SAN/1137-11

MASTER

GEOTHERMAL LOOP EXPERIMENTAL FACILITY

SDG&E

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QUARTERLY REPORT

SAN/1137-11

SDG&E - DOE

GEOTHERMAL LOOP EXPERIMENTAL FACILITY

QUARTERLY REPORT

FOR THE PERIOD

APRIL - JUNE, 1978

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ABSTRACT

The Geothermal Loop Experimental Facility (GLEF) was modified to use a two stage flash process with two parallel flash trains for the extraction of energy from a high temperature, high salinity, liquid-dominated resource. Since plant 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.

This Quarterly Report discusses the general operation and accomplishments of the GLEF during the period April, 1978, through June, 1978.

During this reporting period the GLEF underwent a major redesign as discussed in the Operation and Maintenance Sections. Modifications and inspections of various GLEF equipment and systems are also discussed in the Maintenance Section.

Information about the production and injection wells flow testing and instrumentation are discussed in the Reservoir Operation Section.

The Testing Section includes information regarding coatings and linings for valves and piping.

In the Chemistry Section there is a wide range of data taken from Brine, Steam, Scale, Binary, Condensate, and Cooling Water Systems. Tables and figures in this section aid in the discussion of data received.

CONCISE 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 of generating electric power. See Figure 1-1 for the general appearance of the GLEF.

In May, 1975, construction of the GLEF began and start-up of plant operations commenced on May 3, 1976. This 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 in the center of the anomaly. Magmamax No. 1 produces brine with a 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 produces brine with a temperature and pressure at the wellhead of 380°F and 200 psig, respectively,

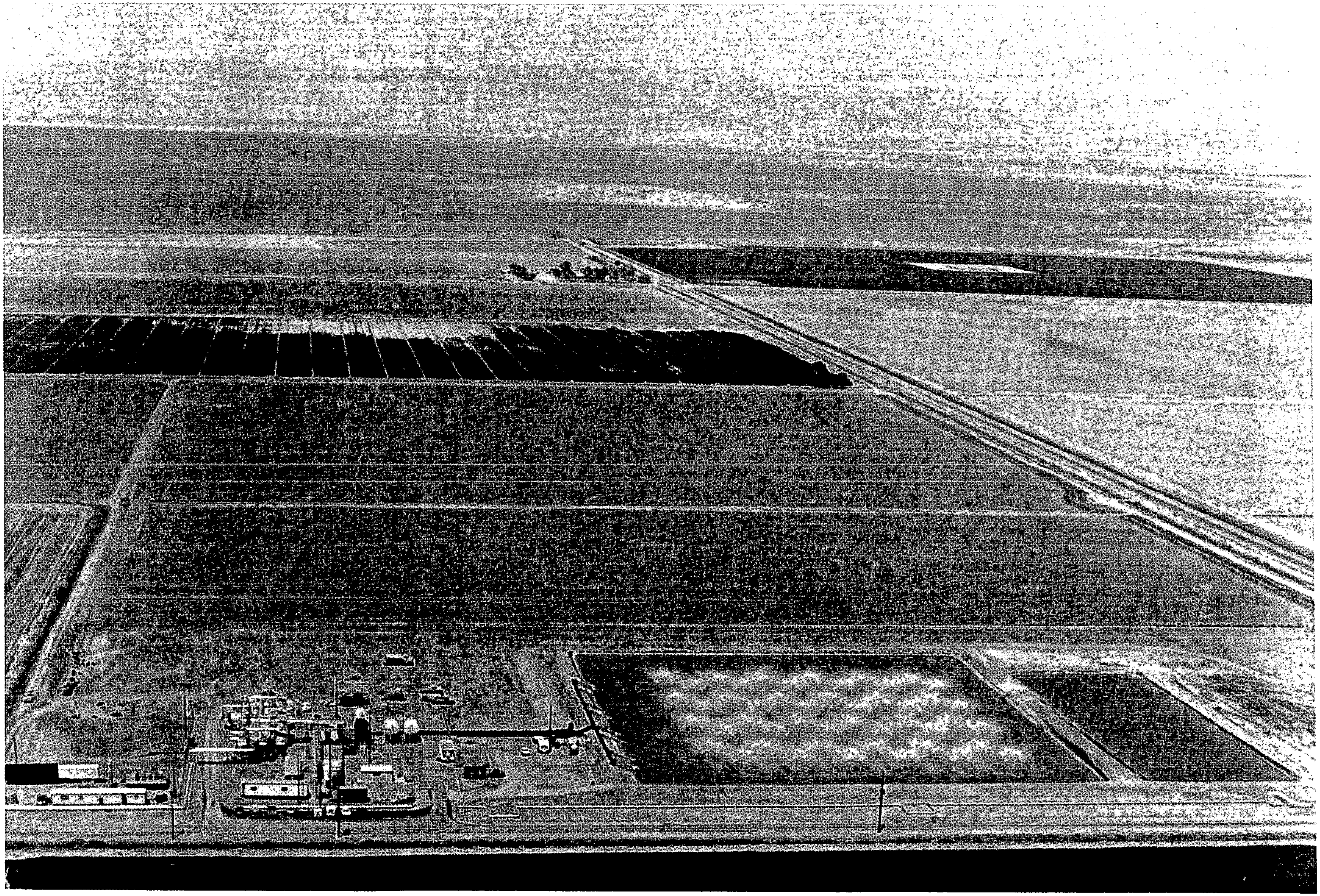


FIGURE 1-1

GEOTHERMAL LOOP EXPERIMENTAL FACILITY
Niland, California

with an average flowrate of approximately 300,000 lbs/hr. However, Woolsey has not produced representative fluids and was not used during this quarter. The plant was modified to accept an inlet temperature of 435°F, pressure of 295 psia, and 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 two injection wells, Magmamax No. 2 and No. 3. Magmamax No. 3 is the primary injection well with Magmamax No. 2 being used as spare.

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 to critical portions of a two stage flash system with two parallel flash "trains". In other words, each supply well has its own two stage system. The steam produced by the flashed brine passes through steam scrubbers to remove 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 being used to dissipate heat energy. The condensed steam, if not used for cooling water make-up is recombined with the brine and injected into the reservoir. The noncondensible gases, 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 vapor is then condensed back to a fluid in the condensers.

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.

1.0 GLEF OPERATIONS

The plant operated for a total of 304 hours in this quarter before the plant was shut down for modifications and cleaning. Approximately 1470 hours of operation were accumulated on this run since the last cleaning. This gives the plant a total of 7419 hours of operation since startup. The average plant capacity factor since startup is 43%. (See Table 1-1 and Figure 1-2)

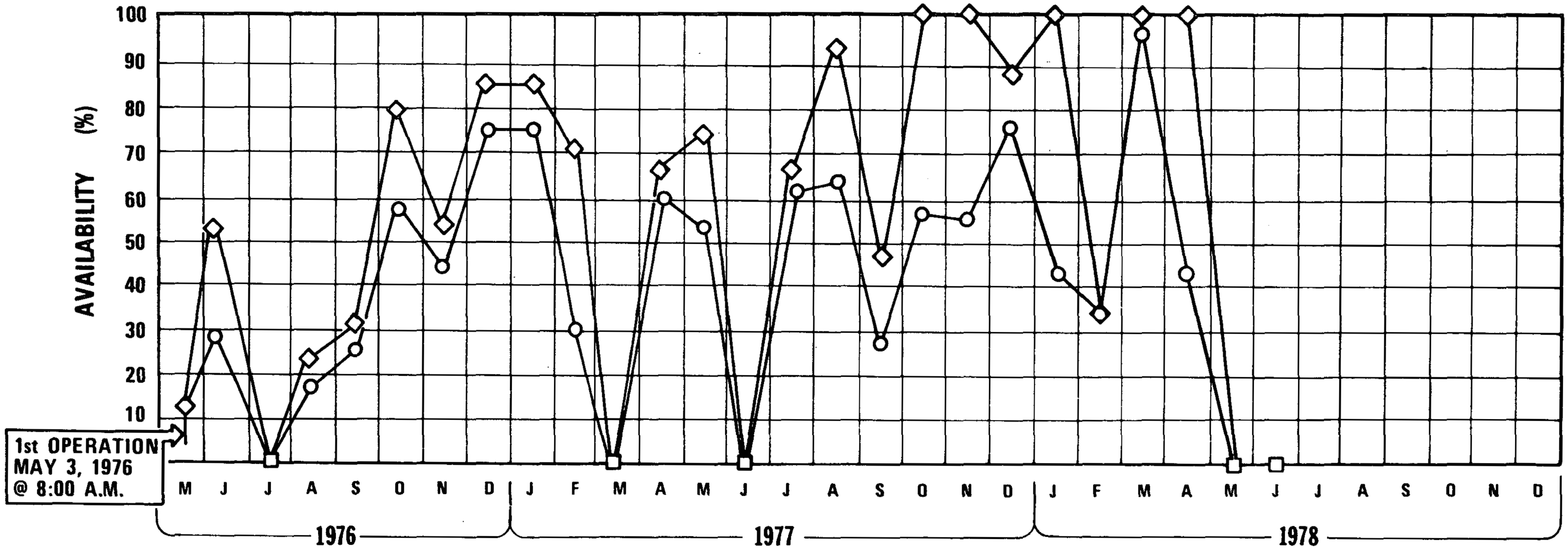
During this quarter, the plant operated in manual control with Magmamax No. 1 as the production well and injecting in Magmamax No. 3 via the baker tanks settling system and pilot clarifier.

The injection pump (P-2) started plugging on April 12, 1978. Although shutdown was planned for the next day, flushing was tried, which was previously quite successful, as indicated in the April Quarterly Report, but with little improvement this time. On April 13, P-2 lost all discharge pressure and the plant was shut down for plant modifications and overhaul for the remainder of this reporting period.

1.1 Plant Modifications

Using The Ben Holt Company's engineering and an SDG&E construction crew, the GLEF was converted from a four stage flash/binary system to critical portions of a parallel two-stage flash system. (See Figure 1-3) Each supply well

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 1-2

GLEF PROCESS FLOW DIAGRAM

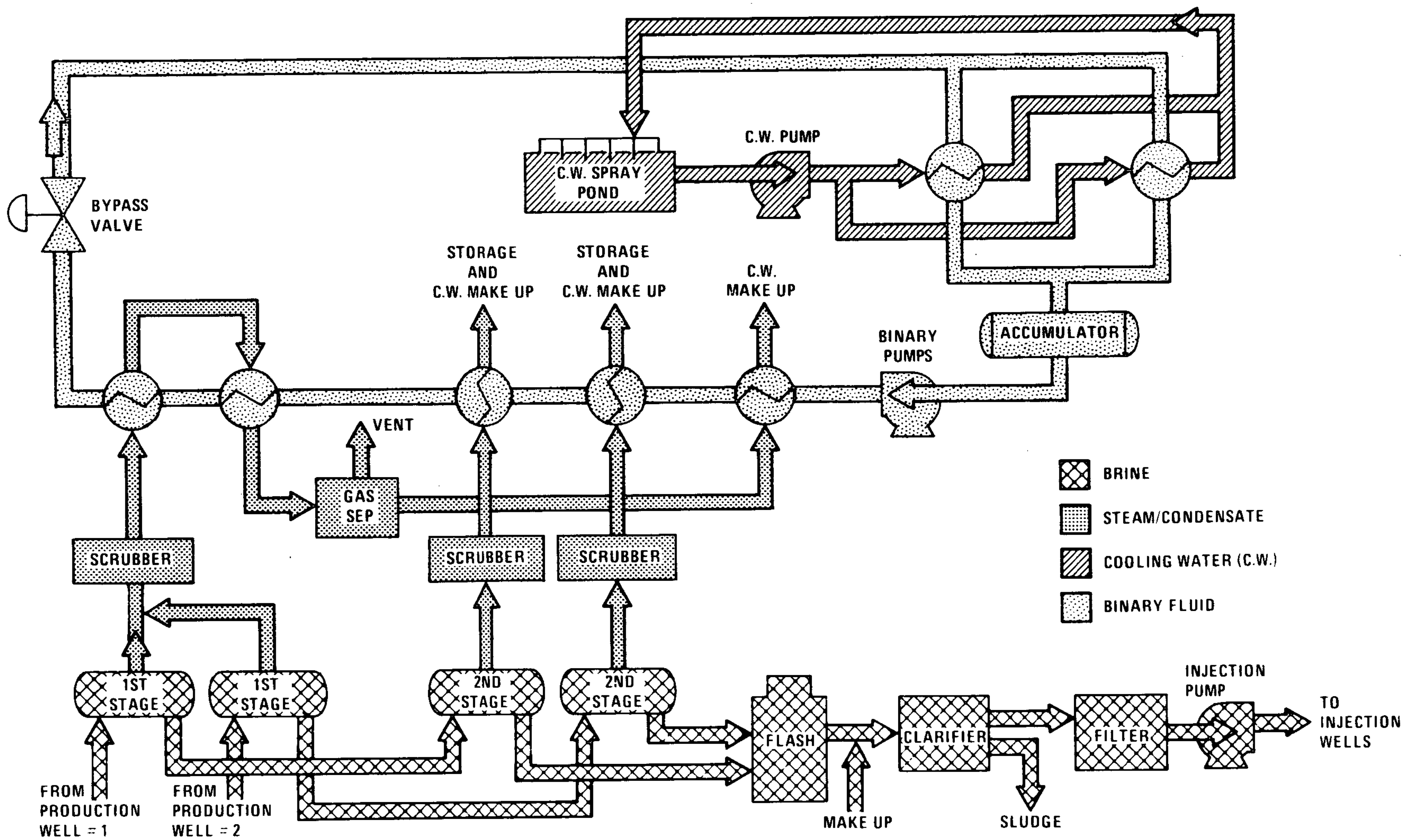


FIGURE 1-3

GLEF AVAILABILITY 1978

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										
AUGUST										
SEPTEMBER										
OCTOBER										
NOVEMBER										
DECEMBER										

TABLE 1-1

will have its own two-stage system. Woolsey supply well brine will flow into 1A separator (V-1) and will flash at 115 psig, then will flow into the 2A separator (V-14) and flash at about 6 psig. Magmamax #1 well brine will flow into 1B separator (V-4), flash at 115 psi, will then flow into 2B separator (V-11) and flash at about 7 psig. Both 2nd stage separators (V-14 and V-11) will flash into a common vessel, the atmospheric flash vessel (V-15). The injection pump (P-2) will take a suction from V-15 and pump the spent brine through Magma's baker tank settling system and into the injection well. Later plant modifications will add a full-scale brine effluent treatment facility. Each system can be cross connected so that Magmamax #1 well can be tied into the "A" or "B" system and vice versa.

A pilot clarifier has been installed to take a small portion of brine from V-15 and discharge back to the injection pump (P-2) suction. The 2A heat exchanger (E1B) was modified to allow the drains to be pumped out with the heat exchanger condensate pump (P-14), into the 2B scrubber (V-12) or cooling water spray pond. The 1st stage scrubber (V-8) and 2A scrubber (V-10) drains were repiped into the atmospheric flash vessel. The vent gas separator drains (V-6) were also repiped into the atmospheric flash vessel. Two new pressure control valves were installed on the steam inlet to the 2nd stage heat exchangers (E1B and E1C) so as to maintain 6 psig on both 2nd stage separators.

2.0 RESERVOIR OPERATION

2.1 Production Wells

A spinner survey in late 1977 was run on the Woolsey No. 1 well and indicated a fluid loss at the 1,370 foot level caused by a hole in the casing. An attempt to repair the hole with a cement squeeze proved futile when another hole developed during a pressure test. A 6 5/8" tie back liner was hung from the 854 foot to the 1821 foot level to aid in blocking off the holes. The well casing on Woolsey No. 1 was milled and scraped to remove the scale.

The Magmamax No. 1 wellhead valve was removed. A caliper indicated approximately 1/2" of scale for the first 900 feet. The scale was milled off and the casing scraped. After the well was cleaned, 1 1/4" tubing was hung in the well to allow flowing pressure and temperature observations.

Magmamax No. 2 was flow tested for 350 hours at three different flow rates: a low flow of 400 GPM, a medium flow of 600 GPM, and a high flow of 900 GPM. At the high flow condition, the wellhead temperature and pressure was 407°F and 280 psig. (For details and graphs see Appendix A) The well has every indication of being capable of producing at a much higher flowrate.

2.2 Injection Wells

During this period, injection was into Magmamax #3 through a series of settling tanks. The settling tanks appear to be effective in reducing the suspended solids to approximately 100 ppm and the silica to close to saturation. About 1 1/4 tons/day of solids are being removed in the settling tanks.

A pilot reactor clarifier was tested on a side stream from the atmospheric flash drum. The objective of the test was to see if the clarifier could reduce the amount of suspended solids and dissolved silica in the brine prior to injection in the Magmamax No. 3 well.

The clarifier generally produced excellent results both reducing the quantity of suspended solids and reducing the concentration of silica remaining in solution at the injection well. Suspended solids were reduced from a range of 130 to 160 ppm in, to a range of 20 to 50 ppm out. Silica in solution was reduced from a super-saturated level of 300 ppm in, to a slightly sub-saturated level of 170 ppm out at 180°F. The effluent from the clarifier performed very satisfactorily when injected by Lawrence Livermore Laboratory through sandstone cores representative of the Niland reservoir. The clarifier also handles sludge concentration, thickening, and removal. The clarifier was not as effective as it had been on Magmamax #1 effluent. However, performance was still significantly more effective than the settling tanks.

2.3 Reservoir Assessment Activities

J. Morse from Lawrence Livermore Laboratory (LLL) instrumented five wells to gain reservoir data during the flow testing of Magmamax #2. The following wells were instrumented to gain data as follows:

Magmamax No. 2 has 1 1/4" tubing run to 3,800 ft. and is instrumented with a Sperry-Sun type chamber in the well with a quartz crystal transducer at the surface. The data to be obtained for computer analysis is:

1. background data prior to starting well
2. draw-down by starting flow from well
3. skin effect
4. permeability in the vicinity of well bore
5. identify flashing zone

Magmamax No. 3 has been instrumented with a Hewlett-Parkard type quartz crystal transducer in the well for fall-off testing when Magmamax #1 was shut-in. Some transducers were placed in the well for fall-off testing when Magmamax #2 was shut-in. The data to be obtained for computer analysis is:

1. permeability of reservoir
2. fracturing
3. storage effect
4. skin effect
5. permeability outside of immediate vicinity of the well

Magmamax No. 4 which is an observation well near Magmamax No. 3, has been instrumented with a Sperry-Sun type chamber at the surface with a quartz crystal transducer. The data to be obtained:

1. interference from flowing well
2. vertical leakage

Elmore #3 has been instrumented with a Hewlett-Packard quartz crystal transducer at the 100 foot depth. The data to be obtained for computer analysis is:

1. interference, average permeability between wells
2. storage effect

Sinclair #3 has been instrumented with a Hewlett-Packard quartz crystal transducer at the 100 foot depth. The data to be obtained for computer analysis is:

1. interference, average permeability between wells
2. storage effect

The data obtained is presently being analyzed by LLL. LLL will publish their findings at a later date.

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 associated with the binary cycle such as heat exchangers, steam scrubbers, etc. However, Phase I of the Feasibility Study has redefined the critical areas to be tested. A report of the results of that program is being prepared by Bechtel National, Inc. and should be issued before the end of the year.

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 direct flash cycle power plant would be the best choice for the first geothermal power plant at the Niland reservoir. As a result, the GLEF was modified to simulate a two-stage flash cycle (as discussed in section 1.1 of this report).

The primary objective of the 1978-1979 GLEF Test Program is to reduce significant risks and costs of constructing and operating a flash-cycle power plant at Niland. This test program will consist of several different tests to be performed separately by SDG&E, Lawrence Livermore Laboratory, and Imperial Magma under the overall direction of

SDG&E. Future progress of the Test Program will be reported in these Quarterly Reports. However, the detailed writeups and results of each test will be issued in separate reports by the participants (Lawrence Livermore Laboratory's and Magma). (For Test Program description see Appendix B)

3.3 Miscellaneous Tests

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 has been some laboratory evidence that PC-lined pipe significantly slows the growth of scale on the pipes. Both of these effects could significantly reduce the costs of geothermal power production.

In March, 1978, Brookhaven National Laboratory contacted SDG&E and inquired whether it would be possible to install PC-lined pipe spools at a couple of locations in the GLEF. It was agreed to install three spools in the GLEF and to expose them to two different brine conditions. One spool was to have been placed in the first to second stage brine piping and two others in the brine injection line.

The spool between the first and second stages was specified to be 8 inches in diameter - to fit into the piping in the old four stage flashed binary system. After the conversion to a two stage flash cycle, the brine drain piping was 10 inches in diameter. Consequently, the 8 inch spool piece will not be installed. After the plant has been shown to operate in a stable manner in the two stage flash mode, the 8 inch spool may be installed in a location where it will not interfere with plant operation.

The two 10-inch PC lined spools in the injection line are designed to allow the entire brine flow to pass through both PC lined pipe spools except during the pigging operation, when valves will be adjusted so that only one spool will see the brine, and hence the pig. The pigged PC lined spool will be checked for abrasion resistance, while the unpigged spool will be monitored for scale buildup.

In addition to the pipe spools, BNL has sent 42 inch by 3 inch test cylinders made of 6 different compositions of polymer concrete. These cylinders have been placed below the liquid level in the first stage flash vessel. They will be inspected during each plant shutdown and sent to BNL depending on the results of the inspection.

3.3.2 "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. A commercial firm, E/M Lubricants of North Hollywood, CA, offered to treat the valves. 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 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.

3.3.3 Corrosion/Scale Resistant Coatings

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.

The test samples will be installed in the first stage (V-4) and second stage (V-11) flash vessels. The size of each vessel is approximately six feet in diameter and 20 to 30 feet long. Upon startup the specimens will be 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 are composed of small coupons of various sizes (less than 5 square inches) and test panels (3" x 64" x 3/8"). The test coupons will be arranged in racks 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 will be mounted between the top and bottom of the vessel. The weight, coating thickness, hardness, and visual appearance of each specimen will be recorded prior to testing. Some of the raw data to be obtained after the test includes 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 will allow observations to be made at the steam-brine interface.

3.3.4 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.

Before conversion to a two-stage flash cycle, both pinch valves were located in the brine line immediately before the fourth stage. The brine flowed through both in series, so that each took approximately half the drop in pressure from the third to fourth stage (14 psig - slight vacuum). Liners in both valves have 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 will handle the entire flow of one of the flash trains.

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

3.3.5 Hydro Test Nozzles

During this reporting period, no cavitation cleaning was done at the GLEF. However, provisions have been made to test various ways to keep the brine piping free to scale. Daedalean Associates, Inc. have manufactured cavitating nozzles that were installed in the brine line between 1B and 2B separators. Brine, clarified and unclarified, will be pumped at high pressure through these nozzles. Tests will be run to determine how long it will take before the nozzles become plugged and if the brine can be used in the hydro pump. Further tests, at a later date, will be run to determine if a line can be hydro-blasted while the plant is in operation.

A Daedalean test valve with nozzles has been installed to determine if a gate valve can be kept clean during operation, using high pressure water or brine. Daedalean has supplied the nozzles and pump.

3.3.6 Pilot Clarifier and Sludge Handling Processes

A pilot clarifier, 8 feet in diameter and 16 feet in height, has been installed at the GLEF to receive effluent brine from V-15. The brine flow will be 26 GPM. This clarifier had previously operated for approximately 60 days at the injection well site on effluent brine from the GLEF. A dual media sand/anthracite gravity filter will be tested along with the clarifier. In conjunction with the clarifier-gravity filter system, three unit processes may be evaluated for handling the sludge and its disposal. These are: 1) filter press, 2) centrifuge, and 3) vacuum drying. The filter press will be initially evaluated and, if successful, other options may be deleted. The purpose of this pilot program is to determine the most cost effective system for the stabilization of spent geothermal brines. Imperial

Magma will have prime responsibility for the operation of these pilot facilities.

4.0 SYSTEMS CHEMISTRY

4.1 Steam Chemistry

Steam composition during the four stage operation in April was similar to that observed during the previous portion of the test and reported in the First Quarterly Report of 1978. Values for this two week period are summarized in Tables 4-1 through 4-9 and Figures 4-1 through 4-9.

Carryover from the first stage separator, as characterized by the sodium concentration in the steam, was quite variable. However, in all cases the scrubber was effective in removing most of this carryover so that the sodium levels in the steam from the first stage scrubber was always below 10 ppm. Little change in pH and conductivity was observed, again demonstrating that these values are not effected by brine carryover.

The second stage separator and scrubbers yielded similar results with the steam from the second stage scrubbers containing 3 to 4 ppm of sodium conductivity and pH values were also similar.

The mineral content of the steam from the third stage was also low. However, the pH rose to 9.5 to 10.2, due to the presence of small amounts of ammonia.

Steam from the fourth stage scrubbers, in which condensate from the previous stages is collected, is somewhat higher in mineral content. The pH is also depressed to

1st STAGE STEAM INFLUENT, GLEF
APRIL 1978
CONCENTRATION IN ppm

DATE	4-3	4-4	4-5	4-6	4-7
Fe	25.2			1.1	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si		1.5			
*(SiO_2)		3.2			
B	9.1				
Ca	29.8				19.5
Na	60.4	46.8	42.4	21.2	45.8
K					
Li					
NH_4	248.4		225.2		
Cl	219.4	176.6	141.2	103.0	193.3
Alk		982.8			962.0
Al					
SO_4					
TDS	452			219	
ORP	–73			–198	
pH	6.45	5.97	6.04	6.34	6.00
Cond	2500	2420	2320	2150	2400

DATE	4-10	4-11	4-12	4-13	4-14
Fe	0.9			0.6	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si			1.0		
*(SiO_2)			2.1		
B	3.3				
Ca	22.4			14.0	
Na	41.6	15.0	16.7	25.0	
K					
Li					
NH_4	338.4		372.4		
Cl	159.0	58.7	62.9	101.8	
Alk		1076.4		998.4	
Al					
SO_4					
TDS	351			188	
ORP	–145			–152	
pH	6.33	6.11	6.06	6.56	
Cond	2500	2480	2600	2300	

*Silicon as SiO_2

TABLE 4-1

1st STAGE STEAM EFFLUENT, GLEF
APRIL 1978
CONCENTRATION IN ppm

DATE	4-3	4-4	4-5	4-6	4-7
Fe	0.4			0.5	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si		1.0			
*(SiO_2)		2.1			
B	5.3				
Ca	6.3				2.9
Na	9.7	5.4	5.1	11.7	3.8
K					
Li					
NH_4	356.4		492.0		
Cl	31.9	23.0	29.6	45.6	31.5
Alk		1081.6			1081.6
Al					
SO_4					
TDS	29			93	
ORP	−153			−187	
pH	6.41	6.09	6.10	6.30	6.05
Cond	2250	2250	2140	2210	2200

DATE	4-10	4-11	4-12	4-13	4-14
Fe	1.2			0.3	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si			1.0		
*(SiO_2)			2.1		
B	3.1				
Ca	4.2			3.3	
Na	6.2	7.5	7.6	4.8	
K					
Li					
NH_4	346.0		313.0		
Cl	30.2	32.9	32.5	25.9	
Alk		988.0		1034.8	
Al					
SO_4					
TDS	44			24	
ORP	−160			−161	
pH	6.22	6.06	5.90	6.48	
Cond	2150	2180	2150	2180	

*Silicon as SiO_2

TABLE 4-2

2nd STAGE STEAM INFLUENT, GLEF
APRIL 1978
CONCENTRATION IN ppm

DATE	4-3	4-4	4-5	4-6	4-7
Fe	1.2			2.3	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si		0.4			
*(SiO_2)		0.8			
B	7.0				
Ca	4.4				4.7
Na	6.4	8.9	5.7	5.3	4.2
K					
Li					
NH_4	408.0		327.0		
Cl	13.4	18.0	9.3	11.4	11.4
Alk		670.8			655.2
Al					
SO_4					
TDS	32			45	
ORP	–145			–170	
pH	6.93	6.69	6.79	6.57	6.50
Cond	1450	1420	1350	1330	1330

DATE	4-10	4-11	4-12	4-13	4-14
Fe	0.9			0.9	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si			0.4		
*(SiO_2)			0.9		
B	3.4				
Ca	4.5			4.0	
Na	7.4	6.8	8.6	5.0	
K					
Li					
NH_4	233.6		208.0		
Cl	13.0	14.1	18.9	12.9	
Alk		634.4		644.8	
Al					
SO_4					
TDS	51			27	
ORP	–130			–155	
pH	6.96	6.87	6.57	7.10	
Cond	1350	1430	1450	1350	

*Silicon as SiO_2

TABLE 4-3

2nd STAGE STEAM EFFLUENT, GLEF
APRIL 1978
CONCENTRATION IN ppm

DATE	4-3	4-4	4-5	4-6	4-7
Fe	2.9			2.8	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si		0.36			
*(SiO_2)		0.8			
B	8.30				
Ca	3.8				3.6
Na	4.0	3.5	4.9	3.1	2.0
K					
Li					
NH_4	205.6		290.4		
Cl	7.4	6.7	9.9	8.9	7.5
Alk		686.4			676.0
Al					
SO_4					
TDS	12			26	
ORP	−126			−160	
pH	6.84	6.53	6.55	6.52	6.32
Cond	1450	1450	1420	1400	1410

DATE	4-10	4-11	4-12	4-13	4-14
Fe	1.3			1.2	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si			0.17		
*(SiO_2)			0.4		
B	3.1				
Ca	3.4			3.5	
Na	4.3	4.1	6.1	3.0	
K					
Li					
NH_4	268.4		217.2		
Cl	9.4	9.3	12.7	10.7	
Alk		665.6		676.0	
Al					
SO_4					
TDS	36			9	
ORP	−130			−145	
pH	6.66	6.68	6.35	6.78	
Cond	1400	1480	1500	1450	

*Silicon as SiO_2

TABLE 4-4

3rd STAGE STEAM INFLUENT, GLEF
APRIL 1978
CONCENTRATION IN ppm

DATE	4-3	4-4	4-5	4-6	4-7
Fe	0			0.1	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si		0			
*(SiO_2)		0			
B	5.7				
Ca	4.1				3.5
Na	3.6	10.6	3.6	9.5	2.7
K					
Li					
NH_4	173.0		192.8		
Cl	9.2	26.5	8.6	22.0	9.4
Alk		83.2 / 301.6			83.2 / 426.4
Al					
SO_4					
TDS	25			59	
ORP	−200			−220	
pH	10.39	10.34	10.28	9.85	10.06
Cond	205	263	230	265	242

DATE	4-10	4-11	4-12	4-13	4-14
Fe	0.1			0	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si			0		
*(SiO_2)			0		
B	2.7				
Ca	3.8			4.8	
Na	3.8	3.6	5.7	6.4	
K					
Li					
NH_4	269.4		166.8		
Cl	15.1	10.6	12.9	19.6	
Alk		156.0 / 338.0		104.0 / 405.6	
Al					
SO_4					
TDS	26			24	
ORP	−220			−217	
pH	9.64	10.09	9.68	10.12	
Cond	215	228	245	243	

*Silicon as SiO_2

TABLE 4-5

3rd STAGE STEAM EFFLUENT, GLEF
APRIL 1978
CONCENTRATION IN ppm

DATE	4-3	4-4	4-5	4-6	4-7
Fe	0			0.1	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si		0.1			
*(SiO_2)		0.2			
B	5.30				
Ca	1.8				1.3
Na	2.3	2.9	2.8	2.1	1.3
K					
Li					
NH_4	157.0		185.4		
Cl	8.0	9.5	9.1	10.4	7.2
Alk		72.8 / 353.6			187.2 / 426.4
Al					
SO_4					
TDS	9			11	
ORP	−183			−214	
pH	10.23	10.17	10.14	9.68	9.90
Cond	252	265	285	278	293

DATE	4-10	4-11	4-12	4-13	4-14
Fe	0.1			0	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si			0.1		
*(SiO_2)			0.2		
B	5.4				
Ca	1.6			1.6	
Na	2.9	3.3	4.6	2.2	
K					
Li					
NH_4	166.8		174.0		
Cl	9.7	10.4	9.7	8.1	
Alk		187.2 / 353.6		203.0 / 364.6	
Al					
SO_4					
TDS	14			15	
ORP	−200			−205	
pH	9.48	9.93	9.54	9.91	
Cond	275	303	300	315	

*Silicon as SiO_2

TABLE 4-6

4th STAGE STEAM INFLUENT, GLEF
APRIL 1978
CONCENTRATION IN ppm

DATE	4-3	4-4	4-5	4-6	4-7
Fe	14.0			10.0	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si		1.2			
*(SiO_2)		2.6			
B	1.70				
Ca	6.4				9.5
Na	13.1	6.2	11.8	12.1	20.6
K					
Li					
NH_4	146.5		157.0		
Cl	21.4	13.8	27.9	23.6	36.6
Alk		343.2			421.2
Al					
SO_4					
TDS	71			79	
ORP	−108			−136	
pH	6.38	6.33	6.29	6.21	6.21
Cond	1100	740	860	940	1050

DATE	4-10	4-11	4-12	4-13	4-14
Fe	0.5			1.2	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si			T		
*(SiO_2)			T		
B	1.2				
Ca	12.3			6.8	
Na	29.4	18.0	24.6	16.5	
K					
Li					
NH_4	98.7		127.0		
Cl	82.9	33.2	73.8	30.8	
Alk		301.6		286.0	
Al					
SO_4					
TDS	182			61	
ORP	−115			−136	
pH	7.43	7.60	6.36	7.23	
Cond	850	808	1150	760	

*Silicon as SiO_2

TABLE 4-7

4th STAGE STEAM EFFLUENT, GLEF
APRIL 1978
CONCENTRATION IN ppm

DATE	4-3	4-4	4-5	4-6	4-7
Fe	3.2				1.5
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si		0.5			
*(SiO_2)		1.1			
B	2.2				
Ca	1.5				1.3
Na	1.9	2.6	2.2	2.0	0.9
K					
Li					
NH_4	143.0		173.0		
Cl	6.6	11.3	14.2	14.1	13.0
Alk		488.8			488.8
Al					
SO_4					
TDS	5			17	
ORP	−137			−156	
pH	6.11	5.94	5.98	5.97	5.91
Cond	1050	1020	1000	980	1000

DATE	4-10	4-11	4-12	4-13	4-14
Fe	2.3			1.8	
Cu					
Zn					
Mn					
Pb					
Sr					
Ba					
Mg					
Si			T		
*(SiO_2)			T		
B	1.4				
Ca	1.4			1.0	
Na	2.3	2.3	5.2	1.4	
K					
Li					
NH_4	141.5		136.0		
Cl	13.3	11.5	13.4	13.0	
Alk		462.8		478.4	
Al					
SO_4					
TDS	12			8	
ORP	−137			−132	
pH	5.98	6.13	5.77	6.13	
Cond	990	1020	1050	1000	

*Silicon as SiO_2

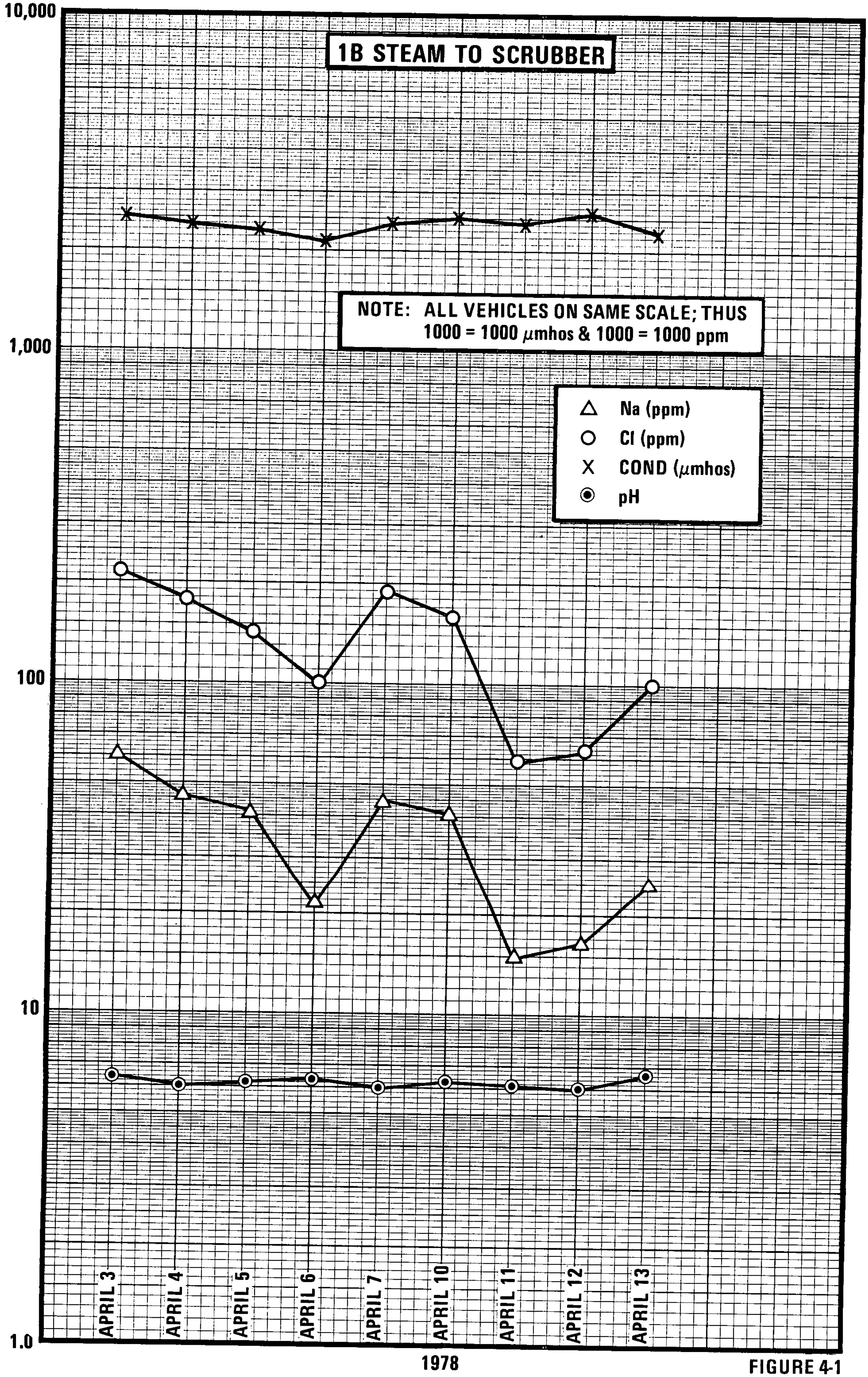
TABLE 4-8

COMBINED CONDENSATE, GLEF
APRIL 1978
CONCENTRATION IN ppm

DATE	4-3	4-4	4-5	4-6	4-7	4-10	4-11	4-12	4-13	4-14
Fe	0.1			0.1		0.3			0.1	
Cu										
Zn										
Mn										
Pb										
Sr										
Ba										
Mg										
Si		1.2						T		
*(SiO_2)		2.6						T		
B	3.7					4.6				
Ca	4.3				3.5	5.2			5.1	
Na	8.1	8.9	8.4	7.2	6.4	10.7	10.8	12.9	9.7	
K										
Li										
NH_4	174.0		297.0			203.2		195.2		
Cl	24.8	25.5	26.3	27.6	22.3	34.0	39.6	30.8	35.8	
Alk		712.4			733.2		707.2		712.4	
Al										
SO_4										
TDS	31			44		54			30	
ORP	−175			−195		−177			−178	
pH	6.35	6.12	6.30	6.22	6.04	6.13	6.19	6.00	6.28	
Cond	1860	1920	1830	1910	2050	1650	1900	2120	2000	

*Silicon as SiO_2

TABLE 4-9



10,000
1,000
100
10
1.0
1B STEAM TO SCRUBBER
NOTE: ALL VEHICLES ON SAME SCALE; THUS
1000 = 1000 µmhos & 1000 = 1000 ppm
Na (ppm)
Cl (ppm)
COND (µmhos)
pH
APRIL 3
APRIL 4
APRIL 5
APRIL 6
APRIL 7
APRIL 10
APRIL 11
APRIL 12
APRIL 13
1978

FIGURE 4-1

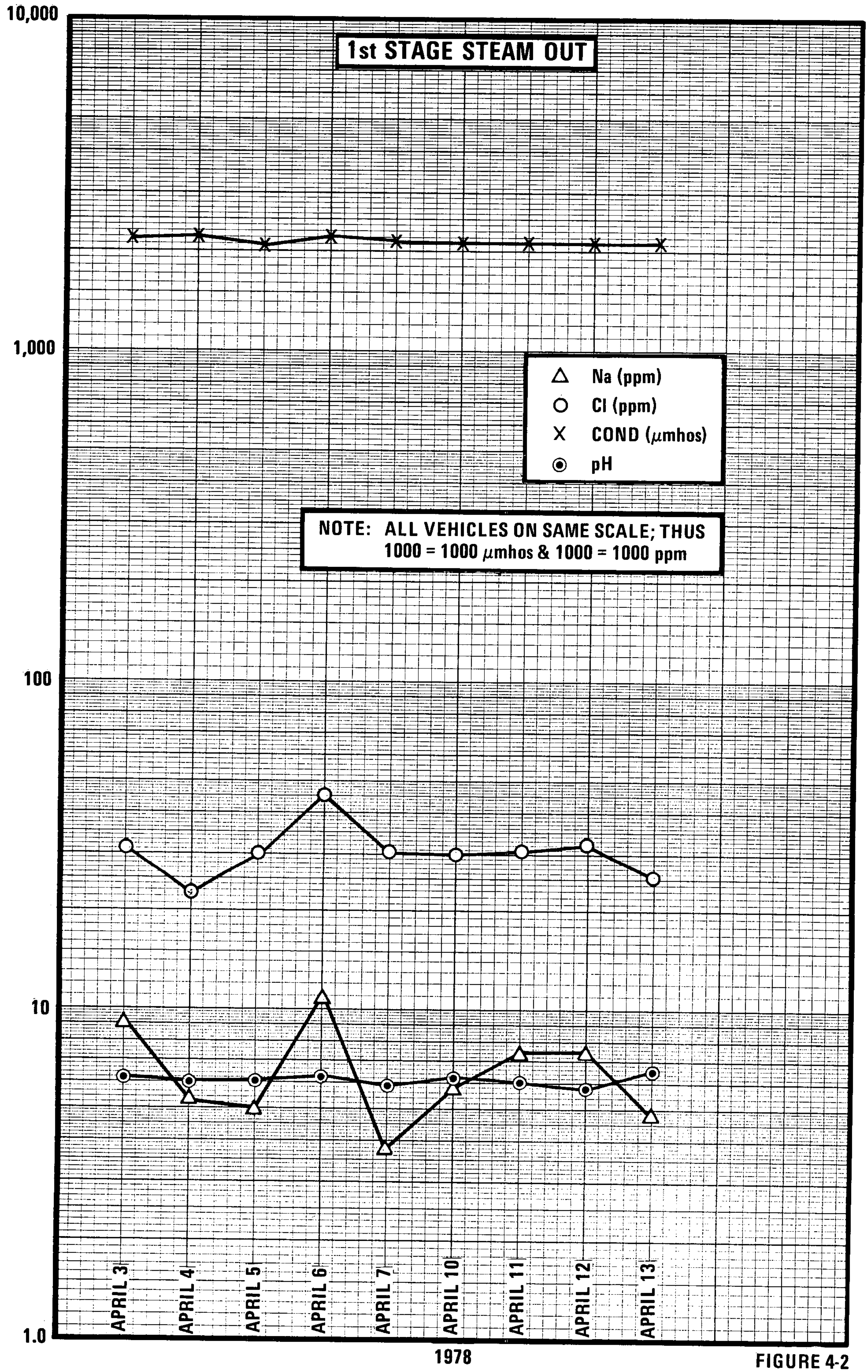
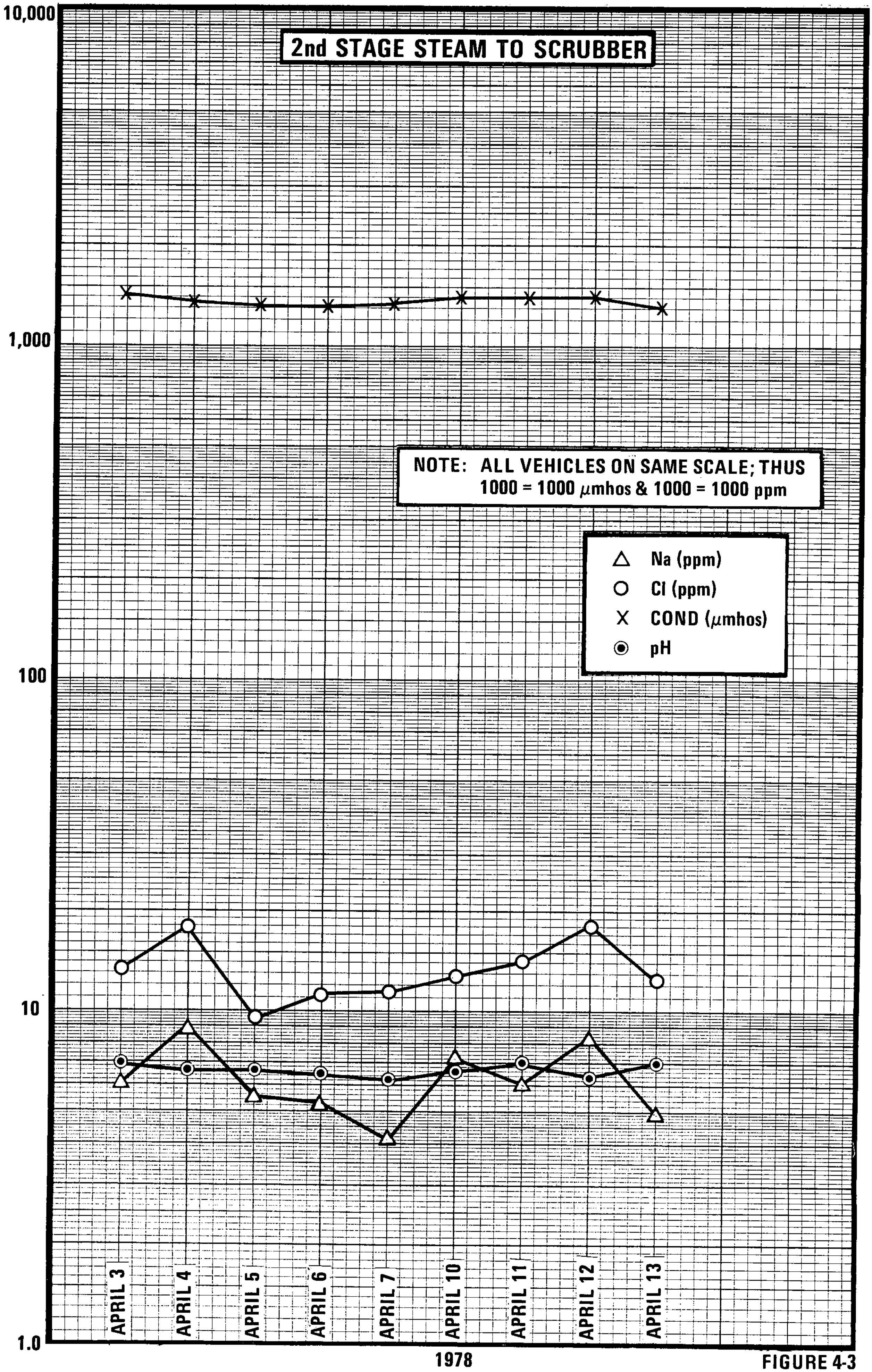

1st STAGE STEAM OUT
10,000
1,000
100
10
1.0
Na (ppm)
Cl (ppm)
COND (μmhos)
pH
NOTE: ALL VEHICLES ON SAME SCALE; THUS 1000 = 1000 μmhos & 1000 = 1000 ppm
APRIL 3
APRIL 4
APRIL 5
APRIL 6
APRIL 7
APRIL 10
APRIL 11
APRIL 12
APRIL 13
1978

FIGURE 4-2



2nd STAGE STEAM TO SCRUBBER
10,000
1,000
100
10
1.0
NOTE: ALL VEHICLES ON SAME SCALE; THUS
1000 = 1000 μmhos & 1000 = 1000 ppm
Na (ppm)
Cl (ppm)
COND (μmhos)
pH
APRIL 3
APRIL 4
APRIL 5
APRIL 6
APRIL 7
APRIL 10
APRIL 11
APRIL 12
APRIL 13
1978

FIGURE 4-3

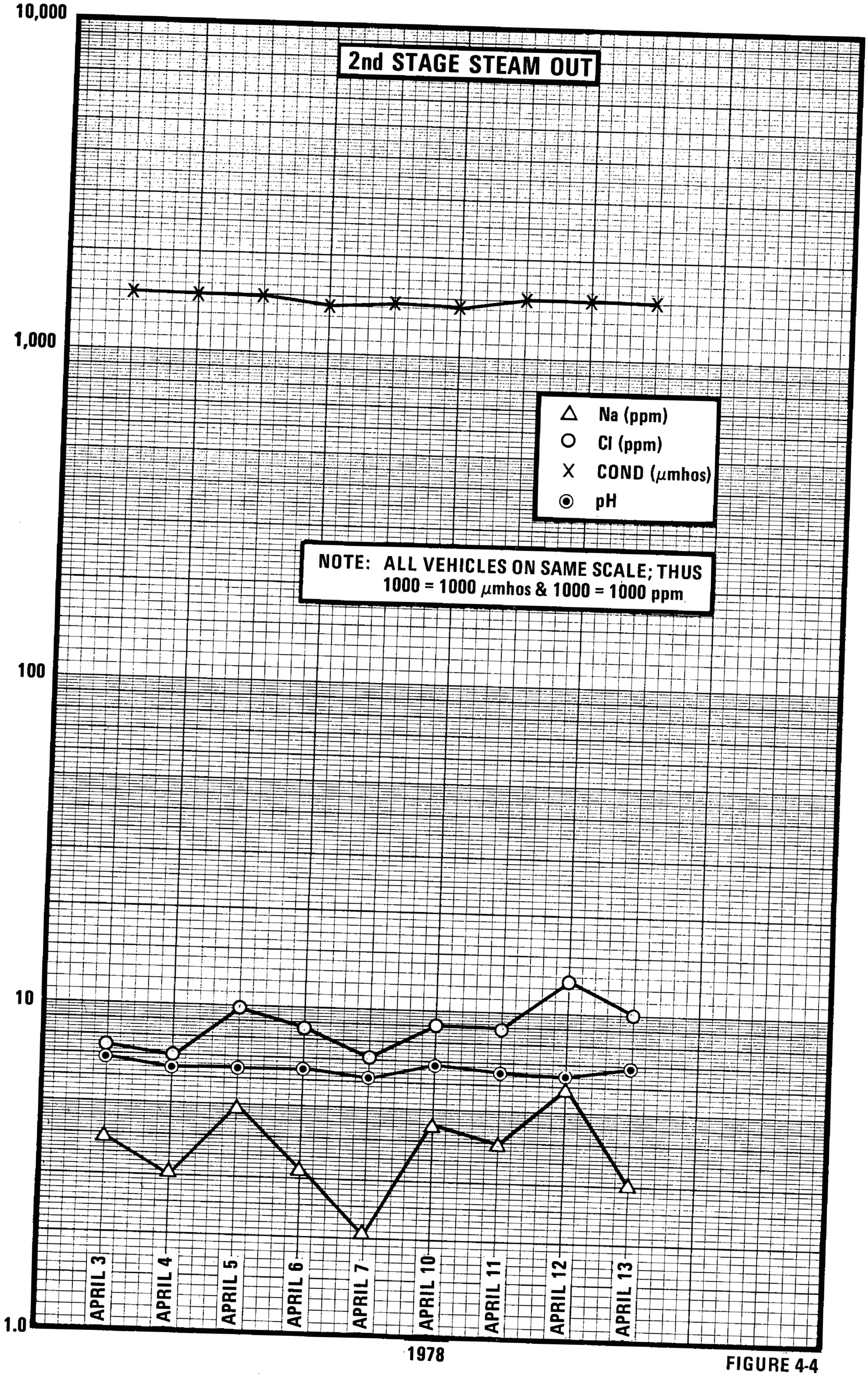
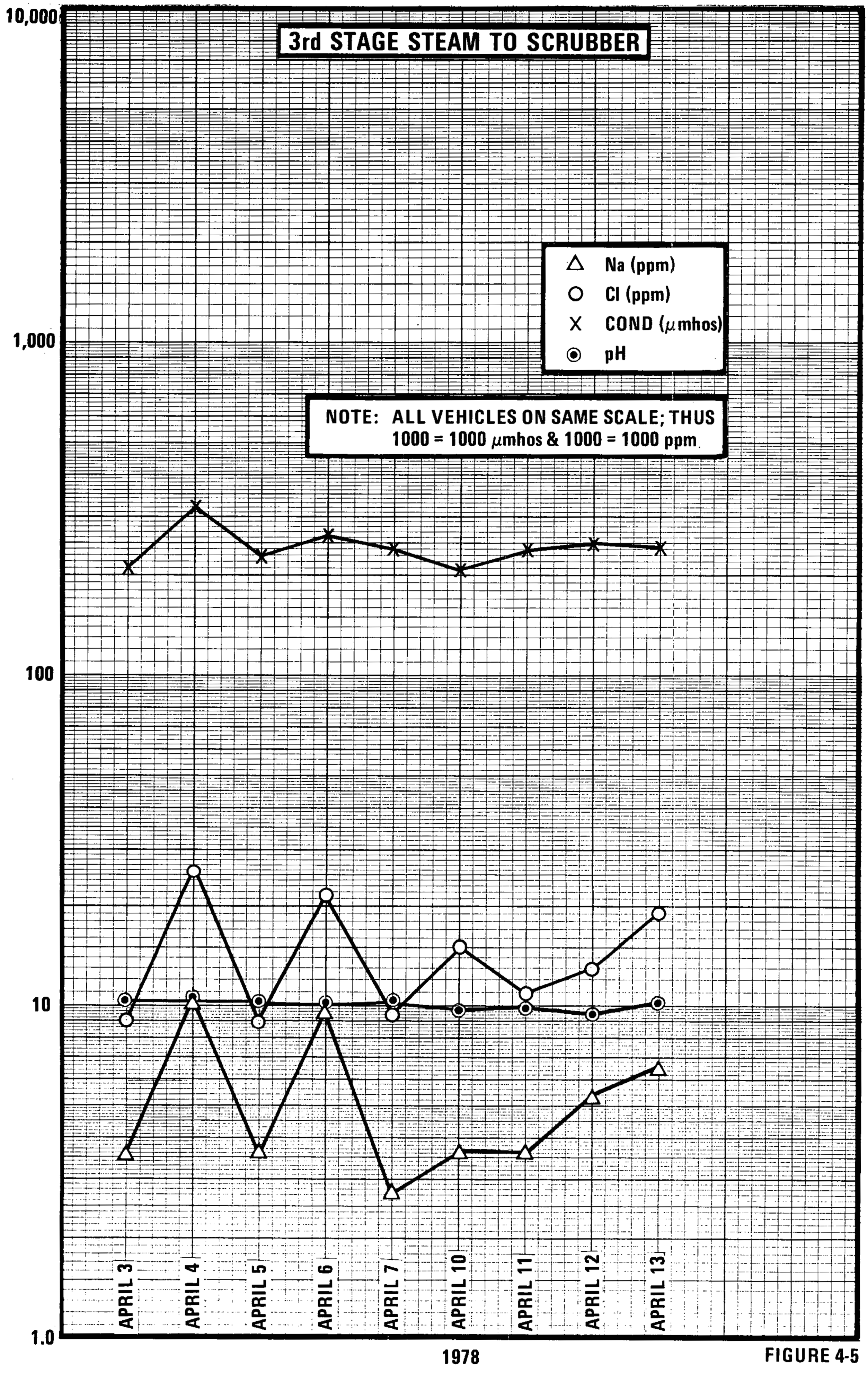
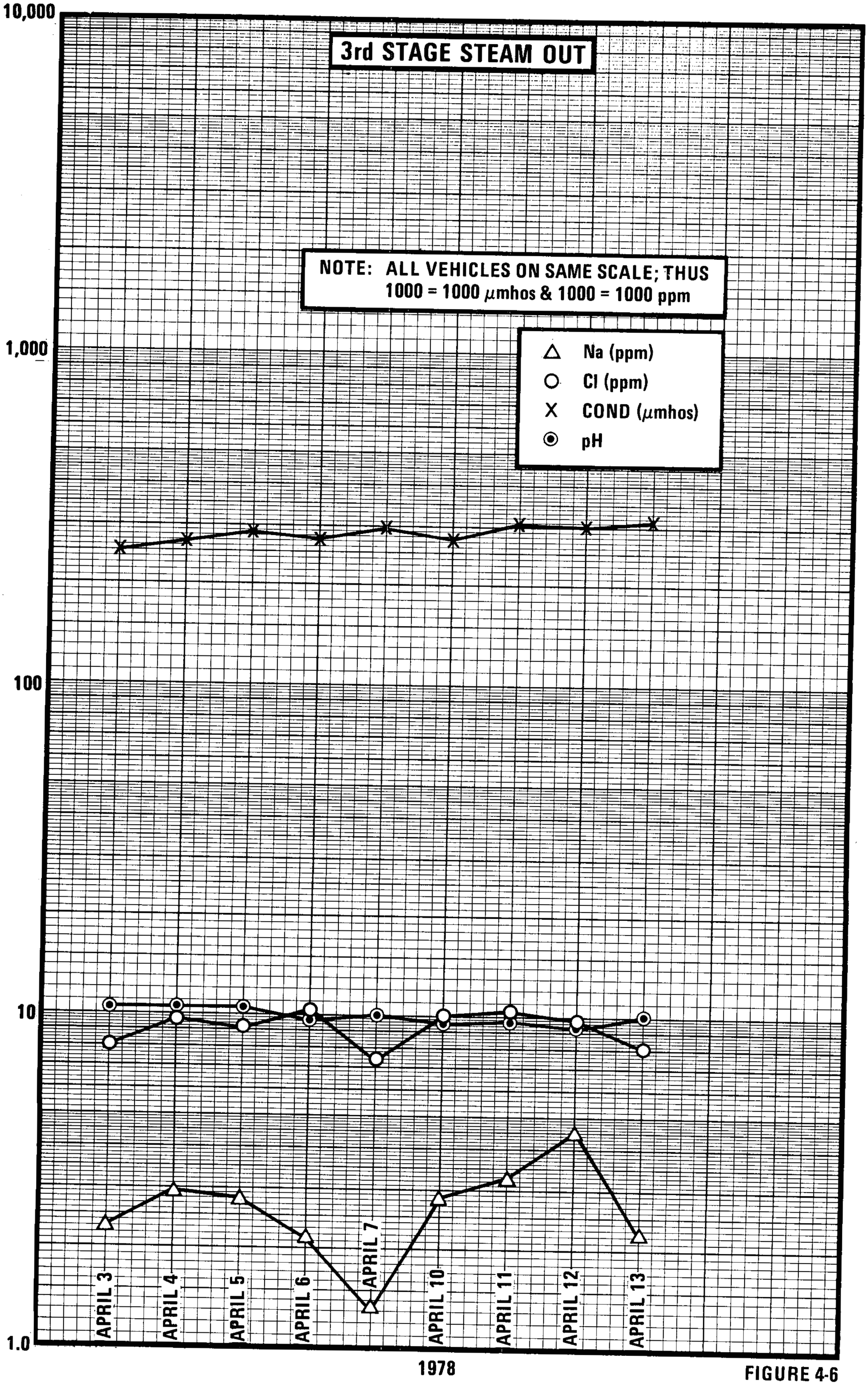

10,000
2nd STAGE STEAM OUT
1,000
Na (ppm)
Cl (ppm)
COND (µmhos)
pH
NOTE: ALL VEHICLES ON SAME SCALE; THUS
1000 = 1000 µmhos & 1000 = 1000 ppm
100
10
1.0
APRIL 3
APRIL 4
APRIL 5
APRIL 6
APRIL 7
APRIL 10
APRIL 11
APRIL 12
APRIL 13
1978

FIGURE 4-4



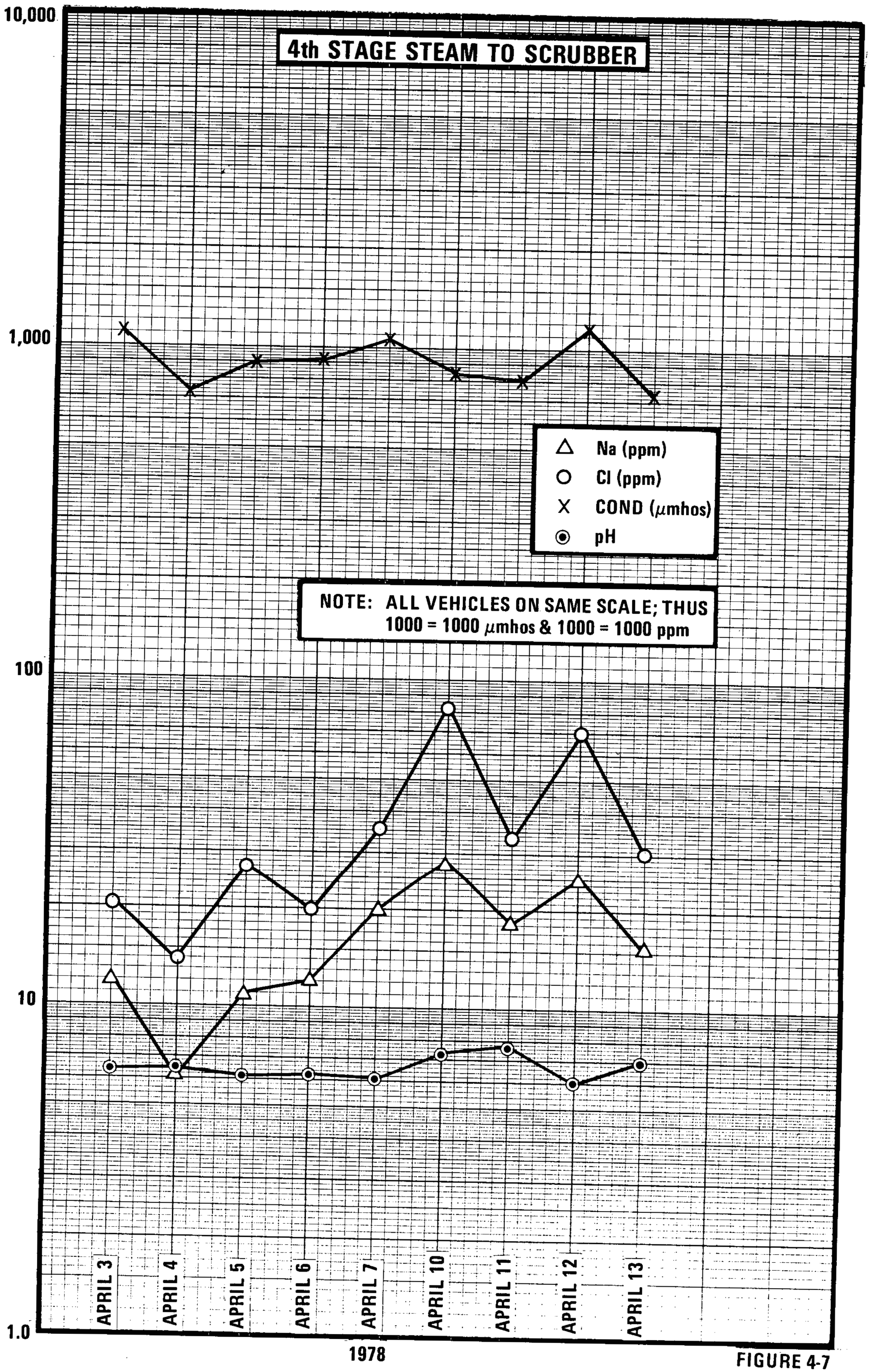
3rd STAGE STEAM TO SCRUBBER
Na (ppm)
Cl (ppm)
COND (μmhos)
pH
NOTE: ALL VEHICLES ON SAME SCALE; THUS
1000 = 1000 μmhos & 1000 = 1000 ppm
10,000
1,000
100
10
1.0
APRIL 3
APRIL 4
APRIL 5
APRIL 6
APRIL 7
APRIL 10
APRIL 11
APRIL 12
APRIL 13
1978

FIGURE 4-5



10,000
3rd STAGE STEAM OUT
NOTE: ALL VEHICLES ON SAME SCALE; THUS
1000 = 1000 μmhos & 1000 = 1000 ppm
1,000
Na (ppm)
Cl (ppm)
COND (μmhos)
pH
100
10
1.0
APRIL 3
APRIL 4
APRIL 5
APRIL 6
APRIL 7
APRIL 10
APRIL 11
APRIL 12
APRIL 13
1978

FIGURE 4-6



4th STAGE STEAM TO SCRUBBER
10,000
1,000
100
10
1.0
△ Na (ppm)
○ Cl (ppm)
X COND (μmhos)
◉ pH
NOTE: ALL VEHICLES ON SAME SCALE; THUS 1000 = 1000 μmhos & 1000 = 1000 ppm
APRIL 3
APRIL 4
APRIL 5
APRIL 6
APRIL 7
APRIL 10
APRIL 11
APRIL 12
APRIL 13
1978

FIGURE 4-7

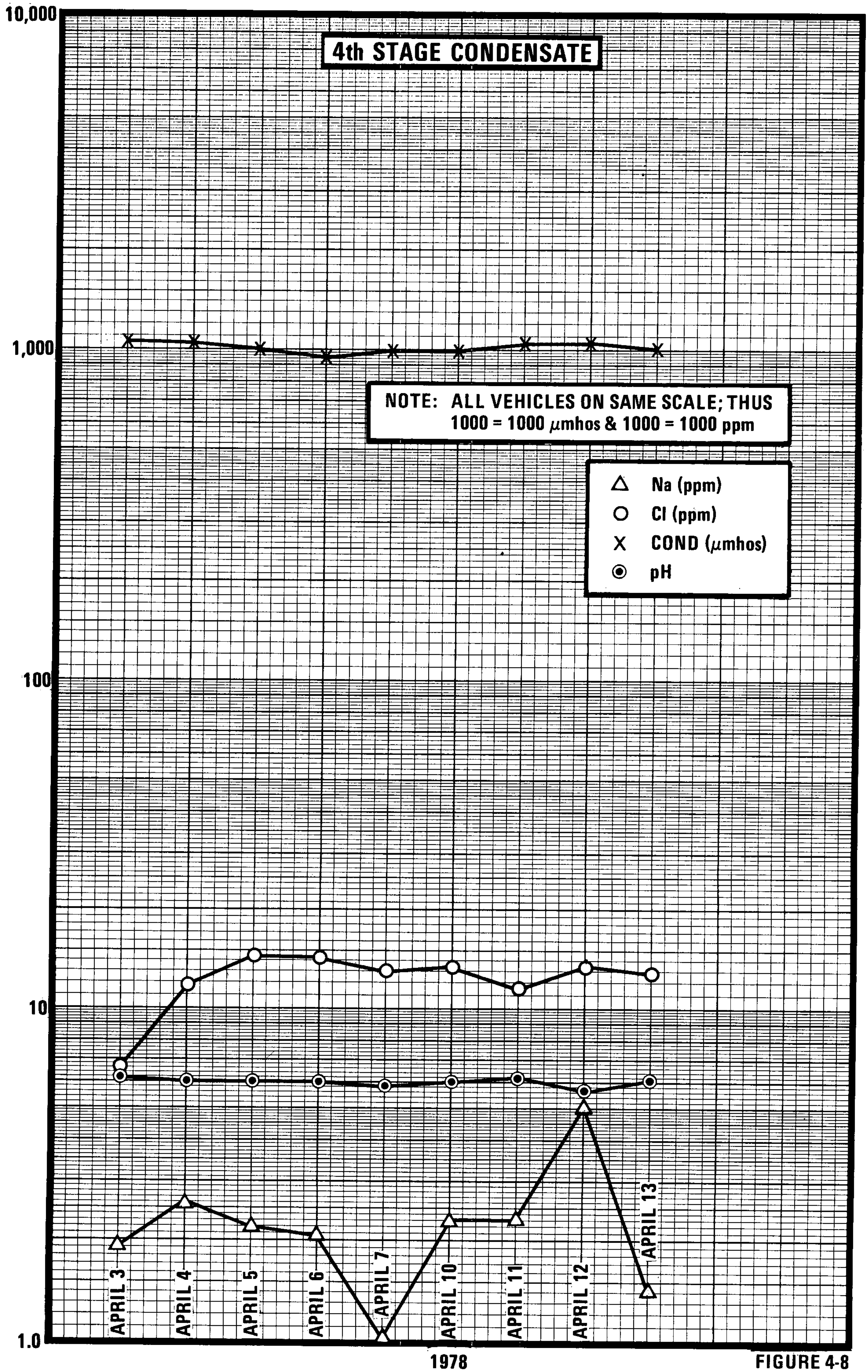
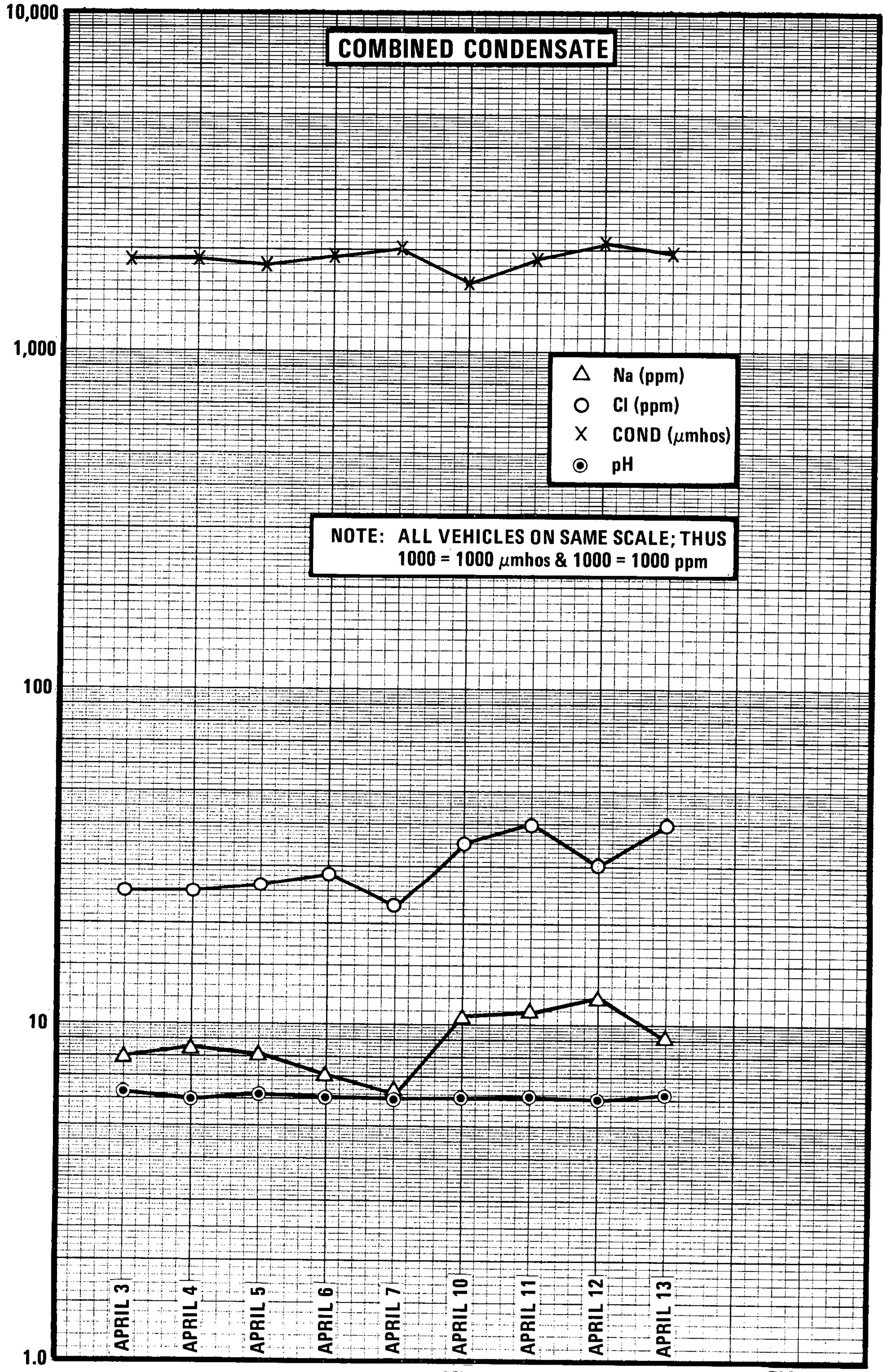

4th STAGE CONDENSATE
10,000
1,000
100
10
1.0
NOTE: ALL VEHICLES ON SAME SCALE; THUS
1000 = 1000 μmhos & 1000 = 1000 ppm
Na (ppm)
Cl (ppm)
COND (μmhos)
pH
APRIL 3
APRIL 4
APRIL 5
APRIL 6
APRIL 7
APRIL 10
APRIL 11
APRIL 12
APRIL 13
1978

FIGURE 4-8



COMBINED CONDENSATE
10,000
1,000
100
10
1.0
Na (ppm)
Cl (ppm)
COND (μmhos)
pH
NOTE: ALL VEHICLES ON SAME SCALE; THUS 1000 = 1000 μmhos & 1000 = 1000 ppm
APRIL 3
APRIL 4
APRIL 5
APRIL 6
APRIL 7
APRIL 10
APRIL 11
APRIL 12
APRIL 13
1978

FIGURE 4-9

a value between 6 and 7, due to reentrainment of noncondensible gases (primarily carbon dioxide) from the four stage scrubber.

4.2 Brine Chemistry

During the last two weeks of this test only the second and fourth stage brine flows were sampled. The results are summarized in Tables 4-10 and 4-11. The composition was also generally similar to that observed during the previous portions of the test and presented in the March Quarterly Report. A slightly higher level of total dissolved solids, 260,000 ppm in the second stage and 270,000 ppm in the fourth stage was observed. Sodium and chloride values were also correspondingly higher.

4.3 Scale Chemistry

At the termination of this test on April 14, the vessels and processed piping in the GLEF were inspected. The results of this inspection are described in Appendix C.

In the first stage most of the scale appeared as debris on the floor of the first stage separator. The only exception being the exit which was heavily scaled to a thickness of approximately 1 inch. Similar results were observed in the second stage flash vessel, although due to a leak in the purge line some carbonate scale was observed on the inlet line.

SECOND STAGE BRINE
APRIL 1978

DATE	4-3	4-6	4-10	4-13
Fe	491		477	
Cu	1		0	
Zn	267		381	
Mn	750		712	
Pb	9		5	
Al	0.4		12	
Ba	198		105	
Mg	107		111	
Si	53		38	
B	350		140	
Ca	26,900		18,600	
Na	51,000		41,800	
K	5,500		3,000	
Li	267		187	
NH_3	197.0		125.0	
Cl	151,400	148,916	113,580	98,436
CO_2		0		0
Sr	98		441	
SO_4	0		45	
TDS	254,200	265,100	196,600	163,300
ORP	-23	-60	-23	-38
pH	5.94	5.91	6.04	6.29
Cond	383,000	370,000	300,000	232,000

FOURTH STAGE BRINE
APRIL 1978

DATE	4-3	4-6	4-10	4-13
Fe	311		354	
Cu	1		0	
Zn	50		406	
Mn	790		913	
Pb	72		65	
Al	0		16	
Ba	173		156	
Mg	1,121		116	
Si	165		117	
B	370		200	
Ca	29,000		27,000	
Na	54,500		56,100	
K	6,150		4,850	
Li	298		310	
NH_3	535.0		114.0	
Cl	164,060	161,536	161,536	159,012
CO_2		36.0		40.0
Sr	125		884	
SO_4	38		16	
TDS	269,700	271,200	275,050	270,200
ORP	+33	−8	+23	+32
pH	5.18	5.20	5.18	5.17
Cond	405,000	400,000	400,000	378,000

Uniform debris across the third and fourth stage flash vessel floor was observed with a heavier depisition up to 30.5 to 45.7 centimeters observed in the fourth stage. Exit of both vessels were heavily scaled.

Analysis of the scales observed throughout the plant are summarized in Tables 4-12 through 4-17. These compositions are similar to those observed previously. A visual indication of how the major constituents of the scale changed as the energy is extracted from the brine passing through the plant is seen in Table 4-18 and Figure 4-10. It can be seen that silica remains the major component of the scale throughout the plant with iron and lead showing almost a continual decline from the first through the forth stage.

4.4 Cooling Water

4.4.1 Spray Cooling Pond and Condensers

The major difficulties experienced by the GLEF cooling system have been corrosion and bacterial contamination of the circulating water. Heavy iron oxide deposits were observed on the condenser tubes during the last shut down. Whether this iron comes from corrosion of the cooling water system or from the condensed steam has not yet been established. Iron concentrations of 0.2 to 13 mg/l have been observed in the steam. Assuming an average iron value of 6 mg/l, some 300 lbs. of iron enter the spray pond every

SCALE ANALYSIS OF SEPARATORS BELOW BRINE SURFACE OR FLOOR DEBRIS APRIL 1978

LOCATION ELEMENT (ION)	PERCENT OF SCALE (DRIED)			
	1B SEPARATOR INLET END	2ND SEPARATOR ON WELL	3RD SEPARATOR FLOOR	4TH SEPARATOR DEBRIS ON FLOOR
Fe	19.51	14.13	4.17	0.75
Cu	0.11	1.10	0.36	
Zn	0.18	0.13	0.09	0.11
Mn	1.76	2.48	0.42	0.26
Pb	9.84	9.37	0.59	
Al	0.87	0.76	0.32	0.10
Ba	0.16	0.06	0.14	0.47
Mg	0.62	0.15	0.45	0.04
Si	18.8	20.1	29.6	22.5
*(SiO_2)	40.3	43.0	63.4	48.2
Ca	1.50	3.00	2.55	5.55
Na	2.10	5.40	4.05	12.35
K	0.31	1.12	0.94	1.65
Li	0	0	0	
Sr	0.06	0.05	0.04	0.22
$CO_3^{=}$	0.35	0.03	1.08	0

*Silicon as SiO_2

SCALE ANALYSIS OF SEPARATORS
AT DRAINS
APRIL 1978

LOCATION ELEMENT (ION)	PERCENT OF SCALE (DRIED)			
	1B DRAIN	2ND DRAIN	3RD DRAIN	3-4 DRAIN
Fe	12.45	9.60	1.28	1.65
Cu	0.49	0.56	0.55	0.95
Zn	0.06	0.09	0.07	0.07
Mn	1.40	2.25	0.36	0.18
Pb	13.78	1.39	0.31	0.54
Al	0.70	0.17	0	0.50
Ba	0.05	0.03	2.10	0.28
Mg	0.51	0.09	0.03	0.03
Si	20.3	19.5	39.9	33.0
*(SiO_2)	43.5	41.8	85.5	70.7
Ca	2.33	3.10	1.65	0.07
Na	2.78	6.15	1.80	1.65
K	0.54	1.13	0.29	0.55
Li	0	0.02	0	0
Sr	0.39	0.16	0.22	0.04
CO_3	0.01	0	0.19	0.03

*Silicon as SiO_2

TABLE 4-13

SCALE ANALYSIS OF SEPARATORS
OFF CEILINGS
APRIL 1978

LOCATION ELEMENT (ION)	PERCENT OF SCALE (DRIED)		
	1B CEILING	3RD CEILING	4TH CEILING
Fe	22.82	59.49	26.28
Cu	0.17	0.06	0.22
Zn	8.10	0.39	0.23
Mn	4.86	1.46	1.22
Pb	4.78	0.21	0.82
Al	0.20	0.10	0
Ba	1.35	1.57	0.89
Mg	0.44	0.04	0.05
Si	9.0	2.0	21.3
*(SiO_2)	19.9	4.3	45.6
Ca	3.65	1.65	1.95
Na	2.10	0.10	3.85
K	0.22	0.15	0.53
Li	0	0	0
Sr	0.05	0.10	0.04
$CO_3^{=}$	3.89	0.22	0.44

*Silicon as SiO_2

TABLE 4-14

SCALE ANALYSIS
INJECTION LINE
APRIL 1978

LOCATION ELEMENT (ION)	PERCENT OF SCALE (DRIED)			
	REINJECTION ELBOW ABOVE 1A SEP.	DANIELS SPOOL LOCATION	1ST EXPANSION LOOP	INLET TO 4TH EXPANSION LOOP
Fe	2.40	0.86	0.55	0.47
Cu		0.42	0.25	0.17
Zn		0.11	0.04	0.04
Mn		1.06	0.23	0.20
Pb		0.61	5.85	3.04
Al		0	0	0
Ba	3.45	3.55	2.32	2.11
Mg		0.02	0.01	0.01
Si	20.3	25.7	18.9	22.0
*(SiO_2)	43.5	55.1	40.5	47.2
Ca	13.95	7.85	4.99	5.55
Na	1.20	6.15	6.75	6.60
K	1.70	0.84	0.86	1.07
Li		0.01	0	0.01
Sr	0.37	0.43	0.31	0.33
$CO_3^{=}$	19.66	3.72	0.29	0.18

*Silicon as SiO_2

TABLE 4-15

SCALE ANALYSIS OF P-2 SUCTION PUMP

LOCATION ELEMENT (ION)	PERCENT OF SCALE (DRIED)	
	P-2 INLET ELBOW BOTTOM	P-2 DISCHARGE
Fe	0.45	0.11
Cu	0.20	0.17
Zn	0.09	0.07
Mn	0.31	0.10
Pb	0.21	0.65
Al	0	0.40
Ba	0.64	0.50
Mg	0.02	0.01
Si	18.0	27.0
*(SiO_2)	38.6	57.9
Ca	6.90	3.60
Na	13.10	7.40
K	2.12	1.26
Li	0.04	0.10
Sr	0.25	0.09
$CO_3^=$	14.02	0.01

*Silicon as SiO_2

TABLE 4-16

SCALE ANALYSIS OF CONDENSER APRIL 1978

ELEMENT (ION)	PERCENT OF SCALE (DRIED)
Fe	46.80
Cu	0.04
Zn	0.33
Mn	0.39
Pb	0.86
Al	0
Ba	0.30
Mg	0.09
Si	2.9
*(SiO_2)	6.21
Ca	2.40
Na	0.75
K	0.17
Li	0
Sr	0.21
$CO_3^{=}$	2.15

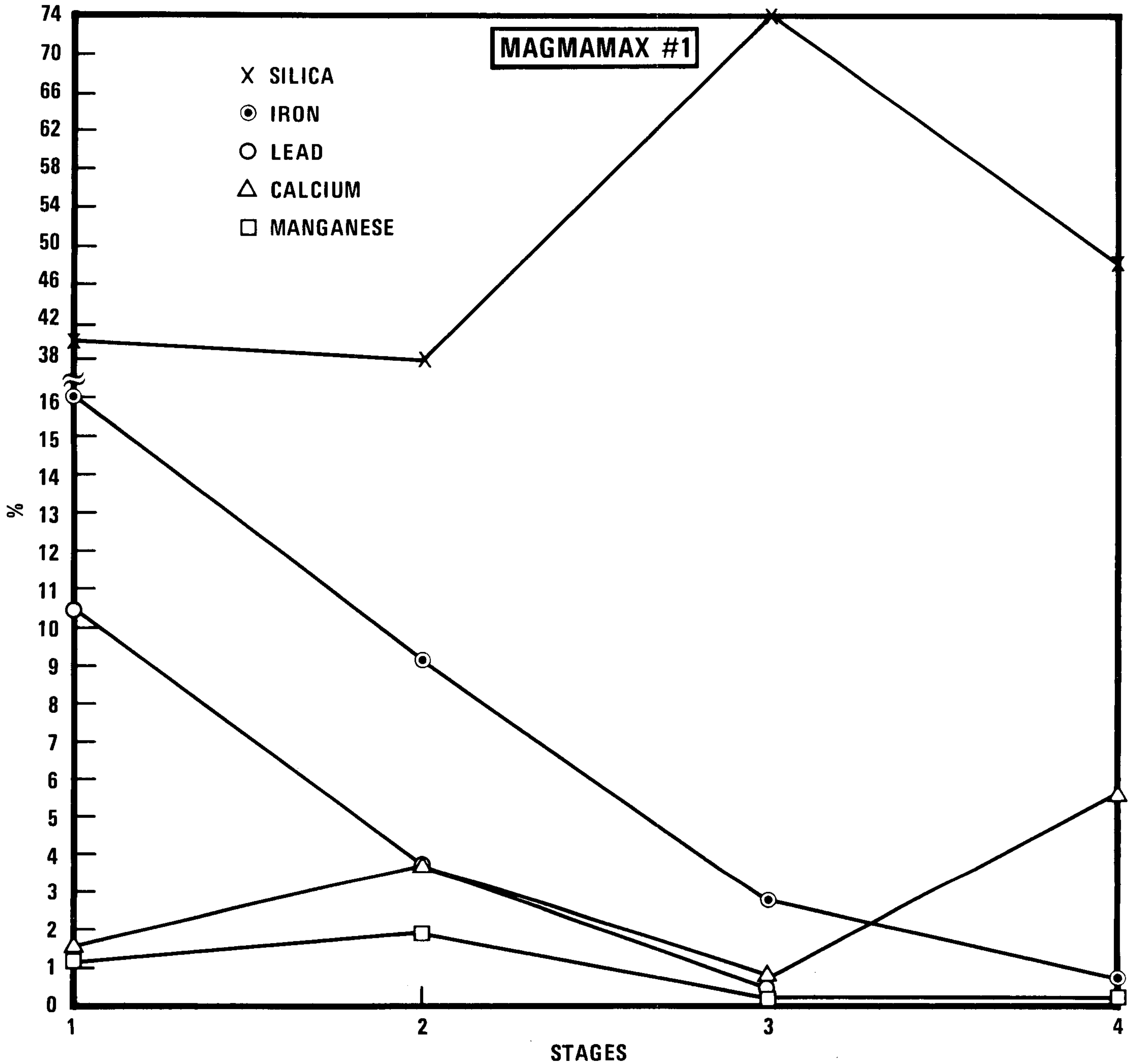
*Silicon as SiO_2

TABLE 4-17

AVERAGE % DEPOSITION IN THE SEPARATOR VESSELS
MAGMAMAX WELL #1
FEBRUARY - APRIL RUN

CONSTITUENT	STAGE 1 %	STAGE 2 %	STAGE 3 %	STAGE 4 %
Iron	16	9.3	2.9	0.75
SiO_2	38.8	38	74	48
Lead	10.5	3.9	0.53	ND
Ca	1.9	3.9	1.9	5.6
Mn	1.6	2.1	0.42	0.26
Na	2.8	7.4	2.3	12.4
Mg	0.6	0.16	0.2	0.04
Sr	0.16	0.16	0.11	0.22
Ba	.08	0.06	0.76	0.47
$CO_3^{=}$	0.2	0.09	0.64	–
Cu	0.23	0.73	0.34	–
Zn	0.12	0.1	0.08	0.11
Al	0.56	0.46	0.22	0.1

TABLE 4-18



MAGMAMAX #1
X SILICA
IRON
LEAD
CALCIUM
MANGANESE
74
70
66
62
58
54
50
46
42
38
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
%
1
2
3
4
STAGES

FIGURE 4-10

month. However, this amount of iron is not sufficient to account for all the iron deposits seen on the tubes and some corrosion of the cooling water system must be occurring. Sampling the combined condensate to characterize the quality of the makeup to the pond will continue.

The condensers were cleaned twice with inhibited HCl during this shutdown. Twenty-six (26) leaking tubes, all in the second pass of condenser E-4B, were found and plugged.

One of the leaking tubes was pulled and examined. The deposits were found to be tightly adhered to the tube metal, which is mild carbon steel. The tubes were severely pitted with corrosion occurring underneath the deposits. Prior to the second acid cleaning the tube sheets were hydroblasted clean of scale. The same corrosion pattern was noted here as on the tubes. There is considerable thinning of the tube metal where the tubes are flared into the tube sheets.

The spray pond was drained and recharged with IID (irrigation) water. A gage was installed to indicate pond level. The chlorine addition point was changed from the circulating pump suction to a diffuser pipe near the back of the pond.

The chemical treatment for the cooling system has been modified. The triazole corrosion inhibitor with a diphosphorate scale inhibitor has been substituted for the zinc base corrosion inhibitor. Chlorine will be the primary organic control agent alternating with a microbiocide chemcal. An iron dispersant will be used as needed to control iron deposition on the tubes. Corrosion monitoring is being done with Petrolite probes with continuous recording in MPY, and with corrosion test coupons.

4.5 Brine-Steam Separators

The steam sampling system was modified to allow determination of ion depletion across the 2 stage flash system in the Magmamax train. New sample lines and Inconel sample coolers have been installed at the following locations:

1. Brine feed to V-4 (1st Stage Separator)
2. Brine feed to V-11 (2nd Stage Separator)
3. Brine outlet from V-11 (Blowdown)

In the past scaling at the pipe wall may have prevented the drawing of a representative and consistent brine sample. To overcome this difficulty a retractable sample probe will be used for taking samples adjacent to the continuous samples lines and the analytical results compared.

Any scale deposition should result in a comparable depletion of this ion from the brine. Estimation of the ion depletion in the brine and the corresponding scale deposition will be made using the following relationships.

$$\text{Concentration factor (CF)} = \frac{\text{Conc. of ion in brine blowdown}}{\text{Conc. of ion in brine feed}}$$

$$\text{Percent of Ion depletion} = \frac{\text{CF of ion of interest}}{\text{CF of sodium}}$$

4.6 Binary System

After the shutdown on April 14, the binary system was drained and cleaned with a solution of sodium hexametaphosphate and sodium sulfite as oxygen scavenger. The loop was flushed and recharged with condensate containing hydrazine as oxygen scavenger and cyclohexylamine to raise the pH to the range 9.0 to 9.5 for neutralization of any carbon dioxide remaining. Petrolite corrosion monitoring probes were installed with continuous readout in MPY.

4.7 Steam and Condensate

A new sample line and Inconel cooler have been installed on the outlet of V-4 to determine the steam purity available from the 1st stage separator. This new sample point will be used in a future study to determine the relationship between sodium and total dissolved solids in the condensed steam. A direct relationship would allow a continuous estimate to be made of steam purity using sodium electrode analyzers. The previous sampling system have been left in place for the purpose of comparing results. Iron concentrations in samples from the 1st stage steam scrubber, V-8 will be used to estimate corrosion in this vessel.

The combined condensate will be analyzed to determine its suitibility as a source of makeup to the cooling pond. Of particular interest is iron and its effect on the cooling system chemistry.

5.0 MAINTENANCE

5.1 Scale Removal

5.1.1 Pigging

On April 13, immediately prior to shutting down the plant for planned modifications, the two articulated pigs manufactured by T. D. Williamson Co., were run down the injection line. Prior to this operation, a Girard wire brush "Poly-pig" was run down the line to ensure that the line was as clean as the "Poly-pig" could make it.

The wire brush articulated pig was launched first. Its travel was very noticeable, as it produced a loud brushing noise as it moved. GLEF personnel tracked the pig during its entire journey and found that it never became stuck for more than a second or two. A brine sample port near Magma's baker tanks was opened and watched for signs of debris, which first appeared when the pig was approximately 100 ft. from the tap. A one gallon sample was taken during the time that the fluid was most turbid. When the suspended solids had settled to the bottom of the container, a layer about 1.6" deep was found. Since the container is 6" high, roughly 27% of the volume of the fluid contained in the sample was debris removed by the pig. For a rough calculation of the amount of scale removed and the thickness of the scale removed. (See Figure 5-1)

THICKNESS OF SCALE REMOVED BY ARTICULATED PIG

The brine sample taken downstream of the pig contained 27% suspended solids. The debris was first noticed when the pig was approximately 100 feet upstream of the sample port. Assuming the debris-laden water all contained the same concentration of solids;

$$\text{Total Amount of Scale Removed} \quad (V) = \left(\begin{matrix}\text{Fraction of Fluid}\\ \text{Containing Solids}\end{matrix}\right) \times \left(\begin{matrix}\text{Volume of Pipe}\\ \text{Containing Solids}\end{matrix}\right)$$

$$= (.027) \times \left(\frac{\pi}{4}\ \frac{9.5}{12}\text{ft}\right)^2 \times (100\text{ ft})$$

$$V = 13\text{ ft}^3$$

$$\text{Thickness of Scale Removed} \quad (t) = \left(\begin{matrix}\text{Total Volume of}\\ \text{Scale Removed}\end{matrix}\right) \Big/ \left(\begin{matrix}\text{Surface Area of}\\ \text{Entire Pipe Length}\end{matrix}\right)$$

$$t = \frac{V}{\pi D L}$$

$$= \frac{(13\text{ ft}^3)(12\text{ in/ft})}{\pi\left(\frac{9.5}{12}\text{ft}\right)(4600\text{ ft})}$$

$$= 0.014\text{ ft}$$

$$t = 14\text{ mils}$$

This is only a rough estimate, based on crude approximations.

FIGURE 5-1

The second articulated pig (the scraper version) was then launched. Its passage was much less noticeable due to its design. At first it appeared to be moving smoothly, but became struck somewhere between the point where the Bureau of Mines injects spent brine and the point where the injection line passes under the road. This was determined by the difference in readings taken from pressure gauges at these points. In an attempt to dislodge the pig, a foam rubber swab was launched down the line. After about 1/2 hour, pieces of the swab began appearing in the baker tanks at the injection well, indicating that the swab had not been effective. However, the pig had moved further down the line, and was determined to be stuck in an elbow at the second expansion loop of the line. This time a brand new wire brush "Poly-pig" was launched, in the hope that it would not disintegrate when it encountered the articulated pig. The "Poly-pig" was tracked down the line until it encountered the Williamson pig, at which point both pigs, squealing and grunting, slowly advanced the rest of the way through the line. Samples of the debris dislodged by the second articulated pig could not be taken, since the sample line had become clogged after the first pigging. As a rough estimate, it appeared that the second articulated pig dislodged almost as much material as the first.

Neither articulated pig has been retrieved as yet, as they immediately sank into the baker tanks. When the tanks have been drained, they will be retrieved, and a report on their condition will be given.

Owing to the crudity of the measurements made during the pigging operation, the only certain conclusion that can be drawn is that the wire brush articulated pig can negotiate the standard radius elbows in the injection line. The scraper articulated pig appears to have some difficulty and may get stuck when tried the next time, but can most likely be retrieved by following it with a wire brush "Poly-pig". The rough estimate of 14 mils of scale removed by the articulated pig cannot be used to conclude that the articulated pigs perform better than the "Poly-pig", since the same results might have been obtained using a "Poly-pig" with longer or stiffer bristles.

If future tests prove the articulated pigs are capable of negotiating the injection pipeline, they should be evaluated against the "Poly-pig" on economic grounds. The use of articulated pigs between flash vessels should be feasible, if they can withstand the higher temperatures and can be shown capable of negotiating the pipe turns in that system. It is recommended that we proceed to further test the articulated pig in the injection line.

5.2 <u>Sulfuric Acid System</u>

The sulfuric acid system has been inoperable due to the bottom of the tank being plugged with corrosion products. Any acid that was used was siphoned off the top of the tank. Very little acid was used in the spray pond since the plant was in operation and there was some question about the condition of the tank interior. The tank, pump, and lines were completely removed. System will be replaced with drum storage if required.

5.3 Condensate Acid System

In November 1977, a temporary acid system was installed to treat the condensate before recombining it with the brine. This system used a rented tanker. Because of various problems with this system, (ref. Jan '78 Quarter Report) and its temporary nature, use of this acid system was discontinued. During this shutdown period, the acid system was removed and the 5,000 gallon HCl acid tanker was returned to Dow Chemical Co. The pump, controls and piping have been used for a new acid system. New acid system will be used for purge water treatment but can be used for condensate treatment if required.

5.4 Purge Water Acid System

The acid system for treating the purge water for (P-2) bearings was also temporary. This system used 55 gal. drums with a pump to pump HCl acid into the suction of purge pump (P-7). This system has been modified to a permanent system as follows: A 5,600 gal. polyurethane tank was installed and placed in a cement berm to contain all of the acid, should there be a leak. Two positive displacement pumps by Neptune Proportional Pumps have been installed inside the berm. Only one pump will be in operation at any time. The discharge line from the pumps is teflon coated inside and goes out of the berm underground. The pipe exits from underground in front of (P-7) purge pump and connects into the pump suction. A scrubber has been installed inside the berm to treat vent gases from the storage tank.

5.5 Binary System

The binary system was completely drained. The system was refilled with distilled water (15,000 gals.). Sodium hexametaphosphate (200 ppm) and sodium sulfite (200 ppm) were added. This was circulated through the system for 24 hours for cleaning purposes. Then the system was completely drained again. The check valve on the booster pump (P-8) discharge was removed to inspect the line. The piping was clean and very little corrosion noted. The system was closed up and refilled with distilled water (15,000 gal.). It was circulated for a couple of hours and dumped to remove any of the cleaning chemicals. The system was refilled for the final time with about 20,000 gal. of distilled water. Two corrosion inhibitors were added - hydrazine for oxygen scavenging and cyclohexylamine to raise the pH to the range 9-10 to remove carbon dioxide.

5.6 Cooling Water Condensers

A spool piece was installed on the 24" inlet line between the two condensers. This will enable inspection into the inlet side or the bottom of each condenser without removing the condenser headers for inspection. During the spool piece installation the condensers were inspected. Significant quantities of debris were found in addition, scale buildup on tubes and tube sheet wad detected. The debris was cleaned out. After the spool piece was installed, the condensers were acid cleaned with inhibited HCl. (See section 7.1 Condensers)

5.7 Cooling Water Pond

The cooling water pond was completely drained during this period. The reason for this action was to remove the concentration of iron and zinc. The pond was empty for about five (5) days to let the sun bake it. The pond was then filled with water from the Imperial Irrigation District Vail canal. (For chemical analysis see section 5.4.1)

5.8 Cooling Water Pump (P-3)

The cooling water pump was removed for inspection during this shutdown period. The pump impeller and the intake cross pieces were badly deteriorated. The pump was sent to SDG&E Machine Shop to be completely overhauled. It was determined by the laboratory that the impeller and suction cross pieces were corroded by ammonia attack and particle corrosion. The impeller was built up to specifications and machined. The intake cross piece was built up.

5.9 Sample Coolers

New sample coolers were installed on the brine system. The old type sample coolers were made with stainless steel tubes. The new coolers are made of Inconnel. The lines leading into the cooler are now stainless steel 3/8" tubing which replaced 1" black iron pipe. There is a sample point and cooler now installed on the brine inlet and outlet of 1st Stage A and B separators and inlet and outlet of 2nd stage A and B separators. The sample cooler on the injection pump (P-2) that was previously used is still in use with 1" black iron pipe.

The sample coolers on the steam side are still in use as before. There is a sample point and cooler on the steam inlet to 1st stage scrubber from 1A and 1B separator, outlet of 1st stage scrubber, inlet and outlet of 2A scrubber and inlet and outlet of 2B scrubber.

In addition to the above mentioned steam sample coolers, there is also installed a new type sample cooler as used in the brine system with stainless steel 3/8" tubing for the steam outlet of 1B separator.

5.10 Magmamax #1 Supply Line

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 1st expansion loop, there was a build up of scale - up to 1" thick in places. This section of line was hydroblasted clean. After the line was cleaned, it was discovered that there were many pits in the line. Some pits were noted to be about 1/8" deep. A double block and bleed valve is now installed as a line stop near the well. Some pitted sections were replaced and 90° elbows were modified to tees with a blank leg. Tees will allow inspection without cutting into the supply line.

5.11 Level Control Valves

Pressure control valve 301 (1st stage B separator brine inlet) and level control valve 714, (2B separator inlet) are ball type valves that have frozen in the past due to scale accumulation. They were sent out to have the casing halves and balls machined and stellite coated. The valves were then sent to E/M Lubricants, Inc., in North Hollywood, CA, to have a micorseal lubricant applied. This was done to test it in operation to determine if coating will prevent scale buildup.

5.12 Ground Fault Breakers

Ground fault breakers were installed on all outside receptacles with the exception of the line to the welding shed. Due to plant modifications, this line is coming from a new panel and the ground fault breaker will be installed upon completion. This is being done to meet new safety code requirements.

5.13 <u>Chlorination System</u>

The chlorination system was modified during this period. The previous system was to inject the chlorine gas into the pump pit. This has been modified by injecting the chlorine gas out into the spray pond at the furtherest point from the pump suction (east side of the pond). The purpose is to treat the spray pond more efficiently with chlorine and prevent chlorine concentration from affecting pump and lines.

5.14 <u>Packing</u>

During a shutdown period in January, SDG&E purchased 2 lbs. of Chesterton teflon packing (style 201) for evaluation. This was enough to pack two valves. After 1480 hours the packing was inspected. The packing itself was still very pliable and soft. The brine apparently has no adverse effects on the packing.

Although the packing seems to be working, it is costly ($25.00/pound). With approximately 30 valves in the system, a packing with a teflon impregnated asbestos, which costs approximately half as much, will be tried.

6.0 SPECIAL PROBLEMS

6.1 Condensers

The condensers (E4A and #4B) continued to cause problems with plant operation. In the brief period of operation since the last acid-cleaning in February, the condenser tubes were again scaled up to the point where they required cleaning. In February, the tubes were initially cleaned of most scale by hydroblasting each tube individually. This procedure was time consuming and expensive, so this time, the condensers were acid-treated without first hydroblasting them. (See Appendix D for procedure) Inhibited hydrochloric acid (3% inhibitor) was circulated at 900 gpm for 15 hours. Upon completion of the acid treatment, the acid was dumped in the brine pond and the cooling water pump was started to flush out the condensers.

During this flushing procedure, some acid along with iron, was dumped in the spray pond. (The spray pond pH was reduced from 8.6 to 7.4. The iron increased from 0.1 to 3.2 ppm.) After the condensers were flushed, the condenser tubes were passivated with Zimmite chemical ZC-362 at 200 ppm. This was circulated for 3 hours and then dumped into the spray pond. Condensers were then flushed again.

The flow through the condensers had not noticeably improved after this first acid-treatment, so the condenser heads were removed for inspection. The tubesheets were covered with debris, which appeared to restrict or totally block flow through the tubes. To remove the debris from the tubesheets and from inside each of the tubes, a low pressure water and air lance was used. This operation took two days, but effectively removed all of the larger deposits in the tubes. While unplugging tubes, it was discovered there were leaking tubes in condenser (E4B). A hydro of 80 psig was placed on the shell side of the condenser and 12 tubes were found to be leaking. One of the leaking tubes was pulled, and its hole in the tube sheet was plugged. The rest of the leaking tubes were plugged in place. The tube that was removed was cut up, split open, and sent to SDG&E's lab for inspection.

The heads were reinstalled on the condensers and acidized again. After removing the acid, it was passivated with Zimite ZC-362. The headers were removed again to inspect the tubes and to check for leaks. The tubes were clean, but there were 14 more tubes leaking. A total of 26 tubes are now plugged on condenser (E4B), all on the upper half. The condenser heads were put back on and the condensers were filled with Zimmite ZC-362 at 200 ppm until ready for start up.

The condenser heads were then reinstalled and another acid-cleaning and passivation was performed. (See Appendix D for procedure) When the condenser heads were removed for inspection the tubes were found to be completely clean. When cooling water flow was later applied, the pressure drop across the condensers was only 6 psi at a cooling water flow of 16,000 gpm. This is the lowest pressure drop ever experienced with the condensers.

Unfortunately, the inspections before and after the second acid-cleaning showed that several of the tubes in the upper half of the east condenser (E4B) were leaking. Before the condensers were returned to service a total of 26 leaking tubes were sealed at both ends with steel plugs.

6.2 Cooling Water Treatment

When the GLEF was shutdown in April, it was apparent that a new water treatment program was necessary. Proposals were solicited from commercial water treatment firms on the best treatment to use. These proposals were based on the assumption that geothermal condensate would be used for makeup to the spray pond. Geothermal condensate represents a very difficult environment and treatment is viewed as experimental. Three proposals were received and one, from Zimmite Corp., was selected for testing.

Prior to implementing the Zimmite program, the cooling pond was completely drained over a period of several weeks. It was hoped that this action would remove undesirable chemical species (such as ammonia, iron, etc.) that would interfere with the treatment program. The pond was subsequently refilled with irrigation water.

When the GLEF begins operating in July, the cooling water chemistry will be closely monitored to determine the effectiveness of the treatment being used. Corrosion coupons and Petrolite corrosion rate monitoring equipment will be installed in the cooling water circulation piping to provide a means of determining the type and rate of corrosion experienced, and concentrations of certain chemical species will be controlled within limits specified by the water treatment company.

6.3 Cooling Water Pump

During the April shutdown, the cooling water circulation pump (P-3) was removed and inspected for the first time since the GLEF began operating. A very large amount of material was removed from the brass pump impeller and other materials at the pump suction. While the pump was being repaired, Bechtel inspected the damaged components. Their report is shown as Appendix E.

6.4 Injection Pump

Over the weekend of March 25 and 26, the brine injection pump began losing discharge pressure and flow. Under normal operating conditions, the flow is about 500 gpm and the pump discharge pressure about 550 psig. By noon on

March 26, the discharge pressure and flow were 365 psig and 274 gpm respectively.

A hydroblast nozzle had been installed at the pump suction bell during the last pump overhaul to evaluate its effectiveness in removing scale formed there. Between 2:00 PM and 4:00 PM on March 26, the nozzle was utilized in an attempt to improve the pump's performance. Very little improvement was noted after the operation was complete.

By 8:00 AM on Monday, March 27, the pump was flowing 435 gpm at 160 psig. Since a shutdown appeared imminent, and doing so would interfere with clarifier tests being conducted by Magma Power, methods of cleaning the pump in place, without shutting down the plant, were discussed. GLEF operating personnel suggested flushing the pump can with irrigation water (introduced into the 3 inch vent line at the top of the can) to remove any scale formed between the pump and the can. It was also suggested that water be forced through the hydroblast nozzles at the pump suction bell to create additional turbulence to help break up any loosened debris.

At 1:00 PM hydroblasting was begun, followed 10 minutes later by the flow of irrigation water through the vent line. At 1:20 PM, more cooling water was introduced through the 3 inch line used to dump cooling pond water into the reservoir. This line enters the 4th stage brine discharge line about 5 feet upstream of the pump suction inlet. The combination of the three cooling water flows plus the brine flow reached a maximum of about 1,000 gpm during the operation.

The flow through the vent line was secured first at 1:40 PM followed by the cooling pond water flow at 2:00 PM. The hydroblast flow was shut off last at 2:10 PM. After adjusting the brine flow control valve back to normal conditions (510 gpm), the pump discharge pressure was 555 psig. The in-place cleaning of the pump was apparently a complete success.

Unfortunately, the pump operated normally for only about a week, after which time the discharge pressure and flow began to drop again. The same procedure was used in an attempt to clean the pump again, only this time the flow through the hydroblast nozzle was the last to be added. The results were disappointing, as the discharge pressure and flow continued to drop, finally forcing shutdown.

When the pump was removed for rework it was obvious that large amounts of scale had been removed from the pump suction line and from the sides of the pump can. From temperature readings taken from a thermocouple in the line, it was determined that most of the scale was removed during the first flushing procedure. The pump suction bell was almost closed off with scale, however. The hydroblast nozzle kept only a very small opening clear of scale. This indicates that the hydroblast nozzle was useful mostly because of the turbulence it produced at the suction bell, which may have helped break up and keep in suspension the scale particles removed by the low velocity flows. The pump discharge was also almost plugged with scale as the 10" pipe diameter was reduced to about 3 inches.

It may be the first pump cleaning worked because the pump's poor performance was originally due to excessive restrictions in the pump suction line. The low pressure water used was shown to be effective in cleaning these areas. The second attempt at cleaning may have failed because the pump's poor performance that time was due to restrictions in the pump internals and discharge piping, where scale removal was not very effective. Such conclusions are very tentative, however. Additional tests will be conducted when the situation occurs again.

When the injection pump was returned to San Diego for rework, Bechtel representatives inspected its condition as it was being disassembled. A report of their findings is included as Appendix F.

6.5 Production Line Corrosion

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 thicknesses varying between 125 and 500 mils. At several points, it appeared that larger obstructions may have built up. Consequently, it was decided to descale the first few hundred feet of the line downstream of the well by hydroblasting.

After the line was cleaned, severe pitting was noted in the carbon steel pipe. The pits were very large (about 1" to 2" across) and quite deep (approximately 50 to 200 mils). Most pitting was concentrated between 5 and 7 o'clock in the pipe. This may indicate that the corrosion occurs during periods when the line was only partially filled with water (i.e. during a shutdown). It has been speculated that oxygen inleakage during shutdown might have contributed to or caused this corrosion. A cross-section of the line analyzed by Lawrence Livermore Laboratory is shown in Figures 6-1 and 6-2.

Concern over the safety of the pitted piping necessitated a proof-pressure test. The pipe was filled with water and a static pressure of 720 psig was maintained for approximately an hour. No leaks were discovered in the pipe.

In the future, the brine production pipeline will be filled with water or an inert gas during shutdowns. This will minimize any oxygen inleakage and, hopefully, minimize corrosion.

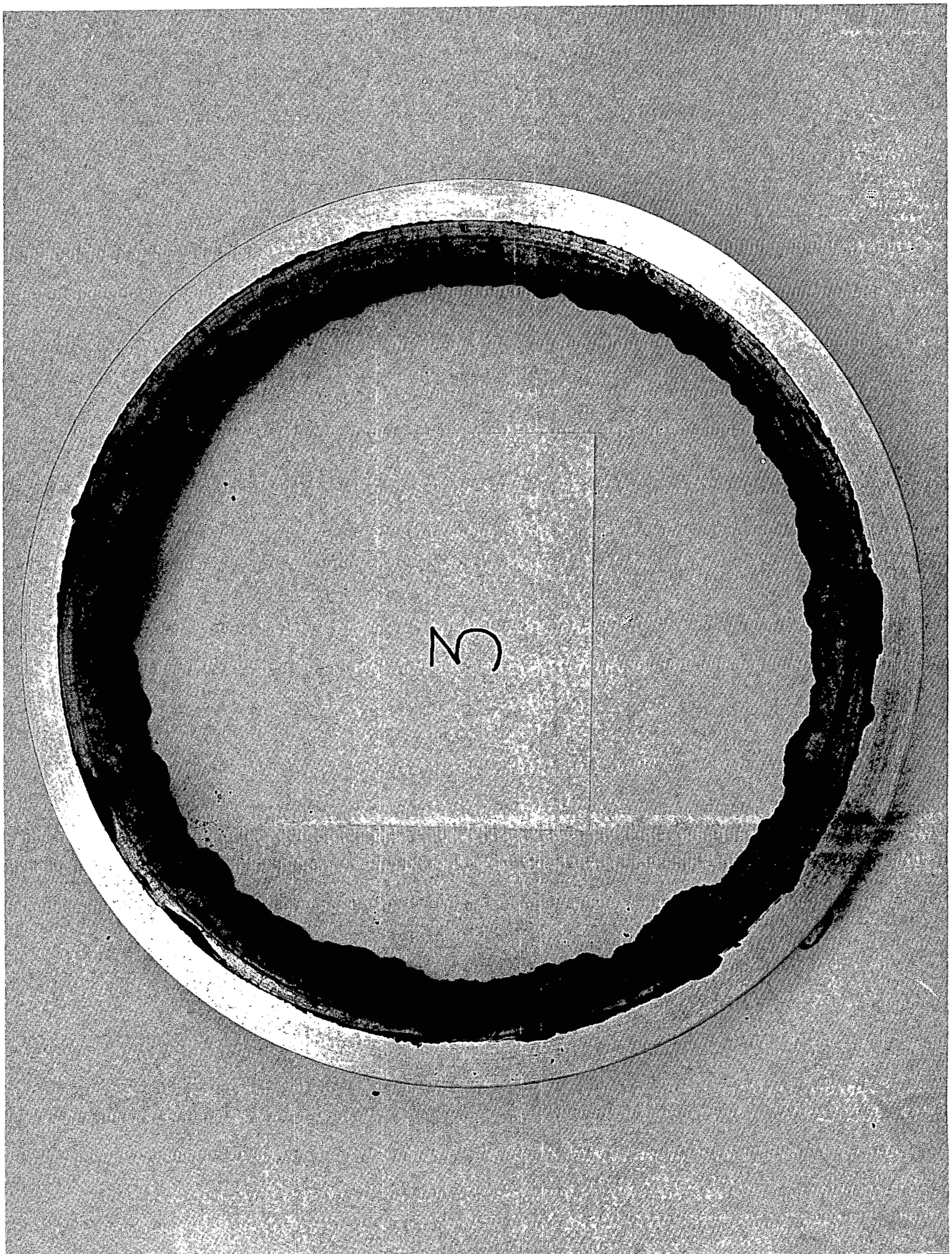


FIGURE 6-1

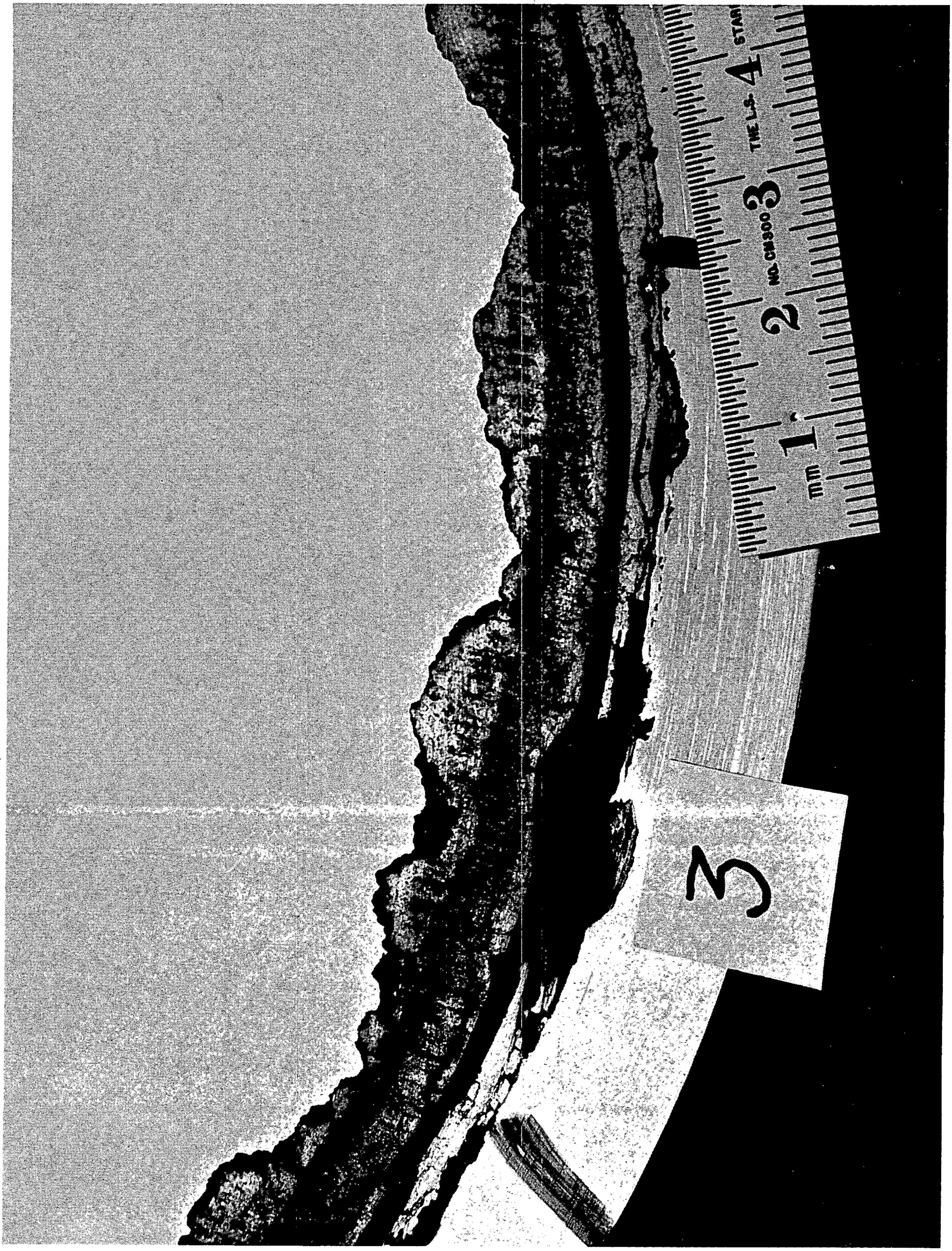


FIGURE 6-2

7.0 OTHER ACTIVITIES

7.1 Feasibility Study

As previously reported, the Phase 1 draft report recommended a dual flash cycle for the initial commercial geothermal power plant. Modifications to the GLEF are to be accomplished to simulate the critical portions of this type of cycle and concentrating future efforts in the high risk areas of scale, corrosion and injection. The final Phase 1 Report was issued on May 10, 1978.

The major recommendations 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 testing of corrosion and scaling, and 3) install a brine effluent treatment system to test for reliable injection of brines.

The preliminary engineering of these changes has been initiated. A solids contact clarifier was chosen as the primary effluent treatment technique rather than settling pond. This selection was based upon the pilot scale testing accomplished by Magma and LLL subsequent to the Feasibility Study. The results of their testing indicated that a silica saturated effluent was produced. By reducing the level of dissolved silica to saturation, downstream precipitation and scaling is minimized. Depending upon the amount and size of the solid particles produced by the clarifier, a filter may also be required to remove the fine particles from the effluent.

One difficulty with a solids contact clarifier is that standard designs will not accept pressure or a flashing fluid. The feasibility study resulted in an optimum second flash drum nominal pressure of 21 psia. Requests (to Envirotech and Ecodyne) to evaluate the impact of flashing or a pressurized clarifier design were made. Responses indicated that flashing might adversely affect performance and that a pressurized design is possible, but cost would be significant. Bechtel and Ben Holt were asked to evaluate the following three options: 1) lower second flash pressure to atmospheric, 2) install a pressurized clarifier, or 3) install an intervening atmospheric flash vessel. Evaluations by both companies indicated that installing an intervening atmospheric flash vessel would be optimum both at the GLEF and at a 50 MWe plant. An atmospheric flash vessel was therefore added to the list of future plant modifications.

7.2 Feasibility Study Addendem

One of the results of the feasibility study cycle analysis was that a flash/binary cycle was significantly more efficient than a dual flash cycle, even though the busbar cost was higher for the flash/binary option than the dual flash cycle. An addendum cycle (single stage flash, followed by direct contact binary) is to be evaluated to determine its potential. This new cycle offers the potential of maintaining the high efficiency of the binary cycle while reducing the overall busbar cost for future second generation plants.

Proposals were received from Ben Holt and Bechtel on this additional effort. Ben Holt was selected. A draft addendum to the feasibility study is in process.

7.3 Test Plan

Revisions to the test plan are in process. The objectives of the GLEF test program have been modified as a result of the feasibility study. The revised test plan will: 1) incorporate SDG&E, Magma/NARCO, LLL and Bureau of Mines activities, 2) emphasize major risk areas identified in the feasibility study, and 3) contain additional tasks that will be accomplished on a non-interference basis. A preliminary outline of the test program is attached in Appendix B.

Future LLL support is now being scoped by SDG&E and DOE. Emphasis will be placed on areas which require a controlled environment which is not achievable at the GLEF. Other LLL areas of support are those which require specialized equipment and/or expertise not readily commercially available.

8.0 SUMMARY

The plant operated for a total of 304 hours during initial portion of this reporting period. This brings the plant a total operating time of 7419 hours since startup.

The plant was shut down for the remainder of this quarter for cleaning, overhaul, and plant modifications. The shutdown was planned to coincide with scaling of the lines and pump in the facility, thus limiting operation.

During this down time the plant was redesigned from a four stage flash/binary system to a parallel two stage flash process with each well having its own two-stage system. A means of cross connecting the two was established by a modified valving arrangement.

Progress was made in the controlling of brine flow with the use of the pinch valve. Although further tests need to be accomplished as to the life of the valve liners, the possibility of using these pinch valves as control valves appears to be promising.

Deterioration of flash vessels due to corrosion poses a serious problem. Test coupons were installed in vessels to find a possible coating or liner to aid in the alleviation of this problem.

The chemistry lab is investigating the problem of heavy iron deposits on condenser tubing from cooling water.

Severe corrosion and deposits have been observed. The cooling water treatment program has been modified, based on data from testing.

A pilot program, with the goal of determining the most cost effective system for the stabilization of spent geothermal brine is being initiated. A clarifier is being installed with a dual media sand/anthracite gravity filter and will be tested.

Pigging is proving to be a reliable means of on-line cleaning keeping injection lines free of scale. Tests are being conducted on the use of cavitating nozzles using high pressure brine to free valves and lines of scale build up. A test will also be made to find if these nozzles can be used while the plant is in operation, thus avoiding the need to take the plant off the line for cleaning purposes.

Temporary acid systems have been replaced by a permanent facility. Safety and operation of the acid system was improved.

APPENDICES

APPENDIX A

INTERNAL CORRESPONDENCE – NEW ALBION RESOURCES CO.
FORM 133-5143

FROM **D. K. Mulliner** DATE **June 19, 1978**

TO **J. M. Nugent** FILE NUMBER **NAG 430**

SUBJECT **MAGMAMAX #2 WELL FLOW TEST**

Flow testing was started on April 27, 1978 and continued for 56 hours. An erosion area in the main control valve caused a shutdown for repair. The well produced some sand during the tests and caused erosion in piping and valves at high velocity points. The high velocity was caused by throttling large valves to very small openings.

Flow testing was again started on May 2, 1978 and continued for 210 hours. Erosion again caused a shutdown. The hole developed downstream from the brine control valve in a piping reducer.

Flow testing started again on May 12, 1978 and continued to May 15, 1978 interrupted by repeated shutdowns for pump repairs. None of these later tests extended for more than 10 hours. The well was shut in on May 15 and the test terminated.

The well was primed with fresh water. After a 24 hour heat up period, the well head pressure was 100 psig. The well was brought on slowly until a stable low flow, approximately 400 GPM, was sustained. The well head temperature and pressure stabilized at 373°F and 144 psig, then gradually increased during the test to 421°F and 300 psig at shut in. Three flow conditions were run, a low flow at 400 GPM, a medium flow at 600 GPM and a high flow at 900 GPM. The high flow condition could be maintained for only 11 hours due to equipment capability. At the high flow condition, the well head temperature and pressure was 407°F and 280 psig. The well had every indication of being capable of producing at a much higher flow rate.

Chemical analysis was run on the well fluid and the non-condensible gas. The salinity of the brine is greater than MM #1, 260,000 PPM. Non-condensible gas quantity was very low, averaging 0.00056% by weight of the well fluid. Scales formed in the piping and vessels were sampled and analyzed. The well fluid contained no detectable H_2S so a lower amount of heavy metals were deposited in the scales than with MM #1 fluid. The scales contained high percentages of silica and iron. The iron chloride content of the brine was high. One effect of the high iron content was to cause the pH to go down from 5.1 to 2.1 as the fluid stands in contact with air.

A side stream from the atmospheric flash drum was flowed into the Eimco clarifier. The sludge blanket formed was of lower specific gravity than that from MM #1. The sludge contained a high percentage of silica with low percentages of heavy metals. This was the effect of having a low or no H_2S to precipitate the heavy metals. The clarifier was not as effective at removing suspended solids as with MM #1 fluid. The clarifier did produce a fluid at silica saturation and low enough in suspended solids to be reinjected.

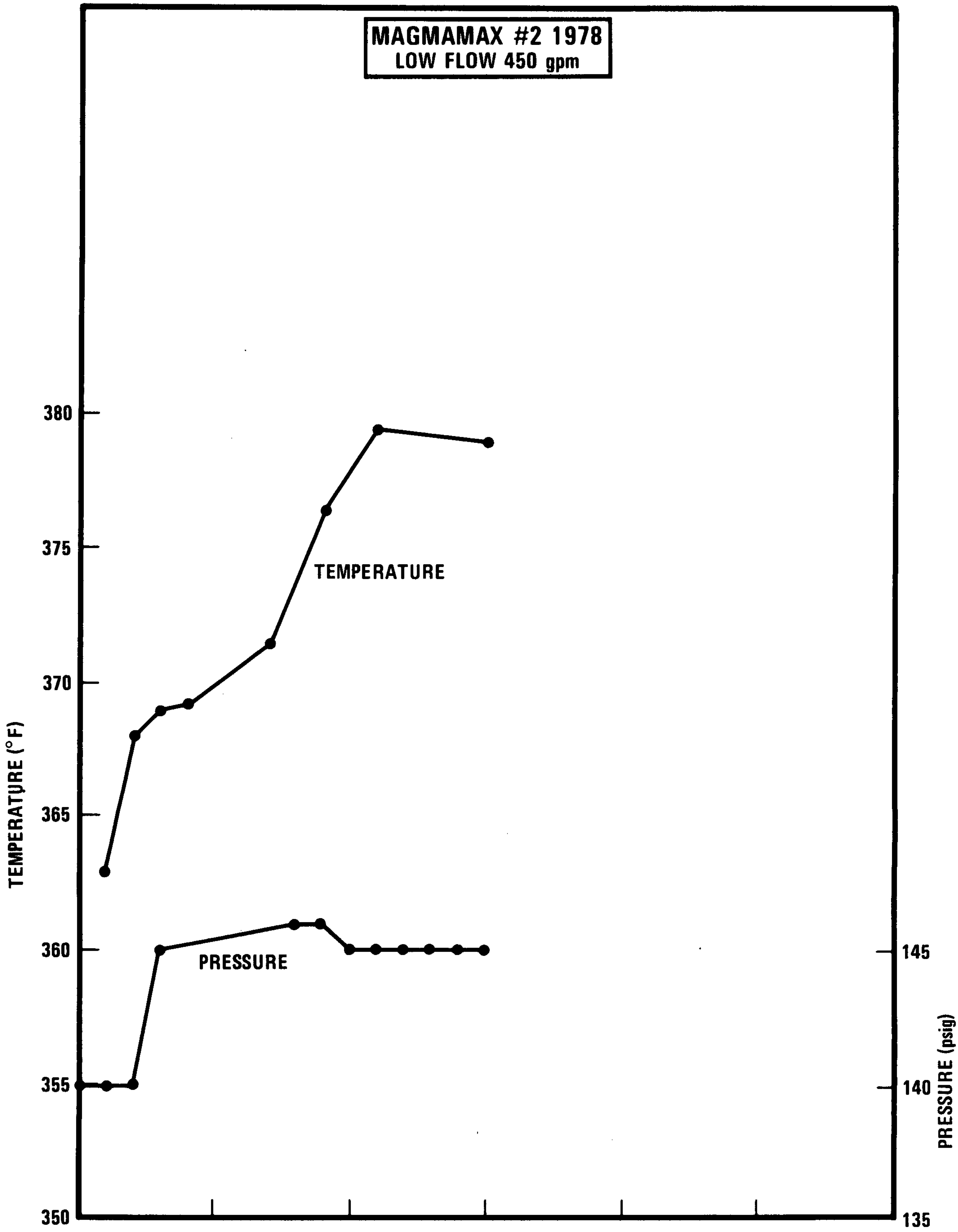
D. K. Mulliner

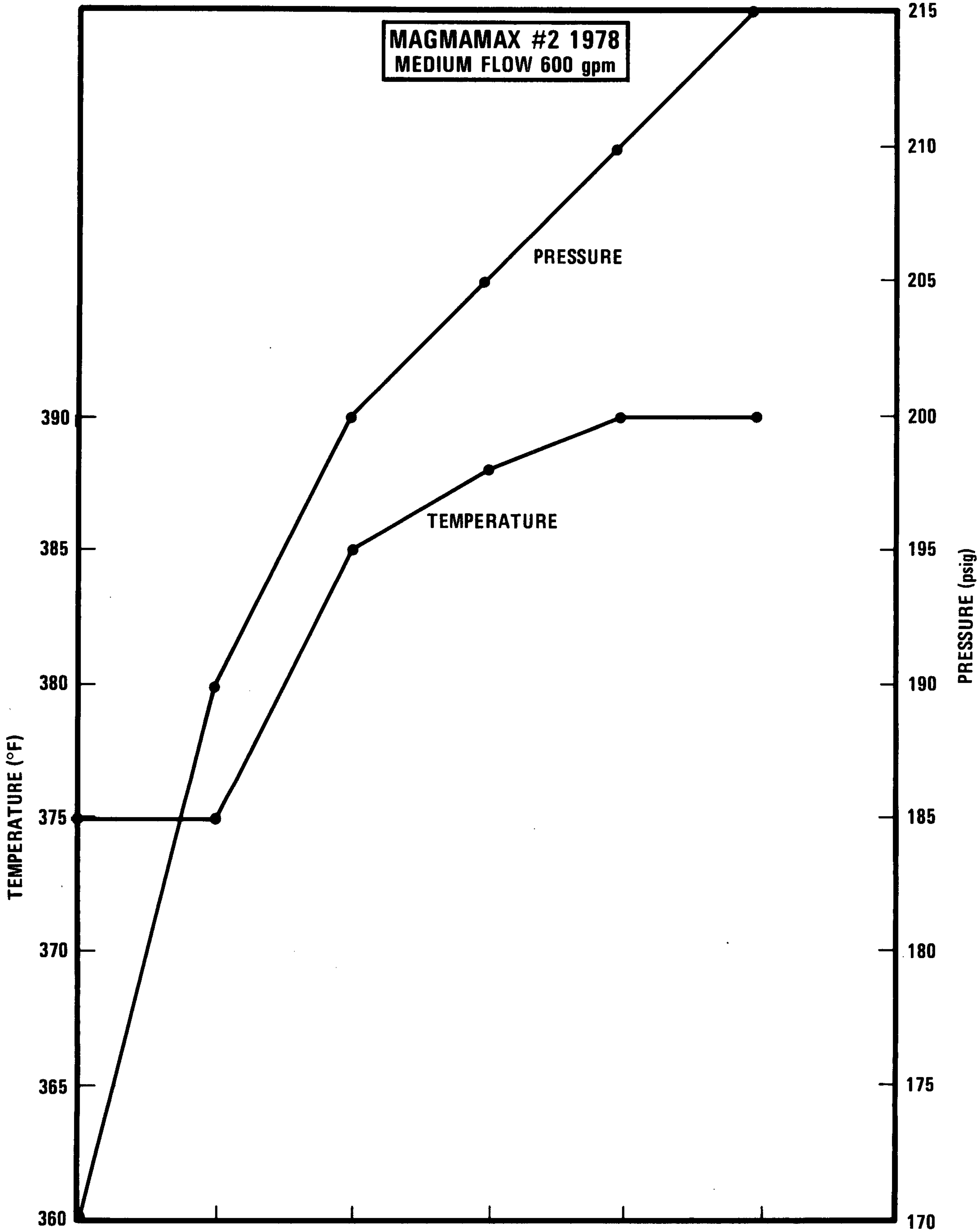
D. K. Mulliner
Ext. 2233

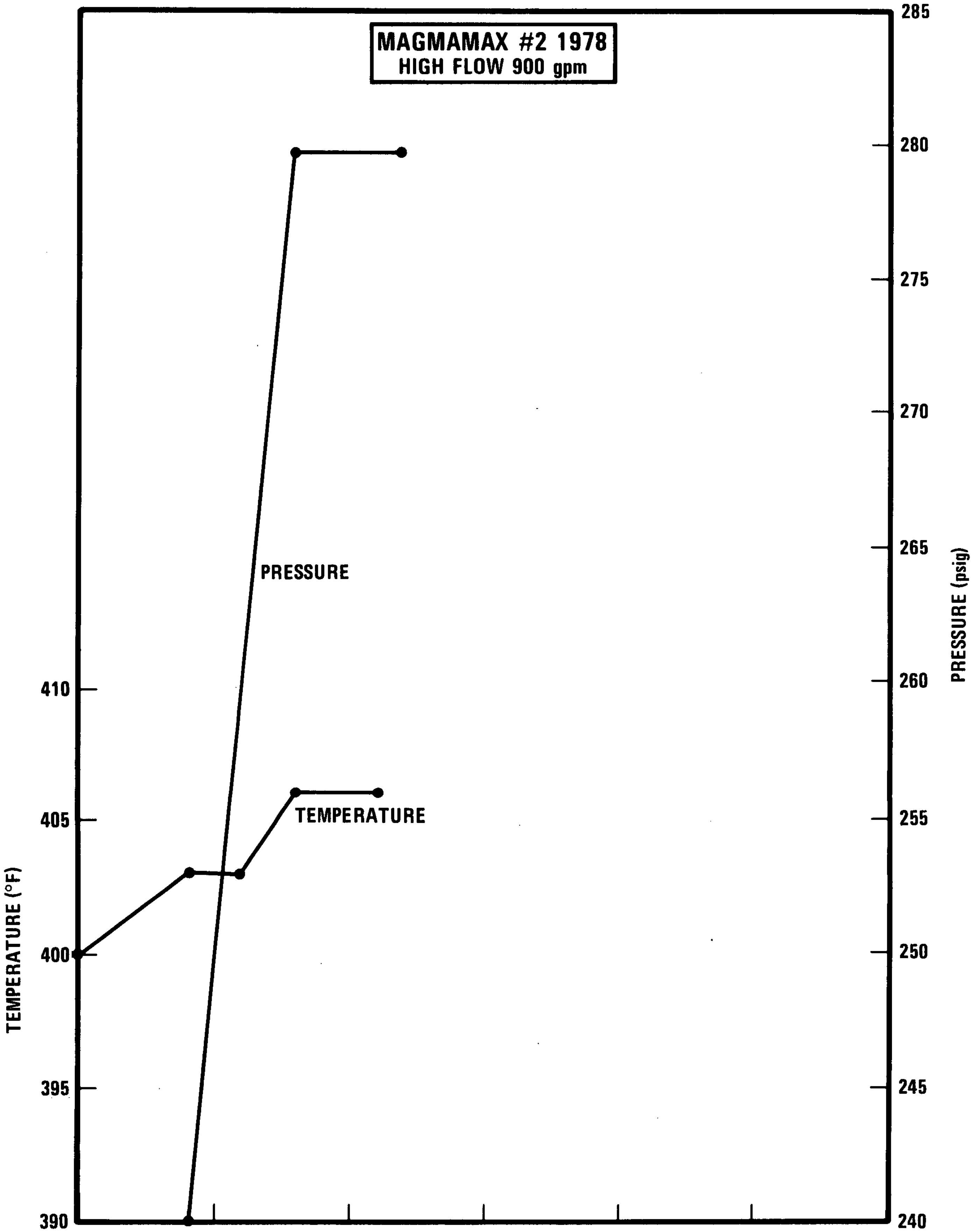
DKM:ks

Attachments

cc: W. O. Jacobson (SDG&E)
John Featherstone
Thomas C. Hinrichs (Imperial Magma)
John Morse (Lawrence Livermore Laboratory)
S. Zajac (Magma Power Company)


MAGMAMAX #2 1978
LOW FLOW 450 gpm
TEMPERATURE
PRESSURE
TEMPERATURE (°F)
PRESSURE (psig)
380
375
370
365
360
355
350
145
140
135


MAGMAMAX #2 1978
MEDIUM FLOW 600 gpm
PRESSURE
TEMPERATURE
TEMPERATURE (°F)
PRESSURE (psig)
360
365
370
375
380
385
390
170
175
180
185
190
195
200
205
210
215



MAGMAMAX #2 1978
HIGH FLOW 900 gpm
PRESSURE
TEMPERATURE
TEMPERATURE (°F)
390
395
400
405
410
PRESSURE (psig)
240
245
250
255
260
265
270
275
280
285

MAGMAMAX #2
1978 WELL TEST

SAMPLE: WELL BRINE

	Mg/liter
Barium	110
Calcium	26,100
Chloride	136,000
Copper	5
Iron	4,150
Lead	55
Lithium	220
Magnesium	10
Manganese	1,080
Potassium	14,900
Silicon	730
Silver	0.08
Sodium	52,900
Zinc	400
pH	5.1
TDS	260,000

MAGMAMAX #2
1978 WELL TEST

The non-condensible gas from the geothermal well Magmamax #2 amounted to 0.00056% by weight of the well fluid.

The gas was analyzed with a Gas-Chromatograph. There was no detectable H_2S.

Nitrogen	2.87%
Methane	1.29%
Carbon Dioxide	95.80%

MAGMAMAX #2
1978 WELL TEST

	#1	#2	#3	#4	#5	#8
Iron	18.82	6.98	31.18	3.41	4.60	28.76
Copper	0.04	0.02	0.11	0.15	0.04	0.13
Zinc	0.12	0.22	0.08	0.08	0.09	0.05
Manganese	0.63	0.21	0.93	0.15	0.44	0.74
Lead	0.14	56.72	0.91	0.49	0.77	2.99
Calcium	1.88	0.35	0.47	4.59	5.06	1.29
Aluminum	*ND	0.22	0.16	0.11	*ND	0.36
Silicon	23.90	4.45	15.55	22.20	12.80	15.00
Barium	3.30	*ND	0.18	3.15	1.85	0.34
Magnesium	0.17	0.31	0.17	0.20	0.16	0.61
Sodium	6.33	0.89	0.78	8.55	14.44	2.89
Silver	0.01	0.02	0.01	0.01	0.02	0.02
Sulfur	0.94	9.69	1.28	0.74	0.77	0.50

GEOTHERMAL SCALE

#1 MM#2 pipe to clarifier 5/78
#2 Wellhead Valve MM#2
#3 First Stage Flash MM#2 pipe nipple
#4 Sludge from clarifier
#5 Atmospheric Flash Vessel 1-1½" thick 5/78
#6 MM#1 well casing scale
#7 Woolsey #1 casing scale from shaker 5/30/78
#8 Mag #2 5/78 First Stage Scale

*ND implies none detected

All results given by weight percent

APPENDIX B

GLEF TEST PROGRAM FOR 1978 - 1979

Test Program Writing Guide

This guide has been prepared to aid those who will be writing the Test Program. The format shown will be used throughout the duration of the Test Program - from its initial preparation through the final report.

A separate list of tests has been prepared in which a single organization has been assigned responsibility for preparing, conducting and writing up the results of each test. Those organizations shall use this guide in preparing the test program.

The sections of each test are identified with a decimal number. The first digit indicates the test number and the second digit indicates the section of each test. For example, the number 2.1 would refer to section 1, "OBJECTIVES" of test number 2.

Certain sections of the test plan will be prepared only after the test has been performed. These sections are noted in the writing guide.

n.o Test Title: XXX XXXX

Responsible Organization: XXXX

Priority: XXX

This section contains the test title, the name of the organization which is responsible for preparing and conducting the test and a number designating the priority of the test in relation to the other tests. The priority designations are explained below:

PRIORITY LEVEL 1: Essential design data or results that have not yet been obtained or items identified as a major technical and/or economic risk areas in the feasibility and risk study. These tests will receive maximum consideration in schedule and budget allocations.

PRIORITY LEVEL 2: Considered to be major areas of potential cost savings or significant environmental impact reduction. These tests will receive considerable, but secondary consideration since successful results will significantly accelerate development.

PRIORITY LEVEL 3: Considered to be moderate risk or important technical areas of understanding. These tests will be accomplished on a noninterference basis. Successful completion will reduce risk and may accelerate significant future development.

n.1 OBJECTIVES

This section describes the goals of the test in detail. The statement of objectives must indicate how the test results will aid in designing a 50 MWe double flash cycle power plant at the Niland reservoir.

n.2 BACKGROUND

Describe briefly, preferably in no more than half a page, those circumstances which create a risk such that testing at the GLEF is required for risk reduction for the commercial plant. Limit the discussion to those items which may assist in understanding and achieving the test objectives, particularly those that may be helpful in analyzing and applying the test results. Indicate relation to other tests in the GLEF program. Use references where appropriate.

n.3 TEST DESCRIPTION AND PROCEDURE

n.3.1 Test Materials and Equipment

This section lists all materials, equipment controls and instrumentation needed to perform the test. If the test is to be conducted utilizing the existing GLEF configuration, this fact must be so noted, along with a list of additional equipment required such as flow meters, special temperature and pressure sensors, test specimens, etc.

Detailed information on the equipment (such as specification sheets) shall be included in an appendix and referenced here.

n.3.2 Test Prerequisites

Any other tests that must be performed prior to or in conjunction with this one are indicated here. In addition, special work that must be accomplished prior to the test (such as obtaining certain permits or licenses, etc.) should be indicated.

n.3.3 Test Conditions

Define the operating conditions which should be established and maintained for each part of the test. Required tolerances on plant or well operating conditions must be included.

n.3.4 Required Data and Observations

The exact location of each data point should be stated, the variables to be measured and the units of measurement to be used should be indicated. Relevant chemical or material testing and analyses should be described. Required tolerances on data gathered should be provided. Sample data sheets, plots, drawings and any special operating instructions for equipment should be included. Provisions should be made for acquisition or estimation of cost data applicable to future power plants. Depending on its bulk and detail, much of the information required for this subsection should be put in the appendices and referenced here.

n.3.5 Test Duration

The amount of time required at each operating condition should be estimated, including any expected re-runs. The time requirements for data analysis and preparation of results should be provided. The accuracy of these estimates should be good enough to allow an integrated well and plant operating schedule to be set up.

n.4 RESULTS

n.4.1 Expected Results

Indicate results expected, in terms of specific data values with tolerances wherever feasible; otherwise, the best information available. Relate to risks for a 30 year lifetime 50 MWe geothermal power plant at Niland. Include criteria for revision or abandonment of tests if justified by on-going test results.

n.4.2 Data and Observations

Completed data sheets and other information recorded for the test should be placed here as part of the test report.

n.4.3 Calculations

Provide instructions, equations, sample calculation sheets, values of constants, sample plots and any other information needed to assist in data reduction and analysis. Statistical correlation tests should be provided for data where appropriate. Completed calculations should be placed here as part of the completed test report. Use appendices as convenient.

n.4.4 Comparisons of Actual and Expected Results

Using the information from the preceding subsections, analyze the results of the test as related to the achievement of the objectives in section n.1 above. Highlight areas of significant variance including cases of both over-design and cases of unexpectedly high risk. This section will be prepared after the test has been performed.

n.5 CONCLUSIONS AND RECOMMENDATIONS

Provide a summary, managerial evaluation, recommend any further action at the GLEF, or elsewhere, such as modifications and additional testing. Recommend appropriate application of the test results to the future 50 MWe plant. All pertinent factors, such as cost, which may not have been explicitly included in the testing, should either be included in the basis of recommendations or else their exclusion noted. This section will be prepared after the test has been performed.

TEST OBJECTIVES

1.0 Title: SCALE REMOVAL

Responsible Organization: SDG&E

Priority: 1

1.1 OBJECTIVES

The objective of this test is to quantitatively evaluate the cost effectiveness of various techniques (in terms of cost of power), for removing scale from brine piping and flash vessels so that the best may be selected for use in the proposed 50 MWe power plant at the reservoir. These techniques are:

1. Pigging (on-line);
2. high-velocity water flush (on-line);
3. cavitation/hydroblash (on-line and off-line);
4. acidizing/hydroblast (off-line).

The cost effectiveness will be evaluated by establishing the cost per Kwhr of each technique (including capital and operating expenses and plant down-time required) for a nominal 50 MWe power plant. A qualitative judgment will also be made of the suitability of each technique for use in an operating power plant. (e.g. The ability of the method to clean effectively around elbows, through valves, etc., will be assessed.)

The type and amount of scale formed in the plant varies greatly throughout the plant, depending on the brine conditions. Each of the above techniques will be evaluated in some or all of the following locations in the GLEF:

1. Production line piping;
2. 1st to 2nd stage piping;
3. 2nd stage to atmospheric flash drum piping;
4. injection line piping;
5. flash vessels (cavitation/hydroblast only).

2.0 SCALING RATE AND SCALE PROPERTIES PREDICTION

Responsible Organization: LLL

Priority: 1

2.1 OBJECTIVES:

The objective of this test is to develop the ability to predict the amount of scale that forms in various sections of the plant and to predict the properties of that scale which affect the effort required to remove it. This information will be used to help size piping, vessels, etc., and to design a descaling system for the 50 MWe power plant proposed for the Niland reservoir.

Scaling rates will be determined at the approximate conditions present in each of the following areas:

1. Production line piping;
2. 1st to 2nd stage piping;
3. 2nd stage to atmospheric flash drum piping;
4. injection line piping.

Scale samples from each of these areas will be analyzed for chemical and mineralogical properties, as well as for mechanical properties such as hardness, adherence to wall etc. The effect of temperature, Reynolds Number, etc., on the scaling rate and the scale properties will also be investigated.

3.0 SCALE CONTROL ADDITIVES

Reponsible Organization: LLL

Priority: 1

3.1 OBJECTIVES:

The objective of this test is to determine the possibility of retarding or eliminating scale formation in a two-stage flash system through the addition of scale inhibiting chemicals or sludge particles to the brine. If these techniques are shown to have a beneficial effect, the cost per unit mass of brine treated will be estimated. This technique, if successful, may greatly reduce the cost of power from the 50 MWe power plant proposed for the reservoir.

In addition, the consequences of successful scale inhibition on corrosion and erosion of plant components, effluent treatment, injection well lifetime, etc., will be addressed qualitatively through observations and analysis of the treated brine.

4.0 CORROSION/EROSION

Responsible Organization: SDG&E

Priority: 1

4.1 OBJECTIVES:

The objective of this test is to measure the rates and types of corrosion/erosion of various materials of construction exposed to the brine and steam conditions that will be experienced ina 50 MWe power plant. This information will be used to determine the cost effectiveness of these materials of construction for a 50 MWe power plant with a 30 year design life. Metals, metal cladding, and corrosion-resistant coatings will be tested in the following environments:

1. Production line piping;
2. 1st stage flash vessel (liquid, vapor, and liquid/vapor interface regions);
3. 1st to 2nd stage piping;
4. 2nd stage flash vessel (liquid, vapor, and liquid/vapor interface regions);
5. 2nd stage to atmospheric flash drum piping;
6. injection line piping;
7. combined steam condensate.

The test will consist of coupon exposure tests in vessels and observation of short pipe spools in the brine piping of the selected materials for qualitative information on the type and amount of corrosion/erosion experienced.

5.0 Title: CORROSION/EXOSION PARAMETERIZATION

Responsible Organization: LLL

Priority: 2

5.1 OBJECTIVES:

The objective of this test is to determine the expected lifetime of carbon steel and other alternate materials of construction in brine, steam and condensate as a function of pH, temperature, exygen content and any other parameters that may vary within the reservoir or over the life of the wells. This test will be primarily a paper study, utilizing existing data from the Bureau of Mines (as it becomes available) and LLL's data on corrosion rates on modified brine (low pH). The effects of standby oxygen corrosion during plant shutdown will also be evaluated in a test designed to simulate shutdown conditions.

6.0 Title: PLANT COMPONENTS AND INSTRUMENTATION

Responsible Organization: SDG&E

Priority: 1

6.1 OBJECTIVES:

The objective of this test is to monitor the performance (operating life, failure history, etc.,) of plant components exposed to the brine and geothermal steam. This includes various types of control valves, line block valves, pumps, thermocouples, flow meters, etc. The failure history of these components will be monitored using a "Failure Mode Analysis" program. The effectiveness of various types of equipment operating in the different brine and steam environments will be recorded and analyzed. Engineered changes will be implemented and their effects monitored to improve component performance and lifetime. This data will be used as a bsis for selecting components and instrumentation for the 50 MWe flash cycle power plant to be built at the Niland reservoir.

Certain components that are required for safe operation of the plant and will also be evaluated for reliable performance. Relief valves, wellheads, shutoff valves, etc. are among the components to be so evaluated.

7.0 Title: BRINE CHEMISTRY

Responsible Organization: SDG&E

Priority: 1

7.1 OBJECTIVES:

The objective of this test is to completely characterize the chemistry of the Niland brine. Analyses will be performed on samples of liquid brine, steam, condensate, and non-condensible gases under varying well flow conditions and a correlation drawn between well flow, plant operations, and fluid composition.

8.0 Title: H_2S ABATEMENT

Responsible Organization: LLL

Priority: 2

8.1 OBJECTIVES:

The objective of this test is to evaluate the technical feasibility and costs of stripping H_2S from GLEF non-condensible vent gas stream with brine effluent. In addition, the impact on the reactor-clarifier of this H_2S addition to the brine effluent will be considered. Technical advantages, disadvantages and costs of this technique will be compared with the Stretford process.

9.0 STEAM SEPARATION

(May be added at a later date.)

10.0 Title: REINJECTION EFFLUENT PROCESSING

Responsible Organization: Magma

Priority: 1

10.1 OBJECTIVES:

The objective of the 10 MW brine injection processing facility is to demonstrate the viability of a complete treatment system. This will include precipitation and clarification, filtration, sludge handling and dewatering, and sludge disposal.

11.0 Title: MAKEUP WATER INJECTION COMPATIBILITY

Responsible Organization: Magma

Priority: 1

11.1 OBJECTIVES:

The objective of this test is to establish the technical and economic feasibility of mixing various makeup waters with geothermal brine in the Eimco pilot plant reactor clarifier. The source of makeup water will be Salton Sea water, plant condensate, irrigation runoff (Alamo River).

12.0 Title: WELL-CASING MATERIALS

Responsible Organization: LLL

Priority: 1

12.1 OBJECTIVES:

The objective of this test is to assess the rates of corrosion and the types of corrosion with different standard well casing materials. To establish the expected service life of well casing materials.

13.0 Title: INJECTION STUDIES

Responsible Organization: LLL

Priority: 1

13.1 OBJECTIVES:

The objectives of this test are to: 1) study the technical and economic feasibility of using Salton Sea water mixed with brine for injection; 2) to determine what additives are necessary to reduce the sulfate concentration; 3) to establish by computer modeling, the effect on the reservoir of injection of Salton Sea water; 4) to determine by core flushing, the injectivity of clarifier effluent from brine and Salton Sea brine mixtures.

1978-1979 GLEF TEST PROGRAM

List of Authors

Author	Test No.	Test Title
Roland Quong (LLL)	2	SCALING RATE AND SCALE PROPERTIES
	3	SCALE CONTROL ADDITIVES
	5	CORROSION RATE PARAMETERIZATION
	8	H_2S ABATEMENT
	12	WELL-CASING MATERIALS
Ted Fick (BNI)	1	SCALE REMOVAL
	4	CORROSION/EROSION
	6	PLANT COMPONENTS AND INSTRUMENTATION
	9	
Harry Bishop (SDG&E)	7	BRINE CHEMISTRY
John Featherstone (Magma)	10	INJECTION FLUID PROCESSING
	11	MAKE-UP WATER INJECTION COMPATIBILITY
Larry Owen (LLL)	13	INJECTION STUDIES

LIST OF REVIEWERS

SDG&E:	C. R. Swanson W. O. Jacobson H. K. Bishop D. G. Newell
LLL:	G. E. Tardiff L. B. Owen R. Quong
Imperial Magma:	T. C. Hinrichs J. L. Featherstone
NARCO:	J. M. Nugent D. K. Mulliner
Bechtel National, Inc.:	T. A. Fick A. N. Rogers F. Schoepflin
DOE:	M. R. Scheve (W) A. J. Adduci (SAN) A. P. Kelley (S.D.)

LIST OF APPROVERS

SDG&E:	C. R. Swanson
LLL:	G. E. Tardiff
Imperial Magma:	T. C. Hinrichs
NARCO:	J. M. Nugent
Bechtel National Inc.:	T. A. Fick
DOE:	M. R. Scheve (W)

1978-1979 GLEF TEST PROGRAM

SCHEDULE FOR TEST PLAN PREPARATION

7-18 to 9-8	Prepare first draft of test plans, mail to Bechtel.
9-8 to 9-15	Draft test plans retyped by Bechtel, mailed to reviewers.
9-15 to 9-22	Review draft test plans, mail back to Bechtel.
9-22 to 9-27	Bechtel returns comments from reviewers to authors for rewrite.
9-27 to 10-6	Final plans prepared by authors, incorporating reviewers comments, and returned to Bechtel.
10-6 to 10-11	Final test plans retyped by Bechtel, issued for approval.
10-11 to 10-22	Final Test Program reviewed and approved.

14.0 Title: WELL TEST DATA REDUCTION AND INTERPRETATION

Responsible Organization: LBL

Priority: 1

14.1 OBJECTIVE:

Complete reduction, analysis and interpretation of data from LLL's FY78 well testing program. Results will be reported as quickly as possible and in a format that will facilitate design of a well field for the initial 50 MWe Salton Sea KGRA power plant.

14.2 BACKGROUND:

Field testing of wells in the vicinity of the GLEF has generated a large quantity of pressure transient data which is related to the flow properties of the geothermal reservoir. Well testing will be completed by the last quarter of FY78, but additional time is required to reduce, analyze and report the raw test results. Pressure measurements have been obtained from production, injection and observation wells. Both single well and multiple well tests need to be analyzed. Results obtained so far include estimates of primary and secondary permeability of three horizons within the reservoir, and estimates of potential injectivity and existing impairment in the Magmamax #3 injection well. Reduction of all the pressure transient data will provide additional permeability values for the reservoir, a measure of interference between wells, and estimates of reservoir storativity and compressibility. Significant data has also been obtained on well testing methodology inhigh temperature corrosive environments.

Standard well testing interpretative techniques (Earloughes, 1977) and, when necessary, computer assisted solution techniques will be used to analyze results of single and multiple well pressure transient tests.

14.3 TEST DESCRIPTION AND PROCEDURE:

14.3.1 Test Materials and Equipment

Equipment necessary for completing field well tests during the last quarter of FY78 is in operation at the GLEF site. The LLL computer facility will be used as required to reduce and compile data files.

14.3.2 <u>Test Prerequisites</u>

Data Collection will be completed by 10/1/78 and no prerequisite tests or work need be done prior to processing the data.

14.3.3 <u>Test Conditions</u>

No special operating conditions for the GLEF are required after completion of well tests in FY78. Operating conditions of the GLEF during FY78 well tests have already been documented.

14.3.4 <u>Required Data and Observations</u>

Data will have already been collected prior to starting this task. Data will consist of pressure transient measurements from MM1, MM2, MM3, MM4, Sinclair 3 and Elmone 3. Results will be compiled in written form and contain assumptions, calculations, data, and pertinent pressure vs. time plots.

14.3.5 <u>Test Duration</u>

Well test data reduction, analysis and reporting will be completed by the end of the 1st quarter of FY79.

14.4 EXPECTED RESULTS:

Reservoir parameters to be provided in the results are: permeability values for the geothermal reservoir from a depth of 1800 ft. to 4300 ft. below ground level, a measure of the communication between wells located near the GLEF, estimates of storativity and compressibility for the reservoir and injectivity and well impairment for Magmamax #2 and Magmamax #3 wells. These results can then be used for optional wellfield design for a 50 MWe Salton Sea KGRA power plant.

REFERENCES:

Earlougher, R. C., 1977, Advances in Well Test Analysis: Soc. Petroleum Engineers, Monograph Vol. 5, H. L. Doherty Series.

APPENDIX C

SOUTHWEST CHEMICAL COMPANY, INC.
DESCALING SERVICE AND CHEMICAL SALES
FOR THE GEOTHERMAL INDUSTRY

291 WEST ATEN ROAD
EL CENTRO, CALIF. 92243
(714) 352-5300

MAILING ADDRESS
P. O. BOX 1068
BRAWLEY, CALIF. 92227

APRIL 14, 1978

PLANT DESCALING SEQUENCE

SECTION I:

Separators 1A, 2, 3, 4th stage

SCALE:

1A- High Fe, medium bonding to separator wall. Lossened flaky material on bottom of vessel.
2- High Fe, medium silica, bonding to separator surface strong. Considerable evidence of pitting.
3- High silica bonding to separator surface strong.
4- High silica bonding to separator wall near the inlet section very strong and approximately 1" thick. At the aft end of this stage material is much softer. Approximately 12 Drums of sludge were removed during the mucking out operation.

CLEANING PROCEDURE:

Hydroblast

TIME REQUIRED: 8 man hours

Rigging: Setting discharge pumps, connecting discharge and high pressure hose, positioning equipment.

TIME REQUIRED:

Hydroblast:	60 man hours	(3 men 20 hrs. @)
Mucking:	48 man hours	(3 men 16 hrs. @)
Equipment:	18 man hours	(Hydroblaster)

CONCLUSION:

These units were relative easy to descale. Extreme caution is necessary in descaling these units due to the enclosed areas. Access is accomplished thru man-hole opening. Vessels must be vented thoroughly prior to entry to insure quality air condition.

Pressure used on stages1,2 were in excess of 4,000 psi. Pressure used on 3rd & 4th stages were in excess of 6,000 psi.

SOUTHWEST CHEMICAL COMPANY, INC.

DESCALING SERVICE AND CHEMICAL SALES
FOR THE GEOTHERMAL INDUSTRY

291 WEST ATEN ROAD
EL CENTRO, CALIF. 92243
(714) 352-5300

MAILING ADDRESS
P. O. BOX 1068
BRAWLEY, CALIF. 92227

APRIL 14, 1978

PLANT DESCALING SEQUENCE

Due to high lead content in 1st stage I would recommend conducting a before and after lead contamination blood study on employees entering vessels to perform descaling operations.

SOUTHWEST CHEMICAL COMPANY, INC.

DESCALING SERVICE AND CHEMICAL SALES
FOR THE GEOTHERMAL INDUSTRY

291 WEST ATEN ROAD
EL CENTRO, CALIF. 92243
(714) 352-5300

MAILING ADDRESS
P. O. BOX 1068
BRAWLEY, CALIF. 92227

APRIL 14, 1978

SECTION I-2

P-2 Pump & pump can

SCALE:

high silica, varying thickness

CLEANING PROCEDURE:

Hydroblast

TIME REQUIRED:

Rigging:	2 man hours
Hydroblast:	10 man hours
Both P-2 Pump & Pump can.	
Equipment:	4 hours

CONCLUSION:

These units are relatively easy to descale removal of slurried scale from pump can in place has necessitated special pumps. No particular problem were encountered in descaling this section.

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SECTION I-3

Acidification of all connecting drain lines. (ie drains from 1st stage outlet to 2nd stage inlet, 2nd stage outlet to 3rd stage inlet 3rd stage outlet to 4th stage inlet).

SCALE:

1st to 2nd stage: High Fe, high PB approx. 1" thick

PROCEDURE:

Acidification followed to rotary hydroblast.

TIME REQUIRED:

Acidification:		
Rigging:	4 men - 4 hours	16 man hours
Hydro system:	2 men - 3 hours	6 man hours
Acidification:	3 men -12 hours	36 man hours
Rinsing:	3 men - 5 hours	15 man hours

HYDROBLASTING:

A. 1st to 2nd stage

Rigging:	2 men - 4 hours	12 man hours
Hydroblast:	3 men -12 hours	36 man hours
Rinsing:	3 men 2 hours	6 man hours
Equipment Hydroblaster		8 hours

SECTION I-3

TIME REQUIRED:

HYDROBLASTING:

B. From control valve into 2nd stage separator

Rigging:	2 men - 2 hours	4 man hours
Hydroblast:	3 men - 6 hours	18 man hours
Rinsing:	3 men - 1 hour	3 man hours
Equipment:	Hydroblaster	4 hours

C. From 2nd stage outlet to control valve prior to 3rd stage inlet

Rigging	2 men - 3 hours	6 man hours
Hydroblast:	3 men -16 hours	48 man hours

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D. From control valve into inlet at 3rd stage also by pass to 3rd stage discharge

Rigging:	2 men - 2 hours	4 man hours
Hydroblast:	3 men - 4 hours	12 man hours
Rinsing:	3 men - 2 hours	6 man hours
Equipment:	Hydroblaster	6 hours

TIME REQUIRRED:

E. From 3rd stage outlet to control valve

Rigging:	2 men - 4 hours	8 man hours
Hydroblaster:	3 men - 30 hours	90 man hours
Rinsing:	3 men - 12 hours	36 man hours
Equipment:	Hydroblaster	42 hours

F. From control valve into 4th stage

Rigging:	2 men - 1 hour	2 man hours
Hydroblast:	2 men - 15 hours	30 man hours
Rinsing:	3 men - 5 hours	15 man hours
Equipment:	Hydroblaster	20 hours

G. From: 4th stage outlet to gate valve before P-2 pump suction

Rigging:	2 men - 1 hour	2 man hours
Hydroblast:	2 men - 2 hours	4 man hours
Rinsing:	2 men - 1 hour	2 man hours
Equipment:	Hydroblaster	3 hours

SECTION I-3

TIME REQUIRRED:

HYDROBLASTING

H. From: P-2 discharge to control valve 65' of 10" lD pipe which has 5 @ 90^{o} "L"s in a 3 dimensioned plane

Rigging:	2 men - 4 hours	8 man hours
Hydroblast:	2 men - 20 hours	40 man hours
Rinsing:	2 men - 10 hours	20 man hours
Equipment:	Hydroblaster	30 hours

I. From: control valve ascending up to out going reinjection line

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Rigging:	2 men - 1 hour	2 man hours
Hydroblast:	2 men - 3 hours	6 man hours
Rinsing:	2 men - 1 hour	2 man hours
Equipment:	Hydroblaster	6 hours

G. 75' of 10" diameter reinjection pipe crossing over plant to flanged elbow

Rigging:	2 men - 1 hour	2 man hours
Hydroblast:	3 men - 5 hours	15 man hours
Equipment:	Hydroblaster	6 hours

CONCLUSION:

SECTION A
Linear progression in this section was 6" per minute. However difficulty in rinsing made it necessary to perform a reverse blow by.

SECTION B
Scale in this section was readily removed, however this is a bell shaped unit (ie the inlet diameter is 6" the discharge diameter is 16")

SECTION C
Scale thickness in this section was 2" in spots. The volume of scale removed presented minor problem in rinsing.

SECTION D
Scale was very hard into the reducing flange fitting for the control valve. Otherwise no problem was encountered in this area.

SECTION E
This area was the most difficult to run in the entire plant. Scale thickness was in excess of 2" in places. Hardness was extreme. Problems encountered in this section were mainly volume of scale related, (ie rinsing and feed speed of cutting nozzel).

SECTION F
This area had a very hard build-up where the pipe expanded from 10" to 16". Difficulty was encountered in removing loosened scale past this area.

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SECTION G

This section was easily descaled and rinsed.

SECTION H

This section was another difficult area to descale. Scale thickness in areas was about 2". Very hard. Problems encountered in this area were primairly related to volume of scale removed.

SECTION I

This section presented no problems.

SECTION J

This srction presented no problems.

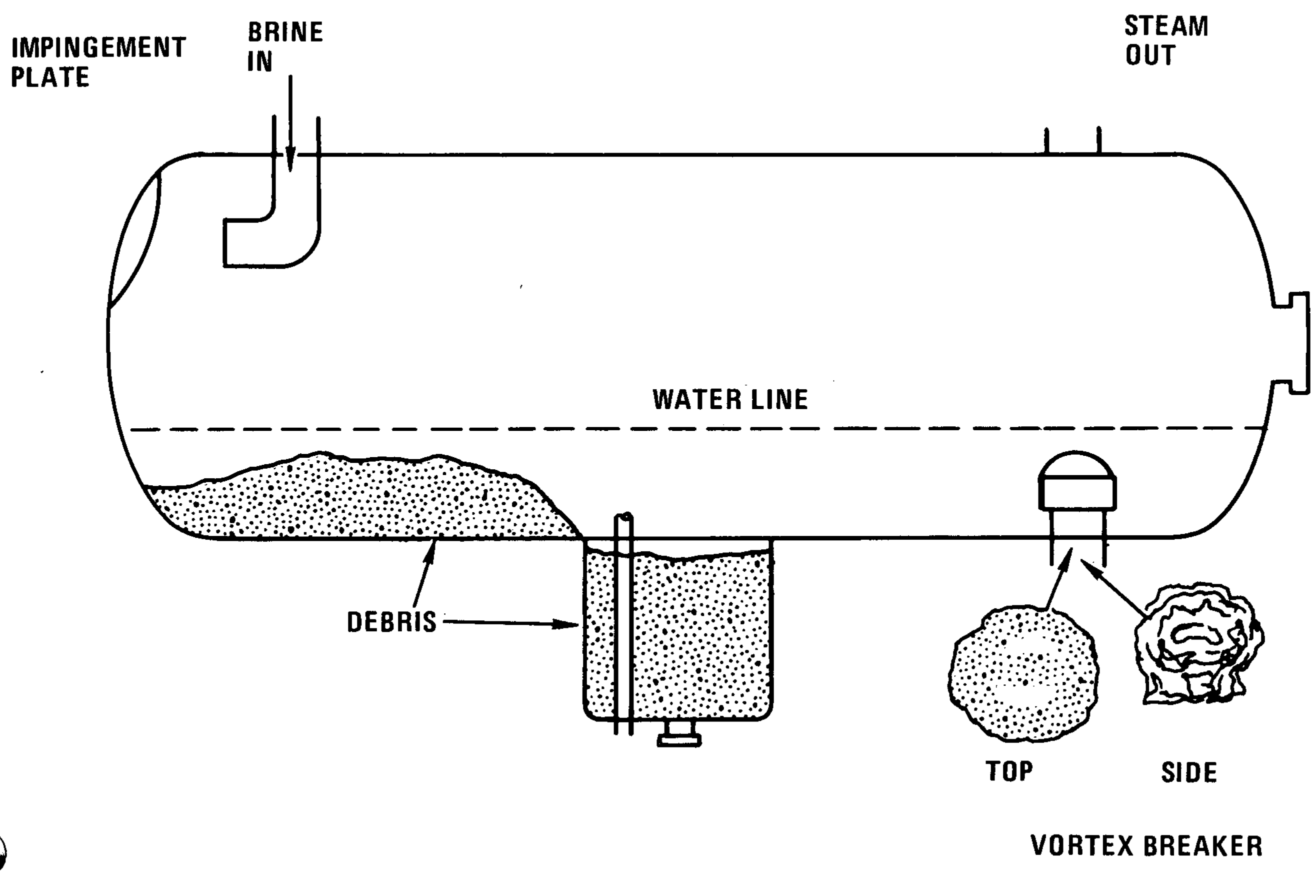
1B FLASH VESSEL

This vessel had debris on the floor that was piled up to nearly 30.5 cm thick at the inlet end. This scale was quite hard and brittle. This same type debris was found in the pit. It was full of scale.

The impingment plate now seems very thin in spots and appears warped. The plate is buckling out away from the wall and covered with a thin layer of scale.

The water line was at 46cm. Pitting is evident below the water line at the inlet end. Rust was noticable at the water line. No indication of the silver type scale was seen in the vessel during this inspection.

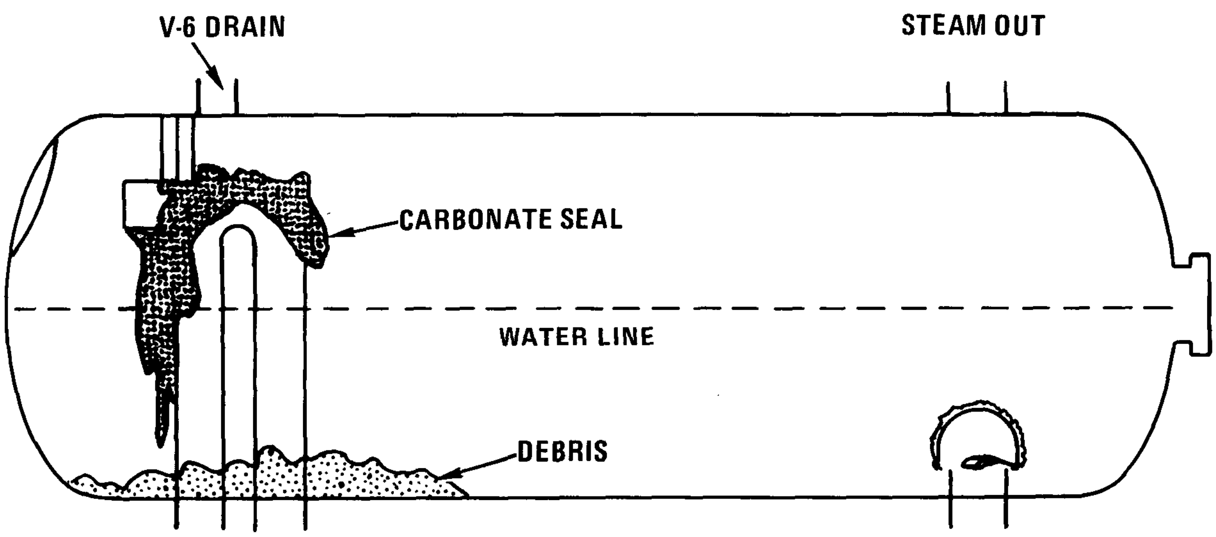
The level indication stand pipe was scaled closed to an opening of approx. 0.5cm. The vortex breaker was packed in a very hard scale approx 1.5cm thick. Two openings remained that were 8.5 cm long by 1.5 cm wide. The inside of the drain line had scale in it but it was not closed off. Scale was very hard and 1 inch thick. Total scale removed from vessel was 2000 lbs.



SECOND STAGE FLASH VESSEL

A very thin layer of rust on the ceiling of this vessel exists where there is no longer any stainless steel cladding. The water line was at 76 cm. Scale below the water line was 1 to 2 cm thick. Majority of the debris on the floor was built up around the inlet pipe. This probably formed as a result of scale building up and falling off the inlet pipe. Two long stalactite formations of carbonate scale were found hanging off the inlet pipe beneath V6 vent. They were approx 46 cm long.

The impingment plate was covered with a green-blue scale that is presumably copper. This was 2 mm thick. A knobby type scale had formed around the level indicator. It was quite porous and had a soft center. The vortex breaker had the same type of scale as third stage flash vessel. The openings were much larger and the scale not as thick. The drain looks clear, with only ½ inch scale found. Total scale removed from this vessel was 2020 lbs.



THIRD STAGE FLASH VESSEL

The cruciform support in this vessel has completely rusted through. Also in this vessel the level indicator was completely scaled over and it too was porous. The vortex breaker had a soft black scale covering it in layers resembling rows of scale on a fish. Four openings remained around the breaker, each about the size of fifty cent pieces.

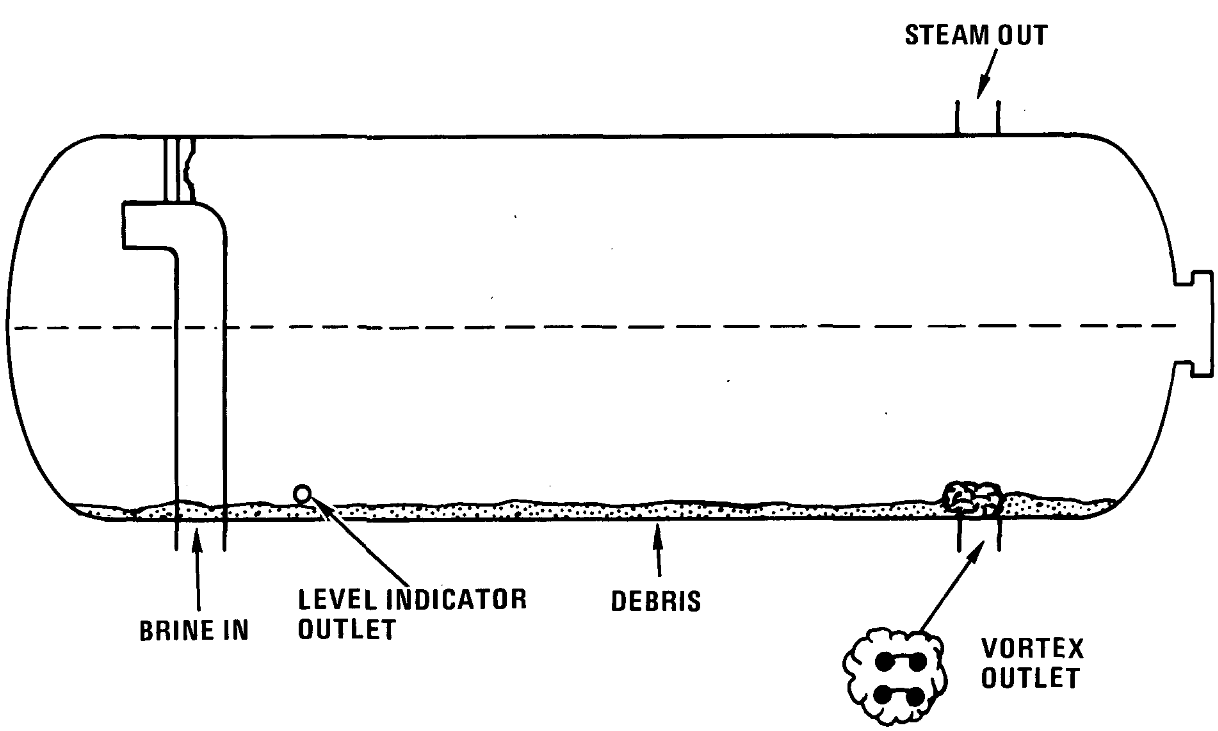
The water line was at 70 cm with pitting on the walls above this level. The scale on the walls was hard and black, very similar to that on the vortex breaker.

Large pieces of scale extending the full length of the vessel were found on the floor, It was a hard black scale formed over layers of rust.

The ceiling showed a rusty black scale with patchy white scale that extended down to the walls. Area around the weld was smooth and hard with no evidence of rust. A smell of ammonia was noticable at the inlet end of the vessel.

Four areas of impingment were found on the walls of this vessel. These spots were very smooth and clean. These areas may have been formed by steam blowing through holes in the scale around the brine inlet line.

Drain from this vessel had scale that was approximately 1½ inch thick. Total scale removed during cleaning process was 2068 lbs.



FOURTH STAGE FLASH VESSEL

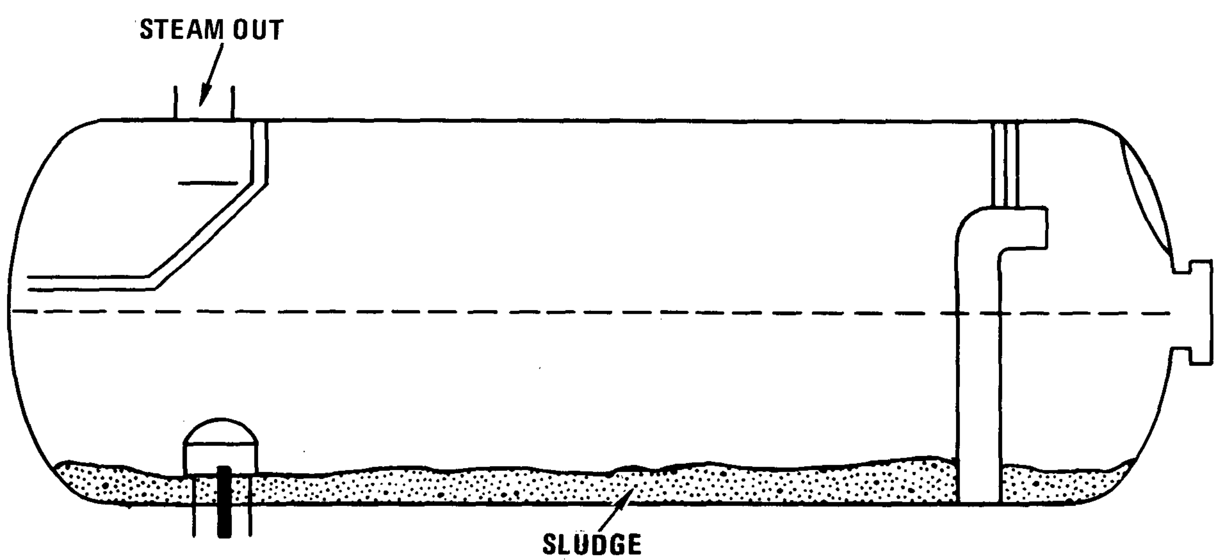
An olive green sludge 30.5 cm - 45.7 cm deep extended the full length of the floor in this vessel. This same type scale extended up the walls to the water line which was at 91 cm. This scale had a spongy appearance. It was a powdery type scale and formed in a bumpy type accumulation along the walls, Above the water line the walls are pitted.

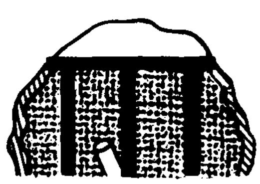
The ceiling had black scale which branched to a white layer. The black scale was quite brittle and was formed over rust. It seems to fall off and reform at the inlet end of the vessel. Scale was approx 2 mm thick.

The baffel plate screen is rusty and bowed. Strong smell of ammonia around this area of the vessel.

Area between the outlet pipe and vortex cover plate was completely packed with scale with only one opening 7.5 cm by 17.5 cm remaining. This opening was probably due to the strong suction.

5405 lbs. of wet sludge like scale was removed from this vessel.





VORTEX
WITH HOLE THROUGH
SEALS

STEAM SCRUBBERS

Scrubber stages 1, 2 & 3 showed much less scaling during this inspection. There was considerably less evidence of rust. A condition of little or no brine carry over during this run probably accounts for the cleaner condition of the scrubbers.

The 4th stage scrubber also showed very little rust. Considerably less carbonate scale was also observed. During post inspection carbonate scale covered the lower walls of this scrubber. Two stairstep type lumps of scale were found developing on the rear wall of the scrubber. One was approx 30.5 cm long and 11 cm thick. The other was nearly as thick but only had a length of 15 cm. Both these samples appeared to be mainly composed of carbonate scale.

CONCLUSIONS

Rusting and pitting are still a problem in all four flash vessels. There is little if any stainless steel cladding left in the second stage vessel. Once again the fourth stage had the sludge type scale. The amount of scale present was consistent with the amount found during last inspection.

The scrubbers were in much better condition this inspection period. Little of no brine carry over is probably largely responsible for this cleaner condition. Chemical analysis show that condensate in the 4th stage during the last couple of weeks of operation was much cleaner than in the past. This leads one to believe that the scrubbers were effectively cleaning the steam.

APPENDIX D

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MAY 15, 1978

ACIDIFICATION OF CONDENSORS - 1st TIME

DESCRIPTION:

The two condensors were opened and inspected. Large amounts of scale were evident in all tubes. It was impossible to determine the number of tubes that were completely blocked. It was decided to attempt acidification to clear the tubes.

SCALE ANALYSIS:

East Condensor

	FE	CA
Outlet	73	1.2
Intlet	59	1.2

West Condensor

Outlet	56.4	.48
Inlet	64.2	.65

TECHNIQUE:

Circulating closed loop.

volume:	900 GPM.
Acid:	Inhibited hydrochloric acid with 3% inhibitor.
Rinsing:	Pond water at approximately 12000 GPM.
Passivation:	Zimmite with closed loop.

TIME REQUIRED:

Man hour consumed

Set up:	4 men - 5 hours	20 man hours
Hydro System:	2 men - 1 hour	2 man hours
Acidification:	3 men - 15 hours	45 man hours
Rinsing:	3 men - 2 hours	6 man hours
Passivation:	2 men - 8 hours	16 man hours

TOTAL: 89 man hours consumed

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ANALYTICAL DATA

SAMPLE NO.	ACID NUMBER	FE	TIME
1	.0	49ppm	0
2	.25	---	30 minutes
3	.14	---	60 minutes
	add 660 liter HCL		
4	.48	11000ppm	90 minutes
5	.32	---	120 minutes
6	.23	---	150 minutes
	added 660 liter HCL		
7	.42	---	180 minutes
8	.31	---	210 minutes
9	.28	---	360 minutes
	added 66o liter HCL		
10	.46	---	540 minutes
11	.44	21500	720 minutes

Due to amount of Fe solubilized and time it was decided to finse and passivate. After this operation, the condensor heads were removed and inspected: Due to the clogged condition of the tubes it was evident the acidification was not successful in descaling the unit. However, the scale was softened sufficiently so that the water-air lance was able to remove substancial quantities of scale thereby freeing the tubes of most blockages.

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SUPPLY LINE DESCALING

DESCRIPTION:

10" supply line from Mag #1 (25') from well head thru 2 @ 90^o elbow, thru gate valve 175' running north-south, 150' running east-west to first 30 ft. Expansion loop in plant: 30 ft. from control valve elbowing into the top of 1B separator.

SCALE ANALYSIS:

PB- approx.	20.70
SiO_2	45.00%
Spec. gravity:	6.25

APPROXIMATE QUANTITY OF SCALE IN LINE
(This is only approximate due to variable thickness.)

370 ft. total x 2.62 ft. = 969.4 $ft.^2$
(Approx. thickness of scale .500")
969.4 $ft.^2$ x .042 $ft.^2$ = 40.71 cu. ft. scale in descaled section.
Specific was 6.25 x 62.5 x 40.71 = 15902 lbs. scale deposited in the length of line. Descaled Material in lengths of pipe cleaned was 43 lbs. per ft.

TECHNIQUE:

Rotary Hydroblast
Pressure: 12,000 PSI
Rinsing: Reverse blast, and swabbing with foam P16
Feed speed of nozzel: 5" to 6" per minute.

TIME REQUIRED:

Man hour consumned:	167 hours
Equipment hours:	42 hours

CONCLUSIONS:

Supply line was completely cleaned to bare metal. Numerous severe pits were ovserved and note made of them.

Scale in this particular section was of very high specific gravity. Difficulty in rinsing this material was encountered.

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Two separate techniques could be utilized to overcome this problem.

A. Use of lower pressure, higher volume of water (ie 1200 PSl at 50 to 100 GPM)

B. Use of foam swabs appear to be very successful in removing loosened scale.

Cavitating nozzel was used in a portion of this section however, due to design its' use in this application was self limiting. In order to keep unit rotating it was necessary to slow feed speed down to about 3" per minute. Jamming of nozzel at this point was still a problem. Also, it appears that the water stream in this design is directed at the scale - pipe interface and that rather than destroying scale/scale bonding it is undercutting and breaking scale away from the pipe surface in larger size pieces. These pieces are being blown in front of the nozzel which accounts for the jamming. We had the manufacturer adjust the lateral impact angle hoping to lessen the undercut - however this was of no avail. Use of this nozzel was discontinued after traveling about 50 ft. into pipe. It consumned about four hours equipment time to remove the debris (blockage) which the nozzel had produced.

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JUNE 25, 1978

ACIDIFICATION OF CONDENSORS (2nd TIME)

DESCRIPTION:

After units had been air lanced to unplug blocked tubes we were to acid treat and remove (or solubilize) an amount of iron corresponding to the weight of iron (as scale) on the tubes. Using weight measurements provided by San Diego Gas & Electric (ie weight of iron scale on condensor tubes total: 1083 lbs.). We circulated material until excess iron was dissolved.

SCALE ANALYSIS:

Mostly Fe as oxide with substantial carbonate present.

TIME REQUIRED:

Rigging:	28 man hours
Acidification:	26 man hours
Rinsing:	10 man hours
Passivation:	10 man hours

TECHNIQUE:

Establish circulation thru condensors until all air locks were forced out. Use of surge tank permits addition of acids and control of solution volume.

Use of 900 gal. per minute acid pump yields adequate circulation for one set of condensors. Due to large amount of carbonate present, acids must be added at a fairly slow rate.

After acidification was completed: (Determined by amount of solubilized Fe) unit was rinsed under a nitrogen cap. Rinsing was accomplished by discharging all contained (spent) acid to the west containment pond. Unit was rinsed twice (both rinses discharged to containment pond).

After rinsing, unit was flushed to pond for a period of 15 minutes until water was clear. And 10 gal. zimmite passivation material was added to condensor water and a closed loop circulation within the surge tank and condensors was set

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ACIDIFICATION OF CONDENSORS (2nd TIME)

was set up and allowed to run for one hour. The unit was then completely shut tight and allowed to stand filled with zimmite for approx. ten hours.

The following, chemical data was provided by San Diego Gas & Electric site laboratory.

SAMPLE NO.	ACID NUMBER	FE	TIME
INITIAL	--------	48.8	-----
1	.66	2102.8	30 min
2	.46	19650.	60 min
3	.24	19000.	90 min
	* added 660 liters HCL		
4	.35	19000.	120 min
5	.50	23000.	150 min
6	.	17500.	180 min
7	.56	35000.	210 min
8	.58	36000.	240 min
9	Began discharging system to rinse.		270 min
10	Under nitrogen cap.		300 min

By using the above data from sample 5 (ie 36000ppm which is approx. 3.6%) and the total circulating volume.

6000 gal. x 8.3 lbs./gal. x .036 = 1792 lbs. Fe solubilized.

I believe there is a need for an oxygen scavenger in both rinse water sequences to inhibited oxidation during rinsing.

Also, rinsing sequences will have to be speeded up if possible. It also appears that after the carbonate has been digested the solution strength should be increased to either 1.5 or 2 normal and allowed to curculate for about one hour time.

Due to the severe pitting and corrosion several pit holes were opened. This unit is going to have to be handled with extreme care in subsequent descalings.

APPENDIX E

APPENDIX E

FROM BECHTEL INSPECTION REPORT DATED MAY 4, 1978

COOLING WATER PUMP

As requested by SDG&E this pump was inspected at the SDG&E Machine Shop in San Diego. It is a Peerless 36 HXB pump with a bronze impeller. There was cavitation erosion on the visible side of the impeller blades. The pump had been in operation in the GLEF for about two years, with interruptions, and the erosion was probably caused, or accentuated, by cavities carried downstream, i.e., upward in the pump, from the four struts, or vanes that hold the lower bearing in the bell-mouth. Reasons for this option: Impeller blades had become feather-edged, showing that cavity-collapse damage was heaviest at the leading edge of each impeller blade. Therefore, the cavities most probably were formed upstream of the impeller. Also, the vanes in the bell-mouth were badly cut-away by cavitation on their trailing edge(s), as well as showing some erosion in the corners of the leading edge(s) on the side that would trail, with pre-rotation against pump rotation.

RECOMMENDATIONS

While the prevention of accelerated wear is not critical to operability, costs can be reduced by checking to avoid over-capacity operation. No short-term action is indicated other than repair.

APPENDIX F

APPPENDIX F

FROM BECHTEL INSPECTION REPORT DATED MAY 4, 1978

INJECTION PUMP

OBSERVATIONS

These observations include results of a visit to the GLEF site on April 19, and a trip to the SDG&E Machine Shop in San Diego on April 20. In the shop the disassembled injection pump, pump P-2, a Peerless nine-stage vertical unit, just received from the site after the last run of some 1,400 hours was inspected and discussions were held with Mr. Mark Ortiz. The following was noted:

- The worst cloggings by scale buildup, are at those places in the injection pump and piping where stationary vanes are positioned across a circular passage in which velocity is relatively low. Fortunately, the higher velocity passages inside the impellers and bowl-diffusers, do not appear to become clogged, although they do acquire a thin coating of hard black scale.

  The two specific places that become clogged are the 4-vaned bottom-bearing holder in the suction bell-mouth and the 4-vaned "spider", (bearing-holder) near the top of the pump, above a tapered increaser.

  It is understood that the bottom-bell-mouth was jetblasted during pump operation by a small manifold of 4 or 8 jets, at least twice during the last run, and that this action did actually prolong the run by about 300 hours.

- Although this pump is rated at 1,700 gpm, and was supposed to operate at about 1,200 gpm (plant being fed from two wells), it has actually been operating at about 600 gpm. (This further reduces the velocities through the 4-vaned bell-mouth and the 4-vaned discharge spider, as well as the whole discharge piping system.)

  This low-flow operation quite likely tends to make the pump operation rough, and could accelerate problems with the bearings, even though they are continuously flushed from the condensate pumps. Normally, a minimum-flow bypass would be used to keep this pump flow above 1,000 gpm, but at the GLEF, use of the bypass was abandoned because of scale problems. This bypass should be restored in the future if the scale situation permits.

RECOMMENDATIONS TO THE GLEF

- Continue with more frequent jet-blastings into the pump bell-mouth. Jet blast the upper spider.
- Consider fabricating a 2-vaned spider (or ask Peerless to design one), as it might clog less than the 4-vaned one.

RECOMMENDATIONS FOR A COMMERCIAL SIZE POWER PLANT

- "Vertical turbine" bowl-type pumps are not advised in this service because of the internal bearings, the propensity to scale and the apparent lack of need for such a pump.
- Injection pumps should be horizontal, not over-sized, with external bearings, and without anti-prerotation vanes in their suction passage. For instance, for a 1,200 gpm flow, a possible pump combination would be a Worthington 6-LN-18 at 1,150 rpm plus a Worthington 5-UNB-13, 2-stage at 3,550 rpm. The 6-LN-18 would have a Nominal Pump Suction Head (NPSH) requirement of 4.5 feet which would develop about 120 feet head, to feed into the 5-UNB-12, 2-stage pump developing about 1,000 feet head.
- If the last stage flash drum could be elevated some 20 feet., then the slow-speed booster pump above could be deleted. Then a Pacific 6 x 12 RHC 2-stage pump could provide 1,500 to 1,700 gpm at 1,000 feet head requiring about 16 to 18 feet NPSH.
- It would be well to arrange these pumps with suction line "angled ta's" pointing into the pump suction nozzle for high-pressure jetting.