E. Tardiff

George E. Tardiff
Project Chemist
Geothermal Energy Program

GET:lm

ADDENDUM B TO
EXHIBIT 1, MARCH 19, 1976
PURCHASE ORDER 2721403
BETWEEN
LAWRENCE LIVERMORE LABORATORY
AND
SAN DIEGO GAS AND ELECTRIC CO.

LLL GEOTHERMAL FIELD PROGRAM
SCOPE OF WORK AT SDG&E SITE

DATED APRIL 15, 1977

LLL GEOTHERMAL FIELD TEST PROGRAM
AT THE SDG&E SITE

May 2, 1977 through December 1977

In addition to the requirements outlined in Exhibit 1, dated March 19, 1976, and Addendum A, dated January 26, 1977, the following describes the installation, operation MagmaMax #3 injection well:

Technical Scope of Work

To address the problems associated with injection of suspended solids in the brine effluent from the GLEF, LLL plans to conduct tests with spent brine.

Test equipment will be located on a 12 x 20 ft. concrete pad located approximately 50 ft. south of MagmaMax #3 injection well. Brine treatment tests will be carried out in a laboratory trailer adjacent to the pad. Two-inch sidestreams tapped into the 10-inch injection line at two locations will be required - one upstream of the recently installed strainers at MagmaMax #3, and one downstream. These two sidestreams will provide feed for tests at the pad. Burial of the lines will be required because of surface traffic. A third 2-inch line is needed to take brine from the pad to the Baker tanks now used by Magma Power to contain backflushed solids from the strainers. LLL will provide a 75 KVA, 480/208 transformer to satisfy power requirements. It will be necessary for I.I.D. to install additional power poles.

The following kinds of tests will be conducted:

- 1) Brine effluent treatment and gravity sedimentation rate tests.
- 2) Tests to evaluate small scale process equipment for solids-liquid separation.
- 3) Core flushing tests at simulated in-situ conditions of an injection well.

Brine effluent treatment tests will consist of adding various chemical agents to coagulate and flocculate effluent brine particulate matter. Flocculation speed will be determined with and without mechanical assistance. Concentration of additives, settling rates, and zone characteristics will be determined. The effect of co-precipitants in enhancing settling properties will also be evaluated. Small scale filtration tests will be carried out to provide baseline data for screening process filtration equipment.

Small scale solids-liquid separation equipment will be field tested using spent brine as feed. Characteristics of various kinds of filtration equipment will be determined for both untreated and pretreated effluent as dictated by the above tests. Continuous feed and discharge centrifuges appear promising and will be tested. We will have the flexibility to test other viable methods. It is anticipated that the final solution in processing the brine effluent may incorporate several separation steps to achieve viable long-term brine injection and practical disposal of separated solids.

Brine from a sidestream at the downstream end of the strainers will be flushed through core samples at simulated in-situ conditions. The change in core permeability as a function of time, flow rate, and total throughout will be determined. Post test petrographic analyses will provide information on any alterations in structure, porosity, fracture characteristics, etc. The chemical and physical characteristics of the entrapped solids will provide insight into a possible similar problem occurring in the formation. These tests will be designed to provide also a simulation of brine flow through a slotted liner to obtain data which may be pertinent to injection well plugging problems.

With the addition of other participants we would expect both a modification and expansion in the above activities.

Site Development Plan (Figures 1, 2, and 3)

1. Site Preparation (Figure 1 & 2)

- a. Fill, Compaction, and Gravel Topping
- b. Concrete Experimental, Instrument & Transformer pads
- c. Utility trenching for Electrical, Reinjection Brine, and Experimental Effluent.
- d. Security fencing
- e. Electrical Service (Figure 3)
- f. Instrument Housing between Magmamax #3 and #4 (Figure 2)