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GEOTHERMAL LOOP EXPERIMENTAL FACILITY

DOE/ET/28443--T4

SDG&E

DOE CONTRACT NO. EY-76-C-03-1137

OCTOBER 1978
QUARTERLY REPORT

DISCLAIMER

SAN/1137-12

SDG&E - DOE

GEOTHERMAL LOOP EXPERIMENTAL FACILITY

QUARTERLY REPORT

FOR THE PERIOD

JULY - SEPTEMBER, 1978

AND

ANNUAL REPORT

FOR THE PERIOD

OCTOBER 1, 1977 - SEPTEMBER 30, 1978

W. S. Bischoff
C. H. Haas
G. J. Hoaglin
W. O. Jacobson
D. K. Mulliner
D. G. Newell
C. R. Swanson

OCTOBER, 1978

San Diego Gas & Electric Company
P.O. Box 1831
San Diego, California 92112

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A. Geothermal Brine Treatment System

ABSTRACT

Since the Geothermal Loop Experimental Facility (GLEF) start-up in May, 1976, a substantial amount of information has been obtained on the operation of the plant, components, brine and steam composition, production and injection wells, and the potential of the Niland Reservoir. The Geothermal Loop Experimental Facility (GLEF) was modified during the last year from a four stage flash/binary process to a two stage flash process with two parallel flash trains for the extraction of energy from a high temperature, high salinity, liquid-dominated resource.

This Report summarizes the general operation and accomplishments of the GLEF during the period from October, 1977 through September, 1978 (Annual Report Section) and details these activities during the period from July, 1978 through September, 1978 (Quarterly Report).

During the Annual Reporting period, the four stage flash/binary process test results were used in a Feasibility and Risk Study which identified the two stage flash cycle as the preferred cycle. The facility was modified to test critical portions of the cycle and testing was initiated.

ANNUAL REPORT

INTRODUCTION

The purpose of the Annual Report is to highlight and summarize the important results from this project during the one year period from October 1, 1977 through September 30, 1978.

Highlights of significant operational problems encountered are included in the Operations Section. The Maintenance Section describes the major maintenance activities and difficulties with plant equipment.

Information on the production and injection wells activities for the year is briefly discussed in the Reservoir Operations Section.

An update on tests conducted for this year are briefly highlighted in the Testing Section. An overview of the Feasibility Study is included in the Other Activities Section.

Typical brine, steam, condensate, cooling water, and binary fluid chemistry is presented in the Chemistry Section.

Only the highlights of the project's annual activity has been included. The Quarterly Reports provide further details, if required.

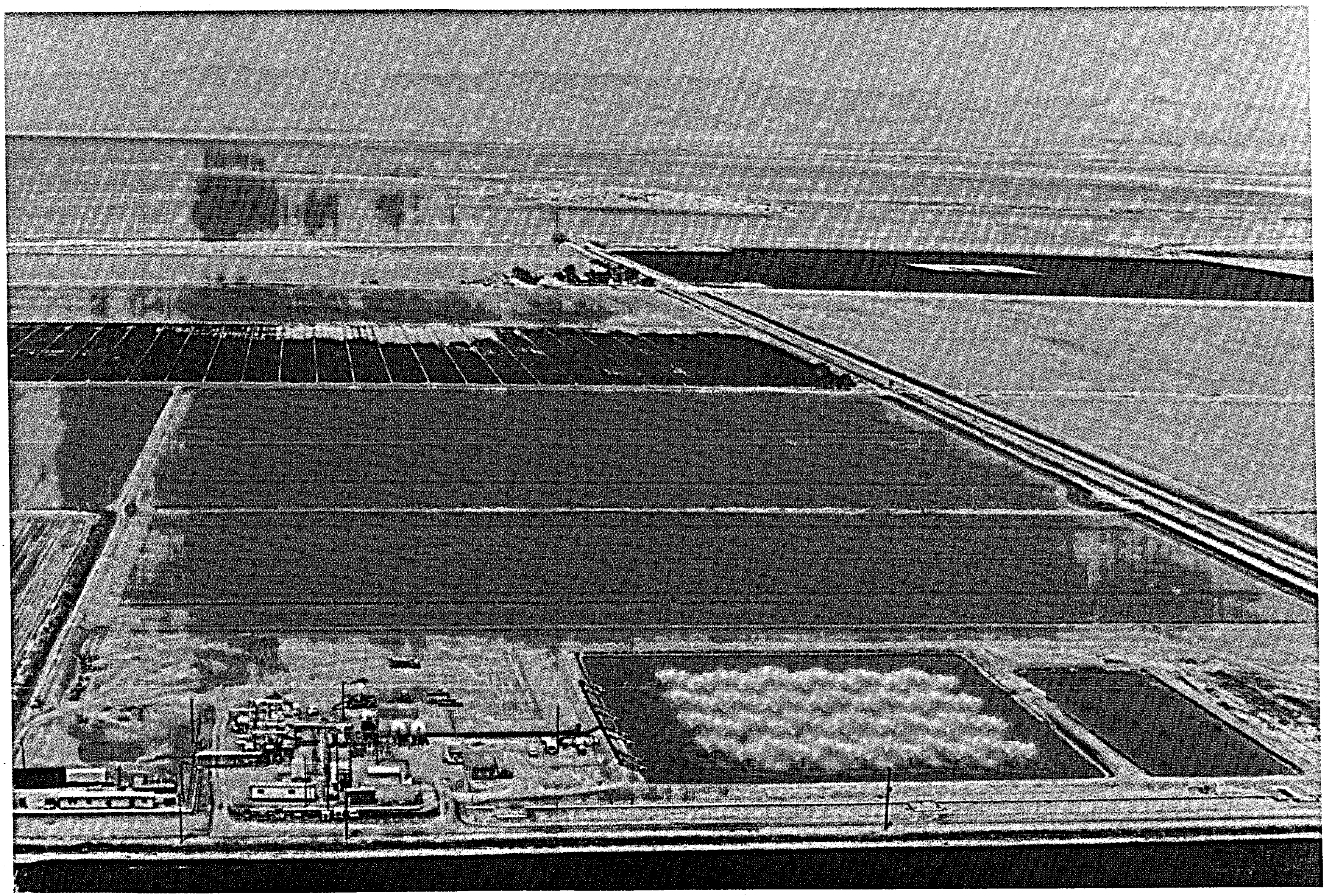


FIGURE 1-1

GEOTHERMAL LOOP EXPERIMENTAL FACILITY
Niland, California

CONCISE HISTORY AND DESCRIPTION OF THE NILAND GLEF

Early in 1972, the concept of building a Geothermal Loop Experimental Facility (GLEF) at the Niland Known Geothermal Resource Area (KGRA) was originated. This area is located on the southern shore of the Salton Sea near Niland, California. SDG&E, in cooperation with Magma Power Company, drilled and flowed a geothermal test well to demonstrate the ability of the Niland Reservoir to produce a significant amount of hydrothermal fluid capable for the production of electric power.

In May, 1975, construction of the GLEF began and start-up of plant operations commenced on May 3, 1976. (See Figure 1-1 for the general appearance of the GLEF). This 10-megawatt size facility is the first of its kind for testing high temperature (in excess of 500°F downhole) and high salinity (250,000 ppm) geothermal resources.

Magma Power Company, jointly with the New Albion Resource Company (NARCO), supply geothermal fluid (brine) from two production wells, Magmamax No. 1 and Woolsey No. 1. These are located near the test facility which is thought to be in the center of the geothermal anomaly. Magmamax No. 1 produces brine with a typical temperature and pressure at the wellhead of 440°F and 350 psig, respectively, with an average flowrate of approximately 400,000 lbs/hr. Woolsey No. 1 has produced brine with a typical temperature and pressure at the wellhead of 380°F and 200 psig, respectively, with an average flowrate of approximately 300,000 lbs/hr. However, Woolsey was not used recently due to required repairs and effluent treatment system flowrate limitations. The plant has been modified to accept a two-well flowrate of 800,000 lbs/hr. The produced brine is flowed through the plant and then injected into the reservoir approximately one mile away through one of two injection wells, Magmamax No. 2 and No. 3. Magmamax No. 3 has been the primary injection well, but Magmamax No. 2 is now being used as the injection well.

On April 13, 1978 the plant was shut down for cleaning and plant modifications. At this time the plant was modified from a four stage flash/binary system (Figure 1-2) to a two-stage flash/binary system (Figure 1-3). Critical portions of a two stage flash system with two parallel flash "trains" are simulated. Each supply well has a separate set of flash vessels. The steam produced by the flashed brine passes through steam scrubbers to remove entrained brine containing salts and minerals. The scrubbed steam is condensed by three heat exchangers at approximately 200,000 lbs/hr, partially vaporizing the binary fluid, which is now being used only to dissipate the heat energy. The condensed steam is primarily used for cooling water make-up, but can be recombined with the brine and injected into the reservoir for test purposes. The noncondensible gases,

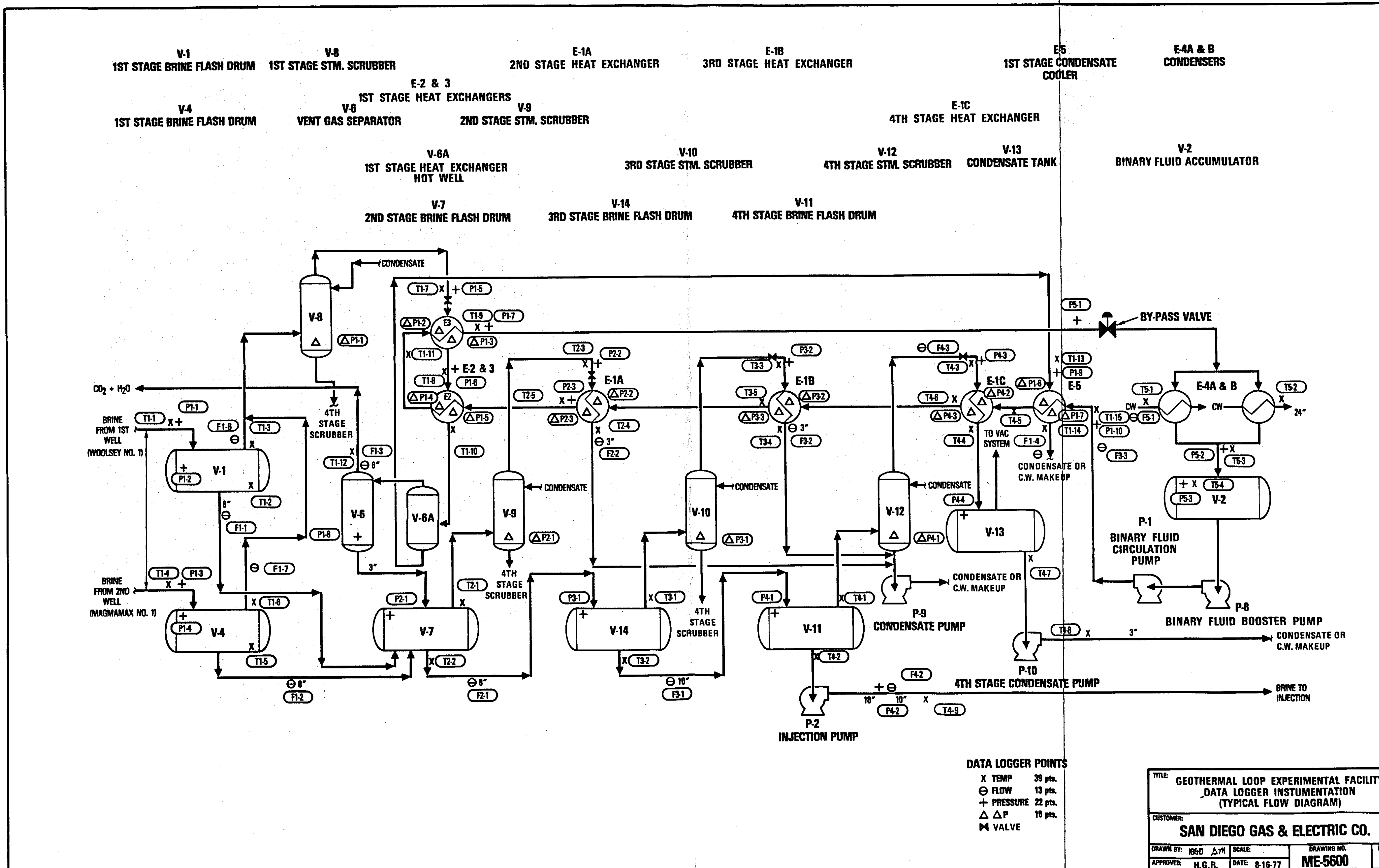

V-1
1ST STAGE BRINE FLASH DRUM
V-8
1ST STAGE STM. SCRUBBER
E-1A
2ND STAGE HEAT EXCHANGER
E-1B
3RD STAGE HEAT EXCHANGER
E-5
1ST STAGE CONDENSATE COOLER
E-4A & B
CONDENSERS
E-2 & 3
1ST STAGE HEAT EXCHANGERS
V-4
1ST STAGE BRINE FLASH DRUM
V-6
VENT GAS SEPARATOR
V-9
2ND STAGE STM. SCRUBBER
E-1C
4TH STAGE HEAT EXCHANGER
V-6A
1ST STAGE HEAT EXCHANGER HOT WELL
V-10
3RD STAGE STM. SCRUBBER
V-12
4TH STAGE STM. SCRUBBER
V-13
CONDENSATE TANK
V-2
BINARY FLUID ACCUMULATOR
V-7
2ND STAGE BRINE FLASH DRUM
V-14
3RD STAGE BRINE FLASH DRUM
V-11
4TH STAGE BRINE FLASH DRUM
CONDENSATE
BY-PASS VALVE
$CO_2 + H_2O$
BRINE FROM 1ST WELL (WOOLSEY NO. 1)
BRINE FROM 2ND WELL (MAGMAMAX NO. 1)
4TH STAGE SCRUBBER
TO VAC SYSTEM
CONDENSATE OR C.W. MAKEUP
P-1
BINARY FLUID CIRCULATION PUMP
P-8
BINARY FLUID BOOSTER PUMP
P-9
CONDENSATE PUMP
P-10
4TH STAGE CONDENSATE PUMP
P-2
INJECTION PUMP
BRINE TO INJECTION
DATA LOGGER POINTS
X TEMP 39 pts.
⊖ FLOW 13 pts.
+ PRESSURE 22 pts.
△ ΔP 18 pts.
⋈ VALVE
TITLE: GEOTHERMAL LOOP EXPERIMENTAL FACILITY DATA LOGGER INSTUMENTATION (TYPICAL FLOW DIAGRAM)
CUSTOMER: SAN DIEGO GAS & ELECTRIC CO.
DRAWN BY: IGSD
SCALE:
DRAWING NO. ME-5600
REV. B
APPROVED: H.G.R.
DATE: 8-16-77

FIGURE 1-2

primarily carbon dioxide with small amounts of other gases including hydrogen sulfide, are exhausted to the atmosphere through a 130 foot high stack.

The binary fluid is then cooled and condensed by cooling water in the condensers. Design of an effluent treatment system (clarifier/filter) has begun.

In addition to testing the critical portions of the two stage flash process, evaluation of the reservoir after the injection of cooled brine and assessing the potential of the Niland geothermal reservoir are underway. San Diego Gas & Electric Company (SDG&E) owns the facility and manages its testing. SDG&E and the United States Department of Energy (DOE) jointly fund the activities of the facility.

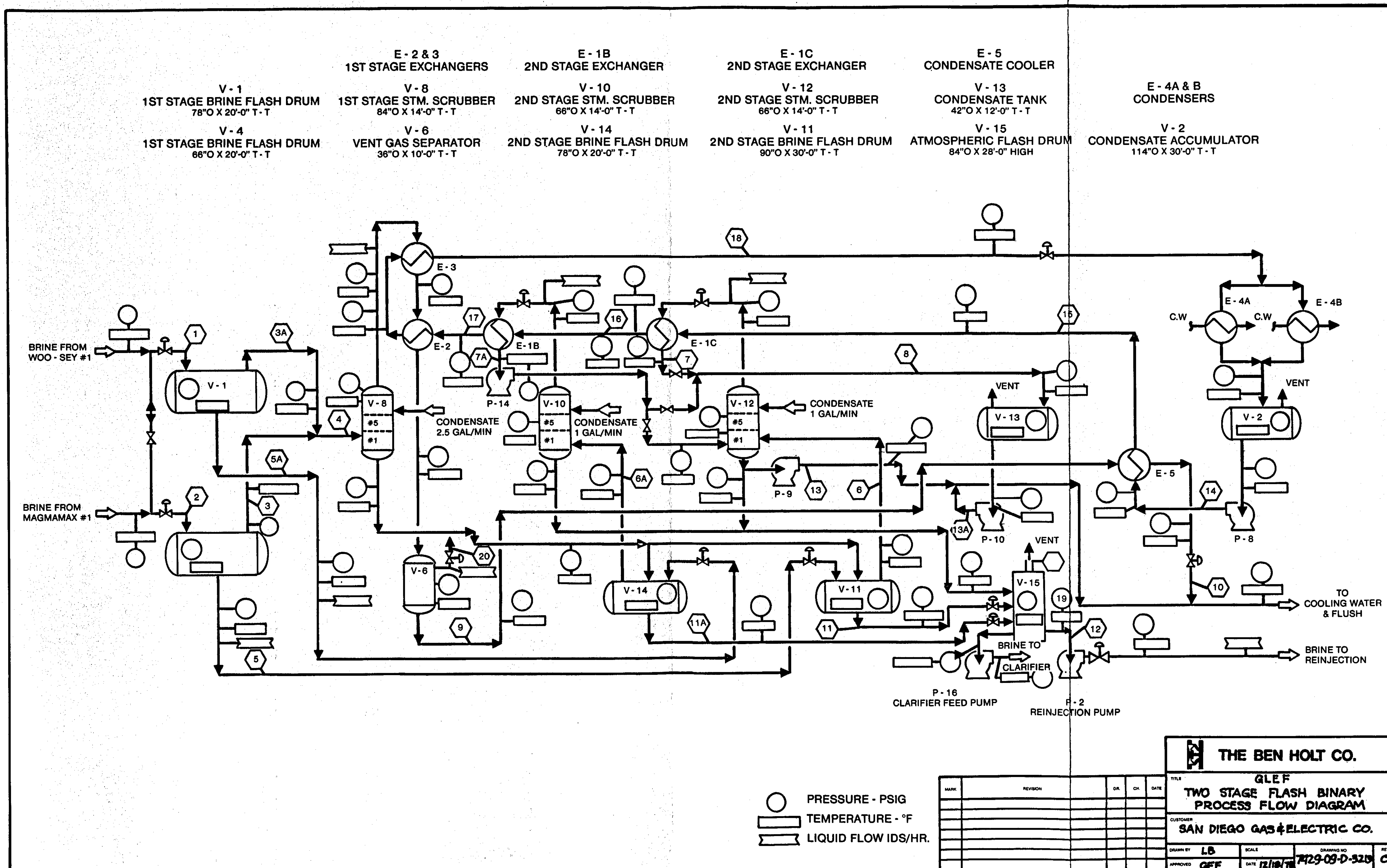

E-2 & 3
1ST STAGE EXCHANGERS
E-1B
2ND STAGE EXCHANGER
E-1C
2ND STAGE EXCHANGER
E-5
CONDENSATE COOLER
V-1
1ST STAGE BRINE FLASH DRUM
78"O X 20'-0" T-T
V-8
1ST STAGE STM. SCRUBBER
84"O X 14'-0" T-T
V-10
2ND STAGE STM. SCRUBBER
66"O X 14'-0" T-T
V-12
2ND STAGE STM. SCRUBBER
66"O X 14'-0" T-T
V-13
CONDENSATE TANK
42"O X 12'-0" T-T
E-4A & B
CONDENSERS
V-4
1ST STAGE BRINE FLASH DRUM
66"O X 20'-0" T-T
V-6
VENT GAS SEPARATOR
36"O X 10'-0" T-T
V-14
2ND STAGE BRINE FLASH DRUM
78"O X 20'-0" T-T
V-11
2ND STAGE BRINE FLASH DRUM
90"O X 30'-0" T-T
V-15
ATMOSPHERIC FLASH DRUM
84"O X 28'-0" HIGH
V-2
CONDENSATE ACCUMULATOR
114"O X 30'-0" T-T
BRINE FROM WOO-SEY #1
BRINE FROM MAGMAMAX #1
CONDENSATE 2.5 GAL/MIN
CONDENSATE 1 GAL/MIN
CONDENSATE 1 GAL/MIN
VENT
VENT
VENT
C.W
C.W
TO COOLING WATER & FLUSH
BRINE TO REINJECTION
BRINE TO CLARIFIER
P-16
CLARIFIER FEED PUMP
P-2
REINJECTION PUMP
P-14
P-9
P-10
P-8
PRESSURE - PSIG
TEMPERATURE - °F
LIQUID FLOW IDS/HR.
THE BEN HOLT CO.
GLEF
TWO STAGE FLASH BINARY
PROCESS FLOW DIAGRAM
SAN DIEGO GAS & ELECTRIC CO.
LB
GFF
12/18/78
7129-09-D-3213
0

FIGURE 1-3

1.0 OPERATIONS

The GLEF operated for a total of 4357 hours from October 1, 1977 through September 30, 1978. This gave the plant an availability of 65% for this time period excluding scheduled outages. This represents a significant increase compared to the 47% plant availability achieved the previous year. If all outages (scheduled and unscheduled) were included, the plant capacity factor for this time period would be 49%. This also represents a significant improvement in facility operations.

During the majority of the operating time, only one of the two supply wells, Magmamax #1 was used. There was limited use of the second well, Woolsey #1 for two well operation in December and early January, however it was concluded the brine from the Woolsey #1 well was not a representative fluid, due to a hole in the casing which precluded further use.

Almost all injection for this entire period was with concentrated brine into Magmamax #3 via a settling tank system. Concentrated brine results from flashing steam without returning the condensate (or other water) as a makeup stream to the brine. A pilot reactor/clarifier was operated on a side stream to develop design data for a full scale unit to be installed as an effluent treatment system. The injection pump (P-2) caused several plant shutdowns when the pump discharge pressure fell off due to plugging caused mostly from a large amount of soft scale buildup. Various flushing, purge, and hydroblast techniques to remove the soft scale were tested with only partial success.

During plant operation the condenser pressure drop increased on several occasions. After shutdown and inspection of the tube sheets, it was determined that a buildup of scale and debris containing large amounts of iron were the cause of the increased pressure-drop. Screens were added to remove debris and the chemical water treatment modified to control corrosion. A spool piece was also installed on the 24" inlet line between the two condensers to enable future inspection into the inlet side or bottom of each condenser without removing the condenser heads. Geothermal steam condensate is being tested as makeup for the cooling water pond at present. This is done by diverting it to the cooling pond and treating the pond with ZM136 to settle the zinc and iron and injecting large amounts of chlorine to kill biological growth present in the condenser tubes.

Pinch valves were installed in the low pressure portions of the brine system. These pinch valves are rubber lined control valves used to control brine flow. They appear to be a promising means of control because of their ability to resist corrosion and scale buildup. Initial use resulted in liner failures. Revised liner materials have improved performance.

Pigging is proving to be a reliable means of soft scale removal in the injection line. This is being done on a daily basis. Some difficulties with short radius elbows and tee's have been experienced.

Settling tanks are being used to settle solids from the effluent flow exiting the plant prior to injection. A pilot clarifier was first installed at the settling tanks and was then moved to the plant to take a small portion of brine from an atmospheric flash tank. Testing of this pilot unit has been on going to enable the development of a positive and cost effective means of brine treatment prior to injection.

On July 10, 1978 the plant was started up for the first time after a major plant modification from a four stage flash/binary system to critical portions of a parallel two-stage flash system. Each supply well has its own two-stage system. (For details see July, 1978 Quarterly Report). Data from the two-stage operation is being obtained and will continue to be used.

2.0 RESERVOIR OPERATION

2.1 Production Wells

In November, 1977 a spinner survey indicated Woolsey #1 had a hole in the liner at the 1,370 foot level. The hole allowed unrepresentative fluids to be produced. The cause of the hole in the liner is not determined. This well, as originally completed, did not produce adequate brine. Deepening was accomplished by drilling through the existing liner. This drilling may have damaged the liner. Corrosion may have also contributed to the failure. Downhole corrosion will be evaluated by planned testing. This problem was corrected in May, 1978 by the use of a tie back liner. Limited capacity of the effluent treatment tanks has prevented the use of Woolsey fluids for plant testing since May, 1978. Both production wells are expected to be used after the clarifier/filter is installed.

Magmamax #1 was the primary production well during this period. This well was cleaned in November, 1977 and was cleaned and scraped in May, 1978. At this time 1 1/4" tubing was installed in Magmamax #1 to allow downhole flowing pressure and temperature observations.

Magmamax #2, normally a spare injection well, was flow tested to obtain additional reservoir production data. Although the test was limited in duration, the well gave good indications of being capable of producing at high temperatures and flowrates.

2.2 Injection Wells

Magmamax #3 has been used as the primary injection well. This well is taking plant effluent brine from a series of settling tanks which aid in removing suspended solids prior to injection. It was expected that removal of these suspended solids should improve injection well performance. These tanks appear to be partially effective in reducing the solids and silica content. The clarifier/filter should reduce silica to saturation levels.

Injection well performance, with reduced solids has been improved. Injection pressure, at a given flowrate, continues to increase with time, but at a reduced rate. The clarifier/filter is expected to further reduce solids and should further improve well performance. In March 1978 a pilot reactor/clarifier was installed and is currently being tested with an objective of determining the feasibility in further reducing the amount of dissolved silica and suspended solids in the effluent brine. Data, to date, shows successful reduction in dissolved silica and suspended solids.

3.0 TESTING

3.1 Scrubber Efficiency Test

Scrubber efficiency tests were conducted in an attempt to determine the performance characteristics of the scrubbers. Unfortunately, variations in steam conditions and composition with time, made test results somewhat inconclusive.

Large, rapid changes in brine and steam flowrates caused a variable amount of brine to be carried over into the scrubbers. True "steady state" operation could not be achieved.

A review of the test procedure and plant surging will be undertaken and sampling techniques will be improved for a possible test rerun.

3.2 1978-1979 GLEF Test Program

A feasibility study conducted by SDG&E, Bechtel National, Inc., and The Ben Holt Company in late 1977 and early 1978 showed that a two stage flashed-steam cycle power plant would be the best choice for initial geothermal power plants at the Niland reservoir. In order to develop design data for this initial power plant, the study recommended the GLEF be modified to simulate critical portions of a 2 stage flash cycle. Modification was accomplished in July, 1978.

The 1978-1979 GLEF Test Program has as its major objective to obtain the data necessary to design the initial commercial scale power plants and reduce the associated risks and costs of constructing and operating a dual flash-cycle power plant. This test program replaces the earlier test program which was to determine the capabilities of the flash/binary cycle originally constructed at the facility. The current test program will consist of several different tests to be performed separately by SDG&E, Lawrence Livermore Laboratory, and Imperial Magma under the overall supervision of SDG&E. The progress of the Test Program will be reported in the future Quarterly Reports. However, detailed writeups and results of each test will be maintained in a separate document.

3.3 Miscellaneous Tests

A variety of independent test activities have been accomplished during the interim period between the end of previous test plan and initiation of the currently planned test programs. Many of these tests will be incorporated into the planned test program.

3.3.1 Materials of Construction

Brookhaven National Laboratory has been conducting research on polymer impregnated concretes (PC) for geothermal applications for several years. These concretes, when used to line the inside of piping, have been found to protect the base metal from corrosive attack by some geothermal brines. There also has been laboratory evidence that PC-lined pipe signficantly slows the growth of scale on the pipes. Both of these effects could significantly reduce the costs of geothermal brine piping and operation. Samples and line pipe sections have been installed at the site. A test was initiated to determine the corrosion resistance of various coatings. This test will be used to evaluate candidate materials for coating the GLEF flash vessels. Different types of coatings on small coupons and larger test panels were obtained from vendors for evaluation.

3.3.2 Components

Two ball type control valves were modified to accept a coating of the ball element. It is hoped that the operating life of two brine control valves will be extended by coating parts of the valve exposed to the brine with a dry film "Microseal" lubricant. Results of this test are pending and will be reported upon as information becomes available.

One of the more promising types of brine control valves being evaluated at the GLEF are pinch valves in which a flexible liner contained inside a metal body is used to squeeze off the flow. The flexing of the liner is expected to prevent large amounts of scale from accumlating in the valve, thus extending its life. Initial testing resulted in liner failures. Improved liner materials are now being evaluated.

3.3.3 On Line Scale Removal

Pigging appears to be an effective on-line method of removing soft silica scale while the plant is in operation. Flexible foam pigs, manufactured by Girard Polly-Pig, have been used to remove scale from the injection line. The pig's effectiveness is reduced in standard elbows, but its effectiveness in straight sections appears to be good.

3.3.4 Cavitation Cleaning

Daedalean Associates, Inc. has developed a cavitating nozzle which, when used in conjunction with a high pressure water supply, has removed the hardest scale without pre-treatment. Testing on this process as an on line scale control technique is planned.

3.3.5 Instrumentation

Ultrasonic flowmeters have been installed to measure brine flowrates. These flowmeters have required frequent calibration and maintenance, but have provided data. Other instrumentation tests have included movable sample taps, reamers and purge flows to keep taps free of scale, and oil filled plenums to damp out extraneous oscillations. Steam turbine flowmeters are also now installed.

4.0 SYSTEMS CHEMISTRY

4.1 Steam

Solids carried over with the steam can adversely influence heat exchanger or turbine efficiency through deposition on the heat exchanger tubes or turbine blade surfaces. To estimate the degree of solids carried over, samples of geothermal steam leaving each separator and each scrubber were taken. The pH, electrical conductivity, total dissolved solids, chloride, sodium, calcium, and iron content of these samples were also measured.

4.2 Brine

Composition of the brine has been measured throughout the plant. The changes in concentration can be attributed to liquid lost as steam. The total solids and conductivity also agree well with the values of sodium, calcium, potassium and chloride, which comprise the major part of the brine.

The changes in pH can be correlated with the loss of ammonia and carbon dioxide in the flash vessels. The increase in brine conductivity also correlates well with the increase in the cation concentrations, the chloride concentration, and the loss of water as steam.

4.3 Scale

During the operation of the plant, scale is deposited on all surfaces wetted by the geothermal brine. The major constituents of this scale are silicon, iron, and sodium. Silicon, mostly as SiO_2, is the predominent specie. With the exception of some of the heavy metals (probably as sulfides) primarily in the initial portions of the plant, the scale is almost entirely an amorphous silica-iron matrix with some sodium, probably as evaporated salts, included.

4.4 Cooling Water

The major difficulties experienced by the plant cooling water system have been corrosion and bacterial contamination of the circulating water. Heavy iron oxide deposits were observed on the condenser tubes. Whether this iron comes from corrosion of the cooling water system or from the condensed steam, now used as a source of makeup, has not yet been established. A change to the water treatment additives program was initiated in July, 1978. The zinc based corrosion inhibitor was replaced with an organic scale and corrosion inhibitor. Initial use shows improved performance, but the condenser cleaning will probably still be required.

5.0 MAINTENANCE

Condenser performance continues to be a problem. Removal of iron rich deposits has required several shutdowns. Fouling on the cooling water side of the condensers (tube side) has caused excessive pressure drops that have bent the water channel baffle plates. Scale is depositing on the tubes and tube sheets, constricting the already small diameter flow passages.

These problems have been studied and it was concluded that limiting the condenser pressure drop to 20 psi, reducing the cooling water flowrate and modified chemical treatment of the spray pond should help in the elimination or reduction of these problems.

The cooling water pond was also drained in June, 1978. The reasons for this action was to remove the concentration of iron and zinc. The pond was then filled with fresh water from the Imperial Irrigation District Vail Canal and a new chemical treatment program initiated. (See Section 4.0)

The brine supply line from Magmamax #1 well was opened at several locations, between the well and the plant, for inspection. Between the well and the first expansion loop, there was a buildup of scale up to 1/2" thick. This section of line was hydroblasted clean. After cleaning it was observed that pits had developed in the line. Some pits were as much as 1/8" deep especially near the elbows. A double block and bleed valve is how installed as a line stop near the well. Some pitted sections were replaced and 90° elbows were modified to tees with a blank leg. Wall thickness inspections are now accomplished on a periodic basis. Replacement of other portions of the production line will probably be required in 1979.

One cause of the corrosion pits appears to be related to shutdown and inspection of the line. Air is introduced at this time, and probably contributes to the corrosion process. A nitrogen purge will be used to minimize this contributor in the future.

Because of concern over the safety of the pipeline, a hydrostatic pressure test was conducted prior to returning the line to service.

6.0 SPECIAL PROBLEMS

6.1 Injection Pump

Failure of the injection pump has been a primary cause of limited plant availability. The plugging of the pump and can are the primary cause for these plant shutdowns. The suction line from the atmospheric flash tank has also been observed to build up a scale which starves the pump. Different means of cleaning this pump (flushing and hydroblasting) while in operation have proven to prolong the use of the pump.

A new pump was manufactured by the San Diego Gas & Electric Company machine shop. This second pump now gives flexibility and less down time should be encountered in the future. Future placement of the pump downstream of the effluent treatment facility should reduce the scaling and high maintenance costs.

6.2 Production Line Scale

During the shutdown for plant modifications, the production line from Magmamax #1 was inspected for scale buildup. Several different points were examined and showed scale thickness varying between 125 and 500 mils. At several points, it appeared that larger obstructions may have built up. Consequently, it was decided to descale several hundred feet of the line down stream of the well by hydroblasting.

The scale buildup rate is small and if properly designed for does not represent a serious problem in a commercial power plant.

7.0 OTHER ACTIVITIES

7.1 Feasibility Study

An evaluation of the test data from the GLEF resulted in questions concerning the energy cycle and areas of uncertainty being addressed. A multiphased Feasibility Study was initiated to accomplish the following goals: 1) define the optimum energy conversion cycle; 2) identify remaining critical areas of risk; and 3) recommend GLEF activities to minimize the risks. The Phase I draft report recommended a dual flash cycle for the initial commercial geothermal power plant. High risk areas of brine scale, corrosion and injection were identified. The final Phase I Report was issued on May 10, 1978.

The major recommendations for GLEF activities of the feasibility study are being implemented. These include modifications to the GLEF which will: 1) convert the brine system from a four stage series of flash drums, to two parallel two stage flash drums, 2) allow access for brine system testing of corrosion and scaling, and 3) install a brine effluent treatment system to test for reliable injection of brines. The first two modifications are complete. The effluent treatment system is in process.

8.0 SUMMARY

The plant operated for a total of 4357 hours during this reporting period.

Good results were obtained with Magmamax #1 as the major production well, injecting into Magmamax #3, through a settling tank system. Side stream testing of a pilot reactor/clarifier was also accomplished which has been identified as the most likely effluent treatment system.

Scrubber efficiency tests were determined to be inconclusive due to the plant variations in the steam conditions. A study is in progress to reduce plant oscillations.

Pigging appears to be an efficient means of cleaning the injection line while the plant is on the line. Some damaging of the pigs has been noted, but overall performance is good.

Various coatings are being tested on coupons and panels. These may identify a possible solution to corrosion problems in the future.

The plant underwent a major modification. It was modified from a four stage flash/binary to test critical portions of a two stage flash process. An effluent treatment system will be added during the next year.

Due to the long term desireability of finding an alternate source of cooling water makeup, the primary mode of operation was defined to be using the condensate as the source of cooling water makeup. This unusual source of cooling water has lead to condenser and cooling system difficulties. Modifications to the cooling water chemical treatment have been accomplished and the condensate feed stream is also being treated. Further work in this area is planned for next year.

QUARTERLY REPORT

INTRODUCTION

This Quarterly Report covers the period from July 1, 1978 through September 30, 1978. Included in this report is some preliminary data stemming from the first run of the new two stage flash modification.

The Operation Section discusses some techniques tried to aid in H_2S abatement and various methods of redirecting the condensate, and equipment operation.

Equipment repairs or modifications are discussed in the Maintenance Section. Engineering required in the repair or modification of plant equipment is discussed in the Special Problems Section.

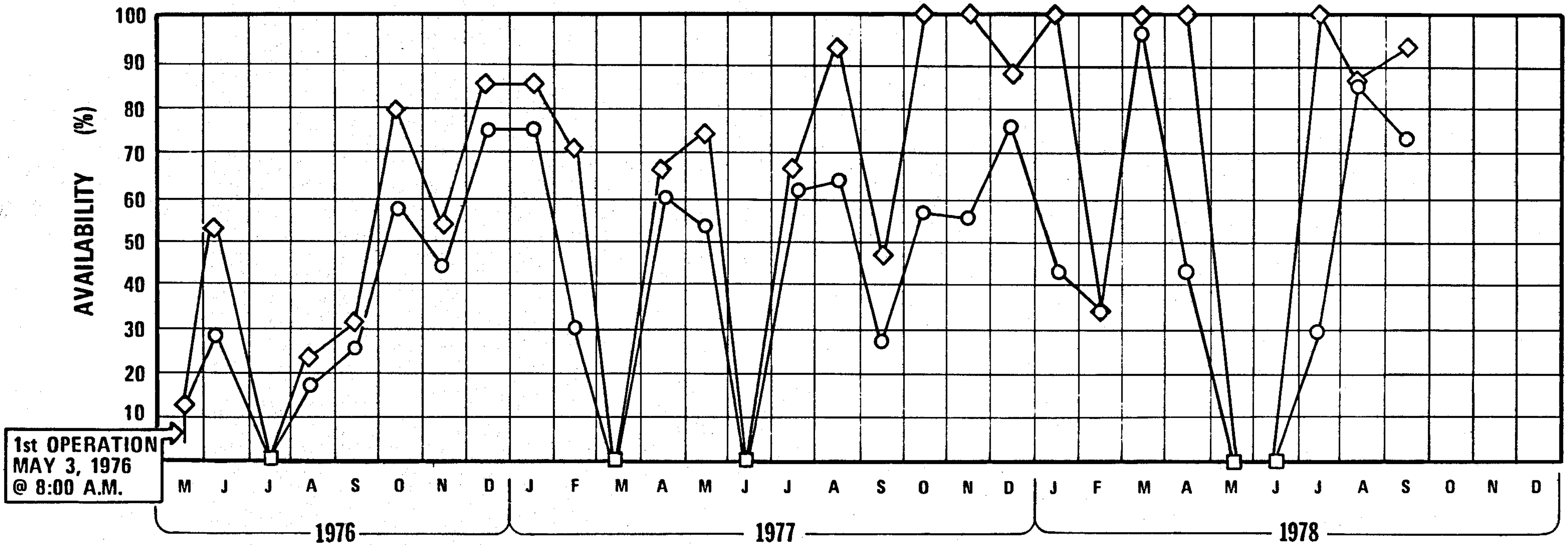
The Chemistry Section brings forth data that poses some questions of the four stage versus two stage operation by tables with scaling information. Steam, cooling water, and binary fluid is also discussed with tables for illustration.

GLEF Test Programs and their status are related in the Testing Section and The Feasibility Study and Injection Risk Study are discussed in the Other Activities Section.

TABLE 1-1

MONTH	FOR MONTH					SINCE START-UP				
	TOTAL GLEF OPERATING HOURS	TOTAL HOURS IN THE MONTH	POSSIBLE HOURS (EXCLUDING SCHEDULED OUTAGES)	% AVAILABILITY BASED ON TOTAL HOURS	% AVAILABILITY (EXCLUDING SCHEDULED OUTAGES)	CUMULATIVE TOTAL GLEF OPERATING HOURS	CUMULATIVE TOTAL MONTH HOURS	CUMULATIVE POSSIBLE HOURS (EXCLUDING SCHEDULED OUTAGES)	% AVAILABILITY BASED ON TOTAL MONTH HOURS	% AVAILABILITY (EXCLUDING SCHEDULED OUTAGES)
JANUARY	315	744	315	42.3	100	6,146	15,296	11,084	40.2	55.4
FEBRUARY	238	672	672	35.4	35.4	6,384	15,968	11,756	40.0	54.3
MARCH	731	744	731	98.3	100	7,115	16,712	12,487	42.6	57.0
APRIL	304	720	304	42.2	100	7,419	17,432	12,791	42.6	58.0
MAY	0	744	0	0	–	7,419	18,176	12,791	40.8	58.0
JUNE	0	720	0	0	–	7,419	18,896	12,791	39.3	58.0
JULY	221	744	221	29.7	100	221 / 7,640	744 / 19,640	221 / 13,012	29.7 / 38.9	100 / 58.7
AUGUST	642	744	730	86.3	87.9	863 / 8,282	1,488 / 20,384	951 / 13,742	58.0 / 40.6	90.7 / 60.3
SEPTEMBER	537	720	570	74.6	94.2	1,400 / 8,819	2,208 / 21,104	1,521 / 14,312	63.4 / 41.8	92.0 / 61.6
OCTOBER										
NOVEMBER										
DECEMBER										

NILAND GEOTHERMAL LOOP EXPERIMENTAL FACILITY
1976, 1977 & 1978 AVAILABILITY BY MONTHS



○ Availability = No. of Hours of Plant Operation/Total No. of Hours in the Month.

◇ Availability = No. of Hours of Plant Operation/(Total No. of Hours in the Month - Hours of Scheduled Outages).

□ Plant Shutdown for Major Overhaul

FIGURE 1-4

1.0 OPERATION

The plant operated for a total of 1400 hours in this quarter. This gives the plant a total of 8819 hours of operation since start-up. The plant availability excluding scheduled outages, for the quarter was 92%. The plant capacity factor with all outages included was 63%. (See Table 1-1 and Figure 1-4)

The plant was started up on July 10, 1978 for the first time after the plant had been modified from a four-stage flash/binary system to critical portions of a parallel two-stage flash system.

On July 11 the plant was shut down for three hours due to a failure of the cooling water pump local switch. The control circuitry was found to be dirty and was cleaned.

The plant was shut down again on July 12 due to open ditches through the site while installing a new drainage system. It was determined these open ditches were a safety hazard. The plant was started up on July 24 after the safety hazard was eliminated.

Because of poor cooling water side condenser performance, a decision was made to temporarily send the combined condensate to the brine pond instead of the spray pond on July 24. This temporary diversion was to allow corrective action to be made on the cooling water system. Blanks on the valves from the condensate pumps to the brine pond were removed and the flapper from the check valve on the condensate discharge line was removed to allow flow to the brine pond. The plant was then started up at 1230 on the same day.

On July 25 the combined condensate was temporarily directed to the second stage separator (2B) due to the inability of the brine pond pump (P-13) to handle all of the condensate drains.

It was concluded that dissolved H_2S in the condensate was a major contributor to the poor performance. After developing a revised program and hardware to treat the condensate, the combined condensate was shifted from the 2B separator to the spray pond, on August 11, through a six-inch line. Sodium hypochloride was injected into the condensate at a rate of about 40 gallons per day in an attempt to eliminate the hydrogen sulfide (H_2S) gas from the condensate. Results indicate the H_2S was significantly reduced but not eliminated.

The small feed line from the atmospheric flash vessel to the pilot/clarifier became plugged on August 14. A plant shutdown was accomplished in order to clean the line. The atmospheric flash vessel was opened and the feed line hydroblasted. At 1634 of the same day the plant was on the line.

On August 18, after 614 hours of operation, the injection pump (P-2) discharge pressure started dropping (See Section 5.1, Injection Pump). The control valve (LCV714) between 1B and 2B separator also started sticking. Flushing of the pump was accomplished but little improvement was noted. Control valve (LCV714) along with the PCV 301 had been machined, stellite coated, and had a dry film lubricant applied in order to test this method of valve protection. (See Testing, Section 3.3.3)

The plant was shut down on August 22 to remove the injection pump (P-2) (See Section 5.1, Injection Pump) A spare injection pump was installed and on August 25 the plant was again started up.

Acidified purge water has been injected around the ball of control valve (LCV714), in order to prevent malfunctions. On August 28, this procedure was attempted when this valve became very sticky. This procedure proved futile, and the valve froze up completely, on August 30, after 819 hours of operation.

In an effort to reduce condensate treatment costs, sodium hypochloride was secured from the combined condensate to the spray pond on August 31. Air was injected into the combined condensate line to determine if the air would give the same results as the sodium hypochloride in partially removing H_2S from the condensate. On September 1, it was determined the air had no effect on the H_2S. On that same day the air was secured and the sodium hypochloride injection was resumed.

On September 5 after 939 hours of operation, draining of the 2B separator became difficult, indicating that the drain line from the 2B separator to the atmospheric flash vessel was plugging up. The pressure on the 2B separator was increased from 7 to 8 psig to enable the separator to drain.

Problems were encountered on September 8, when the sump pump failed. Attempts to turn it by hand were unsucsuccessful (See Section 5.2).

At 0750, September 11, the plant was shut down due to low discharge pressure on the plant injection pump (See Section 5.1). The pump was flushed and the plant was started up again on September 12.

Difficulty in draining the 2B separator increased on September 13. There were periods when the separator pressure had to be increased up to 30 psig in order to allow draining. The brine flow was then decreased and a pressure of 20 psig maximum was kept on the 2B separator. The brine line was flushed with cooling water and air was injected while in operation to flush out scale in the line. This procedure was partially successful and did allow the plant to continue to operate.

On September 24, at 1800, the plant was secured for a scheduled overhaul. This completed the first run using the new plant modification simulating a two stage flash cycle.

2.0 RESERVOIR OPERATION

2.1 Production Wells

Magmamax #1 was used as the primary production well. Although Woolsey #1 was available, the limited capacity of the settling tank system restricted flow to one production well.

2.2 Injection Wells

Magmamax #3 was used as a production well briefly. The high injection pressure at only one well fluid flow indicated injection problems. A scavenger pump is on line at Magmamax #3 site taking the brine from the settling tanks and pumping it to Magmamax #2.

Magmamax #2 was used as an injection well for the majority of this run. Very little back pressure was noted until just before plant shutdown at the end of the run when the back pressure climbed to 40 PSIG. Part of this pressure buildup could be due to a low injection flow allowing the well column fluid to heat up, creating a back pressure.

The settling tanks are being emptied of sludge which is being pumped from the pilot clarifier. We are collecting a considerably greater amount of sludge with the GLEF in a two stage flash mode in comparison with the four stage flash. The shorter fluid resident time could cause the precipitation of sludge to take place after fluid leaves the plant.

2.3 Reservoir Assessment Activities

Magmamax #1 was hung with 1-1/4" tubing to enable drop off pressure measurements to be taken. A Sperry-Sun type pressure chamber was suspended in the tubing with a quartz transducer at the surface. The data to be obtained for computer analysis is:

1. Background prior to starting the well
2. Draw-down by starting flow from well
3. Skin effect
4. Permability in vicinity of well bore
5. Identify flashing zone

3.0 TESTING

3.1 1976-1977 GLEF Test Program

The original program of tests to be performed at the GLEF addressed primarily the performance of the major plant components such as heat exchangers, steam scrubbers, etc. As a result of the Feasibility Study, the original Test Program was abandoned in early 1978. A final report of the results of that program is being prepared by Bechtel National, Inc. and should be issued before the end of the calendar year.

3.2 1978-1979 GLEF Test Program

The 1978-1979 GLEF Test Program is intended to obtain data necessary to reduce the risks and costs of constructing and operating a flash cycle power plant at the Niland Reservoir. Drafts of 14 different tests are being prepared. Drafts will be reviewed by all participants prior to release. An additional test (steam separation) is expected to require a separate effort.

Although the test program has not yet been fully documented, testing should begin in the next quarter. The progress of each test will be summarized in the Quarterly Reports; detailed writeups will be maintained in a separate document.

3.3 Miscellaneous Tests

The following tests were accomplished during the interim period before the formal test plan was documented. Many of these tests will be incorporated into the formal Test Plan.

3.3.1 Polymer Concrete Test Spools

Brookhaven National Laboratory (BNL) has been conducting research on polymer impregnated concretes (PC) for several years. These concretes, when used to line the inside of piping, have been found to protect the base metal from corrosive attack by geothermal brines. More importantly, there was thought some evidence that PC-lined pipe slows the growth of scale on the pipes. Both of these effects could reduce the costs of geothermal power.

In March, 1978, BNL contacted SDG&E and inquired whether it would be possible to install PC-lined pipe spools at several locations in the GLEF.

Two 10-inch PC lined spools were installed in the injection line so the entire brine flow passed through both spools except during the pigging operation, when valves were adjusted so that only one spool was exposed to the brine, and hence the wire-brush pig.

After 1400 hours of operation the PC pipe spools were removed for inspection. The spool that had been pigged showed very little evidence of abrasion and had a nominal scale buildup on the concrete liner. However, the spool that was not pigged exhibited a large amount of scale buildup.

In addition to the pipe spools, BNL sent 42 one-inch by three-inch test cylinders made of six different compositions of polymer concrete. These cylinders were placed below the liquid level in the first stage flash vessel and exposed to brine at an average temperature of 230°F for 1400 hours. When the GLEF was shut down for overhaul, these cylinders were removed. Preliminary inspections indicated good corrosion performance. Cylinders will be sent to BNL for inspection. Initial results indicate that polymer concrete lined pipe will control corrosion but will not prevent scaling.

3.3.2 Corrosion Test Spools - Brine Service

Shown below are the locations of the test spools that have been ordered. In addition, fiber glass piping for the combined condensate and the injection line specifically, is being investigated.

Production Line

Woolsey	Magmamax	Pipe Size
Hastelloy C-276	Hastelloy C-276	Schedule 40, 10"
29 Cr-4 Mo	29 Cr-4 Mo	Schedule 40, 10"
Inconel 625	Inconel 625	Schedule 40, 10"
Incoloy 825	Incoloy 825	Schedule 40, 10"
Carbon Steel 1018/1020	Carbon Steel 1018/1020	Schedule 60, 10"
	PFA (1 foot long)	Schedule , 10"

Interstage (1st to 2nd)

A Train	B Train	Pipe Size
SS 317 LM	SS 37 LM	Schedule 40, 10"
29 Cr-4 Mo	29 Cr-4 Mo	Schedule 40, 10"
Carbon Steel 1018/1020	Carbon Steel 1018/ 1020	Schedule 60, 10"

Interstage (2nd to V-15)

B Train Only	Pipe Size
Carbon Steel 1018/1020	Schedule 40, 12"

Injection

FEP (20 feet long)	Schedule , 10"

Test Spool - Steam Service

Carbon Steel 1018/1020	Outlet 1st stage scrubber, 10", 2 feet long

Schedule 40 and 60 was selected for conformity and compatibility with the existing line.

3.3.3 "Microseal" Lubricant - Coated Valves

This test is an evaluation of a solid film lubricant that has been used to coat the control surfaces of two brine control valves. E/M Lubricants of North Hollywood, CA, treated the valves after preliminary surface preparation. The lubricant, a suspension of molybdenum disulfide, metallic oxides, and corrosion inhibitors, dispersed in a resinous binder-carrier system, may have the potential to reduce scale formation from the brine. In the past, control valves exposed to the brine have scaled up to the point where they became inoperable and freeze in position. By coating the critical operating parts of the valve exposed to the brine with the dry film lubricant, it is hoped that the operating life of the valves will be extended.

During the shutdown period prior to the July 10, 1978 start-up, two control valves, PCV301 and LCV714, were disassembled and cleaned. These valves are a ball type control valve manufactured by Kamyr. The body halves were sent to SDG&E's machine shop and the seats were machined down, flame sprayed with stellite, and remachined to specification. The two balls were machined down, built up with flame sprayed stellite, remachined to design dimensions, and then ground smooth. When the balls were returned to the site and inspected, they were smooth, but not the mirror finish that was expected. Due to time constraints, balls were not returned to achieve a mirror finish.

The complete valves were sent to E&M Lubricants in North Hollywood, California. They applied Ecolube 642, a solid film lubricant suspension in concentrated form containing molybdenum disulfide. These valves were returned to the site and installed.

After 614 hours of operation, LCV714, a ten-inch valve, started to stick. After 819 hours this valve froze up. The valve had been cycled once per shift. When this valve was disassembled there was scale built upon the ball. The lubricant appeared to have no affect on preventing scale from adhering to the ball. This valve was sent to Southwest Chemical Co. to be acid cleaned and hydroblasted clean. When this was done the stellite coating started peeling off the ball. The ball was machined, electroplated with stainless steel, remachined, and ground smooth. This valve was reassembled and will be reinstalled in a different location. The valve will now be classified as LCV719B. It will be used as an emergency dump valve.

PCV301 continued through the complete run (1400 hours) with no problems. The valve did not stick during the run period. After the run was completed the valve was disassembled and inspected. There was scale built up on the ball, but the valve continued to operate. The lubricants again failed to prevent scale from building up. The stellite coating also peeled off the ball but not as much as the other. The stellite was removed and replaced with electroplated stainless steel coating. The valve came back with a mirror-type finish. This lubricant coating will be retested as the lack of a smooth finish on the valve surfaces may have prevented the lubricant from performing effectively.

3.3.4 Corrosion Resistant Coatings

A test was initiated to determine the corrosion resistance of various coatings. This test was used to evaluate potential candidate materials for coating the GLEF flash vessels. Different types of coatings on small coupons and larger test panels were obtained from several vendors for evaluation. Vendors were given the GLEF operating conditions and asked to recommend a coating. Large test panels were originally planned but time and space limitations required the use of some small coupons.

The test samples were installed in the first stage (V-4) and second stage (V-11) flash vessels. Each vessel is approximately six feet in diameter and 20 to 30 feet long. Upon startup the specimens were exposed to brine and flashed steam from Magmamax #1 under the following average operating conditions:

	Pressure, psia	Temp °F
First Stage (V-4)	130	363
Second Stage (V-11)	21	244

The specimens were composed of small coupons with an exposed area of less than 5 square inches and larger test panels (3" x 64" x 3/8"). The small test coupons were arranged in baskets and placed throughout the vessel, those in the upper half of the vessel exposed to steam and those in the lower half exposed to liquid brine. The test panels were mounted between the top and bottom of the vessel. The weight, coating thickness, and/or visual appearance of each specimen were recorded prior to testing. Some of the raw data to be obtained after the test included peel strength, types of observed corrosion, and scale thickness.

The test panels, due to their larger size, provide more accurate data than the smaller coupons. The coupon baskets may scale up, yielding unrepresentative data. The test panels being suspended vertically across the diameter of the vessel allowed observations to be made at the steam-brine interface. However if panels could not be obtained, coupons were used.

The following is a report on the test panels tested during run #1 (1400 hours):

Material	Visual Inspection
Flame sprayed Zn on carbon steel	Failed badly in both stages
Flame sprayed Cr on carbon steel	Failed badly in both stages
Flame sprayed Al-Ti on carbon steel	Failed badly in both stages
Carbon Steel 1020	1st stage - 10 mils lost (brine)
	1st stage - 16 mils lost (steam)
TFE on carbon steel - 1 side	1st stage - poor
	2nd stage - fair
FEP on carbon steel - 1 side	1st stage - fair
	2nd stage - good
PFA on carbon steel - 1 side	1st stage - good
	2nd stage - good
Hastelloy C-276	1st stage - no visible attack

The above materials contacted both steam and brine sections. The Hastelloy C-276 was in excellent condition and will be reinserted in the first stage for the next run.

Material	Location
29 Cr-5 Mo	V-4 (brine and steam)
Hastelloy G	V-4 (brine and steam)
Ti-Cd 50	V-4 (brine and steam)
Carpenter 20 Cd3	V-4 (brine and steam)
Inconel 625	V-4 (if source is located)
Incoloy 825	V-4 (if source is located)

These materials in panel configuration will be tested on the next run.

3.3.5 Pinch Valves

One of the more promising types of brine control valves being evaluated at the GLEF are pinch valves, in which a flexible liner contained inside a metal body is used to squeeze off the flow. The flexing of the liner is expected to prevent large amounts of scale from accumulating in the valve, thus extending its life. Two types of pinch valves, one manufactured by the Red Valve Company and one by the Galigher Valve Company, are presently being tested.

Previously, liners in both valves failed after a short period of operation, but other liner materials are being evaluated. The valves are presently located between the second stage flash vessel (7 psig) and the atmospheric flash drum (0 psig). Each handles the entire flow of one of the flash trains. The results are not available as yet on how well the valves hold up under these conditions.

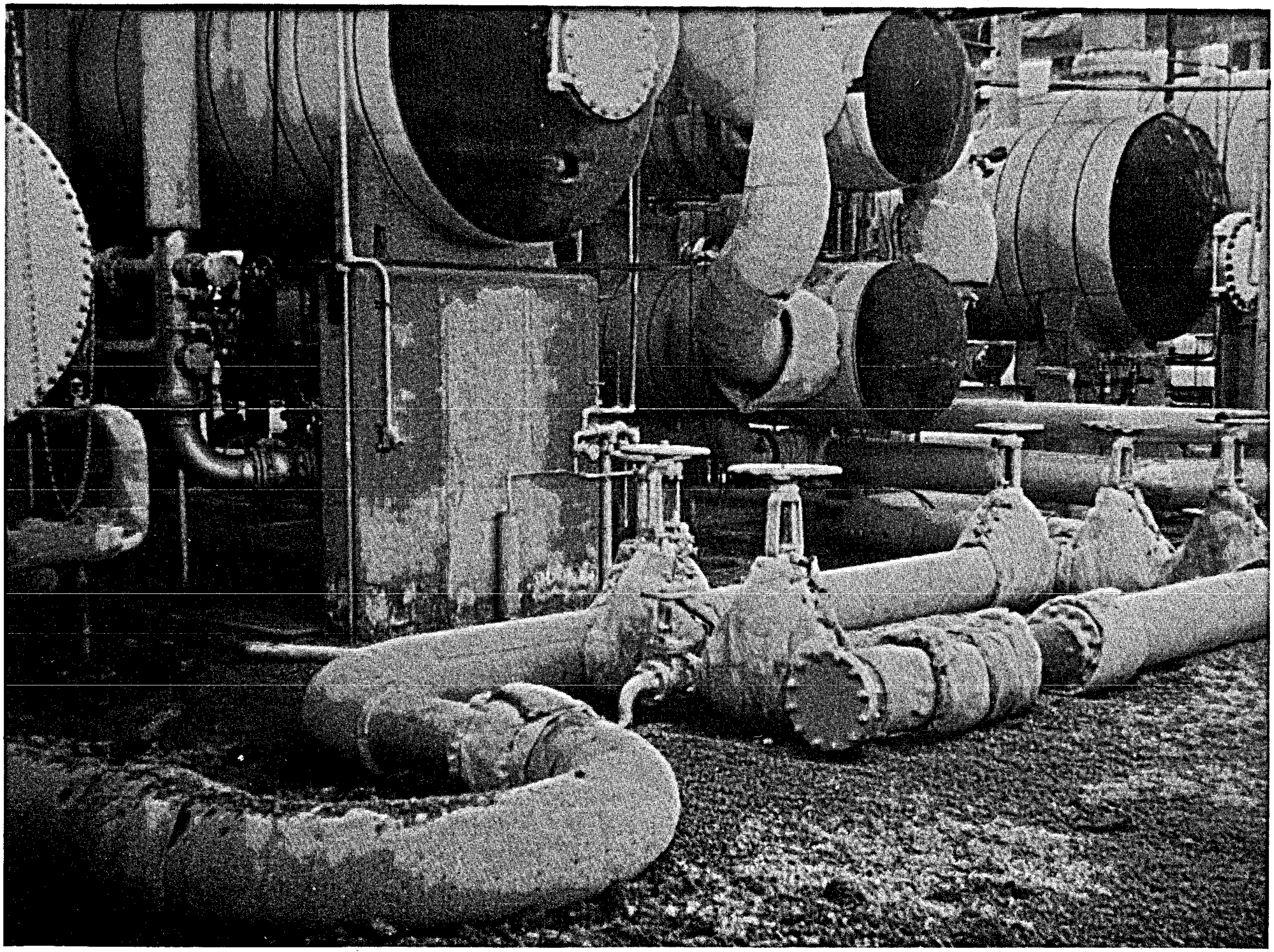


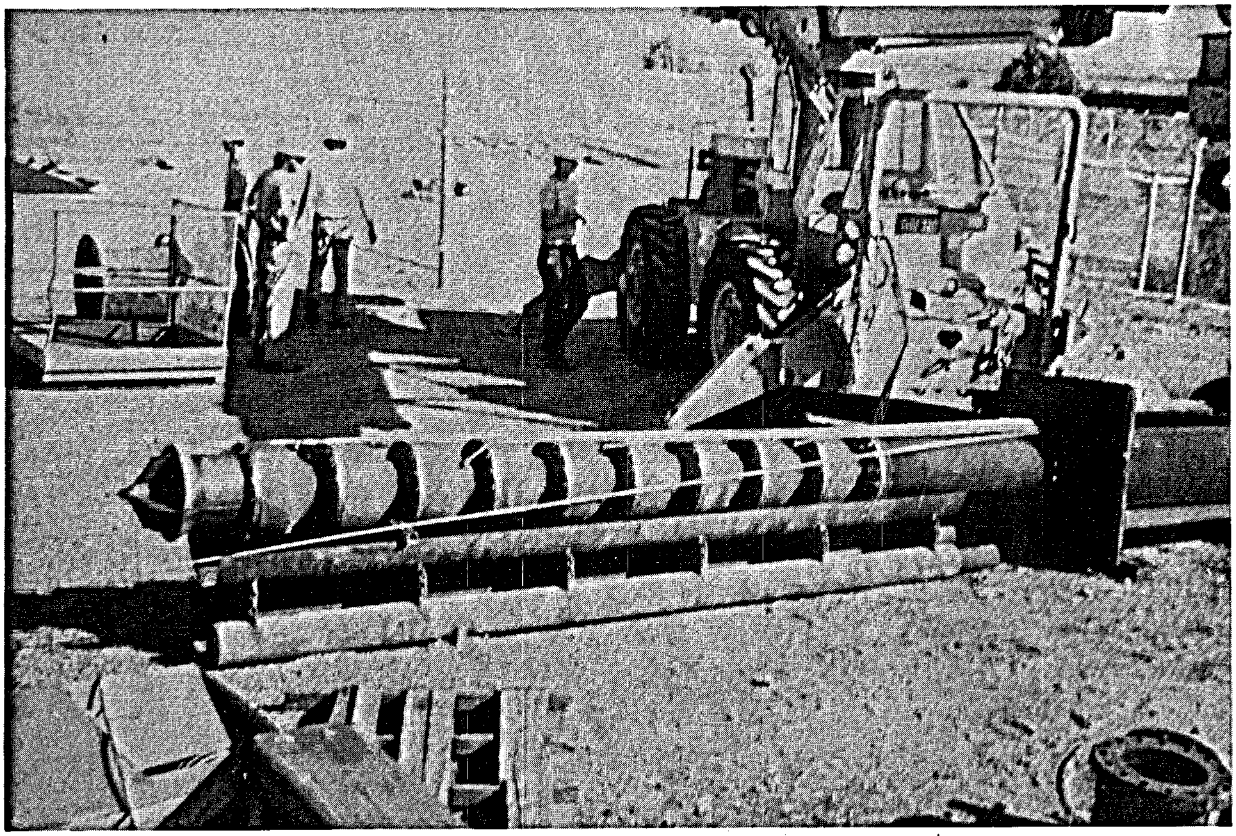
FIGURE 3-1

The possibility of using pinch valves in other areas of the GLEF is being investigated. The testing of other brine control components will be incorporated into the 1978-1979 GLEF Test Program.

3.3.6 Cavitation Cleaning

During this reporting period, Daedalean Associates, Inc. conducted tests of fixed cavitation nozzles in the brine flowing between the first and second stages in the Magmamax #1 flash train. These tests were intended to determine how long the nozzles would last before plugging with scale. The nozzles were operated for brief periods at predetermined frequencies by Daedalean personnel using a high pressure positive displacement pump. The results of this test are not yet available.

Also during this period, a 10-inch gate valve was modified by DAI to include cavitating jets in its body, configured so as to keep the seats of the valve free of scale. This valve was used to isolate a test spool from the brine flow. Upon shutdown, an inspection of the valve seats showed that the jets were relatively ineffective in keeping the seats clean with infrequent activiation. However, more frequent jetting may have been required along with improved location of nozzles. DAI is presently analyzing the results and anticipates a revised test unit. See Figure 3-1 for picture of DAJ's Test Loop)



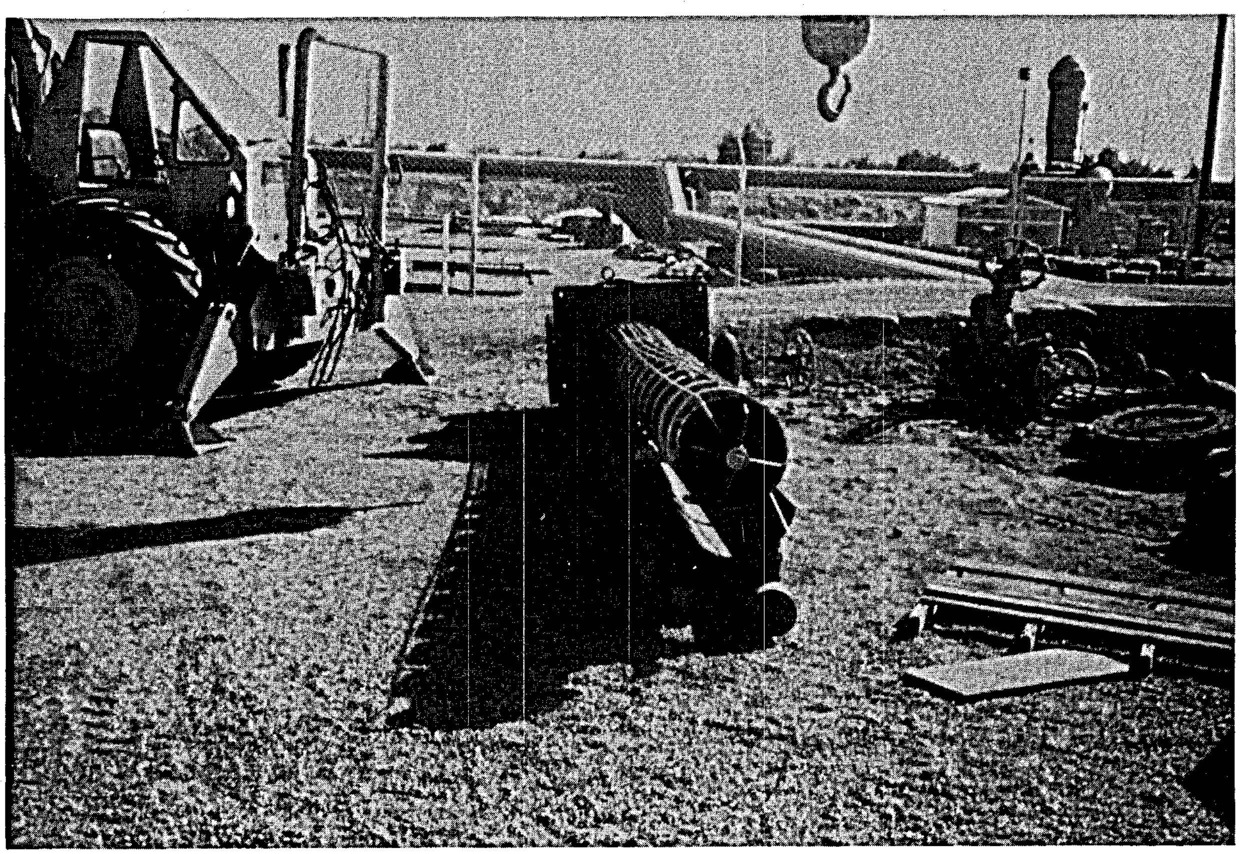


FIGURE 5-1 & 5-2

TABLE 4-1

GEOTHERMAL EXPERIMENTAL FACILITY
STEAM SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
INTO 1B SCRUBBER															
OUT OF 1B SCRUBBER	8-1-78	6.4			2,000			10.74	4.35	0.54				5.60	
INTO 2B SCRUBBER	8-1-78	6.4			1,900			57.57	21.3	18.8				0.20	
OUT OF 2B SCRUBBER	8-1-78	6.6			2,500			42.06	9.13	12.6				0	
COMBINED CONDENSATE	8-1-78	7.45			1,550			25.59	8.48	0.56			0	1.10	
INTO 1B SCRUBBER	8-2-78	6.5			1,900			11.52		0.26					
OUT OF 1B SCRUBBER	8-2-78	6.4			2,000			4.44		11.05					
INTO 2B SCRUBBER	8-2-78	6.4			1,600			59.88		18.30					
OUT OF 2B SCRUBBER	8-2-78	6.4			1,320			16.63		15.36					
COMBINED CONDENSATE	8-2-78	7.4			1,280			24.57		0.29			0		
INTO 1B SCRUBBER	8-3-78	6.6			1,950			9.4		0.44					
OUT OF 1B SCRUBBER	8-3-78	6.6			2,450			4.4		8.78					
INTO 2B SCRUBBER	8-3-78	6.6			1,500			13.7		15.91					
OUT OF 2B SCRUBBER	8-3-78	6.5			1,200			7.1		3.31					
COMBINED CONDENSATE	8-3-78	6.1			1,650			15.0	3.5	0.34	0	0	0		
INTO 1B SCRUBBER	8-4-78	6.6			1,850			8.18		0.43					
OUT OF 1B SCRUBBER	8-4-78	6.6			2,000			2.25		7.99					
INTO 2B SCRUBBER	8-4-78	6.6			1,400			19.41		8.72					
OUT OF 2B SCRUBBER	8-4-78	6.5			1,400			7.54		7.87					
COMBINED CONDENSATE	8-4-78	6.4			1,700			14.11	3.53	0.71	0	0	0		
INTO 1B SCRUBBER	8-7-78	6.2			2,120										
OUT OF 1B SCRUBBER	8-7-78	6.9													
INTO 2B SCRUBBER	8-7-78	6.3			2,730										
OUT OF 2B SCRUBBER	8-7-78	6.3			1,450										
COMBINED CONDENSATE	8-7-78	6.3			1,950										

TABLE 4-2

GEOTHERMAL EXPERIMENTAL FACILITY
STEAM SAMPLE DATA

	DATE	pH	$S^=$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
INTO 1B SCRUBBER	8-9-78	6.47			1,900	292.4		5.67	1.76	0.41					
OUT OF 1B SCRUBBER	8-9-78	6.74			7,000	856.0		21.28	5.88	62.65					
INTO 2B SCRUBBER	8-9-78	6.37			2,200	268.4		63.40	39.41	18.00					
OUT OF 2B SCRUBBER	8-9-78	6.03			1,350	162.2		17.02	2.75	3.88					
COMBINED CONDENSATE	8-9-78	6.03	1.5		1,720	191.8		17.45	4.51	0.06	0	0	0		
INTO 1B SCRUBBER	8-10-78	6.15	3.0	759.2	1,900	232.0		11.24		0.41				6.30	
OUT OF 1B SCRUBBER	8-10-78	6.57	0	2,932.8	6,700	828.0		10.71		101.05				0.20	
INTO 2B SCRUBBER	8-10-78	6.36	0	561.6	1,700	150.4		183.07		11.83				1.00	
OUT OF 2B SCRUBBER	8-10-78	5.91	0	426.4	1,150	132.4		14.45		0.87				1.00	
COMBINED CONDENSATE	8-10-78	5.96	3.0	582.4	1,700	175.0		17.66	3.92	0.17	0	0	0	2.30	
INTO 1B SCRUBBER	8-11-78	6.14	2.0		2,000	229.0	76	6.91		0.25					
OUT OF 1B SCRUBBER	8-11-78	6.61	–		6,100	744.0	429	3.24		171.9					
INTO 2B SCRUBBER	8-11-78	5.96	0.1		1,500	144.0	150	23.38		6.56					
OUT OF 2B SCRUBBER	8-11-78	5.93	0		1,350	149.6	92	7.79		11.16					
COMBINED CONDENSATE	8-11-78	5.78	3.0		1,700	181.2	82	14.71	3.67	0.14	0	0	0		
INTO 1B SCRUBBER	8-14-78	6.17	2.0		1,980	236.4		6.80	2.60	0.22					
OUT OF 1B SCRUBBER	8-14-78	6.47	0		2,100	251.6		2.45	0.80	1.79					
INTO 2B SCRUBBER	8-14-78	7.43	0		2,300	273.8		54.42	11.40	2.12					
OUT OF 2B SCRUBBER	8-14-78	7.60	0		2,250	266.6		59.86	9.40	6.20					
COMBINED CONDENSATE	8-14-78	6.06	4.0		1,800	194.0		18.23	4.60	0.46	0	0	0		
INTO 1B SCRUBBER	8-15-78	6.07	4.0		2,000	235.0		10.43		0.60				6.20	
OUT OF 1B SCRUBBER	8-15-78	6.40	0		4,450	560.0		3.77		44.81				2.10	
INTO 2B SCRUBBER	8-15-78	8.30	0		1,350	185.4		62.32		0.44				1.00	
OUT OF 2B SCRUBBER	8-15-78	8.39	0		680	76.6		15.51		3.55				0	
COMBINED CONDENSATE	8-15-78	6.09	2.0		1,850	177.0		18.70		0.31				3.10	

GEOTHERMAL EXPERIMENTAL FACILITY
STEAM SAMPLE DATA

	DATE	pH	$S^=$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
INTO 1B SCRUBBER	8-17-78	6.26	2.0	811.2	2,150	242.4		3.59		0.67					
OUT OF 1B SCRUBBER	8-17-78	6.51	0	811.2	2,280	245.2		1.79		0.94					
INTO 2B SCRUBBER	8-17-78	8.85	0	499.2	2,000	189.6		136.55		3.39					
OUT OF 2B SCRUBBER	8-17-78	9.08	0	748.8	1,320	229.0		28.97		6.56					
COMBINED CONDENSATE	8-17-78	6.11	3.0	644.8	1,900	200.8		6.48		0.18					
INTO 1B SCRUBBER	8-18-78	6.65	0.5		2,120	254.8	38	7.02		0.89					
OUT OF 1B SCRUBBER	8-18-78	6.92	0		6,050	836.0	188	3.82		88.69					
INTO 2B SCRUBBER	8-18-78	9.35	0		2,000	392.8	216	76.34		0.24					
OUT OF 2B SCRUBBER	8-18-78	9.39	0		1,350	298.4	107	44.27		0.65					
COMBINED CONDENSATE	8-18-78	6.33	1.5		1,650	176.0	92	18.32		0.48					
INTO 1B SCRUBBER	8-21-78	6.44	3.0		2,000	232.		7.08	2.35	2.24					
OUT OF 1B SCRUBBER	8-21-78	7.46	0		3,050	341.		3.08	0.78	2.76					
INTO 2B SCRUBBER	8-21-78	8.66	0		1,350	241.		44.6	1.76	0.06					
OUT OF 2B SCRUBBER	8-21-78	8.71	0.2		1,750	444.		20.0	2.75	3.24					
COMBINED CONDENSATE	8-21-78	5.93	2.0		1,600	158.		24.9	7.45	0.18	0	0	0		
INTO 1B SCRUBBER	8-28-78	6.29	4.0		2,100	247.		14.4	2.14	0.45	0	0	0	5.35	
OUT OF 1B SCRUBBER	8-28-78	7.51	0		2,480	253.		7.33	0	1.75	0	0	0	1.50	
INTO 2B SCRUBBER	8-28-78	9.41	0		1,500	288.		20.0	1.43	0.22	0	0	0	0.20	
OUT OF 2B SCRUBBER	8-28-78	9.21	0		1,380	268.		15.3	1.67	1.76	0	0	0	0	
COMBINED CONDENSATE	8-28-78	6.14	2.0		1,980	168.		21.2	5.36	0.24	0	0	0	2.87	
INTO 1B SCRUBBER	8-29-78	6.19	5.0		1,880	256.		17.3	1.63	0.42					0.03
OUT OF 1B SCRUBBER	8-29-78	6.45	1.0		2,230	267.		8.44	0.20	4.53					0.03
INTO 2B SCRUBBER	8-29-78	9.09	0		995	221.		23.0	2.04	0.21					0.12
OUT OF 2B SCRUBBER	8-29-78	9.47	0		620	182.		20.0	2.04	1.09					0.06
COMBINED CONDENSATE	8-29-78	6.06	3.0		1,700	185.		23.6	9.18	0.19					0.10

TABLE 4-3

GEOTHERMAL EXPERIMENTAL FACILITY
STEAM SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
INTO 1B SCRUBBER	8-30-78	6.11	7.0	780	1,900	242		18.0	4.40	0.54					0.11
OUT OF 1B SCRUBBER	8-30-78	6.92	0	728	2,300	234		14.6	1.80	2.20					0.06
INTO 2B SCRUBBER	8-30-78	8.94	0	582	1,020	195		19.9	2.80	0.09					0.14
OUT OF 2B SCRUBBER	8-30-78	9.29	0	468	580	146		16.8	2.40	0.31					0.09
COMBINED CONDENSATE	8-30-78	5.91	4.0	416	1,650	163		20.3	7.00	0.38					0.11
INTO 1B SCRUBBER	8-31-78	6.18	3.0		1,900	234	31	11.13	2.13	0.56					0.04
OUT OF 1B SCRUBBER	8-31-78	6.53	1.0		2,270	252	25	16.17	1.49	0.83					0.85
INTO 2B SCRUBBER	8-31-78	8.90	0		1,100	188	43	20.52	1.91	0.27					0.26
OUT OF 2B SCRUBBER	8-31-78	9.17	0		7,250	172	123	18.61	1.91	0.28					0.16
COMBINED CONDENSATE	8-31-78	5.92	2.0		1,790	150	233	22.61	14.26	0.51					0.20
INTO 1B SCRUBBER	9-1-78	6.21	5.0		1,950	224		18.0	2.16	0.48					0.03
OUT OF 1B SCRUBBER	9-1-78	6.55	1.0		2,450	248		9.76	0.59	0.25					0.05
INTO 2B SCRUBBER	9-1-78	8.88	0		1,220	195		42.0	2.75	0.12					0.26
OUT OF 2B SCRUBBER	9-1-78	9.34	0		750	168		18.5	1.57	0.31					0.13
COMBINED CONDENSATE	9-1-78	6.03	2.0		1,650	140		101.	12.9	0.60					0.14
INTO 1B SCRUBBER	9-5-78	6.41	5.5	800	1,920	235		15.6	1.25	0.55	0	0	0	5.7	0.02
OUT OF 1B SCRUBBER	9-5-78	6.59	1.0	800	2,320	241		9.67	0.21	0.74	0	0	0	1.5	0.05
INTO 2B SCRUBBER	9-5-78	9.28	0	710	1,200	224		23.1	1.67	0.13	0	0	0	1.4	0.14
OUT OF 2B SCRUBBER	9-5-78	9.53	0	950	1,350	290		20.6	1.88	0.19	0	0	0	1.3	0.22
COMBINED CONDENSATE	9-5-78	6.37	5.0	710	1,950	228		21.1	2.29	0.13	0	0	0	2.5	0.04
INTO 1B SCRUBBER	9-7-78	6.35	6.0		1,750	238	32	11.7	2.26	0.23					
OUT OF 1B SCRUBBER	9-7-78	6.44	3.5		1,970	267	19	5.8	0.97	0.86					
INTO 2B SCRUBBER	9-7-78	9.54	0		870	199	28	17.2	3.55	0.06					
OUT OF 2B SCRUBBER	9-7-78	9.86	0		440	142	2	6.8	1.29	0.07					
COMBINED CONDENSATE	9-7-78	6.17	6.0		1,730	234	19	8.1	2.26	0.08					

TABLE 4-4

GEOTHERMAL EXPERIMENTAL FACILITY
STEAM SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
INTO 1B SCRUBBER	9-8-78	6.43	7.5		1,850	227.6		12.2	2.14	0.44					
OUT OF 1B SCRUBBER	9-8-78	6.50	3.5		2,180	245.2		15.9	2.14	0.13					
INTO 2B SCRUBBER	9-8-78	9.39	0		1,030	180.0		15.9	3.57	0.06					
OUT OF 2B SCRUBBER	9-8-78	9.84	0		525	155.2		8.93	1.90	0.18					
COMBINED CONDENSATE	9-8-78	6.17	9.0		1,900	219.6		9.90	3.57	0.12					
INTO 1B SCRUBBER															
OUT OF 1B SCRUBBER															
INTO 2B SCRUBBER															
OUT OF 2B SCRUBBER															
COMBINED CONDENSATE	9-11-78	6.00	6.0		1,850	178.0		12.7	3.08	0.33	0	0	0		0.02
INTO 1B SCRUBBER	9-13-78	6.45	9.5		1,900	229.0		11.7	2.35	0.30				6.30	
OUT OF 1B SCRUBBER	9-13-78	7.02	1.0		2,200	258.0		8.6	1.18	0.12				3.00	
INTO 2B SCRUBBER	9-13-78	7.58	0		1,750	215.8		15.2	3.82	1.30				1.10	
OUT OF 2B SCRUBBER	9-13-78	9.03	0		1,000	157.6		11.5	5.00	0.32				0.60	
COMBINED CONDENSATE	9-13-78	6.23	6.0		1,670	203.2		10.3	5.00	0.39				2.40	
INTO 1B SCRUBBER	9-14-78	6.19	6.5		1,750	239.2	53	14.6	2.97	0.43					
OUT OF 1B SCRUBBER	9-14-78	6.98	0		2,280	273.8	20	7.9	1.35	0.23					
INTO 2B SCRUBBER	9-14-78	9.30	0		780	176.0	40	14.6	4.86	0.38					
OUT OF 2B SCRUBBER	9-14-78	9.49	0		560	149.6	86	10.9	2.97	0.64					
COMBINED CONDENSATE	9-14-78	6.14	5.5		1,650	208.0	44	15.7	8.65	0.56					
INTO 1B SCRUBBER	9-15-78	6.30	8.0	821.6	1,700	235.		11.9	2.00	0.35					
OUT OF 1B SCRUBBER	9-15-78	7.13	0.3	852.8	2,500	268.4		4.9	1.00	0.94					
INTO 2B SCRUBBER	9-15-78	9.17	0	582.4	930	180.		12.9	4.33	0.18					
OUT OF 2B SCRUBBER	9-15-78	9.42	0	478.4	650	159.6		6.5	1.67	0.23					
COMBINED CONDENSATE	9-15-78	6.11	4.5	540.8	1,450	191.8		9.3	12.3	0.80					

TABLE 4-5

TABLE 4-6

GEOTHERMAL EXPERIMENTAL FACILITY
STEAM SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
INTO 1B SCRUBBER	9-18-78	6.52	10.0		1,750	243.8		11.5	0.79	0.26	0	0	0	7.30	0.02
OUT OF 1B SCRUBBER	9-18-78	7.14	1.0		2,600	246.8		6.3	0.00	0.20	0	0	0	3.05	0.02
INTO 2B SCRUBBER	9-18-78	8.99	0		1,350	210.6		16.0	3.2	1.66	0	0.51	0	2.35	0.40
OUT OF 2B SCRUBBER	9-18-78	9.94	0		565	167.2		7.5	0.26	0.26	0	0	0	1.40	0.04
COMBINED CONDENSATE	9-18-78	6.24	7.0		1,680	209.2		12.8	2.6	0.39	0	0.34	0	4.05	0.02
INTO 1B SCRUBBER	9-19-78	6.36	8.0	832.0	1,800	240.8	47	12.4	1.94	0.24					
OUT OF 1B SCRUBBER	9-19-78	7.05	1.0	821.6	2,250	254.8	26	3.94	0	0.18					
INTO 2B SCRUBBER	9-19-78	9.32	0	572.0	805	174.0	45	10.6	1.94	0.37					
OUT OF 2B SCRUBBER	9-19-78	9.59	0	509.6	560	158.6	25	8.03	0.56	0.43					
COMBINED CONDENSATE	9-19-78	6.19	6.5	644.8	1,600	205.6	60	15.6	3.89	0.44					
INTO 1B SCRUBBER	9-20-78	6.44	5.0		2,000			12.3	1.19	0.79					
OUT OF 1B SCRUBBER	9-20-78	6.68	0		4,730			8.8	0.95	42.7					
INTO 2B SCRUBBER	9-20-78	8.91	0		1,250			21.8	3.33	0.79					
OUT OF 2B SCRUBBER	9-20-78	9.22	0		870			12.3	2.14	1.04					
COMBINED CONDENSATE	9-20-78	6.04	6.5		1,700			22.7	6.90	0.53					
INTO 1B SCRUBBER	9-21-78	6.61	6.0		1,970			5.65	1.90	1.41					
OUT OF 1B SCRUBBER	9-21-78	6.99	0		5,500			5.80	1.19	50.48					
INTO 2B SCRUBBER	9-21-78	9.52	0		610			8.70	3.81	0.58					
OUT OF 2B SCRUBBER	9-21-78	9.65	0		810			18.84	3.33	0.77					
COMBINED CONDENSATE	9-21-78	6.27	6.0		1,500			13.04	3.33	0.45					
INTO 1B SCRUBBER	9-22-78	6.43	7.0		1,750			8.30	2.0	0.86					
OUT OF 1B SCRUBBER	9-22-78	6.78	0		4,800			3.81	0.44	34.82					
INTO 2B SCRUBBER	9-22-78	9.52	0		865			25.58	2.89	0.50					
OUT OF 2B SCRUBBER	9-22-78	9.51	0		640			4.90	2.22	0.57					
COMBINED CONDENSATE	9-22-78	6.17	5.5		1,500			5.31	2.00	0.30					

4.0 SYSTEM CHEMISTRY

The GLEF was operated and samples taken from Aug. 1, 1978 to Sept. 22, 1978. These are described in the following four (4) subsections: steam, brine, binary-cooling water and scale. Geothermal brine was supplied by Magmamax No. 1. Non-condensible gas composition was not measured during this test period, since previous measurements had shown little change in composition. The GLEF facility was operated as a two-stage flash system.

4.1 Steam

Tables 4-1 through 4-6 list daily and weekly monitored constituents of the GLEF steam system. Steam sampling points and collection techniques remained unchanged with the exception of the sample lines to the 1B (first stage) scrubber inlet. These were changed from carbon steel to stainless steel to evaluate the effect of sample lines on iron concentrations. All results given refer to steam samples which have been condensed and are at Standard Temperature and Pressure (STP) when tested.

The steam's physical characteristics in the first stage are low pH, high conductivity, high hydrogen sulfide concentrations, and low brine carryover. In the first stage scrubber, the steam sample going into the scrubber has a lower iron concentration than the steam out of the scrubber. This high variable iron concentration is attributed to the continued use of carbon steel sample lines. Corrosion products can be entrained in the sample and provide spuriously high values. The sample line into the first stage scrubber is stainless steel. Iron concentration in samples from this location are uniform and low. The carryover from the first stage separator, as characterized by the sodium concentration in the steam, was quite variable. Toward the latter phase of the test period, the scrubber efficiency appeared to decrease. This is probably due to the increase in scale build up.

The steam from the second stage varied considerably in pH, sodium calcium and iron concentrations. The pH varied from an acidic pH of 6.4 at the beginning of the test period to a basic pH of 9.52 at the end of the test period. The initial low pH may have been due to a hydrogen sulfide carryover at the beginning of the test period. This is evident in the scale sample taken from the second stage scrubber. The sodium, calcium and iron concentrations were also affected by the scale build up in the scrubber.

Several analysis show mineral concentration in the steam from the scrubber outlet to be higher than that of the inlet. This is attributed to the continued use of carbon steel sample lines which allow rust trapped minerals to build up. These periodically break off and contaminate the sample.

GEOTHERMAL EXPERIMENTAL FACILITY
BRINE SAMPLE DATA

	DATE	pH	$S^=$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
MAGMA MAX # 1	8-1-78	4.75			310,000		191,200	44,118	17,391	101.4	141	28.26	146	225	
OUT OF 1ST STAGE	8-1-78	5.65			330,000		208,750	48,162	19,021	113.8	137.5	37.78	230	150	
OUT OF 2ND STAGE															
REINJECTION	8-1-78	5.90			302,500		188,950	44,853	16,848	100.0	121.8	25.53	222	165	
MAGMA MAX # 1	8-2-78	5.0			300,000		201,850	47,344.9	17,045.5	114.58	140.75	27.27	190.91		
OUT OF 1ST STAGE	8-2-78	6.0			335,000		220,300	50,650.5	19,318.2	123.85	162.16	36.36	183.33		
OUT OF 2ND STAGE	8-2-78	6.0			310,000		199,300	48,624.4	17,424.2	136.00	159.72	32.56	181.82		
REINJECTION	8-2-78	6.2			300,000		197,950	48,091.3	15,909.1	111.11	124.34	30.23	163.64		
MAGMA MAX # 1	8-3-78	5.0			315,000		164,400	44,094.5	16,345.5	108.6	118.4	29.9	173.3		
OUT OF 1ST STAGE	8-3-78	5.9			330,000		205,155	46,850.4	17,787.8	115.6	125.0	38.8	238.5		
OUT OF 2ND STAGE	8-3-78	6.0			300,000		182,440	45,275.5	15,384.0	107.4	106.3	32.4	160.0		
REINJECTION	8-3-78	5.9			305,000		177,050	35,039.3	10,576.5	68.9	103.7	27.5	166.7		
MAGMA MAX # 1	8-4-78	5.2			305,000			42,502.0	17,156.9	110.06	150.0	33.80	193.33		
OUT OF 1ST STAGE	8-4-78	6.2			335,000			47,714.5	19,117.6	127.39	155.4	40.28	213.3		
OUT OF 2ND STAGE	8-4-78	6.0			310,000			43,704.9	16,666.7	113.92	142.9	32.88	168.75		
REINJECTION	8-4-78	6.3			310,000			45,576.0	16,176.5	100.00	128.2	30.99	168.75		
MAGMA MAX # 1	8-7-78	5.0			345,000										
OUT OF 1ST STAGE	8-7-78	5.9			385,000										
OUT OF 2ND STAGE	8-7-78	6.0			355,000										
REINJECTION	8-7-78	6.2			350,000										

TABLE 4-7

GEOTHERMAL EXPERIMENTAL FACILITY

BRINE SAMPLE DATA

	DATE	pH	$S^=$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
MAGMA MAX # 1	8- 9-78	4.57			315,000	273.0		45,744.7	17,156.9	85.71	234.4	27.14	178.6		
OUT OF 1ST STAGE	8- 9-78	5.52			340,000	351.3		46,099.3	18,137.3	120.37	234.4	37.31	223.1		
OUT OF 2ND STAGE	8- 9-78	5.61			320,000	358.0		43,262.4	16,176.5	109.09	225.8	28.79	178.6		
REINJECTION	8- 9-78	5.72			310,000	333.3		45,744.7	16,666.7	124.20	187.5	27.27	178.6		
MAGMA MAX # 1	8-10-78	4.86			305,000	312.5		43,673.9	16,176.5	107.36	128.57	25.00	166.67	280	
OUT OF 1ST STAGE	8-10-78	5.89			315,000	329.0		47,901.5	17,647.1	113.10	131.94	36.84	210.00	300	
OUT OF 2ND STAGE	8-10-78	5.84			275,000	329.0		48,175.2	17,156.9	109.09	139.71	28.95	211.11	280	
REINJECTION	8-10-78	5.90			280,000	429.0		47,931.9	16,176.5	107.36	139.71	25.97	133.33	220	
MAGMA MAX # 1	8-11-78	4.86			290,000	316.5	206,996	44,485.3	16,836.7	112.9	121.8	31.58	192.9		
OUT OF 1ST STAGE	8-11-78	6.02			315,000	327.0	220,772	45,955.9	17,176.9	122.5	121.8	40.00	181.3		
OUT OF 2ND STAGE	8-11-78	5.91			285,000	320.5	194,792	46,078.4	16,836.7	114.4	106.3	31.58	185.7		
REINJECTION	8-11-78	5.82			285,000	322.5	195,424	46,813.7	17,006.8	125.9	128.4	25.00	236.4		
MAGMA MAX # 1	8-14-78	4.66			232,000	306.5		31,632.7	11,000.0	65.71	107.14	31.94	191.67		
OUT OF 1ST STAGE	8-14-78	5.80			395,000	312.5		46,938.8	18,000.0	121.4	132.35	42.03	192.31		
OUT OF 2ND STAGE	8-14-78	5.68			430,000	349.0		59,863.9	27,500.0	125.7	174.24	47.06	200.0		
REINJECTION	8-14-78	5.37			470,000	349.0		56,462.9	23,000.0	151.2	174.24	45.71	192.31		
MAGMA MAX # 1	8-15-78	4.91			333,000	299.0		45,289.9	16,489.4	110.80	142.86	29.17	178.57	260	
OUT OF 1ST STAGE	8-15-78	5.98			390,000	349.0		48,913.0	18,085.1	115.17	181.82	40.28	215.38	330	
OUT OF 2ND STAGE	8-15-78	5.79			340,000	399.5		52,898.6	20,744.7	141.18	160.26	47.22	246.15	370	
REINJECTION	8-15-78	5.47			400,000	391.3		54,347.8	20,744.7	136.63	150.00	44.44	216.67	360	

TABLE 4-8

GEOTHERMAL EXPERIMENTAL FACILITY
BRINE SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
MAGMA MAX #1	8-17-78	5.02			365,000	276.3		40,689.7	16,509.4	111.76	104.84	25.00	192.86		
OUT OF 1ST STAGE	8-17-78	6.05			412,000	353.5		44,827.6	17,924.5	122.02	112.90	38.33	200.00		
OUT OF 2ND STAGE	8-17-78	5.84			450,000	373.0		48,620.7	19,811.3	135.54	133.93	43.33	213.33		
REINJECTION	8-17-78	6.14			400,000	375.5		50,689.7	19,339.6	204.27	77.59	1.92	42.86		
MAGMA MAX #1	8-18-78	4.83			360,000	297.3	203,000	38,167.9	16,836.7	103.45	135.7	28.6	230.0		
OUT OF 1ST STAGE	8-18-78	5.92			400,000	351.3	228,804	42,366.4	18,367.3	115.2	133.3	17.2	181.8		
OUT OF 2ND STAGE	8-18-78	5.76			390,000	386.0	263,060	44,656.5	20,408.2	130.8	159.1	58.3	258.3		
REINJECTION	8-18-78	6.05			400,000	386.0	253,012	51,908.4	20,408.2	226.2	107.1	8.8	108.3		
MAGMA MAX #1	8-21-78	5.04			300,000	299		49,200	18,100	109	114	32.4	189		
OUT OF 1ST STAGE	8-21-78	6.32			340,000	323		48,100	19,100	121	129	43.8	190		
OUT OF 2ND STAGE	8-21-78	6.34			400,000	361		58,100	22,100	143	183	32.8	132		
REINJECTION	8-21-78	5.72			380,000	350		55,200	21,100	151	109	38.2	189		
MAGMA MAX #1	8-28-78	4.99			300,000	309		50,000	18,500	123	92.9	147	225	210	
OUT OF 1ST STAGE	8-28-78	6.04			310,000	363		48,500	20,200	126	102	100	100	225	
OUT OF 2ND STAGE	8-28-78	6.05			390,000	376		47,700	16,700	150	95.6	75.0	36.4	275	
REINJECTION	8-28-78	5.00			375,000	371		49,200	17,900	159	54.7	107	130.0	275	
MAGMA MAX #1	8-29-78	4.99			240,000	317		51,600	17,300	128	82.4	29.2	208		139
OUT OF 1ST STAGE	8-29-78	6.02			280,000	378		52,000	19,400	135	88.2	50.0	214		156
OUT OF 2ND STAGE	8-29-78	6.03			320,000	414		52,700	11,700	145	58.8	39.7	23.1		305
REINJECTION	8-29-78	5.20			300,000	408		15,600	10,700	142	94.1	48.5	264		47.2

TABLE 4-9

GEOTHERMAL EXPERIMENTAL FACILITY
BRINE SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
MAGMA MAX #1	8-30-78	5.06			168,000	303		50,000	17,500	125	94.6	34.4	200		115
OUT OF 1ST STAGE	8-30-78	5.92			300,000	361		50,400	21,000	154	97.2	48.6	8.33		167
OUT OF 2ND STAGE	8-30-78	5.92			310,000	389		50,400	18,000	128	152	47.4	270		163
REINJECTION	8-30-78	5.30			330,000	386		52,300	21,000	156	148	50.0	218		194
MAGMA MAX #1	8-31-78	5.08			290,000	329		49,100	17,600	98.8	97.2	13.9	200		115
OUT OF 1ST STAGE	8-31-78	5.94			313,000	391		50,000	18,100	125	108	57.1	255		135
OUT OF 2ND STAGE	8-31-78	5.86			360,000	429		50,400	20,700	145	134	51.5	300		147
REINJECTION	8-31-78	5.19			330,000	432		50,400	19,100	144	132	63.5	230		143
MAGMA MAX #1	9- 1-78	4.94			298,000	288		50,800	16,200	147	83.3	37.5	172		114
OUT OF 1ST STAGE	9- 1-78	5.89			315,000	363		50,400	17,600	104	83.3	50.0	189		135
OUT OF 2ND STAGE	9- 1-78	5.93			373,000	391		50,000	18,600	154	104	47.7	175		131
REINJECTION	9- 1-78	5.27			368,000	389		49,600	17,600	147	85.7	54.2	188		140
MAGMA MAX #1	9- 5-78	5.04		150	395,000	294		52,000	16,100	128	100	27.4	300	250	130
OUT OF 1ST STAGE	9- 5-78	5.91		85	255,000	345		53,200	17,700	132	132	55.0	264	210	157
OUT OF 2ND STAGE	9- 5-78	5.93		65	370,000	386		54,800	20,300	148	125	43.1	84.6	315	178
REINJECTION	9- 5-78	5.21		80	370,000	384		55,600	18,800	140	119	54.0	214	315	168
MAGMA MAX #1	9- 7-78	5.01			270,000	307	222,536	50,000	17,700	123	103	30.0	200		102
OUT OF 1ST STAGE	9- 7-78	6.01			295,000	371	235,528	51,400	19,400	136	129	43.4	215		115
OUT OF 2ND STAGE	9- 7-78	6.15			325,000	423	266,920	51,900	21,800	133	121	45.8	92.3		131
REINJECTION	9- 7-78	5.27			325,000	417	256,532	52,400	20,200	133	136	51.2	192		124

TABLE 4-10

GEOTHERMAL EXPERIMENTAL FACILITY
BRINE SAMPLE DATA

	DATE	pH	$S^=$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
MAGMA MAX #1	9- 8-78	5.10			313,000	286.3		46,100	23,200	116	132	34.2	188		151
OUT OF 1ST STAGE	9- 8-78	6.03			350,000	365.5		48,100	23,800	122	135	42.5	219		151
OUT OF 2ND STAGE	9- 8-78	6.13			390,000	388.5		48,500	27,400	131	132	50.0	140		187
REINJECTION	9- 8-78	5.33			390,000	386.0		50,500	27,400	138	122	45.0	231		170
MAGMA MAX #1	9-13-78	5.06			260,000	303		45,800	21,300	106	96.2	25.0	150	230	98
OUT OF 1ST STAGE	9-13-78	6.15			300,000	373		47,700	24,300	122	100.0	52.9	159	260	98
OUT OF 2ND STAGE	9-13-78	6.08			340,000	402.5		49,200	25,700	116	99.1	60.3	56.3	300	126
REINJECTION	9-13-78	5.35			320,000	405.5		49,200	24,300	116	92.7	62.5	200	300	141
MAGMA MAX #1	9-14-78	5.25			225,000	292	197,576	41,000	20,300	119	92.6	34.7	200		77.7
OUT OF 1ST STAGE	9-14-78	6.16			270,000	380.8	223,888	41,800	23,000	138	131	48.6	514		117
OUT OF 2ND STAGE	9-14-78	6.09			305,000	417	250,956	43,000	24,300	184	110	51.3	175		131
REINJECTION	9-14-78	5.30			280,000	423	248,100	45,900	26,400	134	145	50.0	600		150
MAGMA MAX #1	9-15-78	4.96		208	215,000	299		40,700	23,300	115	71.4	36.1	220		121
OUT OF 1ST STAGE	9-15-78	6.07		83.2	243,000	373		41,300	27,500	141	100	57.8	218		144
OUT OF 2ND STAGE	9-15-78	6.01		78.0	282,000	417		43,300	27,500	147	107	64.1	260		114
REINJECTION	9-15-78	5.21		83.2	265,000	420		44,300	26,700	101	95.2	60.9	250		183
MAGMA MAX #1	9-18-78	4.90			250,000	314.5		48,300	15,100	106	129	30.4	194	265	121
OUT OF 1ST STAGE	9-18-78	5.82			268,000	368.0		47,900	14,500	120	133	57.1	224	285	153
OUT OF 2ND STAGE	9-18-78	5.92			320,000	394.0		48,300	16,400	149	144	28.8	56.3	330	133
REINJECTION	9-18-78	5.07			300,000	394.0		48,800	16,400	137	150	79.5	238	320	150

TABLE 4-11

GEOTHERMAL EXPERIMENTAL FACILITY
BRINE SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
MAGMA MAX #1	9-19-78	5.10		197.6	352,000	320.5	201,364	47,700	13,200	111	96.8	26.4	194		73.4
OUT OF 1ST STAGE	9-19-78	5.93		72.8	440,000	368.0	228,440	48,900	16,000	130	117	58.3	233		102
OUT OF 2ND STAGE	9-19-78	5.95		72.8	423,000	386.0	248,260	48,900	15,300	113	91.7	15.2	64.3		76.9
REINJECTION	9-19-78	5.17		98.8	380,000	399.5	253,828	48,900	16,000	129	117	53.1	223		108
MAGMA MAX #1	9-20-78	5.41			288,000			50,675	14,286	86.4	78.6	27.8	189		111.1
OUT OF 1ST STAGE	9-20-78	6.27			312,000			52,027	15,476	110.6	90.3	72.9	211		117.6
OUT OF 2ND STAGE	9-20-78	6.06			325,000			53,041	15,476	87.5	85.7	45.6	78		108.3
REINJECTION	9-20-78	5.64			310,000			54,054	16,071	117.3	87.8	39.7	161		105.8
MAGMA MAX #1	9-21-78	4.97			280,000			38,768	11,310	71.4	66.7	9.72	243.8		90.9
OUT OF 1ST STAGE	9-21-78	6.42			325,000			40,942	12,500	73.5	39.5	29.4	105.9		94.7
OUT OF 2ND STAGE	9-21-78	6.17			320,000			47,101	14,881	75.6	78.1	32.9	52.9		102.0
REINJECTION	9-21-78	5.89			273,000			50,725	15,476	103.9	51.5	2.94	25.0		94.7
MAGMA MAX #1	9-22-78	4.75			245,000			37,415	11,111	79.7	73.5	31.67	184.6		77.8
OUT OF 1ST STAGE	9-22-78	6.25			280,000			38,095	12,222	89.3	80.9	42.65	106.7		78.7
OUT OF 2ND STAGE	9-22-78	5.98			320,000			43,197	13,889	99.3	62.5	29.69	28.6		102.3
REINJECTION	9-22-78	5.72			270,000			39,796	12,778	106.6	90.9	51.67	207.1		90.9
MAGMA MAX #1															
OUT OF 1ST STAGE															
OUT OF 2ND STAGE															
REINJECTION															

TABLE 4-12

The characteristics of the combined condensate were relatively stable. Mineral concentrations in the combined condensate did not always agree with values for the first and second stage steam from the scrubbers. This discrepancy is also attributed to the use of a carbon steel sample line. Carbon steel sample lines will be replaced in the future.

4.2 Brine

Tables 4-7 through 4-12 list the daily and weekly constituents of the geothermal brine through the two stage flash system. Ion concentration would be expected to increase as the brine passes through the plant due to loss of water as steam. However some of the analytical results seem to contradict this, e.g., concentration of some species in the 2nd stage exit is lower than the inlet. This is in all probability due to the sampling errors in the brine and the corrective measures will be discussed in the section titled "Future Projects".

4.3 Binary and Cooling Water

Tables 4-13 through 4-21 list the daily and weekly monitored constituents of the binary and cooling water systems. These systems were put into operation on July 10, 1978, and samples were drawn beginning on July 18, 1978.

GEOTHERMAL EXPERIMENTAL FACILITY

BINARY AND COOLING POND SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
BINARY															
FROM POND TO CONSENSERS															
FROM CONDENSERS TO POND	7-18-78	8.11			2,150	6.62				2.89					
BINARY	7-24-78	8.91						56.16		3.44					
FROM POND TO CONDENSERS															
FROM CONDENSERS TO POND	7-24-78	7.73						388.13		4.72					
BINARY	7-25-78	8.6			700			14.6		1.55			2.06		
FROM POND TO CONDENSERS															
FROM CONDENSERS TO POND	7-25-78	7.7			2,300			374.2		3.88			28.01		
BINARY	7-26-78	8.48			650		22	14.93		0.32			0	0.50	
FROM POND TO CONDENSERS															
FROM CONDENSERS TO POND	7-26-78	7.62			2,250		1,615	405.9		3.33			29.59	1.70	
BINARY	7-27-78	8.78		676.0	640			11.52		1.41			0		
FROM POND TO CONDENSERS															
FROM CONDENSERS TO POND	7-27-78	8.18		93.6	2,250			236.52		3.25			31.72		

TABLE 4-13

GEOTHERMAL EXPERIMENTAL FACILITY

BINARY AND COOLING POND SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
BINARY	7-28-78	8.53			840			5.90		1.59			0		
FROM POND TO CONDENSERS															
FROM CONDENSERS TO POND	7-28-78	9.19			2,800			238.5		2.73			26.06		
BINARY	7-31-78	9.2			940			4.11		0.61			0		
FROM POND TO CONDENSERS															
FROM CONDENSERS TO POND	7-31-78	8.6			3,000			463.77		0.15			21.90		
BINARY	8- 1-78	9.25			900			2.84		0.14			0	0	
FROM POND TO CONDENSERS															
FROM CONDENSERS TO POND	8- 1-78	8.25			2,900			333.3		0.14			25.71	0	
BINARY	8- 2-78	9.5			840			5.12		0.18			0		
FROM POND TO CONDENSERS	8- 2-78	8.4			2,800		1,901	380.68		0.43			25.21		
FROM CONDENSERS TO POND	8- 2-78	8.3			2,800		1,893	369.48		0.07			25.21		
BINARY	8- 3-78	10.0			900		1,961	2.5	1.0	0.17		0	0		
FROM POND TO CONDENSERS	8- 3-78	8.3			3,000		1,996	263.8	43.3	0.50	0	0	26.8		
FROM CONDENSERS TO POND	8- 3-78	8.4			3,200			250.0	43.3	0.28	0	0	26.8		

TABLE 4-14

GEOTHERMAL EXPERIMENTAL FACILITY
BINARY AND COOLING POND SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
BINARY	8- 4-78	9.3			870			2.57	0.59	0.26	0	0	0		
FROM POND TO CONDENSERS	8- 4-78	8.1			3,000			341.49	63.73	0.50	0	0	26.79		
FROM CONDENSERS TO POND	8- 4-78	8.1			3,100			337.48	63.73	0.51	0	0	26.79		
BINARY	8- 7-78	8.9			1,200										
FROM POND TO CONDENSERS	8- 7-78	7.9			3,870										
FROM CONDENSERS TO POND	8- 7-78	7.9			4,090										
BINARY	8- 8-78	8.9			1,200										
FROM POND TO CONDENSERS	8- 8-78	7.95			4,000										
FROM CONDENSERS TO POND	8- 8-78	7.95			4,400										
BINARY	8- 9-78	9.20			1,150			9.22	1.18	0.56	0	0	0		
FROM POND TO CONDENSERS	8- 9-78	8.20			4,150	<1.0		397.16	95.59	0.61	0	0	43.20		
FROM CONDENSERS TO POND	8- 9-78	8.31			4,400	3.13		406.03	95.59	0.71	0.13	0	39.75		
BINARY	8-10-78	8.60	0	196.8	1,200			7.15	0.98	0.36	0	0	0	0	
FROM POND TO CONDENSERS	8-10-78	8.11	0	114.4	4,000	<1.0		413.02	112.75	0.53	0	0	29.55	1.20	
FROM CONDENSERS TO POND	8-10-78	8.14	0	135.2	4,300	<1.0		501.82	125.00	0.58	0	0	27.71	1.50	

TABLE 4-15

GEOTHERMAL EXPERIMENTAL FACILITY

BINARY AND COOLING POND SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
BINARY	8-11-78	8.62	0		1,100		60	8.82	1.63	0.27	–	0	–		
FROM POND TO CONDENSERS	8-11-78	7.94	0		3,700	<1.0	2,468	569.9	132.7	0.64	0	0	27.95		
FROM CONDENSERS TO POND	8-11-78	7.94	0		3,800	<1.0	2,422	862.7	193.9	0.68	0	0	27.95		
BINARY	8-14-78	9.00	0		1,150			8.16	1.20	11.06	0	0			
FROM POND TO CONDENSERS	8-14-78	7.65	0		3,450	13.88		605.44	160.0	1.29	0	0	34.62		
FROM CONDENSERS TO POND	8-14-78	7.82	0		3,500	13.88		544.22	115.0	1.05	0	0	34.62		
BINARY	8-15-78	8.89	0		1,280			20.0		1.04				0	
FROM POND TO CONDENSERS	8-15-78	7.51	0		3,450	17.8		561.59		1.12				1.80	
FROM CONDENSERS TO POND	8-15-78	7.63	0		3,850	18.1		547.10		1.05				2.10	
BINARY															
FROM POND TO CONDENSERS	8-16-78	7.77	0		3,200	20.68		259.4		1.14					
FROM CONDENSERS TO POND	8-16-78	7.80	0		3,300	21.96		473.7		1.11					
BINARY	8-17-78	8.93	0	696.8	1,330			11.86		1.29					
FROM POND TO CONDENSERS	8-17-78	7.59	0	218.4	3,650	24.38		558.62		1.18					
FROM CONDENSERS TO POND	8-17-78	7.76	0	208.0	3,950	23.92		575.86		1.61					

TABLE 4-16

TABLE 4-17

GEOTHERMAL EXPERIMENTAL FACILITY

BINARY AND COOLING POND SAMPLE DATA

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
BINARY	8-18-78	9.12	0		1,200		31	9.62		0.71					
FROM POND TO CONDENSERS	8-18-78	7.85	0		3,500	28.8	2,365	484.73	148.0	1.29					
FROM CONDENSERS TO POND	8-18-78	7.96	0		3,700	28.3	2,379	477.10	132.7	1.29					
BINARY	8-21-78	8.65	0		1,150			6.00	1.18	0.37	0	0		0	
FROM POND TO CONDENSERS	8-21-78	7.73	0		3,800	37.2		592	142	1.32	0	0		32.9	
FROM CONDENSERS TO POND	8-21-78	7.73	0		3,800	36.4		585	157	1.21	0	0		28.0	
BINARY	8-22-78	8.92	0		1,350				3.10	5.48	0	0	0		
FROM POND TO CONDENSERS	8-22-78	7.90	0		3,500	36.4		477	149	1.63	0	0	35.7		
FROM CONDENSERS TO POND	8-22-78	7.92	0		3,500	36.4		477	137	1.56	0	0	35.7		
BINARY	8-23-78	8.78			1,200			19.6		0.50	0	0	0		
FROM POND TO CONDENSERS	8-23-78	8.04			3,300	40.5		481	150	1.10	0	0	31.5		83.1
FROM CONDENSERS TO POND	8-23-78	8.04			3,300	37.2		474	144	1.22	0	0	31.5		81.8
BINARY	8-24-78	9.05			1,230			20.2	1.11	0.45					0.39
FROM POND TO CONDENSERS	8-24-78	8.21			3,300	37.5		531	144	1.42					90.1
FROM CONDENSERS TO POND	8-24-78	8.22			3,300	40.5		562	128	1.49					79.3

GEOTHERMAL EXPERIMENTAL FACILITY

BINARY AND COOLING POND SAMPLE DATA

TABLE 4-18

	DATE	pH	$S^{=}$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
BINARY	8-28-78	9.35	0		1,150			10.38	0.48	0.37	0	0	0	0	
FROM POND TO CONDENSERS	8-28-78	7.93	0		3,500	36.4		485	53.6	0.90	0	0	26.4	2.10	
FROM CONDENSERS TO POND	8-28-78	7.94	0		3,900	37.2		489	53.6	0.87	0	0	23.5	2.10	
BINARY	8-29-78	9.10	0		1,120			10.0	1.02	0.66					0.12
FROM POND TO CONDENSERS	8-29-78	7.70	0		3,450	39.6		1,781	91.8	1.39					84.7
FROM CONDENSERS TO POND	8-29-78	7.74	0		3,700	42.0		1,781	81.6	1.44					87.3
BINARY	8-30-78	8.96		686	1,150			7.85	0	0.60					0.11
FROM POND TO CONDENSERS	8-30-78	7.63	0	270	3,600	40.9		512	140	1.69			24.6		82.7
FROM CONDENSERS TO POND	8-30-78	7.54	0	270	3,850	44.0		496	135	1.52			24.6		82.7
BINARY	8-31-78	8.99	0		1,180			5.22	1.06	0.71					0.13
FROM POND TO CONDENSERS	8-31-78	7.71	0		3,850	45		496	74.5	1.44			21.1		81.4
FROM CONDENSERS TO POND	8-31-78	7.73	0		4,000	47		504	74.5	1.47			22.6		82.8
BINARY	9- 1-78	9.14	0		1,200			16.8	1.76	0.81					0.18
FROM POND TO CONDENSERS	9- 1-78	7.96	0		3,900	49		500	123	2.03			33.4		84.3
FROM CONDENSERS TO POND	9- 1-78	7.87	0		4,200	47		500	123	1.67			34.8		87.6

GEOTHERMAL EXPERIMENTAL FACILITY

BINARY AND COOLING POND SAMPLE DATA

	DATE	pH	$S^=$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
BINARY	9- 5-78	9.61	0		1,160			5.97	0.42	0.36	0	0	0	0	0.06
FROM POND TO CONDENSERS	9- 5-78	8.10	0	270	4,150	55		560	125	1.79	0.23	0	31.1	3.4	89.6
FROM CONDENSERS TO POND	9- 5-78	8.07	0	270	4,420	57		567	120	1.54	0.23	0	32.6	3.4	89.6
BINARY	9- 7-78	9.51	0		1,080		36	12.1	0.97	0.42					
FROM POND TO CONDENSERS	9- 7-78	8.00	0		3,900	58.0	2,740	533	145	1.44					
FROM CONDENSERS TO POND	9- 7-78	8.05	0		4,100	64.8	2,747	528	137	1.64					
BINARY	9- 8-78	9.50	0		1,150			13.4	0.95	0.11					
FROM POND TO CONDENSERS	9- 8-78	7.93	0		4,300	54.8		476		1.27					
FROM CONDENSERS TO POND	9- 8-78	7.89	0		4,500	61.6		476		1.28					
BINARY	9-11-78	9.38	0		1,100			6.73	0.77	0.47	0	0	0		0.09
FROM POND TO CONDENSERS	9-11-78	8.07	0		4,380	61.6		538	186	1.91	0	0	36.7		93.2
FROM CONDENSERS TO POND	9-11-78	8.11	0		4,500	70.4		524	186	1.30	0	0	36.7		94.1
BINARY	9-13-78	9.54	0		1,230			20.3	2.94	0.18				0	
FROM POND TO CONDENSERS	9-13-78	7.98	0		4,050	48.4		512	176	0.83				3.80	
FROM CONDENSERS TO POND	9-13-78	7.93	0		4,200	56.0		492	169	1.01				4.10	

TABLE 4-19

GEOTHERMAL EXPERIMENTAL FACILITY
BINARY AND COOLING POND SAMPLE DATA

	DATE	pH	$S^=$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
BINARY	9-14-78	9.66	0		1,200		179	19.7	2.70	1.95					
FROM POND TO CONDENSERS	9-14-78	8.06	0		3,800	49.8	2,587	410	155	1.17					
FROM CONDENSERS TO POND	9-14-78	8.06	0		3,950	53.6	2,560	377	155	1.25					
BINARY	9-15-78	9.47	0	842.4	1,150			18.3	2.00	0.54					
FROM POND TO CONDENSERS	9-15-78	7.72	0	208.0	3,720	53.2		467	200	1.24					
FROM CONDENSERS TO POND	9-15-78	7.64	0	197.6	3,950	56.6		470	192	1.12					
BINARY	9-18-78	9.76	0		1,100			14.3	0.26	0.34	0	0	0	0	0.13
FROM POND TO CONDENSERS	9-18-78	7.84	0		3,980	56.6		504	105	1.37	0.35	0	36.7	5.10	70.3
FROM CONDENSERS TO POND	9-18-78	7.91	0		4,100	60.4		508	98.7	1.45	0.35	0.34	36.7	5.10	73.0
BINARY	9-19-78	9.46	0	832.0	1,250		292	20.2	1.39	1.38					
FROM POND TO CONDENSERS	9-19-78	7.73	0	208.0	4,000	59.2	2,890	500	132	1.60					
FROM CONDENSERS TO POND	9-19-78	7.75	0	208.0	4,100	63.4	2,876	504	146	1.58					
BINARY	9-20-78	9.31	0		1,200			23.2	2.38	0.72					
FROM POND TO CONDENSERS	9-20-78	7.50	0		4,200			514.6	131.0	1.95					
FROM CONDENSERS TO POND	9-20-78	7.55	0		4,370			514.9	131.0	1.57					

TABLE 4-20

TABLE 4-21

GEOTHERMAL EXPERIMENTAL FACILITY
BINARY AND COOLING POND SAMPLE DATA

	DATE	pH	$S^=$	ALK	COND	NH_4	T.S.	Na	Ca	Fe	Ba	Pb	Si	B	Mg
BINARY	9-21-78	9.78	0		1,230			19.71	1.67	0.51					
FROM POND TO CONDENSERS	9-21-78	7.92	0		4,250			550.7	119.0	2.24					
FROM CONDENSERS TO POND	9-21-78	7.95	0		4,480			543.5	113.1	1.59					
BINARY	9-22-78	9.69	0		1,170			11.70	0.67	4.90					
FROM POND TO CONDENSERS	9-22-78	7.75	0		4,460			517.01	111.11	2.08					
FROM CONDENSERS TO POND	9-22-78	7.78	0		4,500			581.63	133.30	1.53					
BINARY															
FROM POND TO CONDENSERS															
FROM CONDENSERS TO POND															
BINARY															
FROM POND TO CONDENSERS															
FROM CONDENSERS TO POND															
BINARY															
FROM POND TO CONDENSERS															
FROM CONDENSERS TO POND															

The binary system was monitored daily for pH, conductivity, sodium, calcium, and iron. The pH attained relative stability after one week of operation, as did the calcium and iron concentrations. Wide fluctuations in the sodium concentration were seen throughout the test period and cannot be explained at the present time.

The differential pressure (dP) across the cooling water condenser increased from six (6) psi to twenty-eight (28) psi just a few days after start up. This was attributed to the residual scale on the pipe walls breaking off and plugging up some of the condenser tubes. The dP changed slightly (from twenty-eight (28) psi to thirty (30) psi) for the remainder of the test period. Zimmite ZC-362, a corrosion and scale inhibitor, was added to the pond water just after the drastic dP change and this may account for the small rise in the dP during the remainder of the test period. The corrosion rate of the pond also decreased from fourty-four (44) MPY to eight to ten (8-10) MPY after the addition of the ZC-362. Thus the Zimmite compound appeared effective in reducing the corrosion rate.

The pH of the pond remained stable throughout the plant operation, but the metal concentrations varied considerably. This variance was due to the addition of the combined condensate to the pond. The pond level was maintained at a depth of five (5) and six (6) feet during this test period.

4.4 Scale

The scale deposited during this period will be described in four (4) subsections: before scheduled shut down, brine system (from well head to reinjection), steam system, and cooling water system. The probable scale compositions are calculated from Atomic Absorption measurements and solubilities of possible compounds.

To differentiate the scale compounds based on solubility, the following procedures were used.

Water Soluble: The scale sample was weighed to approximately 1.0 gm in a 250 ml beaker and 200 ml of distilled water was added. The solution was then slowly boiled for a period to two (2) hours and filtered through Whatman # 42 Filter Paper into a 250 ml volumetric flask and the flask was brought up to volume. The filtrate was then analyzed on the Atomic Absorption. The scale remaining on the filter paper was placed into a platinum crucible and ashed at 900°C for 1-1/2 hours. The crucible was then cooled and weighed to obtain the amount of water insoluble material in the scale. The difference between the original weight is the amount of water soluble material in the scale.

Acid Soluble: After ashing the remaining scale sample, it was placed into a 250 ml beaker and 200 ml of 15% HCl was added. This was again boiled for two (2)

TABLE 4-22

(1)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-30.7	
NH_3-0.08	NH_4Cl- 0.4	NH_4Cl- 0.12
Ca -0.68	$CaCl_2$- 4.5	$CaCl_2$- 1.38
Mg -0.41	$MgCl_2$- 0.3	$MgCl_2$- 0.09
Na -6.63	$MnCl_2$- 0.7	$MnCl_2$- 0.21
Fe -8.72	KCl - 2.4	KCl - 0.74
Pb -7.60	NaCl -91.7	NaCl -28.15
K -0.17		CaO - 0.26
Al -0.51	Acid Soluble-15.3	CuO - 0.34
Zn -0.39	CaO - 1.7	Fe_2O_3- 7.34
Cu -0.30	CuO - 1.5	PbO -17.66
Mn -1.05	Fe_2O_3-48.0	MgO - 0.17
Si -4.18	PbO -16.9	MnO - 0.83
	MgO - 1.1	Na_2SiO_3- 3.59
	MnO - 5.4	ZnO - 0.31
	Na_2SiO_3-23.4	Al_2O_3- 2.96
	ZnO - 2.0	$CaSiO_3$- 1.03
	Acid Insoluble-54.0	Fe_3O_4- 8.85
	Al_2O_3- 5.5	
	$CaSiO_3$- 1.9	$MgSiO_3$- 0.27
	CuO - 0.2	$MnSiO_3$- 2.11
	Fe_3O_4-16.4	SiO_2 -23.37
	PbO -27.9	ZnO - 0.22
	$MgSiO_3$- 0.5	
	$MnSiO_3$- 3.9	
	SiO_2 -43.3	
	ZnO - 0.4	

(2)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-12.6	
NH_3- 0.01	$CuCl_2$- 0.1	$CuCl_2$- 0.01
Ca - 0.09	$PbCl_2$- 1.9	$PbCl_2$- 0.24
Mg - 0.03	$MgCl_2$- 0.1	$MgCl_2$- 0.01
Na - 0.64	$MnCl_2$- 0.2	$MnCl_2$- 0.03
Fe -11.23	KCl - 0.5	KCl - 0.06
Pb - 4.32	NaCl -47.1	NaCl - 5.93
K - 0.01	$ZnCl_2$- 0.1	$ZnCl_2$- 0.01
Al - 0.27	Volatile -50.0	Volatile- 6.30
Zn - 0.12		CuO - 5.38
Cu - 4.68	Acid Soluble-13.9	Fe_2O_3- 8.81
Mn - 0.33	CuO -13.9	PbO - 4.80
Si -22.12	Fe_2O_3-63.4	MgO - 0.01
	PbO -11.3	MnO - 0.22
	MgO - 0.1	Na_2SiO_3- 1.29
	MnO - 1.6	ZnO - 0.14
	Na_2SiO_3- 9.3	Al_2O_3- 1.40
	ZnO - 0.4	$CaSiO_3$- 0.15
	Acid Insoluble-73.5	Fe_3O_4- 6.03
	Al_2O_3- 1.9	
	$CaSiO_3$- 0.2	$MgSiO_3$- 0.07
	CuO - 4.7	$MnSiO_3$- 0.15
	Fe_3O_4- 8.2	SiO_2 -58.96
	PbO - 4.4	
	$MgSiO_3$- 0.1	
	$MnSiO_3$- 0.2	
	SiO_2 -80.2	
	ZnO - 0.1	

(1) End of Spool Piece between 1B and 2B Separators (wet)
(2) 2B Separator (V-11) Inlet above water line (wet)

TABLE 4-23

(1)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-30.7	
NH_3- 0.10	NH_4Cl- 0.3	NH_4Cl- 0.09
Ca - 1.08	$CaCl_2$- 1.0	$CaCl_2$- 0.32
Mg - 0.11	$PbCl_2$- 0.1	$PbCl_2$- 0.03
Na - 5.46	$MgCl_2$- 0.1	$MgCl_2$- 0.03
Fe - 3.25	$MnCl_2$- 0.2	$MnCl_2$- 0.06
Pb - 1.49	KCl - 1.4	KCl - 0.43
K - 0.23	NaCl -37.9	NaCl -11.64
Zn - 0.45	$ZnCl_2$- 0.1	$ZnCl_2$- 0.03
Cu - 0.38	Volatile-58.9	Volatile-18.08
Mn - 2.35		$CaCO_3$- 1.81
Si-32.66	Acid Soluble-14.8	CuS - 0.31
	$CaCO_3$-12.2	FeS - 4.51
	CuS - 2.1	PbS - 0.98
	FeS -30.5	$MgCO_3$- 0.15
	PbS - 6.6	$MnCO_3$- 3.60
	$MgCO_3$- 1.0	Na_2SiO_3- 3.08
	$MnCO_3$-24.3	ZnS - 0.37
	Na_2SiO_3-20.8	CuO - 0.16
	ZnS - 2.5	Fe_3O_4- 0.98
		PbO - 0.65
	Acid Insoluble-54.5	$MgSiO_3$- 0.05
	CuO - 0.3	$MnSiO_3$- 0.27
	Fe_3O_4- 1.8	SiO_2 -52.10
	PbO - 1.2	ZnO - 0.27
	$MgSiO_3$- 0.1	
	$MnSiO_3$- 0.5	
	SiO_2 -95.6	
	ZnO - 0.5	

(2)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-34.8	
NH_3- 0.03	NH_4Cl- 0.3	NH_4Cl- 0.10
Ca - 0.14	$CaCl_2$- 1.2	$CaCl_2$- 0.42
Mg - 0.04	$MgCl_2$- 0.1	$MgCl_2$- 0.03
Na - 1.16	$MnCl_2$- 0.3	$MnCl_2$- 0.10
Fe - 0.23	KCl - 2.0	KCl - 0.70
K - 0.09	NaCl -49.8	NaCl -17.33
Zn - 0.25	Volatile-46.3	Volatile-16.11
Cu - 0.03		CaO - 0.11
Mn - 0.01	Acid Soluble- 1.5	Fe_2O_3- 0.07
Si -31.50	CaO - 7.1	Na_2SiO_3- 1.29
	Fe_2O_3- 4.8	ZnO - 0.65
	Na_2SiO_3-85.7	CuO - 0.19
	ZnO - 2.4	Fe_3O_4- 0.25
		$MgSiO_3$- 0.19
	Acid Insoluble-63.7	SiO_2 -62.82
	CuO - 0.3	
	Fe_3O_4- 0.4	
	$MgSiO_3$- 0.3	
	SiO_2 -98.6	
	ZnO - 0.4	

(1) 2B Separator (V-11) outlet above water line (wet)
(2) 2B Separator (V-11) outlet below water line (wet)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble- 68.7	
NH_3- 0.09	NH_4Cl- 0.4	NH_4Cl- 0.27
Ca - 0.44	$CaCl_2$- 7.4	$CaCl_2$- 5.08
Mg - 0.02	$FeCl_2$- 0.1	$FeCl_2$- 0.07
Na - 4.56	$MgCl_2$- 0.1	$MgCl_2$- 0.07
Fe - 0.52	$MnCl_2$- 0.5	$MnCl_2$- 0.34
Pb - 0.51	KCl - 0.9	KCl - 0.62
K - 0.09	NaCl -47.7	NaCl -32.78
Ba - 0.85	$ZnCl_2$- 0.1	$ZnCl_2$- 0.07
Zn - 0.25	Volatile-42.8	Volatile-29.40
Cu - 0.13		CuS - 0.01
Mn - 0.03	Acid Soluble- 0.9	FeS - 0.14
Si - 8.28	CuS - 2.8	PbS - 0.11
	FeS -15.7	$MgCO_3$- 0.01
	PbS -12.5	Na_2SiO_3- 0.61
	$MgCO_3$- 0.5	ZnS - 0.01
	Na_2SiO_3-67.6	$BaSO_4$- 2.40
	ZnS - 0.9	CuO - 0.09
		Fe_3O_4- 0.27
	Acid Insoluble-30.4	PbO - 0.21
	$BaSO_4$- 7.9	$MgSiO_3$- 0.06
	CuO - 0.3	SiO_2-26.92
	Fe_3O_4- 0.9	ZnO - 0.46
	PbO - 0.7	
	$MgSiO_3$- 0.2	
	SiO_2-88.5	
	ZnO - 1.5	

Discharge of P-2 Pump (wet)

TABLE 4.24

hours and filtered through Whatman # 42 Filter Paper into a 250 ml volumetric flask and brought up to volume. The filter paper with the remaining scale was placed into a platinum crucible and ashed at 900°C for 1-1/2 hours. The crucible was cooled and weighed. The difference in weight of the water soluble portion and the remaining scale was the acid soluble weight.

Acid Insoluble: The remaining scale was then fused with Sodium Carbonate ($Na_2 CO_3$). After the fusion was completed the sample was placed into a 250 ml beaker with 200 ml of boiling distilled water. The solution was boiled for two (2) hours and then cooled. The solution was filtered through Whatman # 42 Filter Paper into a 250 ml volumetric flask and brought up to volume. The filter paper was washed with 15% HCl into a separate 250 ml volumetric flask and brought up to volume. The two solutions were then analyzed on the Atomic Absorption for the Acid Insoluble components.

4.4.1 Scale Samples Before Scheduled Shut Down

The plant was shut down prematurely on August 22, 1978, due to the plugging of P-2 pump. Scale samples were taken at P-2 and also in the 2B separator (V-11). As seen in tables 4-22 through 4-24, the most prominent scale species are sodium chloride (NaCl), iron oxide (Fe_2O_2), lead oxide (PbO) or lead sulfide (PbS), and Silica (SiO_2).

The volatile specie in these scale samples was water since the scales were wet when analyzed.

TABLE 4-25

(1)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble- 8.2	
Ca - 1.74	$CaCl_2$-20.6	NH_4Cl- 0.18
Fe -20.65	LiCl - 0.5	$CaCl_2$- 1.69
Mg - 0.97	$MgCl_2$- 0.7	LiCl - 0.04
Na - 2.93	$MnCl_2$- 1.0	$MgCl_2$- 0.06
Pb -25.29	KCl - 7.4	$MnCl_2$- 0.08
K - 0.43	NaCl -67.4	KCl - 0.61
Li - 0.05	$ZnCl_2$- 0.2	NaCl - 5.53
Zn - 0.48	NH_4Cl- 2.2	$ZnCl_2$- 0.02
Mn - 1.20		CaO - 0.32
Si -16.42	Acid Soluble- 7.9	FeS - 3.67
NH_3- 0.08	FeS -46.5	PbS - 3.36
	PbS -42.5	MgO - 0.17
	MgO - 2.1	MnO - 0.22
	MnO - 2.8	ZnO - 0.41
	ZnO - 2.1	$CaSiO_3$- 0.67
		Fe_3O_4-23.07
	Acid Insoluble-83.9	PbO -21.65
	$CaSiO_3$- 0.8	$MgSiO_3$- 0.25
	Fe_3O_4-27.5	$MnSiO_3$- 1.09
	PbO -25.8	SiO_2 -36.91
	MgSiO - 0.3	
	MnSiO - 1.3	
	SiO_2 -44.0	
	ZnO - 0.3	

(2)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble- 7.9	
Ca - 2.15	NH_4Cl- 1.8	NH_4Cl- 0.14
Mg - 0.68	$CaCl_2$-12.7	$CaCl_2$- 1.00
Na - 4.92	$MgCl_2$- 0.8	$MgCl_2$- 0.06
Fe -11.66	$MnCl_2$- 2.2	$MnCl_2$- 0.17
Pb -19.55	KCl - 4.7	KCl - 0.37
K - 0.26	NaCl -77.6	NaCl - 6.13
Al - 1.81	$ZnCl_2$- 0.2	$ZnCl_2$- 0.02
Li - 0.05		Al_2S_3- 0.02
Zn - 0.55	Acid Soluble- 0.6	CaO - 0.05
Cu - 0.51	Al_2S_3- 2.8	CuS - 0.01
Mn - 1.55	CaO - 7.8	Fe_2O_3- 0.19
Si -20.99	CuS - 1.6	PbS - 0.17
NH_3- 0.06	Fe_2O_3-32.4	MgO - 0.2
	PbS -28.1	MnO - 0.3
	MgO - 3.6	Na_2SiO_3- 0.10
	MnO - 5.5	ZnS - 0.01
	Na_2SiO_3-17.2	Al_2O_3- 3.49
	ZnS - 1.0	$CaSiO_3$- 0.37
		CuO - 0.27
	Acid Insoluble-91.5	Fe_3O_4-10.89
	Al_2O_3- 3.8	PbO -17.66
	$CaSiO_3$- 0.4	$MgSiO_3$- 0.64
	CuO - 0.3	$MnSiO_3$- 0.64
	Fe_3O_4-11.9	SiO_2 -57.10
	PbO -19.3	ZnO - 0.45
	$MgSiO_3$- 0.7	
	$MnSiO_3$- 0.7	
	SiO_2 -62.4	
	ZnO - 0.5	

(1) 1b Separator (V-4) Composite (dried)
(2) Elbow between 1B and 2B brine separators (dried)

TABLE 4-26

(1)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-34.4	
Ca - 2.26	NH_4Cl- 4.6	NH_4Cl- 1.58
Mg - 0.07	$CaCl_2$-25.5	$CaCl_2$- 8.77
Na - 5.09	$LiCl_2$- 1.8	$LiCl_2$- 0.62
Fe - 1.44	$MgCl_2$- 0.4	$MgCl_2$- 0.14
K - 0.23	$MnCl_2$- 1.6	$MnCl_2$- 0.55
Li - 0.25	KCl - 0.3	KCl - 0.10
Zn - 0.24	NaCl -65.6	NaCl -22.57
Mn - 0.26	$ZnCl_2$- 0.2	$ZnCl_2$- 0.07
Ba - 0.94		BaO - 0.23
NH_3- 0.25	Acid Soluble- 0.7	CaO - 0.04
Si -47.87	BaO -32.3	Fe_2O_3- 0.23
	CaO - 6.4	Na_2SiO_3- 0.17
	Fe_2O_3-32.3	ZnO - 0.09
	Na_2SiO_3-24.2	$CaSiO_3$- 0.39
	ZnO - 4.8	Fe_3O_4- 0.65
	Acid Insoluble-64.9	$MgSiO_3$-0.06
	$CaSiO_3$- 0.6	$MnSiO_3$-0.06
	Fe_3O_4- 1.0	SiO_2 -63.68
	$MgSiO_3$-0.1	
	$MnSiO_3$-0.1	
	SiO_2 -98.1	
	ZnO - 0.1	

(2)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble- 3.4	
Ca - 0.66	NH_4Cl- 4.0	NH_4Cl- 0.14
Mg - 0.03	$CaCl_2$- 0.7	$CaCl_2$- 0.02
Na - 2.36	$MgCl_2$- 0.5	$MgCl_2$-0.02
Fe -10.51	$MnCl_2$- 4.0	$MnCl_2$- 0.14
Pb - 1.97	KCl - 6.3	KCl - 0.21
K - 0.17	NaCl -83.8	NaCl - 2.85
Zn - 0.18	$ZnCl_2$- 0.7	$ZnCl_2$- 0.02
Mn - 0.49		CaO - 0.01
Si -36.95	Acid Soluble- 1.2	Fe_2O_3- 0.95
NH_3- 0.07	CaO - 1.0	PbO - 0.38
	Fe_2O_3-79.0	MgO - 0.01
	PbO - 9.7	MnO - 0.03
	MgO - 0.6	Na_2SiO_3- 0.07
	MnO - 2.5	ZnO - 0.11
	Na_2SiO_3- 6.1	$CaSiO_3$- 0.29
	ZnO - 1.1	Fe_3O_4- 3.91
	Acid Insoluble-95.4	$MnSiO_3$- 0.19
	$CaSiO_3$- 0.3	SiO_2-90.15
	Fe_3O_4- 4.1	
	PbO - 0.8	
	$MnSiO_3$- 0.2	
	SiO_2-94.5	
	ZnO - 0.1	

(1) 2B Separator (V-11) Bottom (dried)
(2) 2B Separator (V-11) top (dried)

TABLE 4-27

Wt. %	(1) % Scale Fraction	% Total Scale
	Water Soluble-29.7	
Ca - 2.41	NH_4Cl - 1.6	NH_4Cl -0.48
Mg - 0.08	$CaCl_2$ -16.6	$CaCl_2$ - 4.93
Na - 5.88	LiCl - 0.7	LiCl - 0.21
Fe - 1.46	$MgCl_2$ - 0.1	$MgCl_2$ - 0.03
Pb - 1.52	$MnCl_2$ - 0.8	$MnCl_2$ - 0.24
K - 0.07	KCl - 0.7	KCl - 0.21
Li - 0.16	NaCl -79.4	NaCl -23.58
Zn - 0.40	$ZnCl_2$ - 0.1	$ZnCl_2$ - 0.03
Cu - 0.39		CaO - 0.49
Mn - 0.86	Acid Soluble- 1.1	FeS - 0.19
Si -49.39	CaO -44.4	PbS - 0.09
	FeS -17.6	MgO - 0.02
	PbS - 8.3	MnO - 0.18
	MgO - 1.9	Na_2SiO_3 - 0.05
	MnO -16.7	ZnS - 0.07
	Na_2SiO_3 - 4.6	CuO - 0.35
	ZnS - 6.5	Fe_3O_4 - 0.90
		PbO - 0.69
	Acid Insoluble-69.2	$MnSiO_3$ - 0.35
	CuO - 0.5	SiO_2 -66.85
	Fe_3O_4 - 1.3	ZnO - 0.06
	PbO - 1.0	
	$MnSiO_3$ - 0.5	
	SiO_2 -96.6	
	ZnO - 0.1	

Wt. %	(2) % Scale Fraction	% Total Scale
	Water Soluble-45.8	
Ca - 1.70	$BaCl_2$ - 0.2	$BaCl_2$ - 0.09
Mg - 0.02	$CaCl_2$ -19.7	$CaCl_2$ - 9.02
Na - 6.60	LiCl - 0.6	LiCl - 0.27
Fe - 0.76	$MgCl_2$ - 0.2	$MgCl_2$ - 0.09
Pb - 0.63	$MnCl_2$ - 1.1	$MnCl_2$ - 0.50
K - 0.99	KCl - 7.9	KCl - 3.62
Li - 0.02	NaCl -70.2	NaCl -32.16
Zn - 0.44	$ZnCl_2$ - 0.1	$ZnCl_2$ - 0.05
Ba - 0.04		CuO - 0.39
Cu - 0.21	Acid Soluble- 2.2	Fe_2O_3 - 1.49
Mn - 0.11	CuO -17.9	ZnO - 0.52
Si -50.92	Fe_2O_3 -67.8	PbO - 0.31
	ZnO -14.3	SiO_2 -51.49
	Acid Insoluble-52.0	
	PbO - 0.6	
	SiO_2 -99.0	
	ZnO - 0.4	

(1) Out of 2B Separator (V-11) to V-15 at elbow (dried)
(2) Atmospheric Flash Vessel (V-15) (dried)

TABLE 4-28

(1)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-29.1	
Ca-15.41	$CaCl_2$-21.2	$CaCl_2$- 6.17
Mg- 0.07	$MgCl_2$- 0.2	$MgCl_2$- 0.06
Na- 1.49	KCl -22.9	KCl - 6.66
Fe- 4.04	NaCl -55.4	NaCl -16.12
Pb- 0.84	$ZnCl_2$- 0.3	$ZnCl_2$- 0.09
K - 1.03		$BaCO_3$- 0.88
Zn- 1.24	Acid Soluble-62.5	$CaCO_3$-32.06
Cu- 0.27	$BaCO_3$- 1.4	CuS - 0.44
Mn- 6.79	$CaCO_3$-51.3	FeS - 8.43
Si- 8.61	CuS - 0.7	PbS - 0.81
	FeS -13.5	$MgCO_3$- 0.13
	PbS - 1.3	$MnCO_3$-13.19
	$MgCO_3$- 0.2	K_2SiO_3- 2.31
	$MnCO_3$-21.1	Na_2SiO_3- 2.19
	K_2SiO_3- 3.7	ZnS - 2.06
	Na_2SiO_3- 3.5	Fe_3O_4- 0.13
	ZnS - 3.3	PbO - 0.23
		$MnSiO_3$- 0.03
	Acid Insoluble- 8.4	SiO_2 - 7.94
	Fe_3O_4- 1.6	ZnO - 0.07
	PbO - 2.7	
	$MnSiO_3$- 0.4	
	SiO_2 -94.5	
	ZnO - 0.8	

(2)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-56.8	
Ca- 1.26	$BaCl_2$- 0.4	$BaCl_2$- 0.23
Mg- 0.06	$CaCl_2$-12.1	$CaCl_2$- 6.87
Na- 6.84	LiCl - 0.5	LiCl - 0.28
Fe- 1.41	$MgCl_2$- 0.3	$MgCl_2$- 0.17
Pb- 0.91	$MnCl_2$- 0.7	$MnCl_2$- 0.40
K - 1.56	KCl - 9.5	KCl - 5.40
Li- 0.01	NaCl -76.4	NaCl -43.40
Zn- 0.38	$ZnCl_2$- 0.1	$ZnCl_2$- 0.06
Ba- 1.68		$BaCO_3$- 1.03
Cu- 0.28	Acid Soluble- 4.8	$CaCO_3$- 0.32
Mn- 0.20	$BaCO_2$-21.4	CuO - 0.16
Si-52.19	$CaCO_3$- 6.6	Fe_2O_3- 0.76
	CuO - 2.6	PbO - 0.47
	Fe_2O_3-15.8	$MnCO_3$- 0.10
	PbO - 4.1	K_2SiO_3- 0.87
	$MnCO_3$- 2.0	Na_2SiO_3- 1.22
	K_2SiO_3-18.4	ZnO - 0.21
	Na_2SiO_3-25.5	
	ZnO - 8.6	Fe_3O_4- 0.23
	Acid Insoluble-38.4	$MgSiO_3$- 0.04
	CuO - 0.1	SiO_2 -37.78
	Fe_3O_4- 0.6	
	PbO - 0.7	
	$MgSiO_3$- 0.1	
	SiO_2 -98.4	
	ZnO - 0.1	

(1) North End of Test Spool Piece (Reinjection) (dried)
(2) South End of Test Spool Piece (Reinjection) (dried)

(1)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-36.2	
Ca- 3.72	$BaCl_2$- 0.3	$BaCl_2$- 0.11
Mg- 0.08	$CaCl_2$-18.5	$CaCl_2$- 6.70
Na- 6.06	LiCl - 0.7	LiCl - 0.25
Fe- 6.13	$MgCl_2$- 0.4	$MgCl_2$- 0.14
Pb- 1.23	$MnCl_2$- 0.9	$MnCl_2$- 0.33
K - 1.43	KCl -10.6	KCl - 3.84
Li- 0.02	NaCl -68.5	NaCl -24.80
Zn- 0.72	$ZnCl_2$- 0.1	$ZnCl_2$- 0.04
Ba- 1.52		$BaCO_3$- 1.17
Ca- 0.12	Acid Soluble-11.7	$CaCO_3$- 2.25
Mn- 1.52	$BaCO_3$-10.0	CuO - 0.07
Si-48.09	$CaCO_3$-19.3	Fe_2O_3- 3.79
	CuO - 0.6	PbO - 0.90
	Fe_2O_3-32.4	$MnCO_3$- 1.24
	PbO - 5.9	K_2SiO_3- 0.69
	$MnCO_3$-10.6	Na_2SiO_3- 1.53
	Na_2SiO_3-13.1	ZnO - 0.47
	ZnO - 2.2	$CaSiO_3$- 0.31
	K_2SiO_3- 5.9	Fe_3O_4- 1.72
	Acid Insoluble-52.1	$MgSiO_3$- 0.10
	$CaSiO_3$- 0.6	$MnSiO_3$- 0.10
	Fe_3O_4- 3.3	SiO_2 -49.44
	PbO - 0.4	
	$MgSiO_3$- 0.2	
	$MnSiO_3$- 0.2	
	SiO_2 -94.9	
	ZnO - 0.4	

(2)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-42.2	
Ca- 3.86	$BaCl_2$- 0.3	$BaCl_2$- 0.13
Mg- 0.08	$CaCl_2$-17.7	$CaCl_2$- 7.47
Na- 6.22	LiCl - 0.8	LiCl - 0.34
Fe- 4.44	$MgCl_2$- 0.4	$MgCl_2$- 0.17
K - 1.56	$MnCl_2$- 1.0	$MnCl_2$- 0.42
Li- 0.03	KCl - 9.2	KCl - 3.88
Zn- 0.32	NaCl -70.4	NaCl -29.72
Ba- 2.93	$ZnCl_2$- 0.2	$ZnCl_2$- 0.08
Mn- 0.27		BaO - 2.34
Si-47.60	Acid Soluble- 8.8	CaO - 2.29
	BaO -26.6	Fe_2O_3- 1.28
	CaO -26.0	MnO - 0.04
	Fe_2O_3-14.6	K_2SiO_3- 1.07
	MnO - 0.5	Na_2SiO_3- 1.61
	K_2SiO_3-12.2	ZnO - 0.24
	Na_2SiO_3-18.3	$BaSO_4$- 0.88
	ZnO - 1.6	$CaSiO_3$- 0.25
		Fe_3O_4- 2.06
	Acid Insoluble-49.0	$MgSiO_3$- 0.05
	$BaSO_4$- 1.8	$MgSiO_3$- 0.15
	$CaSiO_3$- 0.5	SiO_2 -45.53
	Fe_3O_4- 4.2	
	$MgSiO_3$- 0.1	
	$MnSiO_3$- 0.3	
	SiO_2 -92.9	
	ZnO - 0.2	

(1) Reinjection line (pigged) (dried)
(2) Reinjection Line between May 2 and May 3 (dried)

TABLE 4-29

4.4.2 Brine System Scale

The scale analyses for the brine system, as seen in tables 4-25 through 4-29 will be listed in a manner that is consistent with the plant operation. That is to say, from the production well through the separators and then to re-injection. As seen in the % Total Scale column, the major scale species are iron sulfide and iron oxide (FeS and Fe_2O_3), lead sulfide and lead oxide (PbS and PbO) and silica (SiO_2), with lesser amounts of sodium chloride (NaCl) and calcium compounds ($CaCl_2$, CaO, $CaSiO_3$). As the brine progresses through the plant the concentration of silica (SiO_2), sodium chloride (NaCl), and the calcium compounds increase, while the iron and lead compounds decrease. This increase in silica, sodium chloride and calcium compounds is probably due to the temperature drop which causes the silica and calcium compounds to precipitate near the end of the plant. The decrease in the percentage of iron and lead compounds is partly due to the deposition of these elements in the first part of the plant. The high sodium chloride concentrations may be due to entrapment in the crystal lattices of the other scale species.

One point of interest was a test spool piece in the reinjection line. One end of the spool (the south end) had a liner inside. This liner came from Corrosion Research. The other end (the north end) was untreated, that is, it was made of carbon steel. A difference in the scale at the north and south ends was observed. As seen in table

(1)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble- 8.0	
Ca- 4.27	$CaCl_2$-38.7	$CaCl_2$- 3.10
Mg- 0.15	$MgCl_2$- 1.6	$MgCl_2$- 0.13
Na- 0.55	$MnCl_2$- 4.8	$MnCl_2$- 0.38
Fe-28.88	KCl -47.2	KCl - 3.78
Pb- 1.81	NaCl - 6.1	NaCl - 0.49
K - 0.93	$ZnCl_2$- 1.6	$ZnCl_2$- 0.13
Zn- 5.45		$CaCO_3$- 9.83
Mn- 2.88	Acid Soluble-63.4	CuO - 0.19
Si- 6.10	$CaCO_3$-15.5	Fe_2O_3-29.16
Cu- 0.11		
	CuO - 0.3	PbO - 3.08
	Fe_2O_3-46.0	$MgCO_3$- 0.32
	PbO - 4.5	$MnCO_3$- 5.45
	$MgCO_3$- 0.5	K_2SiO_3- 2.28
	$MnCO_3$- 8.6	Na_2SiO_3- 2.35
	K_2SiO_3- 3.6	ZnO -11.34
	Na_2SiO_3- 3.7	Fe_3O_4-17.50
	ZnO -17.3	PbO -
		$MgSiO_3$- 0.11
	Acid Insoluble-28.6	$MnSiO_3$- 0.77
	Fe_3O_4-61.2	SiO_2 9.61
	PbO - 0.8	ZnO -
	$MgSiO_3$- 0.4	
	$MnSiO_3$- 2.7	
	SiO_2-33.6	
	ZnO - 1.3	

(2)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble- 0.8	
Ca- 0.53	$AlCl_3$-18.8	$AlCl_3$- 0.15
Mg- 0.03	NH_4Cl- 8.7	NH_4Cl- 0.07
Na- 0.48	$CaCl_2$- 1.7	$CaCl_2$- 0.01
Fe-56.81	$PbCl_2$- 1.7	$PbCl_2$- 0.01
Pb- 0.30	$MgCl_2$- 0.6	$MnCl_2$-0.04
Al- 0.08	$MnCl_2$- 4.4	NaCl - 0.47
Zn- 0.65	NaCl -58.4	$ZnCl_2$- 0.05
Mn- 0.34	$ZnCl_2$- 5.7	$CaCO_3$- 0.17
Si- 4.09		FeS -55.12
	Acid Soluble-56.7	PbS - 0.28
	$CaCO_3$- 0.3	$MgCO_3$- 0.11
	FeS - 97.2	$MnCO_3$- 0.28
	PbS - 0.5	ZnS - 0.74
	$MgCO_3$- 0.2	$CaSiO_3$- 0.34
	$MnCO_3$- 0.5	Fe_3O_4-32.47
	ZnS - 1.3	$MgSiO_3$- 0.13
		SiO_2 - 9.52
	Acid Insoluble-42.5	ZnO - 0.04
	$CaSiO_3$- 0.8	
	Fe_3O_4-76.4	
	$MnSiO_3$- 0.3	
	SiO_2 -22.4	
	ZnO - 0.1	

(1) Steam line out of 1B separator (V-4) to 1B scrubber (dried)
(2) 1st Stage steam scrubber (bottom) (dried)

TABLE 4-30

Sample (1)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-23.3	
Ca- 8.11	$CaCl_2$-38.4	$CaCl_2$- 8.95
Mg- 0.07	$MgCl_2$- 1.1	$MgCl_2$- 0.26
Na- 0.54	$MnCl_2$- 0.7	$MnCl_2$- 0.16
Fe-26.26	NaCl-58.3	NaCl- 13.58
Pb- 0.20	$ZnCl_2$- 1.5	$ZnCl_2$- 0.35
Zn- 2.48		$CaCO_3$-13.80
Mn- 1.70	Acid Soluble-49.1	FeS -28.23
Si- 1.93	$CaCO_3$-28.1	PbS - 0.20
	FeS -57.5	$MgCO_3$- 0.10
	PbS - 0.4	$MnCO_3$- 2.55
	$MgCO_3$- 0.2	Na_2SiO_3- 0.83
	$MnCO_3$- 5.2	ZnS -3.39
	Na_2SiO_3- 1.7	Fe_3O_4-19.24
	ZnS - 6.9	PbO - 0.19
	Acid Insoluble-27.6	$MgSiO_3$-0.08
	Fe_3O_4-69.7	$MnSiO_3$- 0.30
	PbO - 0.7	SiO_2- 5.33
	$MgSiO_3$- 0.3	ZnO - 2.46
	$MnSiO_3$- 1.1	
	SiO_2-19.3	
	ZnO - 8.9	

Sample (2)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-42.9	
Ca-25.93	$CaCl_2$-51.6	$CaCl_2$-22.14
Mg- 0.05	KCl -29.7	KCl -12.74
Na- 0.31	NaCl -15.6	NaCl - 6.69
Fe- 1.99	$ZnZl_2$- 3.1	$ZnCl_2$- 1.33
K - 0.05		$CaCO_3$-48.59
Zn- 0.25	Acid Soluble-57.1	FeS - 3.77
Mn- 2.21	$CaCO_3$-85.1	$MgCO_3$- 0.17
	FeS - 6.6	$MnCO_3$- 3.77
	$MgCO_3$- 0.3	Na_2SiO_3- 0.34
	$MnCO_3$- 6.6	ZnS - 0.46
	Na_2SiO_3- 0.6	
	ZnS - 0.8	

(1) 2nd Stage Steam Scrubber (bottom) (dried)
(2) 2nd Stage Steam Scrubber (condensate) (dried)

TABLE 4-31

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble- 1.5	
Ca- 0.25	$CaCl_2$-57.6	$CaCl_2$- 0.86
Mg- 0.03	KCl -36.4	KCl - 0.55
Fe-30.38	$ZnCl_2$- 6.0	$ZnCl_2$- 0.09
Pb- 0.17		$CaCO_3$- 0.48
K - 0.01	Acid Soluble-28.4	CuS - 0.20
Zn- 0.49	$CaCO_3$- 1.7	FeS -26.01
Mn- 0.79	CuS - 0.7	$MnCO_3$- 1.22
Si- 6.39	FeS -91.6	ZnS - 0.48
	$MnCO_3$- 4.3	Fe_3O_4-44.38
	ZnS - 1.7	PbO - 0.35
		$MgSiO_3$- 0.35
	Acid Insoluble-70.1	$MnSiO_3$- 0.56
	Fe_3O_4-63.3	SiO_2-23.98
	PbO - 0.5	ZnO - 0.49
	$MgSiO_3$- 0.5	
	$MnSiO_3$- 0.8	
	SiO_2-34.2	
	ZnO - 0.7	

2nd Stage Steam Scrubber (top) (dried)

TABLE 4-32

TABLE 4-33

(1)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-39.9	
Ca- 0.48	$CaCl_2$-46.8	$CaCl_2$-18.67
Mg- o.19	$MgCl_2$- 9.6	$MgCl_2$- 3.83
Na- o.33	KCl - 8.5	KCl - 3.39
Fe-35.23	NaCl -35.1	NaCl -14.00
K - 0.02		$CaCO_3$- 0.52
Zn- 0.46	Acid Soluble-24.7	Fe_2O_3-23.24
Mn- 0.45	$CaCO_3$- 2.1	$MgCO_3$- 0.12
Si- 3.01	Fe_2O_3-94.1	$MnCO_3$- 0.40
	$MgCO_3$- 0.5	Na_2SiO_3- 0.27
	$MnCO_3$- 1.6	ZnO - 0.61
	Na_2SiO_3- 1.1	Fe_3O_4-27.08
	ZnO - 0.6	$MgSiO_3$- 0.39
		$MnSiO_3$- 0.25
	Acid Insoluble-35.4	SiO_2- 7.23
	Fe_3O_4-76.5	
	$MgSiO_3$- 1.1	
	$MnSiO_3$- 0.7	
	SiO_2-20.4	
	ZnO - 1.3	

(2)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-90.7	
Ca- 2.96	$CaCl_2$-42.7	$CaCl_2$-38.73
Mg- 0.50	$FeCl_2$-22.3	$FeCl_2$-20.23
Fe-21.22	$MgCl_2$-17.5	$MgCl_2$-15.87
K - 0.04	$MnCl_2$- 1.9	$MnCl_2$- 1,72
Zn- 0.16	KCl -11.7	KCl -10.61
Mn- 1.57	$ZnCl_2$- 3.9	$ZnCl_2$- 3.54
Si- 6.28		$CaCO_3$- 1.12
	Acid Soluble- 5.4	Fe_2O_3- 3.49
	$CaCO_3$-20.8	$MgCO_3$-0.21
	Fe_2O_3-64.6	$MnCO_3$- 0.56
	$MgCO_3$- 3.9	ZnO - 0.04
	$MnCO_3$-10.4	Fe_3O_4- 2.20
	ZnO - 0.3	$MgSiO_3$- 0.03
		$MnSiO_3$- 0.02
	Acid Insoluble- 3.9	SiO_2- 1.63
	Fe_3O_4-56.3	
	$MgSiO_3$- 0.8	
	$MnSiO_3$- 0.6	
	SiO_2-41.9	
	ZnO - 0.4	

(1) Cooling Water Condensers (top) (dried)
(2) Cooling Water Condensers (bottom) (dried)

Wt. %	% Scale Fraction	% Total Scale
	Water Soluble-16.7	
Ca- 2.88	NH_4Cl- 3.6	NH_4Cl- 0.60
Mg- 0.24	$CaCl_2$-25.5	$CaCl_2$- 4.26
Na- 1.77	$MgCl_2$- 2.4	$MgCl_2$- 0.40
Fe-48.34	$MnCl_2$- 0.4	$MnCl_2$- 0.07
Zn- 0.07	NaCl-67.8	NaCl-11.32
Mn- 0.12	$ZnCl_2$- 0.3	$ZnCl_2$- 0.05
NH_3-0.07		$CaCO_3$- 3.75
	Acid Soluble-83.3	Fe_2O_3-78.55
	$CaCO_3$- 4.5	$MgCO_3$- 0.33
	Fe_2O_3-94.3	$MnCO_3$- 0.26
	$MgCO_3$- 0.4	Na_2O - 0.33
	$MnCO_3$- 0.3	ZnO - 0.08
	Na_2O- 0.4	
	ZnO - 0.1	

Cooling Water Inlet Line at Test Spool Piece (dried)

TABLE 4-34

5-4g, a very hard carbonate and sulfide scale was deposited on the north end (without the liner). On the south end (with the liner) a very fluffy scale, which contained smaller amounts of carbonates and sulfides but higher amounts of silica, was observed.

4.4.3 Steam Scale

The major component of the steam scale, in tables 4-30 through 4-32, is iron, either as iron sulfide (FeS) or iron oxide (Fe_2O_3 or Fe_3O_4). Lesser amount of calcium, silicon, lead and sodium were observed. One scale sample from the 2nd stage steam scrubber (condensate) was high in carbonate with a lesser amount of sulfide. This scale is believed to have been caused by a brine carryover from the second stage separator.

4.4.4 Cooling Water Supply Scale

As seen in tables 4-33 and 4-34, the most prominent scale species are calcium chloride ($CaCl_2$), sodium chloride (NaCl), iron oxide (Fe_2O_3 or Fe_3O_4) and Silica (SiO_2). This scale was probably in the line and condensers before the cooling pond was treated by Zimmite. This is evident by the sudden dP change in the condenser described in section 4-4. During the next test period, this problem should be eliminated by cleaning the feed line to the condensers and the condensers themselves, thereby, starting off with a clean system to which the corrosion and scale inhibitors have already been added.

4.5 Future Projects

Because of the wide variations in the collected data, the laboratory is planning an intensive study of sample collection and analysis. The study will be broken down into two (2) phases, 1) evaluate the sampling techniques and 2) develop confidence levels of the analytical procedures.

To improve sample representiveness two (2) systems have been incorporated into the plant. One system will allow flushing the sample lines after the sample has been drawn and the other is a retractable probe. Hopefully, one or both of these sample techniques will give the laboratory a truer picture of the chemistry of the system.

To obtain confidence levels in the analytical procedures, it is the laboratory's intention to do a statistical analysis on the analytical procedures now in use. This will be done on both the wet chemistry and the Atomic Absorption procedures.

This study should be completed by the end of the next operating period, at which time the laboratory should have an idea of the cause of any deviations in the results.

5.0 MAINTENANCE

5.1 Injection Pump

On August 18 after about 614 hours of operation the discharge pressure on the injection pump (P-2) started falling off. The atmospheric flash vessel (V-15) from which the P-2 draws a suction, was continuing to be pumped out. By August 21, the P-2 discharge pressure was down to about 100 psig.

Southwest Chemical Company arrived at the site to hydroblast the suction of the P-2. This has been done on a weekly basis. It was suspected that the pump can was plugged with scale and was preventing brine from entering the pump suction. While the suction was being hydroblasted, cooling water was injected into the top of the pump can through a 2 1/2" fire hose. This was done in an attempt to flush the brine scale down to the pump suction with the hydroblasting keeping it stirred up, while the pump pumped the scale out. This was done for one hour. After completion, the discharge pressure continued to be low.

On August 22, after 693 hours of operation, the level in the atmospheric flash tank V-15 started going high. It was suspected the suction line between the V-15 and the P-2 was plugged. At 0728 the plant was shut down. The 10" suction line was removed and approximately 2" of soft scale was observed inside this line. This was not enough to restrict the flow to the pump suction.

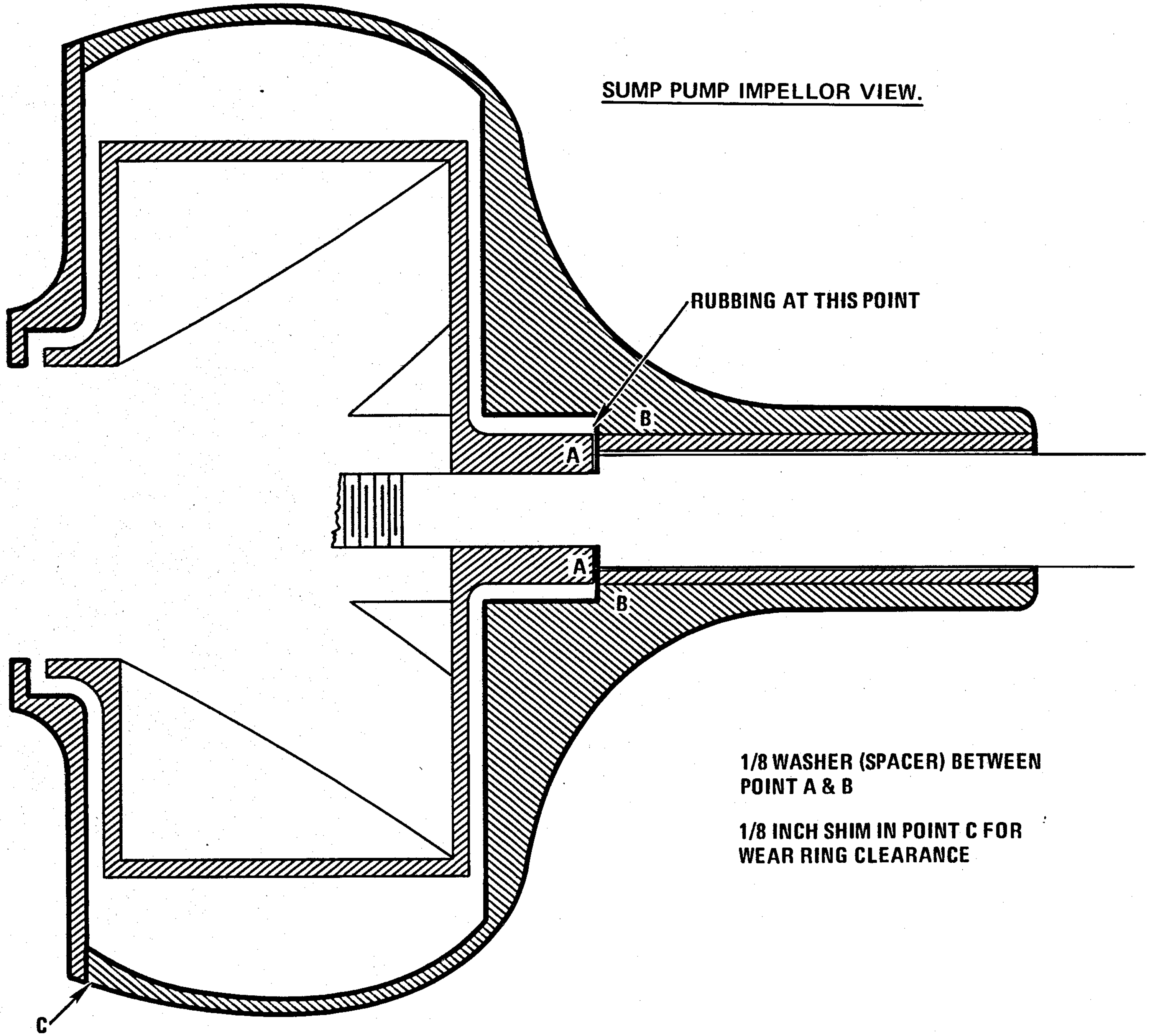
On August 23, the injection pump (P-2) was pulled. The area between the pump and pump can was completely plugged with soft scale. The pump and can were hydroblasted clean and the P-2 reinstalled. The P-2 pump was started to recirculate water from the V-15 and a normal discharge pressure of about 500 psig was observed.

On September 11 at 0001 the P-2 discharge pressure started falling off again and the V-15 water level started going high. By 0730 the discharge pressure was down to about 50 psig. The brine flow had to be decreased to keep the level in the V-15 at a normal level.

A 2 1/2" fire hose was hooked up to the P-2 vent line and cooling water was injected into the pump can in an attempt to flush the scale down into the can. After about 15 minutes of flushing, the discharge pressure increased to about 250 psig with the control valve (LCV718A) open about half way and the by-pass valve open. The recirculation valve was closed. The V-15 level at this point started coming down from a high level.

On September 12, the pump was removed from the can. The scale buildup between the pump and the can was not as bad as the last time. There was between 1-2" of scale remaining on the pump and can. There was evidence the scale buildup had been greater, but the flushing while in operation, removed a good share of the scale. The pump and can were

SUMP PUMP IMPELLOR VIEW.



1/8 WASHER (SPACER) BETWEEN POINT A & B

1/8 INCH SHIM IN POINT C FOR WEAR RING CLEARANCE

FIGURE 5-3

then hydroblasted and reinstalled. (See Figure 5-1 and 5-2) The plant was started up and the pump tested satisfactorily.

5.2 Sump Pump

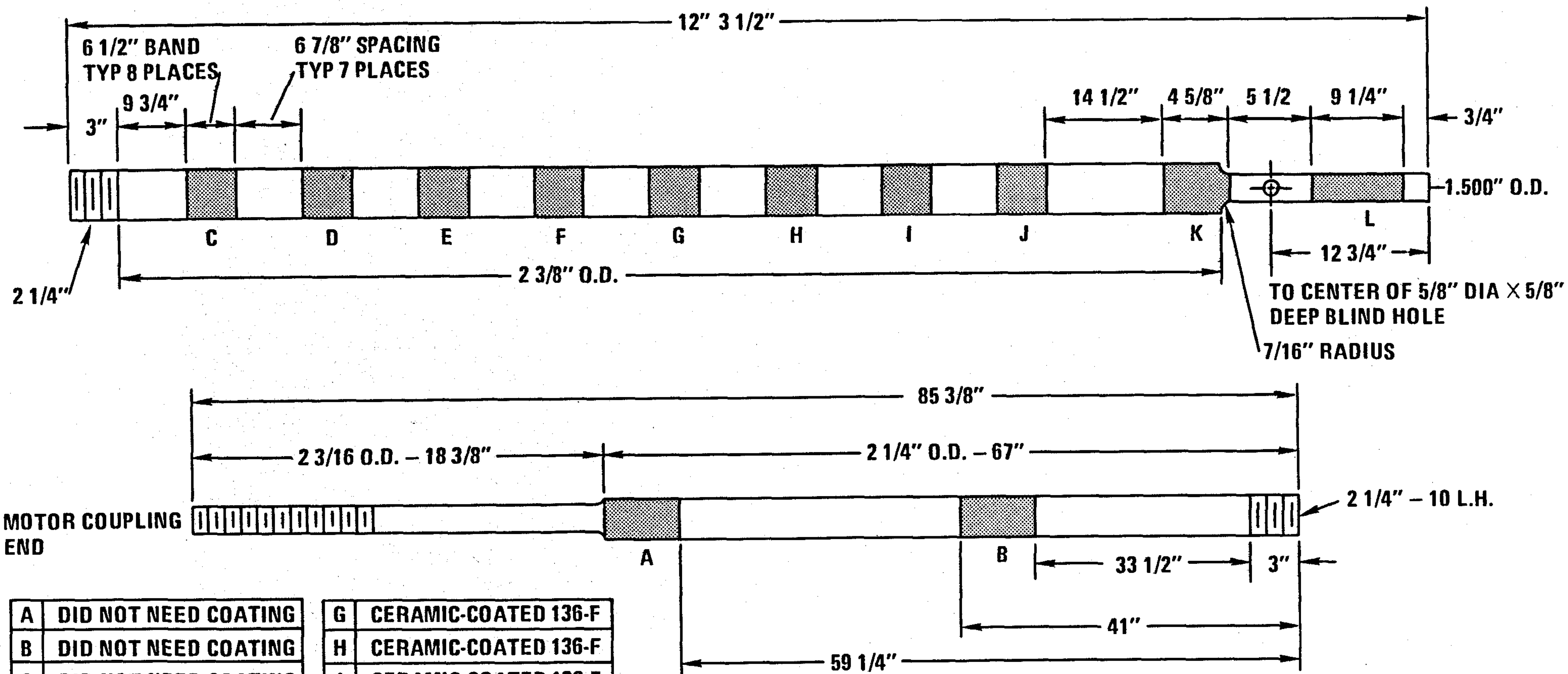
On September 8, the sump pump failed and would not turn by hand. The pump was removed and disassembled for inspection. The pump impellor was found to be rubbing against the top casing. This may be due to the fluid being higher in temperature than originally being pumped.

An 1/8 inch washer or spacer was placed between the top of the impellor and the shoulder of the shaft (See Figure 5-3). This was done to increase the clearance between the impellor and the top part of the casing. An 1/8 inch shim was placed on the bottom of the casing and impellor. This was added to maintain wear ring clearance.

The pump was reinstalled and tested satisfactorily. The pump has tripped off occasionally since this repair. The repair is being considered a temporary repair and will be sent to the SDG&E Machine Shop for a complete overhaul during the next shutdown.

On September 16, the sump pump failed again. The pump was removed and inspected. The adjusting nut lock washer, below the coupling, broke in the keyway, allowing the impellor to slide up during operation and rub against the top of the casing. The lock washer was renewed and the pump was reassembled. The pump was run and tested satisfactorily.

GEOTHERMAL BRINE PUMP SHAFT



A	DID NOT NEED COATING	G	CERAMIC-COATED 136-F
B	DID NOT NEED COATING	H	CERAMIC-COATED 136-F
C	DID NOT NEED COATING	I	CERAMIC-COATED 136-F
D	DID NOT NEED COATING	J	CERAMIC-COATED 136-F
E	CERAMIC-COATED 136-F	K	CERAMIC-COATED 136-F
F	CERAMIC-COATED 136-F	L	DID NOT NEED COATING

JOURNAL COATING
MATERIAL

FIGURE 6-1

INJECTION PUMP (P-2) INSPECTION

#1 SUCTION IMPELLER WEAR RING O.D. 8.609
#2 IMPELLER WEAR RING O.D. 6.900
#3 IMPELLER WEAR RING O.D. 6.895
#4 IMPELLER WEAR RING O.D. 6.900
#5 IMPELLER WEAR RING O.D. 6.899
#6 IMPELLER WEAR RING O.D. 6.899
#7 IMPELLER WEAR RING O.D. 6.899
#8 IMPELLER WEAR RING O.D. 6.900
#9 IMPELLER WEAR RING O.D. 6.898

#1 SUCTION BOWL WEAR RING I.D. 8.644
#2 BOWL WEAR RING I.D. 6.940
#3 BOWL WEAR RING I.D. 6.935
#4 BOWL WEAR RING I.D. 6.938
#5 BOWL WEAR RING I.D. 6.935
#6 BOWL WEAR RING I.D. 6.935
#7 BOWL WEAR RING I.D. 6.938
#8 BOWL WEAR RING I.D. 6.935
#9 BOWL WEAR RING I.D. 6.935
#10 BOWL DOES NOT HAVE A WEAR RING OR AN IMPELLER

ALL NEW 316 STAINLESS TUBING WAS USED ON THE PURGE WATER LINE. (3/8" O.D. X .065 WALL TUBING)

FIGURE 6-2

GEOTHERMAL P-2 PUMP

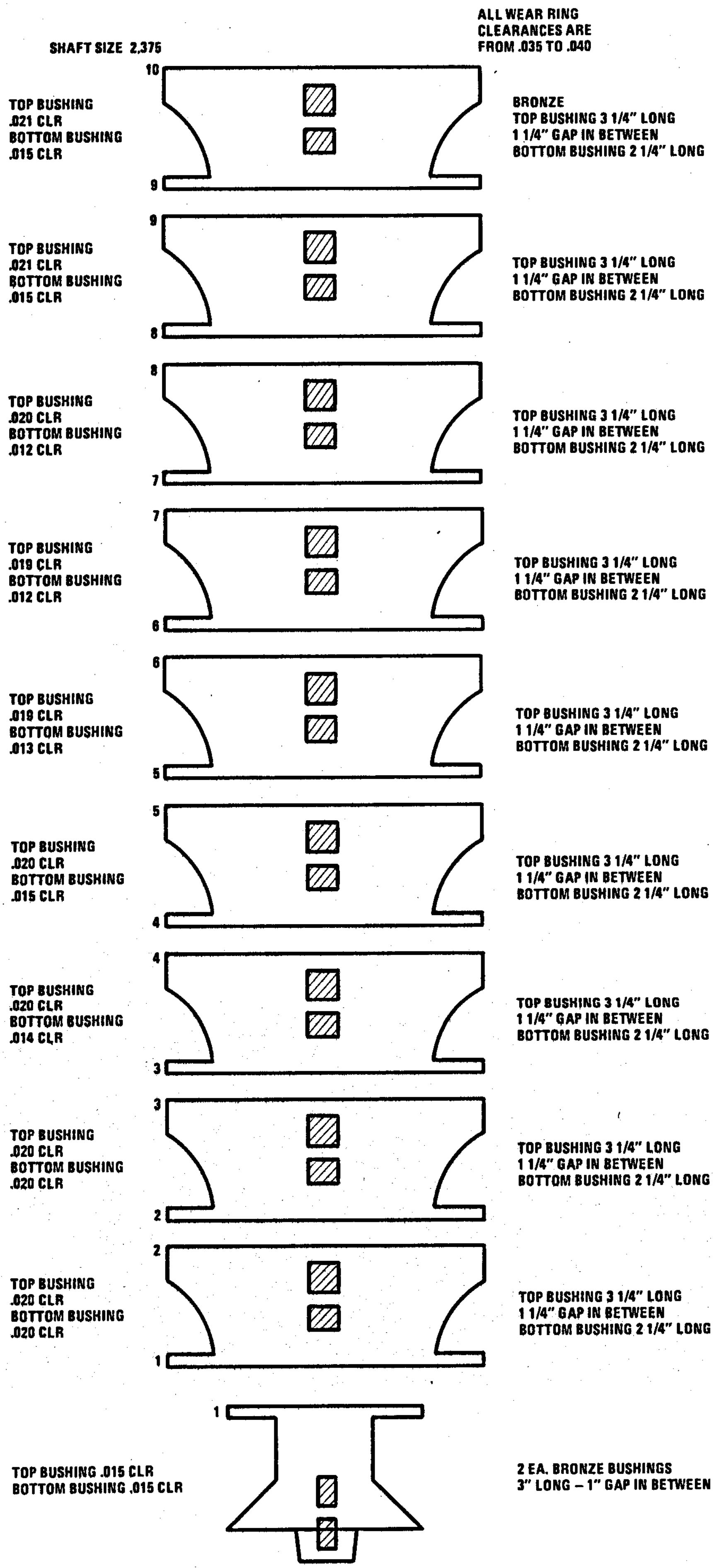


FIGURE 6-3

6.0 SPECIAL PROBLEMS

6.1 Injection Pump

This pump has new bowls that were cast by the SDG&E Machine Shop. The suction bowl was also fabricated by them. All of these bowls have O-Rings on each face for sealing purposes.

A bronze wear ring was installed in the impellor in bowl #8 and #9. The other seven impellors original wear rings were in good condition.

The suction impellor is a new 316 stainless casting. The Impeller size is 5 3/4" high by 10 3/4" diameter. The wear ring diameter is 8.609. The impellor outside diameter has a 1/6" clearance on the inside diameter of the suction bowl. The suction impellor was balanced, prior to installation.

The pump center bushing, wear ring clearances, and shaft coatings specifications can be found in Figures 6-1 and 6-2.

The motor base seal housing had a new bronze bearing installed with a clearance of .014".

6.2 Sump Pump

Upon inspection of the sump pump, all the shaft columns, discharge line, grease lines, and spiders were corroded. All of these items were originally made of mild steel. They were then replaced with 304 stainless in June of 1977. They are now replaced with 316 stainless.

The two shaft spiders had new bronze bushings installed with a .008 clearance over a 1.500 outside diameter 316 stainless shaft. This 316 stainless shaft had the worn packing area ceramic-coated because it was worn. The worn keyway also had to be recut and a new key was made.

The motor base had a new bearing installed because the old one was found to be without grease.

The pump bowl cover on the wear ring area was worn out of round .020. This was welded up and machined true. The pump bowl, pump bowl cover, and impellor are now made of 316 stainless. The pump bowl had a new bronze wear ring and shaft bushing made. Clearance on the wear ring is 0.025 and the clearance on the bushing is .008. The impellor wear rings were machined true and the impellor was balanced.

6.3 Condensate Pump (P-10)

Upon shutdown and inspection, the two 1 1/4" shafts were found to be in good condition and were polished and straightened.

The three spiders on this pump were found in good condition. The bearings had clearances of .012 to .013. These were cleaned and reinstalled.

The column registers were in good condition and were cleaned.

The diffuser bowl shaft bearing showed some wear and a clearance of .016. This clearance was decreased to .011.

The suction bowl shaft bearing had a clearance of .015. This clearance was decreased to .010. The suction bowl wear ring was repaired and machined true.

The impellor was in good condition and was polished. The wear ring clearance was .025.

The purge water lines were found to be in good condition.

7.0 OTHER ACTIVITIES

7.1 Feasibility Study

As previously reported, Phase I Report of the feasibility study was completed. This Phase assumed a settling pond for brine effluent treatment prior to injection. Subsequent work has identified a potentially more effective method of brine treatment based upon a solids contact clarifier.

Lawrence Livermore Laboratory contracted with an independent consultant, Mr. Gordon Richardson, to evaluate the cost impact on a 50MWe power plant. His report was independently reviewed by The Ben Holt Company. (Appendix A) Capital cost estimates were revised slightly (increased by several million dollars), but the basic conclusions remained unchanged.

An estimate of the effect upon operating costs in a 50MWe power plant is being delayed until better operating data is available. Impact on injection well costs will be addressed in subsequent phases of the Feasibility Study.

7.2 Feasibility Study Addendum

As previously reported an addendum to the Feasibility Study was initiated to address the impact of a binary cycle using direct contact heat exchangers on power plant economics. The Phase I Report showed the binary cycle had significant efficiency gains over the flash cycle.

The incorporation of direct contact heat exchangers was hoped would reduce the capital cost of the binary cycle while maintaining the high efficiency. A specific cycle was chosen for study. The cycle consisted of a steam turbine combined with a direct contact bottoming binary loop.

A draft report was completed by The Ben Holt Company. The preliminary conclusion was that the selected cycle maintained the high efficiency, but did not significantly reduce the costs. However, some potential areas for reducing costs were identified. These areas involve changes to the selected cycle.

Alternative cycle changes involve: 1) deleting the steam turbine and use the steam to vaporize the binary working fluid in a conventional heat exchanger, 2) deleting the steam condenser and replacing it with a binary fluid heat exchanger, and 3) common shafting and a single generator for steam and binary fluid turbines.

The addendum scope was increased to briefly review these changes to the selected cycle and identify any promising alternative. It is hoped that one of these alternatives will significantly reduce costs. Preliminary results are expected during the next reporting period.

7.3 Injection Risk Study

Injection of effluent brine is a major area of risk that was identified in the Feasibility Study. Subsequent work with solids contact clarifiers may have reduced this risk. A follow on study of brine injection risks was initiated. Completion Technology was selected as the subcontractor for this study.

The purpose of the study was to identify remaining injection risks and determine if the planned GLEF Test Program is still required. Results indicate the Test Program is still required and significant risks still remain.

Makeup water requirements were also reviewed. When makeup waters are added to the injection requirements, injection risks are increased. The study identified alternatives in the treating and handling of makeup waters.

8.0 SUMMARY

During this quarter the plant operated for a total of 1400 hours. The scheduled plant availability was 92% with an overall capacity factor of 63%. (Based on one well flow)

The plant was started up for the first time after being modified to a two stage flash with two parallel flash trains. This two stage flash plant start up was accomplished with minimal operating problems.

The injection pump (P-2) was removed when the pump can was suspected to be plugged. The spare (P-2) was installed and the plant was returned to service within three days.

Sodium hypochloride addition is showing significant results in reducing H_2S in the condensate. This condensate treatment and cooling water treatment are improving cooling water system performance.

One well flow was continued using Magmamax #1 as the production well, injecting into Magmamax #2. Due to the limited capacity of the settling tank system two well flow was not attempted.

Drafts of the 1978-1979 GLEF Test Program are being prepared. These drafts will be reviewed by all participants prior to release. Interim Tests of materials and components will be incorporated into the test plan.

Pigged polymer impregnated test spools were removed this run and showed very little evidence of abrasion with a nominal amount of scale buildup.

Test spools of other materials will be tested throughout the plant with results to follow. Coating tests to determine corrosion resistance will also be evaluated.

Pinch valves are showing promising results in brine control preventing large amounts of scale buildup in the valve.

Cavitation cleaning is being tested by DAI on selected gate valves modified with nozzles and in a test loop to test cleaning capabilities on plant piping.

Scale control is being studied at length because it is felt this holds the key to economical and efficient operation of geothermal plants of the future.

APPENDIX A

Preliminary Cost
Estimates
Geothermal Brine Treatment System
for
Lawrence Livermore Laboratory

May 1978

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INTRODUCTION

This report contains preliminary cost estimates for the construction of a treatment facility for the reduction of soluble silica and the removal of suspended material from the effluent brine of a 50 megawatt geothermal electrical generating facility prior to reinjection of the brine into the geothermal basin.

Selection of the equipment included in the cost estimates was based upon processes employed at the Lawrence Livermore Laboratories pilot treatment facility at Niland, California.

Conceptually the process employs solids contact reaction, clarification, pressure filtration and solids dewatering.

Process unit sizing was based upon parameters developed during the pilot testing scaled for treating approximately 10 MGD of power plant effluent brine.

Description of Conceptual Brine Treatment Facility

Three alternative conceptual brine treatment facilities were used in developing cost estimates. Two alternative facilities employed either conventional gravity clarification or reactor type upflow contact clarification with granular media filtration. The third alternative investigated the cost of replacing the granular media filters with diatomaceous earth filters.

Figure No. 1 shows schematically the relationship among the process elements for the system employing conventional type gravity clarification with external solids recirculation and mixed reactor tanks.

Sequentially the system shown in Figure 1 contains the following sub system processes:

1. Chemical addition of cationic and anionic polymers.
2. External tanks for mixing clarifier recycle solids with the process influent flow.
3. Clarification
4. Clarifier effluent collection and filter influent pumping.
5. Filtration, granular media or diatomaceous earth.
6. Solids dewatering for ultimate disposal.

Following either type of clarification, the effluent would flow by gravity to a filter pump feed well. The alternative for employing pumps having the capacity to supply the filters to 50 psig and 25 psig differential was examined.

Eight granular media pressure filters, each having an effective filter area of 240 ft^2, receive the clarified effluent for final residual solids removal.

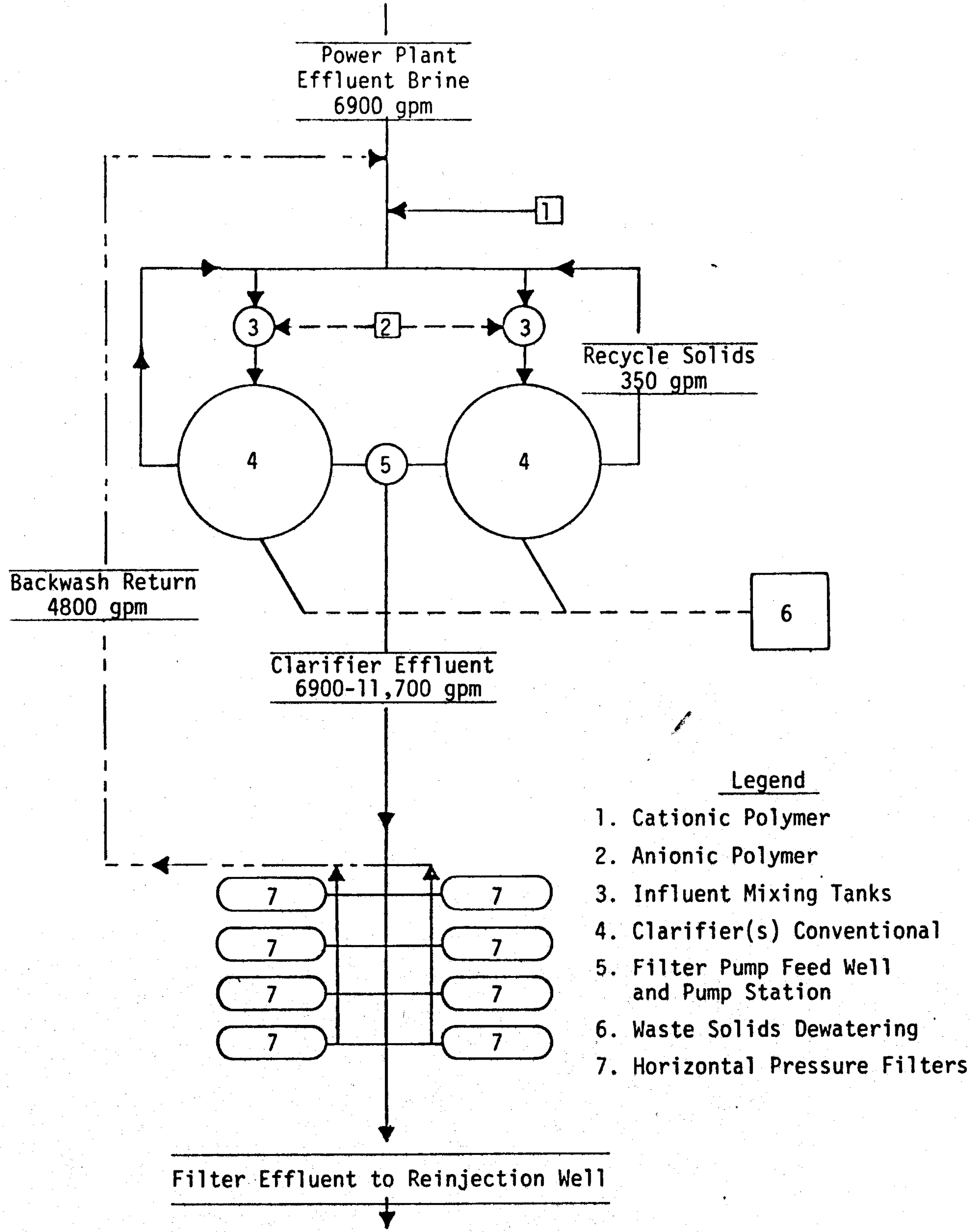

Figure 1: Schematic Diagram Geothermal Power Plant Brine Treatment Facility

The use of eight pressure filters provides compromise in specific filtration rate when one filter is removed from service for maintenance, requiring the remaining filters to carry the entire load. During a filter backwash, the remaining seven filters will provide the necessary backwash water, eliminating the need for a backwash storage tank having a capacity of approximately 72,000 gallons and 4,800 gpm backwash pump station.

Operating in this manner, the filter influent pump station would provide the necessary capacity for filtration, backwashing of the filters, and returning the backwash water to the front end of the plant for clarification. Returning the backwash water to the main plant clarifiers eliminates the need for a backwash clarifier capable of accepting the 4,800 gpm backwash flow or a combination of a backwash waste storage tank, pump station and a proportionately smaller clarifier.

As an alternate to granular media filtration, diatomaceous earth pressure filtration was examined. This alternate resulted in the use of 32 pressure filters arranged in eight banks of four filters. Conceptually, D.E. filter operation would be similar to that described for the granular media filters. Sequential backwash and precoating of the D.E. filters would produce a lower total unit backwash flow than the corresponding granular filter, but require a significantly more complicated control system since each filter must be brought into operation after precoating to insure retention of the precoat on the septum and yet insure that the filter effluent is clear of precoat before discharging to the system effluent.

D.E. filtration would also entail the use of a rather complex bulk D.E. materials handling and storage facility together with an additionally complex precoating and dispensing system for precoating the filters.

Basis of Cost Estimates

Preliminary costs of major equipment items, clarification, filtration and solids dewatering were obtained from manufacturers current estimates (April 1978) for the equipment.

Preliminary costs for pumps, piping, and valves were estimated from published cost information and adjusted according to the February 1978 Chemical Plant cost index for their respective equipment.

Except as a standard material of construction not separately identified, all equipment was estimated as constructed of steel or iron, and painted. Special corrosion resistant materials or coatings were not considered.

The costs for insulating all tankage and piping were estimated separately, based upon 2 inches of fiberglass mat or magnesia type insulation having a sheet aluminum protective covering.

Separate estimates were prepared for the major equipment field materials such as concrete footings for the clarifier and filters, clarifier bottoms, filter valves, operators, and piping.

Estimates for the cost of field materials, labor and the individual costs associated with construction for minor equipment was based upon modular equipment factors.*

Total cost for construction of the treatment facility was based upon the summation of the sub system costs and a 20 percent contingency factor.

Section I of the cost estimates contains the capital cost estimates presented in tabular form, followed by a more detailed breakdown of the sub system costs.

Section II contains operation and maintenance cost estimates following the same convention of the total system, followed by sub systems.

Section III contains a summary of the capital, operation, maintenance, and annual costs based upon dollars per 1,000 gallons of brine processed and mils per kilowatt hour of generation capacity.

* Guthrie K.M., Process Plant Estimating Evaluation and Control, Craftsman Book Company of America, 1974

SECTION I

Data
Brine Treatment System
and
Sub System
Capital Cost Estimates

Equipment Basis of Capital Cost Estimates

1. Polymer equipment includes dual chemical injection pumps for each polymer, and liquid polymer storage tanks having a 2 week storage capacity for injecting 10 mg per liter of cationic polymer and 3 mg per liter of anionic polymer at the system design rate of 10 MGD.

2. Influent mixing tanks include turbine mixers, 37,000 gal, fully baffled, covered and insulated tanks on concrete pad.

3. Clarifier equipment includes two 110 foot diameter conventional or contact clarifiers, insulated tankage and internals, concrete footings and tank bottom.

4. Filter pump feed well and pump station includes 20,000 gallon feed well, insulated, on concrete pad; three 3,900 gpm horizontal split case centrifugal pumps having 50 psig or 25 psig head capacities, on concrete pad with interconnecting piping and valves.

5. Waste solids dewatering includes 40 inch wide moving belt filter press with associated equipment, 18 inch elevated sludge conveyor and elevated sludge storage hopper for dump truck loading, all on concrete pad.

6. Filters include pressure tanks for eight 10 feet x 24 feet filters, underdrains, media, surface wash, control valves with pneumatic operators, electronic differential pressure transmitters, flow control valves, positioners, valve control solenoids, all interconnecting piping, insulation for tanks and pipes, all on concrete pad.

7. Yard piping includes 200 feet of insulated 18 inch filter influent pipe and 200 feet of 14 inch backwash return pipe.

TABLE I

Estimated Total Capital and Construction Cost for Conventional Clarification Treatment Process

1. Process		Estimated Costs	
		50 psig	25 psig
A. Clarification		$ 643,000	$ 643,000
B. Filtration		922,000	906,000
C. Polymer Equipment			
1. Cationic and Anionic		34,000	34,000
2. Cationic	$17,243		
3. Anionic	$16,532		
D. Sludge Dewatering		197,000	197,000
E. Yard Piping		21,000	21,000
2. Total Capital Costs			
A. Total Process Cost		$1,817,000	$1,801,000
B. Less Cationic Polymer		1,800,000	1,784,000
C. Less Polymer		1,783,000	1,767,000
3. Process Construction Cost--20% Contingency			
A. Total Process		$2,180,000	$2,161,000
B. Less Cationic Polymer		2,160,000	2,141,000
C. Less Polymer		2,140,000	2,120,000

TABLE II

Estimated Total Capital and Construction Cost for Contact Clarification Treatment Process

1. Process			Estimated Costs	
			50 psig	25 psig
	A.	Clarification	$ 734,000	$ 734,000
	B.	Filtration	922,000	906,000
	C.	Polymer Equipment		
		1. Cationic and Anionic	34,000	34,000
		2. Cationic $17,243		
		3. Anionic $16,532		
	D.	Sludge Dewatering	197,000	197,000
	E.	Yard Piping	21,000	21,000
2.	Total Capital Cost			
	A.	Total Process Cost	$1,908,000	$1,892,000
	B.	Less Cationic Polymer	1,891,000	1,875,000
	C.	Less Polymer	1,874,000	1,858,000
3.	Process Construction Cost--20% Contingency			
	A.	Total Process	$2,290,000	$2,270,000
	B.	Less Cationic Polymer	2,269,000	2,250,000
	C.	Less Polymer	2,249,000	2,230,000

TABLE III

Capital Cost Summary
Clarification Process

1.	Component		Estimated Clarification Cost Conventional	Contact
2.	Influent Mixing		$518,000	$734,000
	A. Tankage	$39,000		
	B. Mixers	50,000		
		$89,000	89,000	--
3.	Sludge Recycle Pumps		36,000	--
	Estimated Process Cost		$643,000	$734,000

TABLE IV

Estimated Capital Cost
Conventional Clarification

	Component	Estimated Cost
1.	Clarifiers (erected)	$245,000
2.	Field Material	166,000
	Total Direct Cost	$411,000
	Total Indirect Cost	107,000
	Conventional Clarifier Cost	$518,000

TABLE V

Estimated Capital Cost
Contact Clarifiers

	Component	Estimated Cost
1.	Clarifiers (erected)	$417,000
2.	Field Material	166,000
	Total Direct Cost	$583,000
	Total Indirect Cost	151,000
	Installed Contact Clarifier Cost	$734,000

TABLE VI

Estimated Capital Cost
Granular Media Filtration

1. Process Component		Estimated Cost 50 psig	Estimated Cost 25 psig
A.	Filter Pump Feed Well Tankage	$ 17,000	$ 17,000
B.	Filter Influent Pump	128,000	80,000
C.	Filter Tankage	539,000	539,000
D.	Surface Wash Pump	32,000	32,000
E.	Piping, Valves, Positioners	172,000	172,000
F.	Field Instrumentation	30,000	30,000
G.	Concrete	36,000	36,000
2. Filtration Capital Cost		$922,000	$906,000

TABLE VII

Estimated Total Capital and Construction Cost for Diatomaceous Earth Filtration

1. Process		Estimated Cost
A. Conventional Clarification		$ 643,000
B. Filter Pump Feed Well		17,000
C. Filter Influent Pump		80,000
D. D.E. Filtration Equipment		
1. Filter Tankage	$727,000	
2. Precoat Equipment	73,000	
3. D.E. Materials Handling and Storage	20,000	820,000
F. Anionic Polymer		17,000
G. Sludge Dewatering		197,000
H. Yard Piping		16,000
Total Capital Cost		$1,790,000
Contingency @ 20%		358,000
Total Process Construction Cost		$2,148,000

TABLE VIII

Estimated Capital Cost
Diatomaceous Earth Filters

1. Component		Estimated Cost
A.	Filter Tankage	$598,000
B.	Piping, Valves, Positioners	69,000
C.	Field Instrumentation	28,000
D.	Concrete	32,000
	Total Direct D.E. Filter Cost	$727,000
E.	D.E. Precoat Equipment	$ 73,000
F.	D.E. Materials Handling & Storage	20,000
	Total D.E. Filter Cost	$820,000

TABLE IX

Estimated Capital Cost
Polymer Feed Equipment

Component	Estimated Cost
1. Cationic Polymer (40%)	
A. Liquid Polymer Storage Tanks (4,000 gal)	$ 9,000
B. Chemical Injection Pumps	8,200
Total Capital Cost Cationic Polymer System	$17,200
2. Anionic Polymer (25%)	
A. Liquid Polymer Storage Tanks (5,000 gal)	$10,400
B. Chemical Injection Pumps	6,000
Total Capital Cost Anionic Polymer System	$16,400

TABLE X

Estimated Capital Cost
Waste Solids Dewatering

Component	Estimated Cost
1. Filter Press	$148,000
2. Solids Conveyor	37,000
3. Solids Transfer Hopper	12,000
Total Solids Dewatering Capital Cost	$197,000

SECTION II

Estimated Total Brine Treatment System

and

Sub System

Operation and Maintenance Costs

Basis of Operation and Maintenance Costs

Labor Costs: Based upon United States Environmental Agency estimates of the man hours required for the operation and maintenance of similar capacity facility, containing the same processes. Labor rates are those estimated for skilled trade labor.

Power Costs: Based upon $0.02 per kilowatt hour for the cited equipment power demands assumed to operate, with the exception of the filter surface wash pumps, 24 hours per day.

Polymer Costs: Based upon the cost for liquid polymers obtained from Calgon Corporation at the estimated economical storage concentration.

Sludge Disposal: Costs as cited

Diatomaceous Earth: Was estimated based upon .02 pounds per square foot of precoat at the current Johns Manville bulk, 10 tons or more, price, assuming a filter operating period of 15 hours between precoats.

TABLE XI

Annual
Operating and Maintenance
Cost Summary

1. Component		Estimated Cost	
A. Labor		$167,000	
B. Power	50 psig		25 psig
1. Conventional	$74,000		$59,000
2. Contact	59,000		33,000
C. Equipment Maintenance		Conventional	Contact
1. Equipment		$21,300	$23,000
2. Tankage		2,600	3,400
3. Total Equipment Maintenance		$23,900	$26,400
D. Polymer			
1. Cationic		$279,400	
2. Anionic		69,000	
Total Polymer		$348,400	
E. Sludge Disposal @ $20/ton			
1. 50% Moisture		$241,000	
2. 25% Moisture		161,000	

2. Total Annual Costs

A. Conventional Clarification	
1. 50 psig, Total Polymer, 50% Moisture	$854,000
Less Cationic Polymer	575,000
Less All Polymer	506,000
2. 50 psig, Total Polymer, 25% Moisture	774,000
Less Cationic Polymer	495,000
Less All Polymer	426,000
3. 25 psig, Total Polymer, 50% Moisture	839,000
Less Cationic Polymer	560,000
Less All Polymer	491,000
4. 25 psig, Total Polymer, 50% Moisture	759,000
Less Cationic Polymer	480,000
Less All Polymer	411,000
B. Contact Clarification	
1. 50 psig, Total Polymer, 50% Moisture	$842,000
Less Cationic Polymer	562,000
Less All Polymer	493,000
2. 50 psig, Total Polymer, 25% Moisture	762,000
Less Cationic Polymer	482,000
Less All Polymer	413,000
3. 25 psig, Total Polymer, 50% Moisture	816,000
Less Cationic Polymer	536,000
Less All Polymer	467,000
4. 25 psig, Total Polymer, 25% Moisture	736,000
Less Cationic Polymer	457,000
Less All Polymer	388,000

TABLE XII

Summary of Estimated
Process Power and Annual Costs

1. Operating Power	Conventional Clarifier	Contact Clarifier
A. Mixers	120 hp	50 hp
B. Clarifier Drive	20	20
C. Pumps		
1. Filter 50 psig	280	280
2. Filter 25 psig	160	160
3. Filter Surface Wash	4	4
4. Sludge Recirculation	130	--
5. Polymer	1	1
D. Sludge Dewatering		
1. Filter Press	10	10
2. Conveyor	2	2
E. Control Air Compressor	2	2
Total Power 50 psig	569 hp	379 hp
Total Power 25 psig	449 hp	249 hp

2. Annual Operating Power Cost ($0.02/kwh)

Filter Operating Pressure	Conventional Clarifier	Contact Clarifier
A. 50 psig	$74,000	$50,000
B. 25 psig	$59,000	$33,000

TABLE XIII

Summary
Annual Labor Cost

	Item	Cost
1.	Supervision	$ 42,000
2.	Clerical-Technical	9,000
3.	Operation	70,000
4.	Maintenance	46,000
	Total Labor	$167,000

TABLE XIV

Equipment Operation
and Maintenance Costs

Component	Estimated Annual Maintenance Cost	
	Conventional Clarifier System	Contact Clarifier System
1. Mechanical Equipment @ 5%/yr Purchase Cost	$21,300	$23,000
2. Tankage @ 1.5%/yr Tankage Cost	2,600	3,400
Total Equipment O&M Cost	$23,900	$26,400

TABLE XV

Operation Cost
Polymer Application

Polymer	Estimated Annual Cost
1. Cationic (cat floc T) (40% Active) 104,600 gal/yr x $2.67/gal	$279,000
2. Anionic (L 690 E) (25% Active) 50,370 gal/yr x $1.36/gal	69,000
Total Annual Polymer Cost	$348,000

TABLE XVI

Annual Operating Cost
Solids Disposal

Basis: 33,000 lb/day Dry Solids with Ultimate Disposal Cost of $20/ton

% Solids Moisture	Annual Cost
50% - 12.045 ton/yr @ $20/ton	$241,000
25% - 8.030 ton/yr @ $20/ton	$161,000

TABLE XVII

Estimated Annual Operation and Maintenance Costs for Diatomaceous Earth Filters

Component		Estimated Cost
1. Labor		$167,000
2. Power		59,000
3. Maintenance		
A. Tankage	$ 5,000	
B. Equipment	$21,000	26,000
4. Polymer (Anionic)		69,000
5. D.E. Precoat		58,000
6. Sludge Disposal		251,000
Total Annual Cost		$630,000

SECTION III

Summary

of

Brine Treatment System

Capital, Operation and Maintenance

and

Annual Costs

Basis of Total System Cost Summary

Capital and operating costs are retabulated from those previously presented. Total annual costs result from the sum of the system capital cost and the present worth of the operation and maintenance costs at the respective 7% and 9% rates for a period of 20 years. Treatment costs in terms of dollars per 1,000 gallons and mils per kilowatt hour were based upon a waste brine flow of 10 MGD and a plant generating capacity of 50 megawatts.

TABLE XVIII

Summary of Capital, Operating and Annual Costs
For Conventional and Contact Clarification Treatment Processes
(Includes Granular Media Filtration)

System Description	Capital Cost Dollars	Annual O & M Cost Dollars	Total Annual Cost-$ 7% 20 yr	Dollars per 1,000 gal	Mils per kwh	Total Annual Cost-$ 9% 20 yr	Dollars per 1,000 gal	Mils per kwh
Conventional Clarification								
50 psi 50% Cake Moisture	2,180,000	854,000	1,060,000	0.290	2.420	1,093,000	0.299	2.495
Less Cationic	2,160,000	575,000	779,000	0.213	1.779	812,000	0.222	1.854
Less Polymer	2,140,000	506,000	708,000	0.194	1.616	740,000	0.203	1.689
50 psi 25% Cake Moisture	2,180,000	774,000	980,000	0.268	2.237	1,013,000	0.277	2.312
Less Cationic	2,161,000	495,000	699,000	0.192	1.596	732,000	0.200	1.671
Less Polymer	2,141,000	426,000	628,000	0.172	1.434	660,000	0.181	1.507
25 psi 50% Cake Moisture	2,161,000	839,000	1,043,000	0.286	2.381	1,076,000	0.295	2.457
Less Cationic	2,141,000	550,000	752,000	0.206	1.717	785,000	0.215	1.792
Less Polymer	2,120,000	491,000	691,000	0.189	1.578	723,000	0.198	1.651
25 psi 25% Cake Moisture	2,161,000	759,000	963,000	0.264	2.199	996,000	0.273	2.274
Less Cationic	2,141,000	480,000	682,000	0.187	1.557	715,000	0.196	1.632
Less Polymer	2,120,000	410,000	610,000	0.167	1.393	642,000	0.176	1.466
Contact Clarification								
50 psi 50% Cake Moisture	2,290,000	842,000	1,058,000	0.290	2.416	1,092,000	0.299	2.493
Less Cationic	2,269,000	562,000	776,000	0.212	1.772	811,000	0.222	1.852
Less Polymer	2,249,000	493,000	705,000	0.193	1.610	739,000	0.203	1.687
50 psi 25% Cake Moisture	2,290,000	762,000	978,000	0.268	2.233	1,013,000	0.277	2.313
Less Cationic	2,269,000	482,000	696,000	0.191	1.589	731,000	0.200	1.669
Less Polymer	2,249,000	413,000	625,000	0.171	1.427	659,000	0.181	1.504
25 psi 50% Cake Moisture	2,270,000	816,000	1,030,000	0.282	2.352	1,065,000	0.292	2.432
Less Cationic	2,250,000	536,000	748,000	0.201	1.708	782,000	0.214	1.785
Less Polymer	2,230,000	467,000	667,000	0.186	1.523	711,000	0.195	1.623
25 psi 25% Cake Moisture	2,270,000	736,000	950,000	0.260	2.169	985,000	0.270	2.249
Less Cationic	2,250,000	457,000	669,000	0.183	1.527	703,000	0.193	1.605
Less Polymer	2,230,000	388,000	598,000	0.164	1.365	632,000	0.173	1.443

TABLE XIX

Summary of Capital, Operating and Annual Costs for Conventional Clarification and Diatomaceous Earth Filtration[(a)]

Capital Cost	Annual	Total Annual	Dollars per 1,000 gal	Mils per kwh
$2,148,000	$630,000	$833,000	0.228	1.902

(a) System Description: 25 psi, 50% Cake Moisture
7% - 20 years, less cationic