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MASTER

GEO THERMAL LOOP EXPERIMENTAL FACILITY

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BI-MONTHLY REPORT

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SDG&E - ERDA GEOTHERMAL LOOP, EXPERIMENTAL FACILITY

November, 1976 - December, 1976

CONTRACT NO. E (04-3) - 1137

H. K. Bishop

J. R. Bricarello

F. L. Enos

N. C. Hodgdon

K. K. Li

G. L. Lombard

D. K. Mulliner

C. R. Swanson

January, 1977

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SUMMARY

The SDG&E/ERDA Geothermal Loop Experimental Facility (GLEF) operated for 871 hours during November and December, 1976. Based on the total hours in the two months, excluding scheduled outages, the availability of the GLEF was 70.72%.

Operations during this period included the completion of a test run which was initiated on October 23, two consecutive runs on Woolsey No. 1 fluid and one on Magmamax No. 1.

Magmamax No. 1 well continued to produce geothermal fluid at well head temperatures around 410° F. and a pressure of 350 psig with brine flow of 400,000 lbs/hr. A test run to overproduce this well yielded an estimated maximum brine flow of 650,000 lb/hr at a well head pressure of 200 psig.

Woolsey No. 1 well did not meet the design GLEF flow of 400,000 lbs/hr. The maximum flow was estimated to be 298,000 lbs/hr. with a well head pressure of 120 psig. As a result of the Woolsey flow tests, remedial actions have been undertaken to deepen Woolsey No. 1 to about 3490 feet. These corrective actions were started December 6, 1976. Woolsey is expected to be operational in February, 1977.

The plant was run in two modes of operation. In the first one, condensate from the first, second and third stage heat exchangers was introduced into the fourth stage separator. As a result of combining this higher pH condensate with the brine, some significant carbonate scaling was observed in the fourth stage separator and the reinjection system. This mode of operation was subsequently changed and the first, second and third stage condensate was directed into the cooling water system to minimize the carbonate scaling problem. This, however, resulted in a higher silica level in the reinjection fluid than observed with the first operational mode (with condensate dilution). The advantage of this mode was that silica scale is softer than carbonate scale and therefore easier to remove. This high silica level was observed with both Woolsey No. 1 and Magmamax No. 1 fluids. This result will be further confirmed by the same mode of operation in January and February, 1977.

During the middle of November, 1976, installation of the electronic data acquisition system hardware was begun. This includes pressure and temperature sensors, as well as flow meters, at critical locations around the plant to monitor operating parameters. Most mechanical installations were completed in December, 1976. The Data Logger is

expected to be linked to the sensing connections and calibrated in January, 1977.

Hand logging of operating data performed by plant operators will continue. In the event that the data logger system fails to record data, operating parameters will still be obtained.

Computer programs have been written by SDG&E Data System to process the hand logged raw data from the GLEF into meaningful engineering correlations. This information will be included in the next bi-monthly report. Computations will include heat and mass balance and heat exchanger performance. Concurrently, Lawrence Berkeley Laboratory is preparing computer software for data reduction as well as data storage and retrieval. The scopes of the LBL programs contain the conversion and storage of GLEF operating data in formats appropriate for subsequent retrieval and processing; and analysis of the stored data in accordance with the test criteria outlined in Bechtel's "Detailed Test Program for the GLEF". These tasks require specialized computer expertise in data transmission and efficient data management which is available at LBL. All of these computer programs will be refined as the GLEF tests progress.

To better define the chemical characteristics of the GLEF operations, Lawrence Livermore Laboratory during December, 1976, issued its plans for a detailed chemistry program to be integrated into the engineering test program for the GLEF. Both of these programs have been incorporated into the GLEF operation schedules and are expected to commence in February, 1977.

1.0 INTRODUCTION

This bi-monthly test report summarizes the geothermal activities during November and December, 1976, for the SDG&E/ERDA Geothermal Loop Experimental Facility (GLEF). Four continuous operation runs, including the completion of one started in October, were carried out using geothermal brine from Magmamax No. 1 and Woolsey No. 1 wells. Special problems encountered during these operations were noted and corrective actions were taken. System chemistry continued to be monitored and reported. A section on the data management of the GLEF is also included.

2.0 OPERATIONS AND MAINTENANCE

2.1 Introduction

Operations of the Geothermal Loop Experimental Facility during November and December, 1976 consisted of the completion of a test run which was started in October and three operation runs using geothermal brine from both Woolsey No. 1 and Magmamax No. 1.

During the test period, two methods of disposing of the condensed steam were evaluated. These were (1) flowing all the condensed steam from the second and third stage heat exchangers and first stage condensate cooler to the fourth stage separator and (2) flowing all condensate to the cooling pond. Except for the first run which was started in October and completed November 6, the latter method was used throughout the last three tests.

In this section, each test run is summarized. Major operating problems and interruptions are included. Conclusions and recommendations are drawn from these tests with regard to future operations.

2.2 Test Description and Results

2.2.1 Magmamax No. 1 - Condensate to ReInjection Well November 1 through November 7, 1976.

This is the continuation of the operation which was initiated on October 26. Magmamax No. 1 was the supply well for the brine, with Magmamax No. 3 as the reinjection well. The average operation data are summarized in Table 2-1. A total of 160 hours was accumulated from November 1 through November 7, 1976.

During this run, condensate from the first stage condensate cooler was flowed to the fourth stage separator. Condensed steam from the second and third stage heat exchangers was drained to the 4th stage scrubber and then to the 4th stage separator. The combined brine and condensate from the 4th stage separator was pumped to the reinjection well, Magmamax No. 3, with the brine reinjection pump.

No operational problems were experienced during this time except to repair the condensate pump, P-9, (which takes its suction from the 4th stage scrubber) due to excessive clearances on October 30. P-9 was back to service on November 3 after the bronze bearings

TABLE 2-1

START UP OPERATING CONDITIONS*

MAGMAMAX

0000 - 1400

Test No:

Date: 1 Nov to 7 Nov 1976

<u>Parameter</u>	<u>Units</u>	<u>Average</u>	<u>Range</u>
Inlet Conditions			
T	°F	385	375-390
P	psig	355	350-380
1st Stage			
T	°F	370	360-375
P	psig	145	140-150
LF	M #/hr	-	-
SF	M #/hr	4.4	3.5-5.2
2nd Stage			
T	°F	185	180-200
P	psig	46	30-60
LF	M #/h	-	-
SF	M #/hr	No entries	
3rd Stage			
T	°F	250	235-265
P	psig	17	9-25
LF	M #/hr	-	-
SF	M #/hr	2.8	1.9-3.2
4th Stage			
T	°F	211	212-208
P	psig	-4"	0" --6"
LF	M #/hr	-	-
SF	M #/hr	3.6	2.4-4.2
Reinjection			
T	°F	211	211-208
P	psig	210	140-300
LF	M #/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.

were replaced. No interruption to the plant operation was required for this maintenance work. The condition of the bearings will be discussed in Section 4.3 of this report.

The plant was shut down on November 8 for two weeks of inspection and maintenance (Appendices A & B). A list of tasks performed during this outage is included in Appendix C. In addition to these tasks, the sensing elements for the automatic data acquisition system were installed (Section 5.0).

During the installation of the venturi meter sections, sections of the brine system piping, previously not accessible, were inspected. The extent of scale build-up in these areas is covered in Section 3.

One significant area of scale deposition was the 1 1/2 inch scale build-up in the brine reinjection line, about 1/2 mile downstream of the GLEF, (Figure 2-1). It was hypothesized that this was caused by the recombination of the heat exchanger drains, i.e., steam condensate, with the reinjected brine (See Section 3.3). Therefore, it was decided to drain all the heat exchanger steam condensate to the cooling water pond instead of the brine reinjection line during the next

FIGURE 2 - 1

run so as to determine the effect of recombining the condensate on the scale deposition in the reinjection line. (Also, see Appendix D for discussion of scaling problem.

2.2.2 Woolsey Operation - Condensate to Cooling Pond November 24 through December 5, 1976.

The flow problem of Woolsey No. 1 well was described in Section 4.7 of the November, 1976 Bi-monthly report. The first solution to this problem was to set a new Baker plug on top of the remnant plug which had been in the well. This was performed by Magma during the shutdown period preceding this test run.

On November 24, operation was resumed with the production of geothermal fluid from Woolsey No. 1. Woolsey produced approximately 298,000 lbs/hr at 120 psig at the well head. This was still not sufficient to conduct one or two well flow tests. Both the delivered flow and pressure were below the design values of 400,000 lbs/hr and 150 psig. Woolsey No. 1 was flowed in the plant for 2 weeks to gather limited chemical and scale samples and other operating data.

During this run, the condensate drains from the second and third stage heat exchangers was flowed to the fourth stage scrubber and then pumped to the cooling water pond with the condensate pump, P-9. The first stage condensate was flowed directly to the cooling pond. This mode of operation was different from the previous ones where these heat exchanger condensate drains were pumped to the reinjection well. This method of operation was used for the remainder of the testing period covered by this report.

At 8:00 a.m., November 25, 1976 a gasket leak was discovered at the Dupont test spool on the brine reinjection line. Repair of this gasket was completed within 1 1/2 hours and operation was resumed at 9:30 a.m. Another shutdown was required for the modifications of P-7A purge water piping system so that P-7A can be isolated in case of failure of this pump. This task was begun at 12:00 noon, December 1, 1976, and completed at 8:00 p.m. the same day.

On December 5, the plant was shut down for the inspection of the brine reinjection pump, P-2, and the vacuum pump, VP-1. Prior to this shut down, high pitched noise was observed at P-2. Inspection of this pump indicated the Nylon 6/6 bearings on the pump were

severely damaged. Excessive clearances were discovered in the pump motor bearings which was the cause of the high pitch noise. (See Section 4.1). The motor for P-2 was sent to SDG&E Electric Maintenance shop for replacement of the bearings. The vacuum pump was sent to the SDG&E Machine Shop for disassembly and repair. The vacuum pump shaft was broken at the key way for the center bearing and was replaced. It was suggested by the manufacturer of the pump (Kinney) that this is a chronic problem. Therefore, a new pump, manufactured by Nash, has been ordered. Operations will continue with the repaired Kinney pump until the Nash pump is installed. The reinjection pump was returned to service on December 9.

An operation summary of plant data is presented in Table 2-2. A total of 244 hours were accumulated during this run. Flash vessel inspection report is included in Appendix E.

2.2.3 Woolsey Operation - Condensate to Cooling Pond December 10 through December 14, 1976.

Geothermal brine from Woolsey No. 1 was flowed into the plant with the vacuum pump out of service. Partial vacuum under this operation could at

TABLE 2-2

START UP OPERATING CONDITIONS* (WOOLSEY)

0200 - 2400

Test No:

Date: Nov.25,1976 to Nov.30,1976

<u>Parameter</u>		<u>Units</u>	<u>Average</u>	<u>Range</u>
Inlet Conditions				
	T	°F	350	350-360
	P	psig	105	100-110
1st Stage	T	°F	315	310-330
	P	psig	70	65-80
	LF	M#/hr	-	-
	SF	M#/hr	Recorder inoperative	
2nd Stage	T	°F	250	240-270
	P	psig	44	34-60
	LF	M#/h	-	-
	SF	M#/hr	2.4	1.0-3.2
3rd Stage	T	°F	250	240-260
	P	psig	14	9-19
	LF	M#/hr	-	-
	SF	M#/hr	2.4	2.0-3.2
4th Stage	T	°F	210	212-210
	P	psig	-4	-1 to -10
	LF	M#/hr	-	-
	SF	M#/hr	3.4	1.0 to 4.0
Reinjection	T	°F	210	212-210
	P	psig	90	75-150
	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.

TABLE 2-2 (con't)

START UP OPERATING CONDITIONS* WOOLSEY
FROM 2400 TO 1000

Test No: Date: Dec 1, 1976 - Dec 5, 1976

<u>Parameter</u>	<u>Units</u>	<u>Average</u>	<u>Range</u>
Inlet Conditions			
T	°F	350	345-360
P	psig	100	90-115
1st Stage			
T	°F	325	315-335
P	psig	80	70-95
LF	M #/hr	-	-
SF	M #/hr	3.0	2.0-3.5
2nd Stage			
T	°F	230	200-260
P	psig	42	36-48
LF	M #/h	-	-
SF	M #/hr	2.4	2.0-3.0
3rd Stage			
T	°F	255	250-260
P	psig	16.5	11-19
LF	M #/hr	-	-
SF	M #/hr	2.2	1.8-3.1
4th Stage			
T	°F	210	212-210
P	psig	-2"vacuum	0-5"
LF	M #/hr	-	-
SF	M #/hr	2.4	1.0-3.0
Reinjection			
T	°F	210	212-210
P	psig	100	35-150
LF	M #/hr	-	-

LF = Liquid Flow

SF = Steam Flow

M = 1000

NOTE: TOTAL OPERATING HRS FOR DEC/76 = 488:15

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

times be obtained by increased binary and cooling water flow. Manual venting of the non-condensable was performed to maintain atmospheric pressure in the condensate tank, V-13.

During this test run, high vibration was observed in condensate pump, P-10. Therefore, it was sent to SDG&E machine shop for replacement of the shaft and the bearings. The bearing/shaft clearances were enlarged to .100 from a normal .016 inch which caused the pump to vibrate.

The plant was shut down at 10:30, December 14 for Magma Company to perform down hole tests at Woolsey No. 1 and Magmamax No. 3. During the entire run, approximately 95 hours were achieved. The average operation conditions are tabulated in Table 2-3. This was the last test operation with Woolsey No. 1 as the producing well.

Upon the completion of these last two tests, it was clear that the corrective action taken on Woolsey No. 1 had not produced satisfactory results. Therefore, Magma determined to deepen the well to about 3,490 feet. This work would take approximately one month to complete.

TABLE 2-3

START UP OPERATING CONDITIONS

WOOLSEY
1600 - 1000

Test No:

Date: Dec 10 - Dec 14/76

<u>Parameter</u>	<u>Units</u>	<u>Average</u>	<u>Range</u>
Inlet Conditions			
T	°F	348°	335-350
P	psig	90	75-100
1st Stage	T °F	330	320-335
"A"	P psig	85	55-90
	LF M #/hr	-	-
	SF M #/hr	3.0	2.6-4.0
2nd Stage	T °F	215	195-225
	P psig	40	36-44
	LF M #/h	-	-
	SF M #/hr	2.2	2.0-2.5
3rd Stage	T °F	255	250-260
	P psig	15	12-16
	LF M #/hr	-	-
	SF M #/hr	2.4	2.0-2.8
4th Stage	T °F	210	212-210
	P psig	-2	0- -4
	LF M #/hr	-	-
	SF M #/hr	1.0	.5-2.0
Reinjection	T °F	210	212-210
	P psig	127	40-170
	LF M #/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.

2.2.4 Magmamax No. 1 - Condensate to Cooling Pond
December 15 through December 30, 1976.

Operation at the GLEF was resumed after the 4th stage condensate pump, P-10, and the vacuum pump, VP-1, were reinstalled for service at 6:50 p.m. A total of 370 hours were achieved during this run. Magmamax No. 1 was the brine supply well. The average operating conditions are tabulated in Table 2-4, which excludes the data obtained from a December 20 test over-producing Magmamax No. 1. This latter test was conducted for approximately 40 hours. The maximum brine flow was 650,000 lbs/hr. at a well head pressure of 200 psig. The estimates of the brine flow were made with the discharge pressure/capacity curve, a flow recorder chart, and heat/material balance calculations on the separators.

Shortly after the start-up on December 15, the purge water pump, P-7, and the vacuum pump tripped off because of low power voltage supplied to the plant from the Imperial Irrigation District power system. These pumps were restarted immediately.

This low voltage continued throughout the day. The incoming voltage was 31.5 Kv on the 34 Kv

TABLE 2-4

START UP OPERATING CONDITIONS

MAGMAMAX I
FROM 0600 to 2400

Test No: Date: Dec 16 - Dec 20, 1976

<u>Parameter</u>	<u>Units</u>	<u>Average</u>	<u>Range</u>
Inlet Conditions			
T	°F	385	370-390
P	psig	315	265-330
1st Stage	T °F	370	340-375
"B"	P psig	150	134-165
	LF M #/hr	-	-
	SF M #/hr	2.9	0-4.9
2nd Stage	T °F	235	220-250
	P psig	35	20-58
	LF M #/h	-	-
	SF M #/hr	4.0	3.1-5.1
3rd Stage	T °F	260	254-285
	P psig	15	10-25
	LF M #/hr	-	-
	SF M #/hr	2.6	2.0-4.2
4th Stage	T °F	210	212-210
	P psig	-3"vacuum	0"- -6"
	LF M #/hr	-	-
	SF M #/hr	3.4	2.0-5.1
Reinjection	T °F	210	212-210
	P psig	120	50-250
	LF M #/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.

TABLE 2-4 (con't)

START UP OPERATING CONDITIONS

MAGMAMAX # 1

FROM 0001 TO 24

Test No:

Date: Dec 24, 1976 - Dec 31, 19

<u>Parameter</u>	<u>Units</u>	<u>Average</u>	<u>Range</u>
Inlet Conditions			
T	°F	380	350-390
P	psig	290	260-345
1st Stage			
T	°F	360	340-370
P	psig	140	107-162
LF	M #/hr	-	-
SF	M #/hr	4.6	3.5-6.5
2nd Stage			
T	°F	215	185-230
P	psig	60	35-84
LF	M #/h	-	-
SF	M #/hr	2.8	2.2-3.6
3rd Stage			
T	°F	250	235-280
P	psig	16	5-28
LF	M #/hr	-	-
SF	M #/hr	2.8	2.0-3.7
4th Stage			
T	°F	210	212-209
P	psig	-2"	0"- -7"
LF	M #/hr	-	-
SF	M #/hr	3.8	2.4-4.4
Reinjection			
T	°F	-	212-209
P	psig	230	150-290
LF	M #/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.

line. Within the plant, the resulting voltages were 3850 V on the 4160 V supply bus, 415 V on the 440 V supply bus and 107 V on the 120 V supply. This situation was reported to the Imperial Irrigation District for corrective action.

On December 17, 1976 high vibration was observed in P-9. Visual inspection indicated excessive clearances at the pump shaft and bearings. Therefore, it was sent to the SDG&E machine shop for repair. It was in service again on December 19 (Also; see Section 4.3).

On December 21 and again on December 23, P-9 tripped off due to scale build-up in the impeller clearances, which created a drag on the pump motor. A solution of 1 part of hydrochloric acid and 7 parts of water was used to dissolve the scale. The acid cleaning took about 2 to 3 minutes. P-9 was reinstalled in service within 3 hours. (Also, see Section 3-3 on scale formation).

The operation continued until 10:30 a.m. December 27, 1976 when Pressure Control Valve, PCV-301, (Kamyr), brine inlet valve to the 1st stage separator 1B, was inoperative because of frozen packing gland and

bushing. This valve was replaced with PCV 300, (Kamyr), the inlet valve to 1st stage separator 1A, which was not used because Woolsey was not in operation. This shut down lasted until 4:20 p.m. when operation was resumed.

On December 29, 1976 high pressure differential across the P-2 discharge check valve was observed. The plant was shut down at 9:00 a.m. to inspect the check valve. The check valve, as well as the pump discharge elbow to it (Figure 2-2), was plugged with scale deposits which reduced the 10" pipe line to a 3" opening (Figures 2-3 and 2-4). The chemical analyses of these scale deposits are covered in Section 3. It was decided to remove this check valve and install a spool pipe section. There were two more check valves in the reinjection line, one at the well head and one at the corner of the plant. These were not removed. Also, during this shut down, a Fisher V-Ball control valve was installed to replace PCV 301 to compare its brine pressure control performance with the Kamyr ball valve. This shutdown was terminated at 4:30 p.m. The Fisher control valve has operated smoothly since that time.

FIGURE 2-2

FIGURE 2 - 3

FIGURE 2 - 4

2.3 Conclusions

A total of 871 hours of operation was accumulated during November and December 1976. Based on the total hours in these two months, less scheduled outages, the availability of the GLEF was 70-72%.

Two operation modes were conducted with the GLEF to evaluate both operational problems and the brine scale chemical data associated with these modes. The results of chemical evaluations will be presented in section 3 of this report. One of the most critical findings was the change of scale deposition characteristics in the reinjection brine piping when condensate from the heat exchangers was reinjected with the brine. Additional tests will be conducted to confirm these correlations and to establish the mode of plant operation, with the existing process configuration, which will minimize this effect.

The most notable operational problems encountered during the test period included the sticking of the brine system level control valves manufactured by Kamyr and the plugging of liquid level sensing columns. Manual cycling of these valves was necessary to minimize the problem of "freezing". These types of valves are

utilized for pressure control in the first stage separator and level control of the third stage separator.

Another equipment problem was silica scale deposition in the impeller/bowl clearances of the condensate pump. An acid-clean of the pump with a hydrochloric acid solution has proved to be very effective in removing the carbonatescale. Since there are two pumps which afforded redundancy in the condensate system, either one pump or the other can be operated when the other is inoperative. Therefore, the impact of this type of maintenance was minimal on the overall plant operation; i.e., no shut down resulted.

Different bearing materials on the reinjection pump were evaluated. SAE 660 bronze bearings appeared to be the most satisfactory for this application. Further pump operation with this bearing material should confirm this conclusion.

Magmamax No. 1 continued to be the production source of geothermal brine which produced an average mass flow of about 400,000 lbs./hr. at well head pressure of 350 psig. A test to overproduce it yielded an estimated maximum mass flow of 650,000 lbs./hr. at a well head pressure of 200 psig.

Woolsey No. 1 well did not produce the designed GLEF flow of 400,000 lbs./hr. An estimated maximum flow of 298,000 lbs./hr. with a well head pressure of 120 psig was observed. It was determined that this condition could be corrected by drilling the well an additional 1100 feet to a depth of 3490 feet. This work was started in December, 1976 and will be completed by the end of January, 1977.

3.0 SYSTEM CHEMISTRY

3.1 Introduction

In this section chemical parameters associated with the GLEF operations are presented. Important data are tabulated and their effects on the plant are discussed. Also, operational changes are noted with their effect on plant chemistry. The time period covered in this section is from November 1st through December 31st. Within this time frame, both Magmamax No. 1 and Woolsey wells were flowed into the plant.

The subsections within this portion of the report are the same as previous bi-monthly reports; e.g., steam and condensate system, brine system, purge water, vent gas system, cooling water system and the binary loop.

3.2 Steam & Condensate System

Fourth Stage Sampling

Sampling techniques and sample points were the same as those reported in previous bi-monthly reports except for a new sample point, the fourth stage

steam flow into the scrubber, which was added recently. Initially, this stream was not sampled because the entire fourth stage system operates at less than atmospheric pressure. To take this sample, a sample port was installed in the fourth stage steam outlet line and connected to a cooling coil. The sample was drawn by connecting a hose from the vacuum pump to a vacuum flask attached to the cooling coil outlet.

With the addition of the new sampling point the reason for the scaling of the fourth stage scrubber and P-9 is evident. Since the sampling began, brine salts have been observed in the fourth stage steam (Tables 3-1, 3-2 & 3-3). These salts can combine with the carbonate in the steam condensate coming from the second stage, third stage, and purge water, forming carbonate scale. To alleviate this scaling problem some method of preventing the carry-over should be initiated. This could take the form of 1) increasing the pressure in the fourth stage separator to reduce steam flow, 2) reducing the fourth stage separator liquid level, or 3) added mechanical droplet removal in the fourth stage separator.

Magmamax Fluid with Condensate Reinjecting

Table 3-1 summarizes an operating period which started October 19, 1976 and ended November 5, 1976. Geothermal fluid from Magmamax No. 1 was used in the plant during this period. Steam condensate from the second and third stage heat exchangers flowed to the fourth stage scrubber, then to the fourth stage separator and reinjected. First stage steam condensate was sent to the condensate cooler then to the fourth stage separator for reinjection.

Certain trends are evident in the condensate parameters monitored. pH values increased from stage one to stage three, with a decrease in stage four. Ammonia concentration decreased through the stages. This was due to the lower brine temperatures which allowed less ammonia to be evaporated. Alkalinity varied throughout the stages in the following manner: bicarbonate alkalinity was observed in the first stage, carbonate in the second, carbonate and hydroxide in the third and bicarbonate in the fourth. The decline in total alkalinity through the plant can be attributed to the loss of the carbon dioxide in successive stages, with most being eliminated in the first stage. The fourth stage alkalinity increases because the first,

Table 3-1

STEAM & CONDENSATE PROPERTIES -
MAGMAMAX FLUID WITH CONDENSATE REINJECTION

Date 11/2/76

Sample	pH	Cond umho/cm	ORP mv	Na mg/l	Ca mg/l	Alkalinity (as CaCO ₃)			OH mg/l	NH ₄ -N mg/l	SiO ₂ mg/l	S= mg/l	Total Solids mg/l	C ₁ - mg/l
						Fe mg/l	HCO ₃ mg/l	CO ₃ mg/l						
Well Brine	5.50	420,000	+ 5	---	---	---	---	---	---	345	---	---	238,400	137,500
1st Steam In	6.60	2,800	-277	37	19.4	1.5	980	ND	ND	235	0.28	52	---	150
1st Steam Out	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1st Brine Out	5.90	430,000	- 70	---	---	---	---	---	---	360	---	---	261,600	148,500
2nd Steam In	9.05	1,000	-253	9.4	4.7	0.4	ND	700	ND	260	0.006	4	---	34
2nd Steam Out	9.05	900	-242	1.4	1.4	1.3	ND	650	50	255	0.010	4	---	9
2nd Brine Out	6.05	470,000	- 35	---	---	---	---	---	---	360	---	---	279,500	154,000
3rd Steam In	9.80	270	-225	10	5.0	0.3	ND	50	375	165	0.006	1	---	31
3rd Steam Out	9.80	172	-218	1.0	0.9	0.4	ND	80	345	165	0.018	1	---	7
3rd Brine Out	6.00	520,000	- 24	---	---	---	---	---	---	380	---	---	290,800	162,000
4th Steam In	7.65	2,400	-137	30	9.5	7.1	825	ND	ND	305	---	---	---	110
4th Steam Out	8.20	1,900	- 88	7.8	6.7	4.6	825	ND	ND	300	0.022	1	---	28
Reinjection	6.30	385,000	- 68	---	---	---	---	---	---	335	---	---	211,600	123,700

ND - Not Detected

1st Steam In - Steam from 1st stage flash vessel to scrubber.

NOTE:

1st Steam Out - Steam from 1st stage scrubber to heat exchanger.

1st Brine Out - Brine from 1st stage flash vessel.

second, and third stage carbonate bearing condensates were added back into the fourth stage separator during this period. Similar variations in steam properties were observed in previous tests (September and November bi-monthly reports).

Magmamax Fluid with No Condensate Injection

Table 3-2 describes the use of Magmamax No. 1 fluid within the plant, but with a different operating mode. The steam condensate produced from the first, second, and third stages was pumped to the cooling water pond. The condensed fourth stage steam was used for purge water. Thus no condensate was injected into the injection well. Variation in steam properties as the steam passed through successive stages was similar to that observed in the condensation reinjection mode (Table 3-1). One difference, which could be logically expected, is a reduction in total alkalinity of the steam from the fourth stage separator. Without the condensates from previous stages, no additional carbon dioxide is introduced into the fourth stage separator. The second and third stage condensates are added to the fourth stage scrubber and do add alkalinity (carbon dioxide) to the exiting steam, but not as much as when condensate was returned to the fourth stage separator.

Table 3-2

STEAM & CONDENSATE PROPERTIES -
MAGMAMAX FLUID WITH NO CONDENSATE INJECTION

Date 12/17/76

Sample	pH	Cond umho/cm	ORP mv	Na mg/l	Ca mg/l	Alkalinity (as CaCO ₃)			OH mg/l	NH ₄ -N mg/l	Total Solids mg/l	Cl- mg/l
						Fe mg/l	HCO ₃ mg/l	CO ₃ mg/l				
Well Brine	5.80	385,000	+ 27	---	---	---	---	---	---	360	214,200	131,300
1st Steam In	6.90	2,200	-217	6.2	5.4	4.3	1,000	ND	ND	255	---	---
1st Steam Out	6.75	2,400	-279	1.7	0.9	2.2	1,075	ND	ND	295	---	---
1st Brine Out	6.20	420,000	- 56	---	---	---	---	---	---	350	242,300	141,400
2nd Steam In	9.10	810	-232	3.9	3.8	0.5	ND	600	50	190	---	---
2nd Steam Out	9.20	630	-250	2.0	1.6	1.0	ND	450	200	190	---	---
2nd Brine Out	6.20	440,000	- 20	---	---	---	---	---	---	370	251,500	154,000
3rd Steam In	9.80	178	-340	1.2	3.0	0.2	ND	150	375	145	---	---
3rd Steam Out	9.90	270	-276	1.0	0.5	0.3	ND	300	675	270	---	---
3rd Brine Out	6.15	460,000	- 17	---	---	---	---	---	---	370	261,900	156,500
4th Steam In	7.95	1,430	-119	46	21	7.6	300	ND	ND	80	---	---
4th Steam Out	8.60	1,170	-199	11.6	5.5	0.7	400	150	ND	165	---	---
Reinjection	6.15	515,000	- 37	---	---	---	---	---	---	370	263,900	159,100

ND - Not Detected

1st Steam In - Steam from 1st stage flash vessel to scrubber.

NOTE:

1st Steam Out - Steam from 1st stage scrubber to heat exchanger.

1st Brine Out - Brine from 1st stage flash vessel.

Table 3-2

STEAM & CONDENSATE PROPERTIES -
MAGMAMAX FLUID WITH NO CONDENSATE INJECTION

Date 12/22/76

Sample	pH	Cond umho/cm	ORP mv	Na mg/l	Ca mg/l	Alkalinity (as CaCO ₃)			OH mg/l	NH ₄ -N mg/l	SiO ₂ mg/l	Cl ⁻ mg/l
						Fe mg/l	HCO ₃ mg/l	CO ₃ mg/l				
Well Brine	5.25	415,000	+ 48	---	---	---	---	---	---	345	---	131,300
1st Steam In	6.45	2,300	-251	12.5	6.0	1.5	950	ND	ND	250	0.055	66
1st Steam Out	6.55	2,700	-282	2.1	0.6	2.0	1100	ND	ND	295	0.044	18
1st Brine Out	5.75	435,000	+ 2	---	---	---	---	---	---	365	---	141,400
2nd Steam In	8.70	1,220	-252	14.5	7.0	0.2	125	600	ND	210	ND	57
2nd Steam Out	8.90	1,090	-248	1.7	1.1	0.9	125	600	ND	205	ND	9
2nd Brine Out	6.00	460,000	+ 4	---	---	---	---	---	---	370	---	151,500
3rd Steam In	9.70	230	-310	0.8	1.3	0.3	ND	200	650	245	0.010	6
3rd Steam Out	9.60	230	-264	0.9	0.5	0.2	ND	200	400	170	0.006	9
3rd Brine Out	6.00	485,000	+ 1	---	---	---	---	---	---	380	---	156,500
4th Steam In	6.60	1,080	-124	35	17.6	10.7	325	ND	ND	100	0.021	128
4th Steam Out	9.00	1,300	-249	3.7	1.4	0.1	100	850	ND	270	0.028	14
Reinjection	---	---	---	---	---	---	---	---	---	---	---	---

ND - Not Detected

1st Steam In - Steam from 1st stage flash vessel to scrubber.

NOTE:

1st Steam Out - Steam from 1st stage scrubber to heat exchanger.

1st Brine Out - Brine from 1st stage flash vessel.

Table 3-2

STEAM & CONDENSATE PROPERTIES -
MAGMAMAX FLUID WITH NO CONDENSATE INJECTION

Date 12/28/76

Sample	pH	Cond umho/cm	ORP mv	Na mg/l	Ca mg/l	Alkalinity (as CaCO ₃)			OH mg/l	NH ₄ -N mg/l	Cl ⁻ mg/l	Boron mg/l
						Fe mg/l	HCO ₃ mg/l	CO ₃ mg/l				
Well Brine	5.20	410,000	+ 57	---	---	---	---	---	---	355	128,800	---
1st Steam In	6.45	2,300	-259	14	4.7	1.4	950	ND	ND	225	88	9.2
1st Steam Out	6.45	2,400	-284	1.9	0.3	1.2	1050	ND	ND	280	22	3.6
1st Brine Out	5.70	435,000	+ 2	---	---	---	---	---	---	365	141,400	---
2nd Steam In	8.85	1,080	-235	1.8	2.0	0.3	150	600	ND	215	13	5.8
2nd Steam Out	8.80	1,600	-208	49	11.7	0.6	100	600	ND	220	193	5.5
2nd Brine Out	5.90	465,000	+ 9	---	---	---	---	---	---	375	154,000	---
3rd Steam In	9.80	250	-221	9.5	4.7	0.3	ND	150	400	155	28	4.2
3rd Steam Out	9.55	220	-346	4.7	1.7	0.2	ND	250	300	155	14	2.8
3rd Brine Out	---	---	---	---	---	---	---	---	---	---	---	---
4th Steam In	7.70	1,700	-135	93	45	14	350	ND	ND	100	325	2.6
4th Steam Out	9.05	1,010	-247	3.2	1.3	0.2	75	700	ND	225	22	0.4
Reinjection	---	---	---	---	---	---	---	---	---	---	---	---

ND - Not Detected

1st Steam In - Steam from 1st stage flash vessel to scrubber.

NOTE:

1st Steam Out - Steam from 1st stage scrubber to heat exchanger.

1st Brine Out - Brine from 1st stage flash vessel.

Table 3-2

STEAM & CONDENSATE PROPERTIES -
MAGMAMAX FLUID WITH NO CONDENSATE INJECTION

Date 12/30/76

Sample	pH	Cond umho/cm	ORP mv	Na mg/l	Ca mg/l	Alkalinity (as CaCO ₃)			OH mg/l	NH ₄ -N mg/l	Cl ⁻ mg/l	Boron mg/l
						Fe mg/l	HCO ₃ mg/l	CO ₃ mg/l				
Well Brine	5.30	405,000	+ 53	---	---	---	---	---	---	360	131,300	---
1st Steam In	6.45	2,400	-273	11	4.9	0.8	975	ND	ND	245	83	10
1st Steam Out	6.45	2,700	-281	1.6	0.6	2.5	1175	ND	ND	290	31	3.3
1st Brine Out	5.80	415,000	- 20	---	---	---	---	---	---	370	143,900	---
2nd Steam In	9.15	990	-267	145	6.4	0.3	100	600	ND	205	53	6.3
2nd Steam Out	9.05	980	-267	1.8	2.5	0.5	150	600	ND	210	13	4.3
2nd Brine Out	6.15	460,000	- 27	---	---	---	---	---	---	375	149,000	---
3rd Steam In	9.70	590	-253	42	19.4	0.3	ND	300	250	145	132	4.7
3rd Steam Out	9.75	250	-363	2.7	2.2	0.3	ND	300	225	155	13	3.0
3rd Brine Out	---	---	---	---	---	---	---	---	---	---	---	---
4th Steam In	6.55	1,830	-159	107	53	20	400	ND	ND	90	325	3.4
4th Steam Out	9.30	1,020	-297	8.9	2.1	0.06	ND	750	50	235	30	0.5
Reinjection	6.15	505,000	- 36	---	---	---	---	---	---	380	156,500	---

ND - Not Detected

1st Steam In - Steam from 1st stage flash vessel to scrubber.

NOTE:

1st Steam Out - Steam from 1st stage scrubber to heat exchanger.

1st Brine Out - Brine from 1st stage flash vessel.

Woolsey Fluid with No Condensate Injection

Geothermal fluid from Woolsey No. 1 was flowed through the plant between November 29, 1976 and December 13, 1976. This fluid produced trends through the system similar to that observed with Magmamax fluids (Table 3-3). However, concentrations of the various chemical species were lower than those observed with Magmamax No. 1 fluid. This effect was observed because Woolsey No. 1 fluid contains less dissolved species than Magmamax No. 1 fluid, 180,000 ppm TDS for Woolsey vs. 225,000 ppm for Magmamax.

Lower ORP (oxidation-reduction potential) values were obtained from Woolsey brine. Ammonia concentration decreases through the stages as with Magmamax, however, less was originally present in the brine which caused less to be produced in each of the plant stages. Alkalinities of the Woolsey condensate were similar to those of Magmamax. Almost the same amounts of dissolved volatile gases were observed in the Magmamax and Woolsey steam. The amounts of solids carried over with the steam from the first, second and third stage separators were also nearly the same. A significant reduction in the solids carried over with

Table 3-3

STEAM & CONDENSATE PROPERTIES -
WOOLSEY FLUID WITH NO CONDENSATE INJECTION

Date 12/2/76

Sample	pH	Cond	ORP	Na	Ca	Alkalinity (as CaCO ₃)			OH	NH ₄ -N	Cl ⁻
						Fe	HCO ₃	CO ₃			
		umho/cm	mv	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Well Brine	---	---	---	---	---	---	---	---	---	---	---
1st Steam In	6.50	2,300	- 64	2.2	3.5	47	975	ND	ND	215	15
1st Steam Out	6.75	1,690	-124	4.7	3.8	5.9	775	ND	ND	195	19
1st Brine Out	5.55	320,000	+ 28	---	---	---	---	---	---	295	107,200
2nd Steam In	6.55	1,500	-102	6.2	7.2	1.1	650	ND	ND	165	23
2nd Steam Out	6.50	1,430	- 80	0.9	1.0	1.4	650	ND	ND	160	9
2nd Brine Out	6.10	370,000	- 13	---	---	---	---	---	---	320	118,200
3rd Steam In	9.15	520	- 47	1.6	0.8	0.2	ND	400	60	130	9
3rd Steam Out	9.10	530	- 88	1.7	0.8	0.3	ND	400	75	140	8
3rd Brine Out	6.30	385,000	- 33	---	---	---	---	---	---	345	123,700
4th Steam In	6.75	790	- 39	9.3	4.2	11.3	310	ND	ND	85	36
4th Steam Out	6.70	1,060	- 49	0.5	1.4	11.0	460	ND	ND	120	9
Reinjection	6.35	395,000	- 22	---	---	---	---	---	---	345	126,500

ND - Not Detected

1st Steam In - Steam from 1st stage flash vessel to scrubber.

NOTE: 1st Steam Out - Steam from 1st stage scrubber to heat exchanger.

1st Brine Out - Brine from 1st stage flash vessel.

Table 3-3

STEAM & CONDENSATE PROPERTIES -
WOOLSEY FLUID WITH NO CONDENSATE INJECTION

Date 11/29/76

Sample	pH	Cond umho/cm	ORP mv	Na mg/l	Ca mg/l	Alkalinity (as CaCO ₃)			OH mg/l	NH ₄ -N mg/l	Cl ⁻ mg/l	Total Solids mg/l	S= mg/l
						Fe mg/l	HCO ₃ mg/l	CO ₃ mg/l					
Well Brine	---	---	---	---	---	---	---	---	---	---	---	---	---
1st Steam In	---	---	---	---	---	---	---	---	---	---	---	---	---
1st Steam Out	---	---	---	---	---	---	---	---	---	---	---	---	---
1st Brine Out	5.35	335,000	+ 74	---	---	---	---	---	---	330	107,200	181,000	---
2nd Steam In	6.65	1,880	-102	9.3	7.8	1.1	625	ND	ND	170	34	---	2.6
2nd Steam Out	6.65	1,550	-128	1.5	1.3	4.5	610	ND	ND	175	8	---	3.8
2nd Brine Out	5.90	375,000	+ 15	---	---	---	---	---	---	330	115,500	201,100	---
3rd Steam In	9.40	64	-155	1.5	1.1	0.4	ND	400	75	145	6	---	ND
3rd Steam Out	9.25	760	- 83	2.2	1.6	2.2	ND	470	150	140	9	---	ND
3rd Brine Out	6.05	400,000	+ 5	---	---	---	---	---	---	345	121,000	208,500	---
4th Steam In	8.35	850	-144	3.6	3.5	5.5	230	70	0	90	13	---	---
4th Steam Out	7.45	1,600	- 77	4.8	2.0	1.8	535	ND	ND	170	17	---	0.8
Reinjection	6.00	420,000	- 4	---	---	---	---	---	---	350	123,700	214,800	---

ND - Not Detected

1st Steam In - Steam from 1st stage flash vessel to scrubber.

NOTE:

1st Steam Out - Steam from 1st stage scrubber to heat exchanger.

1st Brine Out - Brine from 1st stage flash vessel.

Table 3-3

STEAM & CONDENSATE PROPERTIES -
WOOLSEY FLUID WITH NO CONDENSATE INJECTION

Date 12/1/76

Sample	pH	Cond umho/cm	ORP mv	Na mg/l	Ca mg/l	Alkalinity (as CaCO ₃)			OH mg/l	NH ₄ -N mg/l	Cl ⁻ mg/l	SiO ₂ mg/l
						Fe mg/l	HCO ₃ mg/l	CO ₃ mg/l				
Well Brine	---	---	---	---	---	---	---	---	---	---	---	---
1st Steam In	---	---	---	---	---	---	---	---	---	---	---	---
1st Steam Out	---	---	---	---	---	---	---	---	---	---	---	---
1st Brine Out	5.75	340,000	- 31	---	---	---	---	---	---	320	107,200	---
2nd Steam In	6.70	1,510	-108	7.7	6.8	1.2	675	ND	ND	175	32	0.015
2nd Steam Out	6.55	1,420	- 88	0.3	0.6	1.5	675	ND	ND	180	8	0.020
2nd Brine Out	6.35	360,000	- 47	---	---	---	---	---	---	320	112,700	---
3rd Steam In	9.15	580	- 9	4.2	2.2	0.4	ND	450	75	145	15	0.005
3rd Steam Out	9.15	570	- 31	0.8	0.6	0.5	ND	500	25	145	9	0.025
3rd Brine Out	6.45	375,000	- 43	---	---	---	---	---	---	335	118,200	---
4th Steam In	7.65	740	- 85	4.1	3.8	4.3	335	ND	ND	90	33	0.035
4th Steam Out	7.95	1,120	- 65	13.3	5.2	2.1	475	ND	ND	145	17	0.020
Reinjection	6.45	385,000	- 50	---	---	---	---	---	---	300	115,500	---

ND - Not Detected

1st Steam In - Steam from 1st stage flash vessel to scrubber.

NOTE:

1st Steam Out - Steam from 1st stage scrubber to heat exchanger.

1st Brine Out - Brine from 1st stage flash vessel.

Table 3-3

STEAM & CONDENSATE PROPERTIES -
WOOLSEY FLUID WITH NO CONDENSATE INJECTION

Date 12/3/76

Sample	pH	Cond	ORP	Na	Ca	Alkalinity (as CaCO ₃)			OH	NH ₄ -N	Cl ⁻	Total Solids
						Fe	HCO ₃	CO ₃				
		umho/cm	mv	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Well Brine	---	---	---	---	---	---	---	---	---	---	---	---
1st Steam In	6.40	2,400	- 91	1.5	1.0	32	1060	ND	ND	230	18	---
1st Steam Out	6.35	1,530	-167	2.0	0.8	4.7	685	ND	ND	180	15	---
1st Brine Out	6.50	360,000	- 77	---	---	---	---	---	---	330	112,700	165,700
2nd Steam In	8.85	980	-207	4.6	2.6	0.2	215	370	ND	170	18	---
2nd Steam Out	8.65	930	-190	1.9	1.1	0.3	215	370	ND	180	10	---
2nd Brine Out	6.60	380,000	- 51	---	---	---	---	---	---	320	115,500	171,300
3rd Steam In	9.75	230	-194	5.2	2.6	0.2	ND	150	310	130	15	---
3rd Steam Out	9.60	220	-176	2.0	0.8	0.1	ND	150	310	130	9	---
3rd Brine Out	6.50	385,000	- 26	---	---	---	---	---	---	325	126,500	197,400
4th Steam In	6.85	1,000	- 46	16.2	1.5	3.3	310	ND	ND	92	94	---
4th Steam Out	7.00	1,200	- 54	1.7	21	11.4	535	ND	ND	155	9	---
Reinjection	6.35	395,000	- 19	---	---	---	---	---	---	340	132,000	185,000

ND - Not Detected

1st Steam In - Steam from 1st stage flash vessel to scrubber.

NOTE:

1st Steam Out - Steam from 1st stage scrubber to heat exchanger.

1st Brine Out - Brine from 1st stage flash vessel.

when Woolsey fluid was flowed through the test loop. This was probably caused by a combination of factors, less dissolved solids in the brine, lower temperature in the fourth stage and lower flow rates.

The results of low liquid level in the first stage separator can also be seen in Table 3-3. On December 1 and 2, the pH of the second stage steam was observed to be lower than the second stage steam from Magmamax fluids. The cause of this was found to be a very low operating level in first stage separator "1A" for Woolsey Fluid. The quick flow through of the brine prevented proper flashing and venting of the noncondensables. Hence, unflashed brine flowed to the second stage where it was allowed to flash properly, as it should have in the first stage. This led to the observance of first stage steam type values for pH & carbonates in the second stage steam. The liquid level control was corrected and a higher, "normal", 1st stage steam pH was observed on December 3.

Boron Analysis

An additional element, boron, has been added to the steam analysis (Table 3-2). Boron was found in the steam condensate, with more observed in the steam

entering the scrubber than exiting. Also the boron concentration was observed to decrease through the stages with no apparent dependence on carryover. This implies the boron concentration in the steam was temperature dependent. The higher the temperature, the more efficient is the boron distillation process. It is postulated that the boron existed in the brine as positive trivalent boron such as $B(OH)_3$ which could come from a decomposed BCl_3 intermediate compound.

3.3 Brine System

Magmamax Fluid

Composition of the geothermal fluid produced by Magmamax No. 1 remained constant during the tests conducted in November and December (Table 3-4). Table 3-5 shows the concentration of the brine at each stage in the plant. Tables 3-5 & 3-6 compare the well fluid and the reinjection fluid, with and without condensate recombination. The major change in dissolved species between the well head and the injection line involved silicon. Variation in other species were small and could be attributed to analysis and sampling inaccuracies.

TABLE 3-4
MAGMAMAX NO. 1 WELLHEAD BRINE

Date	12/17/76 mg/l	12/23/76 mg/l	12/29/76 mg/l
<u>Element</u>			
Sodium	37,500	37,500	37,800
Potassium	9,100	10,500	10,000
Calcium	21,400	21,300	20,800
Chlorides	131,000	131,000	131,000
Iron	285	265	295
Manganese	715	685	670
Zinc	225	210	175
Lead	56	27	34
Copper	0.3	0.5	0.5
Barium	150	145	135
Silicon	215	245	240
Magnesium	130	150	115
Strontium	---	---	440
Lithium	---	---	180
Sulfate	---	17	5
Boron	---	---	290
TDS	---	---	219,000

TABLE 3-5
MAGMAMAX NO. 1 FLUID WITH CONDENSATE REINJECTION

Date 11/1/76

<u>Element</u>	Wellhead Brine mg/l	1st Stage Out mg/l	2nd Stage Out mg/l	3rd Stage Out mg/l	Reinjection * mg/l
Sodium	37,500	41,300	45,800	46,800	37,500
Potassium	10,100	10,600	11,100	11,500	9,100
Calcium	21,500	23,500	25,400	26,200	20,800
Chloride	134,000	151,000	156,000	162,000	129,000
Iron	290	315	350	355	280
Manganese	650	745	790	840	645
Zinc	215	240	225	225	210
Lead	42	70	67	67	47
Copper	0.7	0.9	1.1	1.1	0.7
Barium	160	165	175	160	140
Silicon	260	230	265	260	195
Magnesium	130	135	155	165	130
TDS	216,000	238,000	264,000	270,000	190,000

*Includes some unknown amount of fluid from brine pond.

TABLE 3-6
MAGMAMAX NO. 1 FLUID WITH NO CONDENSATE INJECTION

Date 12/30/76

<u>Element</u>	Wellhead Brine mg/l	Reinjection mg/l
Sodium	38,800	47,500
Potassium	10,300	11,900
Calcium	21,600	26,000
Chloride	131,300	156,000
Iron	265	315
Manganese	640	795
Zinc	200	240
Lead	35	62
Copper	0.6	1.0
Barium	135	150
Silicon	235	155
Magnesium	160	205
TDS	217,000	265,000

Woolsey Fluid

Woolsey fluid contained the same elements as Magmamax fluid, but the elemental concentration in the Woolsey fluid was lower. (See Tables 3-7, and 3-8). Generally, the sodium, calcium, potassium, and chloride ratios of the Woolsey fluids were similar to those of Magmamax. However, the levels of some of the heavy metals such as iron, manganese, and lead, were lower in the Woolsey fluids. The Woolsey fluid did not appear to be saturated with silicon as is the Magmamax fluid. Thus the silicon appears to remain in solution throughout the GLEF (Table 3-8) rather than precipitate as it did with Magmamax fluid (Tables 3-5 & 3-6). Both Woolsey and Magmamax fluids had about the same concentration of barium and appeared to be barium saturated. This indicated that 140 to 175 mg/lit might be the solubility limit of barium in these brines. Composition of the Woolsey brine, once flowing, remained constant during the test (Table 3-7).

Scale - Magmamax Fluid

During the November 8 and 9 inspection a new scaling mode was observed in the "1 B" separator. The scale was composed of lead, probably as lead sulfide,

TABLE 3-7
WOOLSEY WELLHEAD BRINE

<u>Element</u>	10/28/76* mg/l	11/30/76 mg/l	12/2/76 mg/l	12/13/76 mg/l
Sodium	30,000	30,000	30,000	30,000
Potassium	7,300	7,400	7,450	7,800
Calcium	18,000	18,000	19,000	18,000
Chloride	105,000	107,000	107,000	107,000
Magnesium	385	270	250	290
Iron	75	70	67	71
Manganese	360	400	400	395
Copper	0.4	0.4	0.3	0.5
Zinc	105	54	105	91
Lead	26	28	26	22
Silicon	150	170	125	130
Barium	140	140	125	125
Lithium	145	---	---	---
Strontium	350	---	---	---
Sulfate	7	5.6	---	7.0
Ammoniacal Nitrogen	305	---	---	---
Conductivity	350,000	---	---	---
pH	5.80	---	---	---
ORP	-82	---	---	---
TDS	---	187,000	180,000	181,000

*Sample Taken shortly after well was first flowed.

TABLE 3-8
WOOLSEY FLUID WITH NO CONDENSATE INJECTION

Date 11/29/76

<u>Element</u>	1st Stage Out mg/l	2nd Stage Out mg/l	3rd Stage Out mg/l	Reinjection mg/l
Sodium	30,000	32,500	33,000	33,800
Potassium	1,080	8,020	8,550	8,500
Calcium	17,700	20,000	20,000	20,500
Chloride	105,000	113,500	119,000	121,700
Iron	85	140	75	50
Manganese	395	475	455	445
Zinc	125	130	115	110
Lead	32	26	30	32
Copper	0.7	0.7	0.6	0.7
Barium	135	135	155	145
Silicon	145	130	150	175
Magnesium	265	265	310	305
TDS	181,000	200,000	208,000	215,000

and silica and was observed in the drain line leading to the second stage separator. Scale thickness was approximately 15 mm. No scale deposition of this magnitude has ever been found in this line during previous shutdowns. The only cause, since the brine composition did not change, must be a difference in some operating procedure. So far no operation change that could cause this increase in scaling has been discovered. Severe scaling was also observed in the brine drain and reinjection lines. A detailed report describing the scale found during the November 8-9 inspection is included in Appendices A & B.

Scale - Woolsey Fluid

Woolsey geothermal fluid produced scale similar to that from Magmamax fluid (Table 3-9). However, due to the lower concentration of heavy metals, silicon and other scaling elements, much less scale was observed in the vessels and lines. In the first stage, lead, probably as lead sulfide, again predominated. However, very little scale adhered to the vessel wall with most of the solid material observed as a sludge on the vessel floor. This sludge was 78% lead, equivalent to 95% lead sulfide, and was probably formed during the time the plant was operated with a low liquid level in

TABLE 3-9
WOOLSEY SCALE

Date 12/6/76

	1st Stage Separator	2nd Stage Separator	3rd Stage Separator	4th Stage Separator	P-2 Discharge Line
Color, Form	Silver Gray Sludge	Black, yellow Red	Black	Underlayer Rust, White Yellow, Tan	Black under layer, green Tan
Thick- ness	Varies	5-6 mm	5 mm	3-4 mm	2-3 mm
<u>Element</u>					
Iron	0.34%	15.80%	10.30%	15.00%	3.05%
Copper	0.21%	0.21%	0.31%	0.16%	0.56%
Zinc	0.04%	0.58%	0.28%	0.33%	0.10%
Manganese	0.03%	1.45%	0.53%	0.60%	0.14%
Lead	77.63%	6.45%	1.84%	1.45%	7.63%
Calcium	0.36%	1.37%	1.47%	0.88%	0.48%
Aluminum	0.13%	0.58%	0.45%	0.42%	0.50%
Silicon (vs SiO ₂)	2.00% 4.30%	18.64% 39.89%	26.36% 56.40%	22.00% 47.00%	16.82% 36.00%
Barium	0.29%	0.34%	2.29%	3.71%	1.26%
Magnesium	0.07%	0.66%	0.39%	0.26%	0.17%
Sodium	0.23%	2.10%	1.95%	0.09%	0.18%
Carbonate	ND	ND	ND	ND	0.15%
Sulfur	12.00%	2.00%	1.50%	3.50%	5.65%

ND - Not Detected.

the separator. The lead content of the scale, as with Magmamax fluid, decreased through the plant until a high velocity flow is encountered, e.g., in the injection pump, (Table 3-9). As with Magmamax fluid, silicon increased in concentration through the plant. Table 3-9 represents analyses of samples taken from the separators and reinjection pump during the inspection of December 6. A detailed description of the vessel condition is presented in Appendix E.

An unusual amount of barium was observed in the scale deposited in the second and third stage separator, (Table 3-9). The cause of this increase in barium was not clear. A large quantity of surface (irrigation) water, estimated to be 30,000 gallons, was initially injected into Woolsey No. 1 in an attempt to induce flow. It was possible this surface water, which contains significant amounts (approximately 350 ppm) of the sulfate ion, reacted with the barium in the geothermal brine to form an insoluble barium sulfate. This insoluble sulfate could be the source of the barium found in the second and third stage separator.

Injection Well Plug

During the November 9th shutdown and inspection

an attempt was made to remove a deposit of scale and particulates that had recently been observed in the reinjection well, Magmamax No. 3. The deposit was observed to start at a depth of 2780 feet. It was removed by bailing. The first portion of the deposit was quite firm. However, either due to the action of the bailer or the natural condition of the deposit, it had a very soupy appearance at lower depths.

Samples were taken of the material removed from the well. Analyses of the materials and their approximate depths are given in Table 3-10. The major constituents of this material were iron and silica. The last sample was very liquid and contained a large amount of trapped brine. Due to the small quantity of sample involved and its fine particulate nature, this last sample was not washed, and the sodium content appeared higher.

No real trend other than a steady increase in barium was observed. The concentration of this element may be related to the quantity of canal water pumped into the well since no similar concentration of this element had previously been found in the plant scale. It is postulated that the sulfate ions in the canal water will react with the barium in the geothermal

fluid to form an insoluble barium sulfate. Although the exact amount of canal water injected into Magmamax No. 3 is not known, attempts have been made in recent months to minimize the amount of canal water injected. This recent limitation on the amount of canal water injected might account for the smaller quantity of barium observed in the top, and last deposited portion, of the plug.

The deposit material, by physical appearance, seemed to be pieces of scale removed from the plant and a solid slurry of fine particulate matter mixed together. The size of the particles was observed to be smaller at the lower depth.

3.4 Purge Water

The purge water system contained the same elements as reported in previous bi-monthly reports. Dissolution of carbon dioxide with the formation of carbonates still posed a problem where purge water and calcium bearing fluids mix. Since the fourth stage steam condensate is used for purge water, purge water composition may be determined from Tables 3-1, 3-2. & 3-3. It has been proposed that the purge water be acidified to help prevent formation of carbonate scale.

Recently, a one normal solution of inhibited hydrochloric acid was fed to the bearings of P-9, the condensate pump, when the pump began seizing. After, approximately 4 gallons were drawn through the pump, the pump shaft spun easily. Thus, if a mildly acidic purge water, pH 4 to 5, were continuously pumped through the system carbonate scale problems should be reduced.

3.5 Vent Gas System

The gas from Magmamax No. has approximately the same composition as reported previously. Sample bombs were purged carefully and kept hot until the sample could be analyzed. The results of this improved technique are presented in Table 3-10. No oxygen was observed and less nitrogen was found.

A gas analysis from Woolsey No. 1 is also presented in Table 3-11. Both oxygen and nitrogen were observed. Unfortunately, this gas analysis was not done on site due to a malfunction of the on-site laboratory gas chromatograph. The valves on the gas sample bomb were found to be unreliable when the bomb was heated for analysis and may have allowed contamination of the sample. However, the analysis did indicate the well gas from Woolsey was quite similar to that found in Magmamax.

TABLE 3-10
COMPOSITION OF SOLIDS
from
MAGMAX NO. 3 CLEANING

Date 11/11/76

Well Depth, Feet	2780	2810	2840	2900*
<u>Element</u>				
Iron %	13.56	13.56	11.58	11.30
Copper %	0.06	0.13	0.07	0.07
Zinc %	0.15	0.13	0.17	0.18
Manganese %	0.61	0.73	0.93	0.86
Lead %	0.27	0.18	0.29	0.36
Calcium %	3.97	2.97	3.87	4.64
Aluminum %	0.06	0.06	0.09	0.09
Barium %	1.10	2.10	3.00	4.50
Silicon % (as SiO ₂)	11.90	13.81	13.81	10.95
Magnesium %	0.67	0.50	0.44	0.45
Sodium %	4.38	4.63	4.88	8.12
Carbonate %	ND	0.2	1.0	1.7
Sulfur %	1.80	1.60	1.65	1.15

ND - Not Detected

*This sample not washed to remove excess brine.

TABLE 3-11
GAS ANALYSIS

Date 12/21/76

Magnamax Fluid

Sample from 1st Stage Separator
%

Carbon Dioxide	98.14
Methane	0.68
Nitrogen	0.02
Oxygen	*ND
Hydrogen	*ND
Hydrogen Sulfide	0.18

Woolsey Fluid

Date 12/2/76

Carbon Dioxide	95.3
Methane	1.3
Nitrogen	1.6
Oxygen	0.5
Hydrogen	1.2
Hydrogen Sulfide	0.05

*ND - None Detected.

3.6 Cooling Water System

During most of this test period, the steam condensate was directed to cooling water system. This procedure has not caused any significant change in the dissolved solids content of the cooling water pond. Only steam condensate from Woolsey and Magmamax (no surface water makeup) was added to the cooling pond. No appreciable rise in pond level has been observed and it appeared the condensate addition balanced the loss due to evaporation. However, because of the previous pond contamination with brine it is recommended that the condensers be inspected prior to changing to isobutane as the binary fluid.

3.7 Binary Loop

The pH of the distilled water in the binary loop was still somewhat lower than desired. Even with the addition of cyclohexylamine, a volatile neutralizing chemical, the pH could not be brought above 6.9. The system's pH without cyclohexylamine addition was 6.3. The persistently lower pH was attributed to rapid loss of the cyclohexylamine to the vacuum system. Oxygen was controlled with hydrazine. No large amount of iron oxide had been detected, therefore, corrosion appears minimal.

3.8 Conclusion

Of special interest during this past operating period was the flowing of Woolsey No. 1. Fluid from this well was similar, but less concentrated than that from Magmamax No. 1. Woolsey contained a lower concentration of scaling elements than Magmamax, however, its temperature and pressure were also less than Magmamax No. 1. The quality of steam produced by both wells was quite similar and presented no problem to the steam and condensate systems. Good quality steam, containing less than 10 ppm of sodium, was still being produced by the system. The flowing of condensate to the cooling water system appeared to present no problem of overflow or total dissolved solids buildup in the cooling water pond. Magmamax No. 1 has not changed in composition significantly (within sampling and analytical technique error) since plant start up in May.

4.0 SPECIAL PROBLEMS

4.1 Brine ReInjection Pump

4.1.1 Introduction

This section of the report summarizes the operation and maintenance of the brine reinjection pump at the GLEF during November and December, 1976. It discusses the bearing modifications and material tested during this time.

Conclusions are drawn regarding the recommended modifications of the shaft bearing material design.

4.1.2. Summary

The brine reinjection pump, P-2, operated for an approximate total of 871 hours during November and December. During these months the brine reinjection pump took its suction from the 4th stage separator and reinjected brine to Magmamax No. 3. Performance of the pump was satisfactory, with discharge pressure at about 500-530 psig and temperature at 220°F.

Three bearing materials were evaluated during this period. These materials were SAE 660 bronze, G-10, which is an epoxy laminated material, and Nylon 6/6 materials. At all bearing locations, the shaft was coated with aluminum oxide.

Lubrication of the bearings with purge water, from the 4th stage scrubber, was used continuously. Each bearing was fed with purge water through individual lines at 50 to 80 gallons per hour.

Results of the testing of the bearings during November and December indicated that SAE 660 bronze material was by far the most satisfactory material for the brine reinjection operation. Both G-10 and Nylon 6/6 materials were unable to sustain long term exposure to the bearing loads, adverse fluid characteristics and high temperatures.

4.1.3 Operation - November 1 through November 8, 1976

This test run was the continuation of a test which was initiated on October 26. Prior to the start-up, all injection pump bearings, but two, were replaced. The G-10 bearings, of an epoxy laminated material, were installed for all but the spider bearing and the suction

bell bearings which were SAE 660 bronze. The G-10 bearings, which had been tested in the brine sump pump for over 300 hours, appeared to be a potential candidate for the reinjection pump. Table 4-1 shows the G-10 material specifications. The bearing design is shown in Figure 4-1. It was machined in two sections to admit and hold more flushing or purge water in intimate contact with the shaft. It also eliminated a "wiping" edge which tended to "pick up" brine scale particulates as the shaft rotated.

The shaft was 17-4 PH material. Tables 4-2 gives the chemical analysis. The shaft was enlarged from 2 3/16 inch diameter to 2 1/4 inch diameter which eliminated machining. At all bearing locations, the shaft was coated with 10 mils of ceramic (aluminum oxide).

4.1.4 Maintenance Inspection - November 8, 1976

The brine reinjection pump was removed and shipped to the SDG&E Machine Shop for disassembly and inspection. All G-10 bearings were badly scored (Figure 4-2); the spider bottom suction bell bearings were in good condition. All G-10 bearings were replaced with Nylon 6/6 bearings. The two bronze spider & suction

**MODIFICATION NO. 3.
SHAFT-BEARING (TYPICAL) SECTION
BRINE INJECTION PUMP**

FIGURE 4

FIGURE 4-2

TABLE 4-1

Physical and Mechanical Properties of G-10

Reinforcement	Glass Fabric
Density (grs./cc)	1.84
Charpy Impact Strength (ft.-lbs.)	1.85
Water Absorption (%)	.03
Axial Compressive Strength (1000 psi)	80.0
Tensile Strength (1000 psi)	44.0
Flexural Strength (1000 psi)	71.0

TABLE 4 - 2

CHEMICAL ANALYSIS OF 17 - 4 PH SHAFT

Description & Specifications	Size
17 - 4	2-4" RD

CHEMICAL ANALYSIS

C	.048
Mn	.36
P	.026
S	.011
Ag	.67
Ni	4.26
Cr	15.75
Cu	3.20
Cb	.28
Ta	.01
Fe	75.39

100%

bell bearings were reinstalled. Table 4-3 shows physical and mechanical properties for the Nylon 6/6 material. The bearing configuration, used in the previous test was utilized once again.

4.1.5 Operation - November 23 through December 5, 1976

On November 23, the brine reinjection pump was returned to operation with two bearing materials, Nylon 6/6 and SAE 660 bronze. The supply of geothermal fluid to the facility was from Woolsey No. 1. The pressure at the pump suction was between 15.0 psia and 13.0 psia and a corresponding temperature of 212°F. to 200°F. respectively. The brine total dissolved solids was about 200,000-205,000 ppm. The pump discharge flow averaged 230,000 lbs./hr. On December 5, 1976, a high pitch noise was observed in the motor. The plant was shut down for a thorough inspection of the pump and the motor. Throughout the entire run, the pump operated smoothly without trouble.

4.1.6 Maintenance Inspection - December 6, 1976

The bearings in the reinjection pump motor were excessively worn. Both sets, one at each end of the motor was replaced with identical bearings. The

TABLE 4-3

Mechanical Properties of Nylon 6/6

Property and Test Method	Nylon 6/6
Impact Strength	1.0-2.0
Notched Izod (1/2" x 1/2" Notched Bar)	
ASTM-D-256	
Tensile Strength	9000-12000
ASTM-D-638 & 651	
Tensile Modulus	1.75-4.15
ASTM-D-638	
Elongation	60-300
ASTM-D-638	
Flexural Yield Strength	No Break
ASTM-D-790	
Flexural Modulus	1.75-4.1
ASTM-D-790	
Compressive Strength	6700-12,500
ASTM-D-695	
Compressive Modulus	--
ASTM-D-695	
Heat Deflection Temp.	150°-220°
@264 PSI Fiber Stress	
ASTM-D-648	
Heat Resistance Continuous	180°-300°
Thermal Expansion	8.0
ASTM-D-696	
Thermal Conductivity	5.85
ASTM-C-177	
Rockwell Hardness	R108-R120
ASTM-D-785	
Specific Gravity	1.14
ASTM-D-792	

Trade Names an/or Resin Manufacturers

DuPont
Zytel
Celanese Corp.
Monsanto
Allied Chem.
Corp. Capran
ICI Maranyl

top motor bearing is an open thrust bearing with bronze retainer. The bottom motor bearing is an open roller bearing with steel retainer. This was the first time since the start of the GLEF that such replacements were necessary. The Nylon 6/6 bearings in the pump were badly worn (Figure 4-3). The top and bottom bronze bearings were in excellent condition. Therefore, all pump bearings were replaced with SAE 660 bronze bearings. Three different types of coatings were applied to the shaft journals. These were aluminum oxide for the top two and bottom as well as No. 4 and 5 bearings, aluminum bronze coating at the No. 6 and 7 bearings and chromium carbide at No. 2 and No. 3 bearings. (The bearing locations are numbered from the bottom up). The pump was in service on December 9, 1976.

4.1.7 Operation - December 10 through December 31, 1976

Throughout this period, the brine reinjection pump operated with all bronze bearings. From December 10 through December 14, the supply brine was from Woolsey No. 1. For the rest of the operation period, Magmamax No. 1 was used as the supplying well. Operation of the brine reinjection pump was very satisfactory. Continued operation of this pump should further confirm the compatibility of the SAE 660 bronze bearings.

FIGURE 4-3

4.1.8 Conclusions

During November and December 1976, all operating conditions of the reinjection pump were within the manufacturer's specifications.

The operation of the purge water system to the bearings and to the mechanical seal was satisfactory and will be continued in future operations.

Since the start up of the GLEF operation in May, 1976, several bearing materials were tested in the brine reinjection pump. These materials were: SAE 660 bronze, SS 416 hardened to Rockwell C-60, carbon bearings, Tungsten Carbide-Cobalt alloy, Teflon with 15% carbon fill, G-10, and Nylon 6/6 bearing materials. From these materials, SAE 660 bronze proved to be the most promising to date. It appears to have the correct hardness that is compatible with the bearing loads, the ceramic coating and the reinjected brine. This conclusion was drawn after repeated test runs and will be further confirmed by continued operations.

While these findings are significant and encouraging, they would not preclude tests of other bearing materials in the future. The test results of

SAE 660 bronze has established a datum against which other bearing materials can be evaluated under similar operating conditions.

4.2 Vacuum Pump

4.2.1 Introduction

The purpose of the Vacuum pump, VP-1, at the GLEF is to maintain vacuum at the fourth stage of the facility where geothermal brine is flashed to produce steam at 13.0 psia. It also provides a means to eliminate the noncondensable gases in the accumulator. Also, it can be used to draw vacuum in the binary loop when charging or draining the isobutane system.

This section presents a detailed description of the pump design and installation, operating conditions and performance. It summarizes the operation and maintenance of the pump.

4.2.2 Pump Description

The vacuum pump is a single stage, liquid ring vacuum pump, manufactured by Kinney Vacuum Company, a division of General Signal Corporation. This pump is

located at the north end of the GLEF adjacent to the condensate accumulator (V-13) from which it takes suction (Figure 4-4). A 3" line connects the vacuum pump to the V-13. A control valve on the line is used to maintain a vacuum of 6" of mercury in V-13 (Figure 4-5).

A manufacturer's drawing of the pump is shown in Figure 4-6. Total length of the pump is 38 5/8" and the width is 16 5/6". The pump casing is cast iron, the shaft is stainless steel and the impeller is carbon steel. The manufacturer's specification gives the capacity head as 360 ACFM at 5" of water vacuum and 250 ACFM at 125" of water vacuum. A 25 HP, 220 volts motor by Reliance is hardcoupled to the pump which rotates at 1765 rpm.

The vacuum pump was installed on a base supplied by the manufacturer along with a gas/liquid separator (Figure 4-7) which receives the pump discharge.

4.2.3 Operations and Maintenance

Figure 4-8 shows the cross-section of the vacuum pump. When the pump is operating, a continuous

- REFERENCE DRAWINGS**
- 7429-3200-PD-20
 - 7429-3200-PD-20A
 - 7429-3200-PD-21
 - 7429-3200-PD-22
 - 7429-B-100
 - 7429-B-101 SHTS. 1 & 2
 - 7429-B-102
 - 7429-B-105
 - 7429-B-132
 - 7429-B-133
 - 7429-B-134
 - 7429-B-154
 - 7429-B-155
 - 7429-B-188
 - 7429-B-189
 - 7429-B-200
 - 7429-B-201
 - 7429-B-202
 - 7429-B-203
 - 7429-B-212

REV.		SAN DIEGO GAS & ELECTRIC COMPANY GEOTHERMAL TEST FACILITY	
		Vacum Pump System	
		DWN: PLS	SCALE: —
		DATE: 11-03-75	

FIGURE 4.

FIGURE 4-5

1	End Casing	2	23	Tie Rod and Nuts	8
3	Intermediate Side Plate D.E.	1	24	Screw	8
6	Intermediate Side Plate N.D.E.	1	25	Plug	9
7	Impeller D.E.	1	27	Screw	4
8	Impeller N.D.E.	1	28	Manifold	1
9	Impeller Casing D.E.	1	29	Lantern Ring	2
10	Impeller Casing N.D.E.	1	30	Spacer	1
11	Shaft	1	31	Impeller Lock Nut	1
12	Bearing Housing	2	33	Screw	4
13	D.E. Bearing Cover	1	34	Screw and Nut	12
14	N.D.E. Bearing Cover	1	38	Dowel Pin	4
15	Gland Studs and Nuts	4	39	Grease Cup	2
16	Gland Ring	2	40	Gland Harness	1
17	Bearing (FAFNIR 308W)	2	43	Intermediate Casing	1
18	Spacer	1	44	Intermediate Side Plate D.E.	1
19	Impeller Key, D.E.	1	45	Intermediate Side Plate N.D.E.	1
20	Impeller Key, N.D.E.	1	46	Spacer	1
21	Gland Packing (two glands)	1	47	Tab Washer	1
22	Bearing Lock Nut	1		Not Shown Gaskets (in sets)	1

Single Stage Pump Model KLR-360

FIGURE 4-7

Cross Section Showing Liquid Ring.

flow of purge water from P-7A enters the pump and forms a seal between the impeller and the casing. The impeller is off-set above center of the casing. As the pump rotates, the pumping action occurs in the space between the impeller and casing by filling and emptying similar to a reciprocating compressor. Gas inlet and discharge ports are positioned to draw gas into the cavity during the expansion segment, and discharge gas along with some liquid during the compression segment. The discharge liquid is recovered and recirculated through the gas/liquid separator.

The vacuum pump was placed in service on May 3, 1976. It takes its suction from the condensate tank, V-13, and maintains a pressure of 6" mercury vacuum at V-13. The pressure in the fourth stage separator would be about 13.0 psia. Therefore, when the operation of the vacuum pump is interrupted, vacuum is lost and the geothermal brine in V-13 will be flashing at atmospheric pressure. Although this will not cause a shut down of the GLEF operation, it alters the operating parameters of the flash/binary process in the fourth stage.

Routine maintenance was performed on the pump whenever the plant was shut down for maintenance inspec-

tion. This included cleaning of the pump shaft, impeller, replacing mechanical seals and changing worn-out bearings.

The mechanical seal was originally designed to operate without the use of cooling water. The mechanical seals were replaced with packing and glands to minimize maintenance. The packing was supplied with cooling water from the cooling pond. This arrangement has operated with less maintenance than previous operation with mechanical, carbon face seals.

During a maintenance inspection on October 5, 1976, a new Fafnir 308W bearing was installed at the motor drive end and a Koyo Ball bearing was used at the other end. These were identical to the old bearings.

On December 15, 1976, the shaft of the vacuum pump was broken at the center bearing key way. It was replaced with the same material and returned to service. The manufacturer of the pump indicated this failure was a chronic problem which they could not explain. Therefore, a new pump, manufactured by Nash Pump Company, was ordered. Operations will continue with the repaired Kinney pump until the Nash pump can be installed.

4.3 Condensate Pumps P-9

4.3.1 Introduction

This section covers the operation and maintenance of the condensate pump, P-9, during November and December 1976. Much of the discussion of this pump has been presented in the November, 1976 bi-monthly report. Therefore, only enough information for continuity will be discussed here.

4.3.2 Operation and Maintenance

Condensate pump, P-9 takes its suction from the 4th stage scrubber. On November 1, 1976, high pitch noises were heard in the pump. P-9 was shut down and inspected. Excessive clearances between the SS316 shaft and the bronze bearings were observed. All bearings to the shaft were replaced. P-9 resumed operation on November 3, 1976.

On December 17, the same problem was indicated with the bronze bearings and shaft clearances. No interruption of plant operation occurred since the condensate pump, P-10, was utilized to pump the 4th stage steam scrubber drains.

The repaired pump was returned to service on December 19, 1976. On December 21 and December 23, P-9 tripped off. The shaft was frozen (could not be turned) due to scale deposits between the impeller and bowl. The scale was black in color and consisted mainly of calcium and iron carbonates. The amount of scale which closed the bearing and shaft clearances apparently had created a drag force large enough to overload and trip the motor. The same problem happened again on December 23, 1976.

Fortunately, the scale was readily soluble in a solution of 1 part of hydrochloric acid and 8 parts of water. Within 2 to 3 minutes, the scale was dissolved and the pump was back to service in 3 or 4 hours.

Since December 23, 1976, P-9 was operated successfully without any problem.

5.0 DATA MANAGEMENT

5.1 Data Acquisition

Data management for the GLEF consists of two main components: data acquisition and data reduction. The former includes the recording of plant operating parameters at critical locations of the plant as well as chemical data from geothermal brine and steam, binary fluid, and scaling samples, etc. Two means of data collection are used at the GLEF: a.) the hand logging of data and b.) the electronic data logging system. These two systems are redundant for most data points. Therefore, should either one system fail to record data, vital statistics of plant operation will still be available.

The hand logging of data has been performed since the start up of the GLEF in May, 1976. Appendix F shows the data entry for this method of recording. The electronic data logging system was briefly described in the September and November 1976 Bi-monthly reports. Upon the completion of the installation, a more detailed description of the system will be presented including the operation of the data system.

During November and December, 1976, all mechanical installations were completed. These installations were for the pressure and temperature transducers, differential pressure points and venturi flow elements. Also, electric conduits and junction boxes were completely installed.

The electricians have begun pulling the wire for power source and electric signals from the measuring devices. The Data Logger electronic hardware calibration was in progress.

It is expected that the entire data logging system will be ready for service by the end of January, 1977.

5.1 Data Reduction

Computer programs will process the raw data obtained by the data acquisition system into meaningful engineering correlations. The large amount of data recorded at the GLEF requires the application of computer data reduction. During November and December, 1976, SDG&E Data Systems devised computer programs to calculate a plant heat and material balance, as well as heat transfer coefficients for the heat exchangers. The results of these calculations will be included in the next bimonthly report.

About the same time Lawrence Berkeley Laboratory initiated the writing of computer software systems for both data storage/retrieval and data manipulation. Such computations will follow the Engineering Test Program of the GLEF (compiled by Bechtel Corporation, September, 1976), which is to be incorporated into the GLEF operation schedules in February, 1977.

All of these data reduction programs are to be refined as the GLEF operation progresses.

APPENDICES

APPENDIX A

SELECTED SCALE ANALYSIS FROM THE GLEF

The values contained in this report were selected from analysis of scales found within the GLEF. The scales do not represent any particular operational period, however, they were all collected after the November 7 shutdown. Common points and lines in and around the four separators were picked to present scaling trends, if any. Unfortunately, these scales are subject to sampling bias and most probably do not represent entire vessels or sections of pipe. Also included are analyses of scale found around the reinjection pump.

Stage to stage scaling trends are evident. There is an increase in silica from the first and second to third and fourth stages. Also iron decreases through the system. Generally lead decreases in concentration from the first to fourth stage, with sulfur content lessening also. Other assumptions can be drawn by observing the scale analyses.

The vortex breaker and brine outlet lines were picked for each vessel since they were all coated with scale and would be under approximately similar flow conditions during

operation. Generally, the scales are alike except for the lead content in the third and fourth stages. The lead is higher on the vortex unit than in the separator drain line.

Scale around the reinjection pump is quite different. On the suction side the scale is similar to that found in the fourth stage. However, in the pump pit and reinjection line the scale drops in silicon content and increases in carbonates. As can be seen, the manganese and calcium concentrations in the scale increase.

Also observed during the shutdown was a difference in scale thickness on the third stage separator drain line. The scale at the lowest point of the loop was approximately five times thicker than eight feet higher up the line. A shoulder was located approximately eighteen inches from the base of the loop which was approximately half the base thickness. The thickness measurements were, base 30 mm, after shoulder 15mm, top of section 6mm. The higher thickness of the base can be partially caused by brine sitting in the line with subsequent precipitation. Soft and hard layers within this scale lead to this conclusion.

Scale in the remainder of the plant was much like that experienced previously. High iron corrosion debris was found in the scrubbers. Brine lines into the separators contained little scale, and some corrosion products.

ELEMENT	1ST STAGE		2ND STAGE	
	VORTEX BREAKER	OUTLET LINE	VORTEX BREAKER	OUTLET LINE
Color	black	black, olive	black	black
Thickness	20-30mm	15-30mm	1-5mm	2-4mm
Iron	12.71%	16.01%	16.67%	12.15%
Copper	0.03%	0.07%	0.61%	1.92%
Zinc	0.04%	0.06%	0.09%	0.07%
Manganese	1.29%	1.43%	1.93%	1.86%
Lead	18.05%	18.05%	1.67%	4.86%
Aluminum	0.67%	0.80%	0.78%	1.25%
Silicon	11.74%	13.91%	23.48%	23.48%
Barium	* ND	* ND	* ND	* ND
Magnesium	0.46%	0.51%	0.20%	0.10%
Carbonate	* ND	* ND	* ND	* ND
Calcium	2.07%	0.87%	1.00%	1.43%

* ND implies none detected.

ELEMENT	3RD STAGE		4TH STAGE	
	VORTEX BREAKER	OUTLET LINE	VORTEX BREAKER	OUTLET LINE
Color	black, red	black	grey, yellow brown	black
Thickness	10-15 mm	15 mm	150 mm	10-15 mm
Iron	2.18%	1.18%	3.95%	4.34%
Copper	0.08%	0.97%	0.50%	0.43%
Zinc	0.06%	0.07%	0.50%	0.11%
Manganese	0.29%	0.22%	0.93%	0.64%
Lead	5.93%	0.49%	9.87%	0.28%
Calcium	1.07%	1.19%	0.81%	0.94%
Aluminum	0.08%	0.12%	*ND	0.12%
Silicon	36.52%	36.11%	36.57%	36.57%
Barium	0.05%	*ND	0.31%	0.15%
Magnesium	0.08%	0.06%	0.04%	0.06%
Carbonate	*ND	*ND	*ND	*ND

* ND implies none detected.

REINJECTION PUMP

ELEMENT	SUCTION LINE	SUCTION PIT	DISCHARGE	REINJECTION SPOOL
Color	grey-green	black,yellow	black,yellow	green,black
Thickness	10-20 mm	1-5 mm	10mm	15-20mm
Iron	3.61%	2.97%	3.25%	3.11%
Copper	0.30%	0.07%	0.11%	0.12%
Zinc	0.63%	0.98%	1.03%	0.70%
Manganese	0.80%	4.54%	4.97%	3.70%
Lead	0.57%	1.01%	0.33%	0.82%
Calcium	1.08%	15.14%	17.30%	10.97%
Aluminum	*ND	*ND	0.36%	0.06%
Silicon	36.67%	16.67%	11.43%	14.76%
Barium	0.05%	0.10%	0.20%	0.37%
Magnesium	0.01%	0.01%	0.07%	0.04%
Carbonate	*ND	28.6 %	29.6 %	18.5 %

* ND implies none detected.

THIRD STAGE SEPARATOR BRINE OUT LINE

ELEMENT	BASE OF LOOP, CUT SECTION	TOP OF CUT SECTION
Color	Multi-layered black, gray	multi-layered black, gray
Thickness	30mm	6 mm
Iron	14.00%	7.75%
Copper	0.46%	0.52%
Zinc	0.05%	0.08%
Manganese	0.49%	1.46%
Lead	0.56%	0.83%
Calcium	1.75%	1.29%
Aluminum	0.12%	0.12%
Silicon	30.48%	30.00%
Barium	0.23%	0.05%
Magnesium	0.08%	0.06%
Carbonates	-	-
Moisture	34.4 %	22.66%

APPENDIX B

FLASH VESSEL INSPECTION 8 & 9 NOVEMBER, 1976

TEST RUN ENDING 7 NOVEMBER, 1976

I. First Stage Flash:

A. Floor below water line

Constant solid black scale, no silver color found in this inspection. There was a pile of broken scale debris approximately 1 meter long, 75 cm wide and 15 cm deep lying in the center of the vessel, just aft. of the pit.

In the pit itself there was a similar pile of debris built up at the back to approximately 15 cm tapering off at the front to about 4 cm. The drain hole did not appear to be completely closed off this time. A fair estimate of the debris in comparison with the previous inspection would be that present amount is approximately 10% of the previous concentrations.

The vortex breaker in the discharge line had a build up of hard black scale which restricted the opening.

B. Side walls above water line and ceiling

The thickness of the side wall scale has increased from a previous 0.5 mm to 2-5 mm in thickness. It appears, however, to have formed a more permanent bond with the wall.

CONCLUSION:

The first stage shows little sign of increased wear. The scale though thicker seems to be holding longer prior to break up. The walls show little sign of wear. No pitting,

The steam outlet shows little sign of wear.

The drain pit did not show debris build up to be as big a problem this time.

However, there was a large build up of scale in the brine outlet line just before the Posi-Seal isolation valve. This had not been a problem before. The valve itself was coated with a hard black scale and had begun to leak around the plate which covers the valve stem at the bottom of the valve. Scale build up at the Posi-Seal valve in the line was 1.5-2 cm in thickness.

1. Vortex breaker restricted by 2-3 cm of hard black scale.

2. Drain pit containing 4-15 cm hard black scale debris.
3. Pile of scale debris on floor 1 meter by 75 cm by 15 cm in thickness.

II. Second Stage Flash:

A. Floor below waterline

Floor covered with hard black scale nearly identical to the first stage 1-6 mm in thickness. This scale is multi-layered.

There is a debris pile extending from the inlet pipe increasing from approximately 4 cm in depth to approximately 15 cm at the center of the vessel then tapering off as it approached the outlet pipe. Very little scale build up on the outlet pipe. Scale in this area is 0.5 - 20 mm. The thermometer well was covered completely.

B. Walls above waterline and ceiling

Scale in this area is multi-layered 2-5 mm in thickness. One distinct layer is forest-green in color. Scale tends to separate at this layer. This scale is very hard and brittle and is subject to cracking and falling with the heating and cooling of the vessel.

The color inside is uniform black with slight greyish color along water line.

The steam line out shows little if any increased pitting.

The brine inlet line had a build up of carbonate scale approximately 10 cm thick on the upper surface. This is localized and is directly beneath the cascade inlet line.

The inlet line support brace shows no increase in deterioration.

Dwg No. 3

1. Side wall- This area has the largest accumulating of green scale.
2. The inlet pipe support shows no increase in deterioration.
3. Pile of debris maximum depth of 15 cm
4. Vortex breaker scale approximately 5 mm
5. Carbonate scale approximately 10 cm localized.

CONCLUSION:

The differences in scale formation are extreme. Previous scale was soft and varying in color. Present scale is hard

brittle and uniformly black.

The build up of carbonate scale on the inlet line indicates a cascade line condensate leak into the second stage separator.

Vortex breaker lacks the scale build up of the other three stages.

The vessel itself appears in excellent shape with no increase in wear. There is no visual evidence of chloride stress cracking.

III. Third Stage Flash:

A. Floor below water line

The floor was liberally covered with clumps of hard grey-black scale. This scale had a core of iron from the vessel wall. The iron core is 1-2 mm thick with a build up of approximately 0.5 cm on each side. The

texture is very porous.

The floor walls were coated with a uniform black scale approximately 2-5 mm thick.

The vortex breaker was coated with approximately 1-1.5 cm of hard black scale.

The thermometer well was closed off completely with scale by a hard crust over sludge which filled the thermometer well. The thermometer does not penetrate into the vessel.

B. Walls and ceiling above water line

As before, large amounts of rust and scaling are present. Debris on the floor indicates scale is falling as it reaches approximately 1-2 mm in thickness. Pitting itself has not increased.

The inlet support does not show an appreciable amount

of increased wear.

CONCLUSION:

There a possibility that the vessel was affected by its long shut down period where it was open to the atmosphere, and that subsequent shut downs and opeings have aggravated the situation.

It is difficult to determine the rate of vessel wear as there are no deep pits or pitting. Wear appears to be even.

Dwg. No. 4

1. Floor covered with scale
2. Heavy rusty scaling above water line.
3. Inlet support shows little increase in wear.
4. Vortex breaker shows 1-1.5 cm build up in scale.

IV. Fourth Stage Flash:

A. Floor below water line

Floor area was covered with soft olive sludge from 10 to 25 cm deep. Scale below water line appears uniform and unbroken, approximately 0.5 cm thick.

The vortex breaker was nearly closed off. The scale buildup was olive in color and resembled a cauliflower. Scale was semi-soft, hard in center approximately 15 cm thick. The openings were reduced to four holes approximately 4 cm in diameter.

B. Ceiling and walls above water line

The scale build up varied. On the inlet end the scale built up from the diffuser plate where it was approximately 1-2 mm to a curl of approximately 2-3 cm behind the inlet line.

The rest of the scale built to approximately 10 mm before breaking off. I'm not sure that this breaking off is continuous as there appears to be little or no scale of this type in the sludge which lines the bottom. It may, infact, occur only after shutdown during the cooling period.

CONCLUSION:

There is some evidence of rust which is probably from being exposed to the air after shutdown. The vessel

itself appears in excellent condition.

- Dwg. No 6
1. Inlet scale builds from diffuser plate and curls back. Manhole opening reduced by scale.
 2. Vortex breaker excessive buildup of scale reducing opening by greater than 50 %.
 3. Wall scale approximately 10 mm in thickness
 4. Soft sludge 10-25 cm thick.

CONCLUSION OF FLASH VESSEL INSPECTION:

1. The wear on vessels with the exception of the third stage appear minimal. It is possible that the third stage wear may be reduced by elimination of air from the vessels during lay up.

2. The scaling of Vortex breakers appears to be becoming a major problem.

Note that the second stage flash has nowhere near the accumulation of scale as do the other vessels.

There is one major difference in the brine outlet. In the second stage only, the outlet is flush with the floor. It is possible that this difference in flow pattern has reduced the scale buildup on the Vortex breaker and it may be beneficial to modify the remaining three vessels.

Consideration must also be given, however, to the scale which the raised section prevents from going through the suction line. Still this does not appear to be an immense problem with the second stage, as the debris distribution appears identical in all vessels.

V. Scrubbers

The scrubbers appear to be in very good condition with one exception; that is, the rust at all levels which has blocked the pruge trays throughout all vessels.

The scale build up in each vessel on bottom of drain level is as follows:

1st stage scale approximately 15 cm deep.

Does not close drain

2nd stage scale approximately 10 cm deep.

Fine texture scale completely closed the drain.

3rd stage scale approximately 4-5 cm deep.

Drain not closed.

4th stage scale approximately 4 cm deep.

Drain not blocked.

CONCLUSION:

1. I feel that the rusting and flaking of rust comes from the periods when vessels are open to the atmosphere.
2. The clogging of purge trays is therefore, inadvertently caused by the system being open to the atmosphere.

Solution:

- (a) Prevent air from entering into scrubbers.
- (b) Modify scrubber trays.

The debris appears to be entering the purge tray through the "V" shaped cuts in the outer wall.

Close off the "V" slots in one of the scrubbers. Force the water to go over the wall. This should exclude the scale.

APPENDIX C

NOVEMBER 8, 1976 SHUTDOWN
ACTIVITIES

INSPECTION

1. Open all separators, take scale samples, note condition of interior, clean out if necessary, take photographs and close vessels.
2. Open all scrubbers, take scale samples, note condition of interior, take photographs, clean if necessary and close vessels. All five trays in each scrubber.
3. Open vent gas system vessels, V-6 & - 6A, take scale samples, note condition of interior, take photographs, clean if necessary and close up.
4. Open condensate storage tank, note condition of interior, take photographs, clean if necessary and close up.
5. Pull reinjection pump, P-2, ship to Machine Shop for complete disassemble and inspection. F. L. Enos arrange with Marc Ortiz and Transportation Department. Machine Shop to reassemble, ship to GLEF site, reinstall pump/motor

assembly and test.

6. Pull condensate pumps ~~NAAMA~~ P-10, for inspection at site, take photographs, disassemble for inspection, clean (if necessary), reassemble pump(s)/motor(s) assemblies, reinstall and test.
7. Pull brine sump pump for inspection at site, take photographs, disassemble, clean(if necessary), reassemble pump/motor assembly, reinstall and test. Inspect sump.
8. Remove Du Pont pipe spools from injection line for inspection. If Du Pond representatives agrees, reinstall spools for further exposure. If not, reinstall present carbon steel spools.
9. Remove all brine level control valves (LCV's) except LCV-714 (3rd stage) for inspection, clean up if necessary, reinstall and check controls/actuation.

10. Remove pressure control valves PCV -300 & -301, disassemble, ship to Marc Ortiz (Machine Shop) for installation of shaft sleeves, reassemble with .020 inch ball-to-seat clearance, reinstall and check controls/actuation.
11. Inspect all brine system gate valves, clean if necessary, reinstall. Do not remove and inspect the brine injection system valves.
12. Remove the injection pump discharge check valve, take scale samples, photograph, clean and reinstall.

MAINTENANCE

1. Change lube oil in P-2, P-3, P-8, P-7 & P-7A pump motors.
2. Replace carbon steel float switch rod on sump pump with type 316 ss.
3. Tighten all steam orifice flange studs and nuts. Check gaskets first and replace if necessary.
4. Ream brine sample taps and pressure taps.
5. Remove brine system thermowells, inspect, clean and reinstall.
6. Complete painting and insulation repairs.
7. Remove level control valve (LCV-722) trim, inspect and clean, reinstall and check valve actuation.
8. Clean up debris at circulating water pump.
9. Remove stored material from northwest area of site and locate at north end of brine pond.

10. Remove brine system Posi-seal valves, ship to Marc Ortiz, Machine Shop, for sand blast.
11. Replace dirt on brine pond and compact.

PLANT ADDITIONS

1. Data Logger - Installation of pressure/temperature taps and Venturi meters by Jim Ames and crew. Dave K. Mulliner will be coordinating this work with Jim.
2. Install orifice flange sets in brine system. Connect orifice flange taps to existing differential pressure transmitters.
3. Install new C/W system blowdown flow meter.
4. Install 1" condensate fill line to tanks T-1 & T-2.

PLANT MODIFICATIONS

1. Straighten first stage separator, V-4, inlet line, hang this line for support. Reference drawing 7429-B-157.
2. Relocate thermowell on 3rd stage separator brine drain line to provide safe personnel clearance.
3. Brine pond- Move discharge lines to north end of pond.
4. Install 3" vacuum drag from brine pond to 4th stage separator and install check valve.

INSTRUMENT WORK LIST FOR SHUTDOWN

1. Recalibrate all instruments
2. Stroke all control valves
3. Retube supply and signal lines with stainless steel tube
4. Install and calibrate brine flow orifices

APPENDIX D

INTERNAL CORRESPONDENCE

FORM 115-6143C

FROM H. K. Bishop
TO C. R. Swanson

DATE December 2, 1976

FILE NUMBER CNB 300

SUBJECT SCALING CONFERENCE

A meeting was held on November 23rd at the GLEF Site to discuss the heavy scaling recently observed on the GLEF piping. Attending were representatives of SDG&E, Lawrence Livermore Laboratory (LLL), The Ben Holt Company and plant operators (see attached list).

During the last inspection of the GLEF, significant scaling in the brine lines between the first, second, third and fourth stage flash vessels as well as the injection lines within the plant boundary was observed. This scale reached the thickness of 1 1/2 inches in the injection line. None of these lines have been opened since the plant was constructed.

In an attempt to define possible causes of the scaling deposition, the plant operation since startup was reviewed. It was determined that the plant had been operated in six distinct modes and subjected to frequent stops and starts and loss of control during this period. Because of this, it is not possible to define what operations contributed most significantly to the scale formation.

LLL commented that their X-ray measurements of certain parts of the plant had not shown any significant scale deposition as of September. However, because of limited observations made, this was not considered conclusive evidence that substantial scaling could not have occurred prior to this time.

It was decided that rather than trying to determine the cause of scaling from the ambiguous data so far assembled, it would be better to start anew with a detailed program to evaluate scale formation. It was proposed that for the next six weeks, the GLEF would be operated in the following manner.

1. No water from the brine holding pond would be introduced into the fourth stage as it has in the past.
2. The first stage condensate will be sent to the cooling water pond via the first stage cooler.

3. The second and third stage condensate will be directed to the fourth stage scrubber and thence to the cooling water pond.
4. The first, second and third stage scrubber drains will be directed to the fourth stage flash drum.
5. On shutdown, all vessels and lines will be drained.

Concern was expressed by LLL over the introduction of the scrubber drains into the fourth stage flash drums. Gil Lombard discussed his concern about possible contamination of the cooling pond if the scrubber drains were introduced into this system. Also, because the scrubber drains constitute only approximately 3 percent of the total stream flow, their contribution to scaling is expected to be minimal. Chemical properties of the scrubber drains will be carefully monitored during the six-week test.

To determine the amount and composition of scale generated in this operating mode, removable sections of pipe have been installed in all brine lines between each flash vessel and in the injection line. These will be removed and inspected every 200 hours. It was also suggested that removable sections be placed in the injection line half way between the plant and the injection well (MagmaMax No. 3) and near MagmaMax No. 3. Initial observations indicate that injection line scaling is confined to the plant area, however, examination removable sections in the downstream injection lines will confirm this supposition.

Larry Owen of LLL postulated that scale decrease with distance in the injection line could be attributed to particle growth in the injection line. Initially small particles would adhere to the surfaces of the pipe. However, as particle size increased, the injection fluid flow would carry them down stream into the injection well without attachment to any surfaces.

No plans were made to clean any of the injection or brine lines between stages with the exception of the first stage which has already been cleaned. However, all removable sections will be cleaned at the beginning of this test.

LLL plans to provide assistance to this scaling test through their industrial support program. This will

December 2, 1976

include additional measurements of particulates (suspended solids) in the geothermal fluid and scale analysis. In addition, LLL plans to conduct evaluations of the acidification process which promises to reduce or eliminate scaling in the geothermal facility.

I expect to review this industrial support program as it applies to the GLEF with Larry Owen and Roland Quong during the formal geothermal review scheduled for December 14 through 16 at LLL. A final review by ERDA, SDG&E and conference participants is scheduled for December 21, 1976.

H. K. Bishop

HKB/vbw
Attachment

cc: J. R. Bricarello
F. L. Enos
K. K. Li
G. L. Lombard

1895

BRINE LINE SCALE DEPOSITION MEETING
NOVEMBER 23, 1976 10:00 am
GEOTHERMAL TEST FACILITY

<u>NAME</u>	<u>COMPANY REPRESENTED</u>
GEORGE TARDIFF	LAWRENCE LIVERMORE LABORATORY
HARRY BISHOP	SDG&E
KAMWAH LI	"
GIL LOMBARD	"
F. L. ENOS	WESTEC SERVICES, INC.
JOHN BRICARELLO	WESTEC " "
DAVE MULLINER	SDG&E
LARRY OWEN	LAWRENCE LIVERMORE LABORATORY
ROLAND QUONG	" " "
JACK MOONEY	WESTEC SERVICES, INC.
BEN HOLT	THE BEN HOLT COMPANY
A. J. HUTCHENSON	" " " "
GEORGE VISBAH	" " " "

APPENDIX E

M A. R. Gonzalez

DATE December 8, 1976

G. L. Lombard/H. K. Bishop

FILE NUMBER CNB 300

ECT FLASH VESSEL INSPECTION OF 6 DECEMBER, 1976

This report concerns the visual inspection of vessels 1A, 2, 3 and 4 after completion of the run ending 5 December, 1976. During this run vessel 1 A was used for the first time and was supplied by Woolsey No. 1. Condensate was directed into the binary cooling system for addition to the spray pond.

A. R. Gonzalez

ARG:bt

cc: Roland Quong- LLL

FLASH VESSEL INSPECTION 6 DECEMBER, 1976

TEST RUN ENDING 5 DECEMBER, 1976

1. First stage "A" flash vessel. Stainless steel

- A. There are in this vessel two distinct water levels. The first and by far the most distinct is approximately 5" from the bottom of the vessel. The second is at 30" from the vessel floor.
- B. Throughout the area covered by the first and lowest water level, was an accumulation of lead sulfide powder approximately 0.5cm deep.
- C. The entire floor area up to the second water line is

covered by a layer of hard black scale less than 1 mm in thickness. This layer is well bonded at the center line but the bonding is less as distance increased from center. At the water line itself, the scale is flaky and rapidly falling away.

There is no debris of any significant size on the floor area. Only the deposits of lead sulfide.

- D. The vessel above the water lines is virtually clear of any scale. There appear to be visual evidence of pitting in the vessel wall.
- E. The domed cap over the closed outlet in the ceiling shows deterioration. Rust trails cover the ceiling of the vessel. All trails emanate from this cap and the steam outlet line.

CONCLUSION: Under the conditions of operation to which this vessel was subjected, there was no appreciable scale buildup. Walls suffered little if any damage. The only notable possible problem seems to be the capped opening in the vessel ceiling.

However, the operating conditions were abnormal in that pressure was reduced to 100-110 psi, while the brine level was maintained at approximately 5" through most of the run due to faulty level indication.

II. Second Stage Flash Vessel. Stainless Steel.

- A. Water level approximately 33". Scale up to water line 5-6 mm thick, black with 2-3 layers of reddish-yellow overcoating.
- B. Above water line very little scaling. Indications of pitting.
- C. Inlet end of vessel including wear plate covered with a dense black scale. Scale 5 mm thick, cracks and breaks away easily.
- D. Pile of debris approximately 5 cm deep. Drain outlet clogged with debris.

E. Some carbonate scale on inlet line indicating leak
in condensate cascade line into vessel.

CONCLUSION: Much less scale deposit. Debris concentration
down by half. There is however, some visual indication of
possible pitting vessel walls.

III. Third Stage Flash Vessel. Carbon Steel.

A. Water level in third stage vessel was at approximately
28". The scale below this level was approximately
5 mm thick uniform throughout except at the inlet end.

The scale was well bonded at the outlet end but to a lesser degree at the inlet end. Debris accumulation on the vessel floor appears to be from the rust scale from the ceiling .

- B. The vortex breaker was covered uniformly with 0-2 mm of hard black scale. The scale within the outlet pipe however, was 1.25 cm thick.
- C. The water line itself is well defined by a 10 cm wide band of salt crystals. This is very thin and washed away easily.

The rust scale immediately above this line appeared to be the worst observed in this vessel to date.

- D. Inlet end of vessel was covered with the same salt formation as that which defined the water line. This extended from ceiling to floor both above and below the water line. It covered the whole end bell of the vessel from the verticle weld to the end.

It may be noted that the inlet pipe was covered by the salt to well below the water line but not above it.

- E. The ceiling is in the same state of decay as previously noted. A continual rusting away of the vessel itself. In most part no worse than before except along the water line.

CONCLUSION: Although scaling appears less below the water line, deterioration of the metal surface at the water line appears to have increased. I also found that the scale below the water level was tightly bound at the outlet end but was flaking and falling off at the inlet end.

IV. Fourth Stage Flash Vessel. Carbon Steel.

- A. Water line approximately 33", scale below water line is 2-3 mm thick. Uniform in thickness except where old scale was not removed. The scale below the water line was peeling off and a pile of debris was formed in the center of the vessel. The vessel wall below

the waterline is rusting beneath the scale causing it to flake off.

- B. Scale above the water line is also 2-3 mm but is a rust scale. The vessel wall shows the same type rusting as is taking place in the third stage, with wall pitting in evidence.
- C. Vortex breaker is in good condition with very little scaling.
- D. The inlet pipe is being subjected to the same type of rusting as the vessel walls.

CONCLUSION: For the first time the fourth stage has been subjected to serious attack. The rust in evidence is identical to that in the third stage. In areas where the scale was not removed previously there appears to be no rust and the scale remains tightly bonded to the metal.

OVERALL CONCLUSIONS:

It appears that the plant as a whole suffered less during this run. But there were several things not seen before.

1. Lead sulfide deposits in the first stage.
2. Indications of pitting in the stainless steel vessels.
3. Rust scaling and debris in the fourth stage vessel.

These could be either an extension of previous deterioration or a new result of new factors introduced by using Woolsey at low pressure.

A. R. Gonzalez

APPENDIX F

GEO THERMAL TEST DATA

[illegible]

GEO THERMAL TEST DATA

[illegible]

GEOTHERMAL TEST DATA

[illegible]

GEO THERMAL TEST DATA

[illegible]

GEO THERMAL TEST DATA

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