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GEOHERMAL LOOP EXPERIMENTAL FACILITY

MASTER

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

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**OCTOBER 1977
QUARTERLY REPORT**

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SDG&E - DOE
GEOTHERMAL LOOP EXPERIMENTAL FACILITY

QUARTERLY REPORT
FOR THE PERIOD
JULY - SEPTEMBER, 1977
AND
ANNUAL REPORT
FOR THE YEAR
ENDING SEPTEMBER, 1977

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ABSTRACT

This report is divided into two parts. The first part, Annual Report, summarizes the activities at the Geothermal Loop Experimental Facility (GLEF) from September, 1976, through September, 1977. The second part, Quarterly Report, details the activities during the last three months of this period.

This facility utilizes the flash/binary process for the extraction of energy from geothermal brine. Substantial data on brine and steam chemical characteristics, scaling characteristics, scaling rates, and the interaction of these parameters with other plant operating parameters has been obtained. This data is being stored and reduced by Lawrence Berkeley Laboratory (LBL).

Tests are continuing for one and two-well operation. Development of solutions to the scaling problem, and additional testing are being performed as required.

CONCISE DESCRIPTION OF THE NILAND GEOTHERMAL LOOP EXPERIMENTAL FACILITY

Early in 1972, the concept of a Geothermal Loop Experimental Facility (GLEF) to be built in the Niland Known Geothermal Resource Area (KGRA) was first conceived. This area, located near Niland, California, on the southern shore of the Salton Sea, is where SDG&E, in cooperation with Magma Power Company, drilled and flowed a geothermal test well. See Figure 1-1 for the general appearance of the GLEF.

In May, 1975, construction of the GLEF began with start-up of plant operations commencing on May 3, 1976. This 10-megawatt size facility is the first of its kind for testing high temperature (550°F downhole) and high salinity (250,000 ppm) geothermal resources utilizing a flash/binary conversion cycle for the production of energy.

Magma Power Company, jointly with the New Albion Resource Company (NARCO), supply geothermal fluid (brine) from two production wells, Magmamax #1 and Woolsey #1. These are located near the test facility in the center of the anomaly. Magmamax #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 #1 produces brine with a temperature and pressure at the wellhead of 380°F and 200 psig, respectively, with an average flowrate of approximately 300,000 lbs/hr. The plant is designed for an

GEOHERMAL LOOP EXPERIMENTAL FACILITY
Niland, California

inlet temperature of 370°F, pressure of 165 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 #2 and #3.

As brine enters the plant it is directed through four flash steam separators in series. The steam produced by the flashed brine is flowed through steam scrubbers (one for each stage) to remove salts and minerals. The scrubbed steam then passes through six heat exchangers at approximately 200,000 lbs. per hour, vaporizing the binary working fluid, and is then cooled and condensed. This water, if not used for cooling water make-up, is recombined with the brine and injected into the reservoir. The noncondensable gases, primarily carbon dioxide with small amounts of hydrogen sulfide, are exhausted to the atmosphere through a silencer and a 130 foot stack. This stack disperses the gases in order to meet the APCD requirements for ground level concentration of hydrogen sulfide.

The binary working fluid is vaporized when heated and is flowed through a simulated turbine (throttling valve). The binary working fluid is condensed back to a liquid and recirculated. This closed loop system, presently filled with distilled water as the binary working fluid, is designed for isobutane or a fluid with similar characteristics.

In addition to testing the flash/binary process, evaluating the injection of cooled brine into the reservoir, and assessing the potential of the Niland geothermal reservoir, are underway.

The 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.

ANNUAL REPORT

1.0 INTRODUCTION

The purpose of the Annual Report is to highlight and summarize some of the important results from this project during the one year period September, 1976, through September, 1977.

The Operations Section discusses the general operations of the plant, and specialized problems such as scaling, the injection pump, instrumentation problems, and the injection well. The Testing Section outlines the "Test Program" and the tests that were accomplished during this period. The Chemistry Section discusses steam, brine, scale, cooling water and chemical analysis results. The Maintenance Section covers scale removal, subsystem and component modifications. For any detailed discussions of the results, refer to the following reports: Test Program (September 1976), Brine Injection Pump (January, 1977), and GLEF Bi-Monthly Reports.

2.0 OPERATIONS

2.1 GENERAL OPERATIONS

During September, 1976 through September, 1977, the GLEF operated for 4100 hours with a plant availability of 47%, excluding scheduled outages. The majority of the operation and testing during this period utilized one well. Magmamax No. 1 was utilized the majority of the time although some infrequent use of Woolsey No. 1 and some two-well testing occurred. The performance of Magmamax No. 1, 2, 3 and Woolsey No. 1 (after its deepening in January, 1977), was generally acceptable. See subsection 2.6 below for work done on Magmamax No. 3.

2.2 MODES OF OPERATION

Three basic condensate handling modes of operation were tested: cascading, non-cascading, and cooling water makeup. The dominate scale species in each of these modes of operation is silicia; however, when the condensate is recombined with the brine, as in the cascading and non-cascading modes, calcium carbonate scale forms.

In the cascading mode, condensate flowed from the heat exchangers to the next lower stage flash drums. Since large amount of calcium carbonate scale were deposited in the second, third, and fourth stage using this mode, which is highly undesirable because of hard scale formation, the facility operated mainly in the non-cascading mode.

In the non-cascading mode, the second and third stage condensate was directed to the fourth stage flash drum or scrubber. The result of combining this relatively high pH CO₂-saturated condensate with the brine produced significant carbonate scaling in the fourth stage flash drum and the injection system.

In the cooling water makeup mode, all condensate (except that required for plant processes) was diverted to the cooling water pond. When condensate was flowed to the cooling pond, the dominant scale specie in the injection line was silica. Silica scale is softer than carbonate scale, and easier to remove. This high silica scale was observed after operation in this mode with each of the producing wells.

The cooling water pond properties were significantly modified by the addition of the condensate. The modifications consists of an increase of ammonia (200-300 ppm), boron (4-5 ppm), iron (to one ppm), and pH (to 6.5) concentrations. The concentration amounts may require some major changes to the cooling water treatment and/or handling. Any changes are yet to be determined.

2.3 SCALING

Massive scaling occurred throughout the system with the greatest deposition generally in the injection pump and injection line. Scale composition was of a silica and carbonate nature which seemed to vary according to the mode

of condensate operation. Other characteristics such as quantity and hardness were difficult to predict. The average scaling rate was approximately 1 mil/hour utilizing one-well operation. See Table A-1 for the typical composition of the scale.

The most important function of scale accumulation appears to be temperature. As the temperature of the brine is reduced, minerals, such as silica, tend to become supersaturated. Precipitation and scaling result from these (cooled) supersaturated solutions. Scaling is generally cemented by the silica particles in an amorphous form.

A second function of scale accumulation is velocity. Low velocity regions such as vessels tend to form a soft scale while high velocity regions, such as restrictions, tend to form hard scale.

Residence time (kinetics), and pH of fluid. Also have an effect on scale accumulation. Other parameters, such as flashing, may have a significant impact but have not been defined.

2.4 INJECTION PUMP

Operation of the injection pump has been within the specifications of pressure and temperature for one well flow. The pump has not been tested for two well operation since the plant has been operating primarily on one-well. To date, the injection pump has proven to be a critical problem to the plant's operation due to scaling. Modifications

SCALE COMPOSITION

LOCATION	1st STAGE VENTURI RUN %	2nd STAGE VENTURI RUN %	3rd STAGE VENTURI RUN %	REINJECTION VENTURI RUN %
IRON	19.66	15.75	1.80	0.78
COPPER	0.40	0.45	0.38	0.14
ZINC	0.07	0.08	0.07	0.10
MANGANESE	1.45	2.22	0.34	0.20
LEAD	17.57	2.43	0.43	0.33
CALCIUM	1.37	1.57	1.79	3.25
ALUMINUM	0.70	0.83	0.13	0.20
SILICON	12.25	20.45	34.50	27.15
(as SiO ₂)	26.20	43.75	73.83	58.10
BARIUM	0.07	0.73	0.07	0.63
MAGNESIUM	1.00	0.20	0.03	0.04
SODIUM	2.28	3.00	2.93	5.50
CARBONATE	*ND	ND	ND	0.30
SULFUR	2.85	0.70	0.12	0.20

*ND -- nondetected

to the pump which have improved the operation include: using bronze for bearings, decreased the bearing loads, added purge water for cooling, increased the shaft size and improved shaft materials. All of these improved the operation of the pump, but long term reliable operation is yet to be demonstrated.

2.5 INSTRUMENTATION

The collection of data from instrumentation is a critical problem area of operation. Scale formation is a primary cause of instrumentation difficulties. Slug flow of brine, where vapor produces gaps in the brine, is also a problem of data collection.

Improvements in instrumentation have included: applications of cleanable orifice meters, a noncontact ultrasonic flow meter, provisions for scale cleanout access for pressure taps, and installation of blowdown valves for instrument lines. These measures have improved the quality of the data acquired, although further improvements are necessary to achieve acceptable quality.

2.6 INJECTION WELL

In February, 1977, high back pressure was observed at the plant indicating a potential injection well problem. The injection line was cleaned and a rework of Magmamax #3, consisting of pressure washing and caustic soaking, was completed in March.

Spinner surveys, used to determine the injection zones in the well, were run in March, May and August. The surveys revealed that the injection zones had increased between March and May, and then decreased between May and August. The rework of the well in March accounts for the increase of injection zones. The decrease from May to August, may be evidence for actual slot or sand face plugging either by scaling of particle embedment.

In June, the well was bailed which consists of removing the sediment from the bottom of the well. Also in June, a section of tubing was installed from the surface to a depth of 2970 feet to determine the scaling rates downhole. After 47 days of injection (not continuously flowing), the scale on the tubing was 1/16 to 1/8 of an inch thick of varying hardness depending on the location. The scale on the tubing was found to be softer on the bottom slotted portions compared to the upper joints.

Instruments were installed in April for recording pressures, temperatures, and flowrates. Also, in April strainers were installed at the wellhead to remove the larger particles from the brine. The strainers improved brine injection, but increased the operations cost. The increase is due to the frequent cleaning of the strainers. Other methods for solid controls are being investigated to prevent injection well problems, since it appears that suspended solids in the effluent brine have substantially contributed to injection well problems. However, this has not been confirmed.

3.0 TESTING

The GLEF is intended to serve two purposes: to determine the technical and economic feasibility of using geothermal resources in a heat exchange train in order to provide basic information necessary for the design, construction, and initial operation of hydrothermal-geothermal power plants; and to gain information on the extent and characteristics of the geothermal reservoir at the site.

To obtain this information a Test Program including a series of 18 tasks has been designed by the Bechtel Corporation. Refer to Appendix A for a list of these tasks. Implementation of the Test Program commenced in January, 1977, but was hampered by problems associated with the high salinity brines.

Although some two well tests were performed, the plant emphasized one well performance. The tests that were accomplished are as follows: (1) Baseline operation and plant control stability, (2) heat and mass balance, (3) heat exchanger and scrubber performance, and (4) determination of nonequilibrium and boiling point elevation. The data results of these tests were given to Lawrence Berkeley Laboratory (LBL) where the data analysis is being accomplished.

LBL has completed the writing of the computer software system for data storage and retrieval. LBL, together with SDG&E's data systems personnel, have completed writing the data reduction programs. The capabilities presently

include storage, retrieval, reduction, chart making, and putting data into a usable form. These programs are being refined as the GLEF operation progresses.

To enhance the collection of data, installation of a multichannel automatic cycling data logger system was accomplished during January and February, 1977. This system consists of the following: field installed sensors and transmitters, data logger and tape printer, dual magnetic tapes, CRT display, hard copy printer, and acoustic coupler.

Electronic data acquisition and hand logging are the two means of data collection used. These two systems are redundant for most data points; thus vital statistics of plant operation will still be available if either system fails.

The data being collected includes: stability of brine steam, condensate, cooling water, purge water, binary fluid and gas pressures, temperatures, flowrates, composition of steam (upstream and downstream of scrubbers), brine composition, scaling rates, cooling water composition and noncondensable gas composition. The data collection system was found to be inadequate for the transient and oscillatory conditions experienced at the plant. Provisions are being made to improve the data logger capability to record transient performances.

The testing to date shows that the plant is inherently stable (forcing functions are not significantly amplified)

with little damping by the control system. Thus, significant oscillations occur in many plant parameters. The analysis has indicated that these oscillations will not significantly effect the power output, if a turbine-generator were added to the facility. However, oscillations seriously detract from the accuracy of data gathered.

Tests of flash vessels and scrubbers have shown generally acceptable utilizing one well. Using distilled water, instead of isobutane, is the primary cause for the heat exchangers not performing as expected rather than scale deposition. Problems with the cooling water condensers appears to be related to the cooling water treatment rather than binary fluid conditions. Heating and mass balance and boiling point elevations has not been adequately determine in the plant due to inaccurate data and off design conditions in the plant. Laboratory determinations will be relied upon.

4.0 CHEMISTRY

Some corrosion of the mild steel vessels and piping in contact with the geothermal steam has been observed. However, the major operating difficulty appears to be scale deposition. In the production line and first stage flash vessel, the scale is primarily a thin layer of heavy metal sulfides. In the lower-pressure, lower-temperature portion of the plant the scale is predominantly silica and, if condensate is recombined with the brine, calcium carbonate is also observed. The calcium carbonate is quite hard and has caused operating problems with valves and pumps. Silica is much softer; however, it, too, will build up to sufficient thicknesses to cause operating difficulties. Acidification of both the condensate and the brine in conjunction with various modes of condensate operation are being investigated for controlling scale deposition. Efforts are being undertaken by Lawrence Livermore Laboratory (LLL) under its Industrial Support Program.

The noncondensable gases observed were predominantly carbon dioxide with small amounts of hydrogen sulfide, (approximately 1800 ppm). The quantity of noncondensable gases observed (0.1 to 0.5%) was much less than was expected from initial flow testing. The composition is similar to that observed earlier but the total amount is sufficiently lower that hydrogen sulfide emissions has not been a problem in this facility.

Ammonia has also been observed in the geothermal steam; however, most of this ammonia is absorbed by the steam condensate and does not appear in the noncondensable vent gas.

The steam separator and scrubber system appears to be working satisfactory producing steam with a solids content of less than 20 ppm. The pH of the condensed steam was approximately 6 in the first stage due to the presence of carbon dioxide. The pH then gradually increased to between 9 and 10 in the third stage due to the presence of ammonia. Most of the carbon dioxide is vented in the first stage.

Production well fluid composition has been found to change very little during the year of operation. Some minor differences in constituents between the two productions wells, Magmamax No. 1 and Woolsey No. 1 were observed. Table A-2 shows the typical compositions of the two wells. A major unexpected constituent in Woolsey No. 1 is sulfates. This may indicate an intrusion of surface water into the well or formation.

BRINE COMPOSITION

	MAGMAMAX #1	WOOLSEY #1
SAMPLE	mg/Lit	mg/Lit
Na	51,300	39,000
K	10,400	81,000
Ca	21,100	18,900
Cl	131,300	
Fe	280	245
Mn	635	535
Zn	220	110
Pb	47	1.0
Cu	0.9	38
Ba	140	135
Si	240	165
Mg	110	150
NH ₄ - N	365	305
pH	5.65	5.85

5.0 MAINTENANCE

5.1 SCALE REMOVAL

In removing scale from flash vessels, hydroblasting, replacing hand scraping, appears to be the most effective method tested to date. Acid soaking, used on hard scale when necessary, weakens scale adhesion to the components of the plant. This process, followed by rinsing and hydroblasting, is used in the flash vessel drain lines, at times in the injection line, and various components of the plant.

Rotor-rooter was attempted but without any apparent success.

Pigging of the injection line is being implemented once per day and has proven effective in maintaining minimum scale build-up. Upstream of the pigging operation on the 10", inside diameter, injection line after 1000 hours of operation resulted in a scale build-up of two and three quarter inches leaving an opening of five and one half inches. Where the pigging was implemented during this same period, the scale build up was only one eighth inch leaving an opening of nine and three quarter inches. The cost and time savings for cleaning the injection line shows a major improvement. The costs of pigs is \$150 and 30 minutes running time per day compared to \$50,000 and six weeks shutdown for hydroblasting.

5.2 SUBSYSTEM AND COMPONENT MODIFICATION

Numerous modifications of plant subsystems and components have led to an improved operation of the GLEF.

For example, special coatings of stellite or ceramics on valve internals have improved corrosion resistance on the valves. Changing the V-ball control valve to a U-ball shape resulted in smoother valve operation. Ceramic coating of parts of the injection pump has lengthened the operating hours between overhauls of the pump. Modifications of the condensate pump bearings together with acidified purge water has improved operation under the scaling environment.

Important modifications on plant subsystems include scale clean-out accesses on the brine line to facilitate scale cleaning by hydroblasting and by pigging. Provisions for condensate and brine acidification were installed for scale control. In addition, components or subsystems were being evaluated such as pinch valves for non-contact control of the brine flow, and coatings on other parts of plant components.

6.0 CONCLUSION

This plant operated for 4100 hours during the twelve month period ending September 30, 1977. The plant has operated for a total of 4508 hours from start-up to September 30, 1977. In January, Woolsey No. 1 was deepened and in March, Magmamax No. 3 was reworked.

Massive scaling continues to be a problem with operation. Scaling hampers the operation of the injection pump and makes data collection difficult. Most effective methods of scale removal thus far are: hydroblasting, acid soaking followed by hydroblasting, and pigging. Acidification looks promising for scale prevention, but corrosion may be a problem with this.

The tests performed were (1) baseline operation and plant control stability, (2) heat and mass balance, (3) heat exchanger and scrubber performance, and (4) determination of nonequilibrium and boiling point elevation.

Two methods of obtaining data are used: electronic data logger and by hand. This is done so vital statistics of plant operations will be available if either system should fail. All of the data is given to LBL to be analyzed.

The following condensate handling modes were tested: cascading, non-cascading, and cooling water makeup. Cascading produced calcium carbonate scale, which is a hard scale, throughout the system. Non-cascading, used mostly, produced carbonate scale mainly in the fourth stage flash

vessel and the injection line. The cooling water makeup produces a softer silica scale. The plant can be operated in any of these modes with a difference of scaling locations.

QUARTERLY REPORT

1.0 INTRODUCTION

The remaining portions of this report covers the project results for the period July through September, 1977. The Operations Section discusses the general operations of the plant. The tests that were accomplished under the Test Program are discussed in the Testing Section. The Chemistry Section discusses the chemistry of the fluids and solids produced by the GLEF in the areas of steam, brine, scale, and cooling water. The Maintenance Section discusses two methods for the removal of scale: Pigging and a hydrodynamics scale disintegrator. Also discussed are pinch valves and the differential pressure transducer for component optimization. In the Special Problems Section, injection pump problems, and large pressure variations in the fourth stage flash drum are discussed.

2.0 OPERATIONS

The GLEF utilized Woolsey No. 1 as the source of brine supply with Magmamax No. 3 as the injection well during July and August. Two-well flow was conducted in September. Other than pressure difficulties, there were no apparent difficulties utilizing these wells. The plant operated for a total of 1090 hours giving a 55% plant availability excluding scheduled outages. This gives the plant a total of 4508 hours of operation from start-up.

Reduced amounts of scale were observed with Woolsey fluids as compared to Magmamax No. 1 fluids with physical scale properties remaining unpredictable. Details of the scale thicknesses and composition observed during the planned shutdown in August are in Appendices B through D. The scale deposition rates range from 0.01 mm/hr. in the first stage to 0.08 mm/hr. at the injection pump discharge. Scaling deposition rates subsequently decreased to 0.01 mm/hr. at the injection well.

Two methods of scale removal are being tested during this period using Girard Polly Pigs and a hydro-dynamics scale disintegrator. Pigging appears to be working successfully while there the disintegrator does not appear promising. For detailed information regarding these methods see the Maintenance Section of this report.

The injection pump, P-2, was damaged twice during this period. SDG&E's machine shop made the repairs and modified the pump for improved operability. The Special Problems Section discusses this in detail.

3.0 TESTING

3.1 GENERAL TEST OBJECTIVES

For detailed objectives of the operational stability test, the reader is referred to the "Test Program" report.

In general, the objectives of these tests are as follows:

- a. To establish operational safety emergency procedures in case of equipment failures.
- b. To verify the structural design safety of the plant during upsets.
- c. To determine flashing characteristics in flash drums, including conditions of foaming, stratification, and flooding.
- d. To establish methods of controlling the flash process independently of the heat exchange process and conversely, to control the heat exchange process independently of controlling the flash process.
- e. To determine how to control the level of liquid in the main condenser.
- f. To determine the response of the plant to various postulated upset conditions while the binary system is charged with distilled water.

3.2 TEST REQUIREMENTS AND MEASUREMENTS

The test conditions and types of data acquired are detailed in the "Test Program" report. Test requirements can be categorized into five subtasks.

1. Baseline operating conditions;
2. Reduction of temperature range over which flashing occurs to provide data for future plant design.
3. Flashing over equal temperature difference between consecutive stages;
4. Flashing over equal pressure difference between consecutive stages; and
5. Elimination of level control at the flash vessels to verify the stability of the flashing process.

3.3 RESULTS AND OBSERVATIONS

Woolsey No. 1 was the production well for each of these tests which were run for at least 48 hours. The accuracy achieved for the temperature and pressure was plus or minus five percent.

Typical pressures in the flash drums are plotted in Figures 3-1 through 3-5 over a 65 hour span of operation during the test for baseline operating conditions. In general, fluctuations in the flash drum pressures, with the exception of the fourth stage, were found to be within 10% of the test conditions. The periodic sharp spikes were attributable to plugging of the pressure taps. These pressure taps were cleaned whenever possible. The data on the remaining tests was recorded and stored at LBL. Bechtel will publish the results of these tests at a later date.

Emergency operating and safety procedures were established for the following situations: rupture in a

FIRST STAGE FLASH DRUM

FIGURE 3-1

SECOND STAGE FLASH DRUM

FIGURE 3-2

THIRD STAGE FLASH DRUM

FIGURE 3-3

FOURTH STAGE FLASH DRUM

FIGURE 3-4

CONDENSATE TANK

FIGURE 3-5

stream or brine line, loss of cooling water, electric power, binary loop condensate, control air, and purge water to plant equipment.

Brine temperatures at the inlet and outlet of the plant were relatively stable at about 374°F and 200°F, respectively. In general, temperature measurements were satisfactory despite the difficult brine environment.

Accurate brine flow rates were difficult to achieve even using a Daniel Flow Meter (with removable orifice plate) due to scaling. To improve brine flow measurements, an ultrasonic flow meter has recently been purchased and installed. This meter should not be affected by the brine chemistry (scaling) or pipeline resonance effects. For this reason, it appears to be a promising candidate for the flash drum drain flow measurements.

3.4 DISCUSSION - STABILITY AND CONTROL

In general, continuous operation of the GLEF could be maintained by a minimal manual effort. Periodically, upsets of the plant were experienced. Sources of perturbations can be categorized as external or internal disturbances. External disturbances are mainly created by the slug flow in the brine supply line possibly due to flow fluctuations in the supply well and flashing of brine along the supply line. Internal perturbations are due to miscellaneous malfunctions of instrumentation, fluctuations of the flashing brine between stages, resonance effects, etc. These perturbations

are suspected to be interrelated, although no direct correlations can be deduced from the test data.

There are several areas of interest regarding the stability of the GLEF operations. For instance, the flowrate, quality, temperature, and pressure of the supply brine vary with time. The nature of such parameters are of utmost importance in the design and operation of the plant. Their immediate impacts and subsequent effects on plant controllability, rate of heat transfer and structural adequacies are to be evaluated. Therefore, stability can be construed as a measure of acceptability of these parameters.

Another area of concern is the evaluation of the flashing process in which steam is generated. Flashing is inherently sensitive to external perturbations. Any fluctuations in flow, pressure, or temperatures of the incoming brine will upset the dynamic equilibrium in the flash drums. This results in further changes in the amount of steam produced, amount of brine flowing to subsequent stages, heat transfer performance of the heat exchangers, and chemistry characteristics. These parameters should be investigated from the perspective of rate of change and their interdependency.

The application of the binary system to extract geothermal energy also requires consideration of stability. The primary concern here is the impact of instability on the heat extraction process. Investigation in this area will not only produce data on transient effects in this system but will also help develop turbine control and loading philosophy.

4.0 CHEMISTRY

4.1 STEAM

Tables 4-1 through 4-4 present the daily and weekly chemistry monitoring accomplished by the GLEF laboratory on Woolsey #1 supply steam. Steam sampling points and techniques have been reported in a previous Bimonthly Report (March 1977). All results given refer to steam which has been condensed and is at standard temperature and pressure (STP) when tested.

Changes in steam properties, as the geothermal fluid passes through the plant, are similar to those reported previously. These include:

1. pH: Steady increase to fourth stage where it decreases again. The fluctuation in the volume of second stage steam is dependent upon some, yet unknown, operational control.
2. ORP: Generally constant (within 50 mv).
3. Conductivity: Decreases through the first three stages but increases in the fourth stage. Follows dissolved gas content (see succeeding paragraph).
4. Ammonia: Decreases through the plant.
5. Iron: Fluctuates with the pH of the steam. Low pH fluids exhibit high iron content, as in the first stage. Note in Tables 4-1 through 4-4, as pH goes up iron content goes down and vice versa.

WOOLSEY NO. 1 STEAM

Date: August 1, 1977

Sample	pH	ORP MV	Cond umho/cm	Na Mg/Lit	Ca Mg/Lit	Fe Mg/Lit	Cl Mg/Lit	NH ₄ -N Mg/Lit	Total Solids Mg/Lit
1st Stage in	6.70	-125	2400	3.3	2.44	13.1	16	266	77
1st Stage out	6.55	-170	2250	2.3	0.92	2.03	5	274	28
2nd Stage in	7.45	-155	1700	8.9	8.70	1.38	26	191	197
2nd Stage out	7.30	-140	1700	8.4	6.88	2.23	29	188	157
3rd Stage in	9.85	-235	250	5.0	3.51	0.17	13	117	67
3rd Stage out	6.40	-120	1600	2.9	0.92	3.71	8	203	33
4th Stage in	6.55	-135	820	1.0	4.89	0.86	29	90	98
4th Stage out	6.25	-115	880	1.6	2.44	5.33	5	98	30

ORP: Oxidation reduction potential (SCE Reference)
 Steam in: Condensed steam from flash vessel to scrubber
 Steam out: Condensed steam from scrubber to heat exchanger

WOOLSEY NO. 1 STEAM

Date: August 4, 1977

Sample	pH	ORP MV	Cond umho/cm	Na Mg/Lit	Ca Mg/Lit	Fe Mg/Lit	Cl Mg/Lit	NH ₄ -N Mg/Lit	Acid Equivalent Mg/Lit
1st Stage in	6.15	-200	2150	2.0	2.25	18.5	18	266	18.5
1st Stage out	6.20	-165	2350	2.8	1.25	20.0	5	290	20.0
2nd Stage in	8.20	-220	1450	1.2	6.50	1.78	41	177	12.0
2nd Stage out	8.20	-225	1400	2.8	2.87	0.43	9	183	11.5
3rd Stage in	9.40	-265	420	6.7	9.62	0.10	32	119	8.0
3rd Stage out	8.65	-205	860	3.0	3.75	1.05	10	133	9.0
4th Stage in	6.65	-165	1000	2.9	14.8	0.40	101	85	5.0
4th Stage out	8.25	-210	975	1.1	5.0	0.36	34	122	7.5

ORP: Oxidation reduction potential (SCE Reference)
 Steam in: Condensed steam from flash vessel to scrubber
 Steam out: Condensed steam from scrubber to heat exchanger

WOOLSEY NO. 1 STEAM

Date: August 9, 1977

Sample	pH	ORP MV	Cond umho/cm	Na Mg/Lit	Ca Mg/Lit	Fe Mg/Lit	Cl Mg/Lit	NH ₄ -N Mg/Lit	Acid Equivalent Mg/Lit	B Mg/Lit	S= Mg/Lit	SiO ₂ Mg/Lit
1st Stage in	6.80	-150	2500	8.4	3.35	11.3	23	288	19.5	2.0	6.3	0.24
1st Stage out	6.55	-160	2550	1.1	0.13	8.1	8	326	21.5	0.8	1.0	0.18
2nd Stage in	8.80	-140	1250	8.8	5.36	0.67	27	164	11.5	5.8	0.3	2.6
2nd Stage out	8.65	-200	1200	2.0	2.55	0.19	7	170	11.7	4.8	0.5	0.16
3rd Stage in	10.20	-165	205	3.8	4.56	0.19	14	127	8.0	2.5	0.2	0.40
3rd Stage out	9.40	-155	530	2.7	3.35	0.60	8	122	8.5	2.6	0.3	0.42
4th Stage in	6.90	-145	910	15.7	5.77	1.46	44	94	6.0	0.7		0.20
4th Stage out	7.45	-155	1300	10.1	5.77	0.70	32	149	9.5	1.9	0.3	0.18

ORP: Oxidation reduction potential (SCE Reference)
 Steam in: Condensed steam from flash vessel to scrubber
 Steam out: Condensed steam from scrubber to heat exchanger

WOOLSEY NO. 1 STEAM

Date: August 12, 1977

Sample	pH	ORP MV	Cond umho/cm	Na Mg/Lit	Ca Mg/Lit	Fe Mg/Lit	Cl Mg/Lit	NH ₄ -N Mg/Lit	Acid Equivalent Mg/Lit	Total Solids Mg/Lit
1st Stage in	6.60	-140	2250	42	21.0	22.0	122	272	16.5	294
1st Stage out	6.65	-110	1900	1.7	0.86	14.6	5	248	17.0	62
2nd Stage in	8.75	-140	1400	7.3	4.20	0.92	19	207	13.0	92
2nd Stage out	8.10	-80	1550	3.8	3.58	0.59	14	201	13.0	57
3rd Stage in	10.45	-135	230	2.1	3.21	0.09	7	170	11.5	54
3rd Stage out	9.60	-130	680	2.6	2.22	0.25	9	174	10.5	61
4th Stage in	7.35	-115	1050	20	9.89	0.77	59	111	6.0	177
4th Stage out	6.50	-100	1200	1.0	1.36	1.88	5	154	9.5	72

ORP: Oxidation reduction potential (SCE Reference)
 Steam in: Condensed steam from flash vessel to scrubber
 Steam out: Condensed steam from scrubber to heat exchanger

6. Dissolved Solids (Na, Ca, Cl): Fluctuates with operational control.
7. Boron: No discernable trend.
8. Sulfide: Decreases through the plant.
9. Silica: No discernable trend.

Several other items have been added to the weekly steam condensate analysis. They are first stage total CO_2 , dissolved CO_2 at STP (see below) and acid equivalent. Acid equivalent is referred to as the amount of acid necessary to lower the pH of steam condensate to 4.3. This pH value is the point at which essentially all the CO_2 is removed at room temperature. The pH 3.7 to 4.3 is the equivalence point of the steam after titration with acid. These acid equivalent numbers, given in milliequivalents per liter, were measured to give an indication of the amount of acid necessary to treat the condensate to prevent carbonate scale.

Total CO_2 in the first stage steam and the CO_2 dissolved in the steam are presented below. With proper flow data, accurate numbers concerning total CO_2 in the brine can be obtained since the total first stage CO_2 represents almost all of the noncondensibles. However, its composition (98% CO_2) has not changed.

TOTAL CO₂

<u>Date</u>	<u>% by Weight in 1st Stage Steam</u>
August 2	3.5
August 4	2.8
August 5	3.8
August 9	3.4
August 17	2.3

Dissolved CO₂ in Condensate at STP

<u>Date</u>	<u>1st Stage (mg/lit)</u>	<u>2nd Stage (mg/lit)</u>	<u>3rd Stage (mg/lit)</u>	<u>4th Stage (mg/lit)</u>
August 2	-	480	160	270
August 9	1240	380	360	-
August 17	1560	690	130	190

One added sample point for the steam condensate was located at the fourth stage flash vessel where condensate is recombined. The sample represented the combined condensate, first through the fourth stage. This sample was monitored for pH. The pH of this fluid was between 6.2 to 6.6.

Also notable is the pH of the third stage steam at the outlet of the scrubber, which is much lower than the pH of the steam before the scrubber. This was caused by errors through estimating the flow rates because of an inoperable

scrubber purge water meter. The low pH shows the effectiveness of the steam in scrubbing CO₂ from the purge water (1st stage condensate) and how little excess purge water is necessary to change the characteristics of the steam.

4.2 BRINE

The brine chemistry of Woolsey No. 1 fluid exhibited little change during the months of this reporting period. Some representative analyses are given in Table 4-5. Tables 4-6 and 4-7 list the concentration of the fluid through the GLEF with condensate recombination. The third stage is not included in some of the tables due to the installation of the one inch sample line located on top of the ten inch brine line. With the plant in automatic operation, this brine line may be only partially full, so the sample is usually diluted with steam. The sample tap has been relocated on the vertical rise of the outlet pipe to provide accurate samples.

The GLEF laboratory has also started to monitor suspended solids in the injection brine. The values obtained are listed below. These solids were measured using LLL's sampler and flowing the sampled fluid through a 10 micron filter.

WOOLSEY BRINE THROUGH GLEF

Element	pH	ORP MV	Chloride Mg/Lit	Conductivity umho/cm	Total Solids Mg/Lit
Date: August 1, 1977					
Wellhead	5.10	+65	113,300	305,000	190,300
1st Stage out	5.85	-40	125,700	325,000	209,300
2nd Stage out	5.80	-30	134,500	340,000	219,000
4th Stage out	5.66	-15	108,300	280,000	180,500
Date: August 2, 1977					
Wellhead	4.90	+40	114,500	305,000	
1st Stage out	5.95	-55	124,500	335,000	
2nd Stage out	6.00	-45	129,500	355,000	
3rd Stage out	5.45	+30	133,200	360,000	
4th Stage out	5.60	-1	113,300	310,000	
Date: August 4, 1977					
Wellhead	4.80	+3	112,000	300,000	
1st Stage out	5.80	-80	124,500	325,000	
2nd Stage out	5.95	-100	132,000	345,000	
3rd Stage out	5.55	-65	138,000	360,000	
4th Stage out	5.60	-80	112,000	305,000	
Date: August 9, 1977					
Wellhead	4.80	-2	112,000	310,000	
1st Stage out	5.75	-65	125,700	355,000	
2nd Stage out	5.90	-80	135,700	375,000	
3rd Stage out	5.75	-70	139,400	390,000	
4th Stage out	5.80	-100	109,500	325,000	
Date: August 12, 1977					
Wellhead	5.10	+90	112,000	310,000	192,700
1st Stage out	5.90	-20	132,000	350,000	221,300
2nd Stage out	5.95	-40	137,000	365,000	227,100
3rd Stage out	5.80	-15	137,000	370,000	228,100
4th Stage out	5.75	-30	117,000	320,000	196,200
Date: August 17, 1977					
Wellhead	4.55	+50	110,800	300,000	
1st Stage out	5.95	-80	124,500	330,000	
2nd Stage out	5.85	-35	129,500	345,000	
3rd Stage out	5.90	-45	129,500	350,000	
4th Stage out	5.70	-45	112,000	300,000	

WOOLSEY BRINE THROUGH GLEF

Date: August 1, 1977

Sample Point	Wellhead Mg/Lit	1st Stage Out Mg/Lit	2nd Stage Out Mg/Lit	4th Stage Out Mg/Lit
Na	38,000	42,600	44,700	36,700
K	8,680	9,720	10,070	7,990
Ca	19,800	22,200	23,200	19,100
Cl	113,300	125,700	134,500	108,300
Fe	210	265	285	215
Mn	500	550	585	465
Zn	145	165	175	140
Cu	1.0	0.7	0.7	0.8
Pb	39	23	31	31
Bu	150	130	135	115
Si	185	150	165	145
Mg	135	165	175	145
B	225	235	245	215
Li	130	150	165	125
Sr	330	380	390	330
SO ₄ (Total)	77	62		

WOOLSEY BRINE THROUGH GLEF

Date: August 8, 1977

Sample Point	Wellhead	1st Stage Out	2nd Stage Out	4th Stage Out
Na	38,000	42,000	45,800	38,700
K	8,700	9,780	11,230	8,700
Ca	19,000	21,100	22,900	19,000
Cl	109,500	124,500	132,000	109,500
Fe	185	205	255	215
Mn	475	530	575	485
Zn	125	135	150	125
Cu	0.8	0.8	1.0	1.0
Pb	41	41	41	27
Bg	165	150	160	110
Si	195	130	160	135
Mg	135	150	170	145
B	260	280	290	240
Li	115	130	140	120
Sr	330	375	410	345
SO ₄	76	60		

SUSPENDED SOLIDS AT MAGMAMAX NO. 3
USING WOOLSEY #1 PRODUCTION WELL

(at injection temperature)

<u>Date</u>	<u>Before Strainer (mg/lit)</u>	<u>After Strainer (mg/lit)</u>	<u>After Magma's Iron Filings Strainer (mg/lit)</u>	<u>Downhole 2" Pipe (mg/lit)</u>
July 22	6	8		
July 7	23	-		
August 3	55	36		
August 5	10	60		
August 8	13	39		
August 11	8	9	71	35

As observed, the suspended solids are fairly low. However, it appears when the fluid passes through the iron filings strainer, located at MagmaMax No. 3, the solid content increases. Also, from a downhole sampler operated by the Magma Power Company, solids growth appears to continue in the injection well, since the solids content is higher than either of the above-ground injection line samples. The increase in suspended solids observed in samples from the strainer outlet for the dates August 5 and August 8 may have been due to sand remaining in the strainer after it was hydroblasted with a mixture of water and sand.

Tabulated in Table 4-8 is the composition of scale and suspended solids collected from the strainers and the injection fluid at Magmamax No. 3. As indicated, there is not a major specie in the solids from the strainers. The high lead content in the suspended solids is probably lead carbonate although crystalline Pb and BaO_3 have been identified within the injection line scale upstream of the strainers.

4.3 SCALE

Scaling of the vessel, injection line, and Magmamax No. 3 two inch sample pipe are discussed in Appendices B through D.

4.4 COOLING WATER

Problems of the cooling water which must be controlled are its corrosiveness (O_2 saturation) and scaling potential (high calcium content). With the completion of condenser cleaning, a program of cooling water quality management is being initiated. This will include a zinc base corrosion inhibitor, a phosphonate scale inhibitor and improved pH control. Chlorine will continue to be the active biocide for algae control. An electrically heated tube and shell heat exchanger to simulate the condenser tubes is being fabricated and will be mounted between the cooling pond supply and return line to monitor the effectiveness of the scale and corrosion inhibitors.

STRAINER AND SUSPENDED SOLIDS CHEMICAL COMPOSITION

Sample	1	2	3	4	5
	Wt %	Wt %	WT %	Wt %	Wt %
Element					
Fe	1.35	1.52	3.58	2.83	21.38
Cu	0.59	0.25	0.96	5.76	1.65
Zn	0.28	0.25	0.32	0.58	0.75
Mn	2.46	2.46	3.19	4.06	1.01
Pb	32.47	1.90	3.72	22.08	7.53
Ca	9.53	7.30	9.84	10.94	3.28
Al	0.06	0.06	0.06	0.17	0.26
Si	3.70	9.85	10.45	2.40	12.70
Bu	6.50	4.05	5.95	0.45	1.40
Mg	0.05	0.07	0.05	0.08	0.07
CO ₃	-	10.8	15.1	-	
S	-	5.95	4.38	-	

- 1) downstream of iron filling strainer
- *2) east strainer (stainless stell wire wound)
- *3) west strainer (carbon steel slotted)
- *4) suspended solids before strainers
- *5) suspended solids after strainers

Note: Samples 2 and 3 contaminated with pieces of pigging material which could not be separated from scale.

5.0 MAINTENANCE

5.1 SCALE REMOVAL

Composition and physical properties of scales and scaling characteristics are important factors of any cleaning technique. Southwest Chemical Company tested scale samples for ease of cleaning. Major cleaning was not attempted since only a light scale build up was observed. However, pigging and a hydrodynamics scale disintegrator were tested in the injection line.

5.1.1 PIGGING

There are several styles of Girard Polly Pigs. Basically, pigs have a polyurethane core which is covered with a nonpermeable plastic where wire brushes are embedded. Figure 5-1 shows a new and used pig.

Pigging is expected to facilitate scale removal on freshly deposited scale. After a pig is launched on a daily basis, the brine effluent together with the pig is discharged into open tanks near Magmamax No. 3 injection well. The effluent is allowed to settle, and the liquid injected. The amount of sediment indicates that pigging is successful in scale removal. After three days of operation the line was inspected, and a substantial portion of the line was found to be clean. Based on this inspection a permanent pig launcher was installed, see Figure 5-2. Inspection after 896 hours of operation, during which pigging was conducted once a day, revealed the majority of the pipeline was being

FIGURE 5-1

FIGURE 5-2

cleaned. Upstream of the pigging operation on the 10", inside diameter, injection line after 1000 hours of operation resulted in a scale build-up of two and three quarter inches leaving an opening of five and one half inches. In locations where the pigging was conducted during this same period scale build-up was only one eighth inch leaving the opening of nine and three quarter inches. Exceptions to this are hard scale observed in the elbows, tees, and overhead pipelines in the facility.

Hard scale is more prevalent after a shutdown and more difficult for a pig to remove than freshly deposited scale. The exact reason for the difficult removal is not understood, but several possibilities exist: poor quality pigs, less scale build-up during operation compared to accumulation after shutdown, composition of scale (carbonate increased during operation), kinetics of scale adherence, and higher pressures generated during operation. Based upon observations, the most likely reason appears to be dehydration. Scale exposed to air is generally harder than scale not exposed. Scale remaining in overhead pipelines (first drained and exposed to air) appears to confirm this inference.

The pigs were damaged beyond reuse during operation. The damage appears to be due to distortion of the pig rather than abrasion when running through the line. Various combinations of flowrates and pressure were attempted to reduce the damage, but without success. Scale accumulation at elbows and tees tends to confirm distortion at these points.

Flow diverters have been installed at the injection line tees to minimize distortion and damage to the pigs. If further damage to the pigs is still observed, then the injection line will be sectioned and evaluated to identify the damage-causing portion.

Continued inspections should indicate the pig's cleaning ability as injection line scale vary with plant operating conditions.

5.1.2 HYDRODYNAMICS SCALE DISINTEGRATOR

This device is expected by the manufacture to redirect magnetic dipoles in the brine stream thereby reducing scaling tendencies. Preliminary inspection (after 3 days of operation) indicated that the device downstream of the magnets was clean. Later inspection, however, showed scale build-up in all areas. Probable causes, empirically, are that magnetic factors are not important in geothermal scale deposition, and initial success was due to outgasing of the plastic lining in the device. The manufacturer suggested that better results would be achieved with higher flowrates.

After continued operation, the effectiveness of this device with higher flowrates will be evaluated in October. If it is not effective, the device will be removed.

5.2 COMPONENT OPTIMIZATION

Test results of material, components and configuration modifications are conducted to optimize component

selection. Testing of pinch valves and a differential pressure transducer are discussed below.

5.2.1 PINCH VALVES

Brine control valves tend to freeze if scale formation is excessively hard or thick. Pinch valves are expected to be better able to slough off scale from the flexible sealing material. Two pinch valves will be placed in series in the 3rd to 4th stage drain line for operation. This installation will minimize the differential pressure across the valves. Temperature limitations of the materials in construction may limit the application of this valve. Installation of these valves is expected in the next report period.

5.2.2 DIFFERENTIAL PRESSURE TRANSDUCER

The 4th stage sonic type level control transducer, which acts as a five step controller, has been replaced with a differential pressure transducer. Advantages of using this type of transducer include: faster response, improved rangeability, and invulnerability to foaming. The primary disadvantage is susceptibility to vibrations. The operation of this control valve is fairly smooth but the large oscillations are not eliminated in the injection line flows and pressures. Potential reasons for these oscillations include: Pump oscillations, faulty instrumentation, pipeline vibrations, injection well variations, and control valve instability. The most likely cause appears to be

pipeline vibrations. Vibration-damping supports are being evaluated to reduce the vibration.

Further operation of this transducer and one at the first stage level control will provide full evaluation of its geothermal application.

6.0 SPECIAL PROBLEMS

6.1 BRINE INJECTION PUMP

The brine injection pump, P-2, had operated for 896 hours prior to its failure in July. Disassembly and inspection of the injection pump at SDG&E's machine shop indicated the existence of scale and wear. Inspection indicated that the original seals were not effective in preventing scale formation in the bearings. The labyrinth seals were modified and relocated. An acid pump was obtained from LLL, and provisions were made to acidify the purge water supply to the bearings to further minimize scale deposits. Since the acid pump was not capable of continuous duty, periodic shock treatment with acid for one half hour per every two hours was instituted. With scale characteristics high in calcium carbonate, shock acid treatments should be effective. The acid addition lowered the pH to between 4.0 and 4.5. Analysis indicated this would not damage the pump or injection line components.

Inspection also revealed that the 800 HP drive motor top bearing was damaged. The motor vendor confirmed that the bearing had been overloaded. Two bearings were to be installed at this location, but one had been replaced by a blank.

The reason for the blank is unclear since the bearings have been replaced before. The motor vendor indicated that blanks are used in smaller motors with the same frame.

Two new top motor bearings were installed per the manufacturer's specifications. The brine injection pump was returned to service and operated until the planned shutdown on August 22, 1977, a total of 797 hours.

The pump was again returned to SDG&E's machine shop after shutdown. Inspection revealed bearing failures and damage to the glass lined cast iron impeller (Figure 6-1), and bowl (Figure 6-2).

The apparent cause for at least one of the failed bearings was a leaking purge supply line. The supply of purge water was cross connected to improve reliability.

Another potential cause of bearing failure is differential thermal contraction between steel and bronze. This happens as scale forms on the bearing surfaces. With the pump running, the top scale layers might be removed. Upon shutdown, the top scale would not be removed and cooling (hence thermal contraction) may cause the bearings to seize. This has not been observed in the past, but the scale properties (portion is now calcium carbonate) have changed.

Damage to the glass-line impeller was probably due to acid soaking during cleaning. Vulnerability to acid exposure does not allow its continued usage. Therefore, it was replaced with carpenter 20-material.

FIGURE 6-1

FIGURE 6-2

6.2 FOURTH STAGE FLASH DRUM

This drum has produced steam with the highest TDS of the four separators. Carryover in this vessel was initially thought to be in the form of droplets. A simple baffle system previously installed indicates a mist or foam condition. The carryover data (see Tables 4-1 through 4-4) in the Chemistry Section, shows significant variation. A foaming condition is thought to be a more likely cause of the observed large variations. A plastic coated screen installed late in August is expected to reduce a foam condition. If these simple techniques are not successful, more complex devices will be required.

7.0 CONCLUSION

The plant operated for a total of 1090 hours during this period, bringing the total plant operation from start-up to 4508 hours.

The production wells operated satisfactorily while Magmamax No. 3 experienced some pressure difficulties.

Testing to date shows that the plant is inherently stable and could be maintained by a minimal manual effort. Periodically, oscillations occurs, but the analysis indicates that they will not significantly effect the power ouput.

In-line cleaning and scale control methods continue to show promising results. Pigging the injection line has kept the majority of the line clean while the hydrodynamics scale disintegrator does not appear promising.

The installation of acid purge lines to the injection pump bearings continues to help keep the bearings from scaling.

The Program Evaluation Committee met on September 29, 1977 and recommended doing a feasbility study. See Appendix E for the minutes of that meeting.

APPENDICES

APPENDIX A

APPENDIX A

The Bechtel Corporation has written a detailed test program comprised of 18 tasks for the Niland GLEF.

A list of those tasks follows:

1. Operational stability of the flash/binary process, plant response to transients and upsets.
2. Overall heat and mass balance of the plant under baseline conditions.
3. Clean-tube heat transfer coefficient with water as the binary fluid.
4. Purity of vapor; scrubber performance.
5. Scale prevention.
6. Materials and component evaluation.
7. Effect of noncondensable gases on the heat transfer coefficients.
8. Continued monitoring of heat transfer coefficients and fouling resistance in multistage heat exchangers.
9. Restoration of clean-tube transfer coefficients.
10. Operational stability of the flash/binary process during isobutane runs.
11. Overall heat and mass balance baseline for isobutane runs.
12. Condenser performance with isobutane as the working fluid.
13. Heat transfer and pressure drop performance in and around the critical region of isobutane.

14. Performance of liquid isobutane heat exchangers E-1A, 1B, 1C, and E-5.
15. Determination of nonequilibrium and boiling point elevation.
16. Comparison of flashing devices and mist eliminators.
17. Analysis of turndown capability of the flash process.
18. Long-term run under baseline conditions.

APPENDIX B

SAN DIEGO GAS & ELECTRIC COMPANY

INTERNAL CORRESPONDENCE

FORM 115-6143C

FROM A. R. Gonzalez

DATE September 1, 1977

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

FILE NUMBER

SUBJECT Inspection of Flash Vessels 1, 2, 3 and 4
Shutdown Date August 22, 1977

Operating time since last inspection was 896 hours and 22 minutes. This shutdown was for scheduled inspection of machinery. The running period was to conduct a series of flow tests.

During this run time, all vessels were treated equally with respect to shutdown and operating time.

Brine source was Woolsey # 1.

A. R. Gonzalez
A. R. Gonzalez

ARG:kw

cc: K.K. Li, SDG&E (Original)
R. Quong, LLL
N. Hodgdon
Mr. Jackson

First Stage Flash Vessel Inspection

The first and most obvious discrepancy was the broken vortex breaker fin. The fin had broken away completely and was lying across the outlet opening. It had reduced the outlet opening by one half. The fin was then rewelded into position. It may be noted that the fin thickness is somewhat reduced in thickness. Scale on vortex was approximately 2-4 mm.

Due to the nature of the scale buildup, the water level appears to have been at approximately 1.05 meters.

The scale below the water line was hard, porous and black in color. It was 3-8 mm thick and was undergoing a breaking away and reformation process.

The scale above the water line was 1-2 mm thick and black in color. There was an area of bare metal extending from above the inlet nozzle, sweeping down to the water line and back the full length of the vessel. The ceiling scale does not appear to be falling away but remains well bonded to the vessel wall. The weld around the inlet end of the vessel is virtually free of scale above the water line as is the inlet pipe itself.

The drain pit was completely filled with debris. Debris on the vessel floor lay in uneven piles the entire length of the vessel. The debris itself appears to be fallen scale from below the water line. The stand pipe opening is closed with scale from 2" to 1/2".

Second Stage Flash Vessel Inspection

The water level in the second stage flash vessel appeared to have been at approximately 60 cm. The scale below the water level was approximately 1 cm thick, color was black and was hard and porous. The scale below the water line was undergoing the falling away reformation process.

The scale above the water level was very sparse and appeared to be less than 1 mm in thickness.

The horizontal vessel weld is undergoing rust pitting at the inlet end of the vessel. Rust appears to be moving to the vessel wall itself. Future inspection should confirm or deny this observation.

The ceiling of the second stage is covered approximately 75% by a thin film of rust. This appears to be coming from the outlet in the vessel ceiling from V-6 drain.

Scale formation on the impingement shield and in the throat of the inlet nozzle was of a hard glossy black. On the shield was approximately 5-7 mm thick while .5-1.5 cm within the nozzle.

There was a large formation of carbonate scale approximately 12 cm thick on the inlet nozzle directly below the V-6 drain inlet line.

The debris on the floor was of two types, large pieces of carbonate scale located under the inlet pipe and a pile of wall scale approximately 12 cm deep and 1 meter long just behind the inlet pipe.

There was one large piece of carbonate scale lodged in the vortex breaker completely blocking one side of the outlet line.

The vortex breaker itself was rusted nearly in half and was reduced in thickness by more than 50%. (See drawing)

Original Vortex
Breaker.

Vortex Breaker
with wings
cut off.

Vortex Breaker
AS Found eaten
away.

1. Water line.
2. Vortex breaker.
3. Debris.
 - A. Carbonate.
 - B. Wall Scale.
4. Rusting weld.
5. Glossy black scale.
6. Carbonate scale.

Third Stage Flash Vessel

The water line was at approximately 100 cm. The scale above the water line was approximately 1-2 mm thick predominately rust falling away and reforming.

The scale below the water line was 5-7 mm thick, color was black, scale was forming and falling away.

Debris formed in this vessel was the largest accumulation during this inspection. The scale was approximately the same thickness as that on the wall with some larger. The larger scale was based around the ceiling scale, while that from the wall seemed to remain fairly stable. The accumulation was approximately 20 cm at the deepest and 10 cm at the lowest point. It formed from the inlet pipe to the entrance of the vessel. The largest accumulation was just after the inlet pipe and the lowest point just inside the entrance around the vortex.

The vortex was encrusted with 5-8 mm of scale. The outlet pipe had approximately 2.5 cm of scale around the lip. Very little wear on the vortex breaker was observed.

The cruciform brace on the inlet nozzle is undergoing substantial wear as indicated in the drawing below.

- 1. Water level.
- 2. Debris.

- 3. Vortex breaker.
- 4. Inlet pipe and support.

Fourth Stage Flash Vessel

The water level was at approximately 1 meter. The scale above the water line was basically rust, 1-2 mm thick, which built up and fell away. The ceiling is becoming more pitted from this action.

The scale below the water line was approximately 1 cm thick. The color was a greenish black.

Scale on the inlet end of the vessel was coated with a green film probably a copper oxide, possibly from P-2 bearings. This would be deposited by the recirculating system into the brine inlet.

The welds on the vortex breaker are being attacked by rust and are being watched.

The welds on the baffle plate support angle iron are rusting and appear in poor condition. Failure of these could cause the baffle plate to fall, breaking the vortex breaker, thus shutting off suction to P-2.

Debris in this vessel is now of the type seen in the third stage, formed by falling debris, where scale forms on the rust. The scale was approximately 15 cm deep and extended from the outlet to just beyond the center of the vessel.

The inlet line had a hole in a weld through the line. The hole was welded shut. See drawing.

1. Water line.
2. Vortex breaker.
3. Baffle.

4. Inlet line.
5. Debris.

Conclusions

The first stage flash vessel differed somewhat from the last inspection. The water level was carried about 20 cm higher than previous indications. The scale below the water line was somewhat thicker, 3-8 mm vs 3-5 mm. The color now nearly entirely black instead of reddish brown to black.

The debris was a series of small piles instead of one long one but the drain pit was completely filled where before it was less than half full.

Finally the level control stand pipe being 75% closed off threatens to close completely which could result in problems with level control.

The vortex breaker had rusted away above the weld and fallen partially blocking the outlet line.

The second stage flash vessel water level was carried approximately 10 cm lower than the previous run. The debris was less evident and the scale thinner by approximately 0.5-0.8 cm before falling away. The amount of scale present indicates possibly there is less scale being formed. There is however much more carbonate scale, enough in fact to create large pieces which fall and one did block half the outlet line. The vessel was closed with several of these pieces remaining on the floor beneath the inlet nozzle. There is a possibility that these pieces will wash to the outlet end and clog the outlet line.

The vortex breaker showed wear not previously noted having eaten away in the center where welds had attached wings to the breaker. The new plate being solid with no welds in the center should fare better. However, some of this excessive deterioration may have been caused by the attachment of two dissimilar metals. Finally, rust was noted on the horizontal weld and in the adjoining stainless cladding.

The third stage flash vessel was noted to be carrying a water level 30 cm higher than the previous run. The scale though thinner was in far greater abundance than previously seen. It was 7.5 cm deeper and far more tightly packed than before. The rust on the ceiling is working as before to reduce the wall thickness. The vortex breaker was covered by only about 1/2 the accumulation of scale. Finally, the inlet nozzle brace is continuing its wear pattern.

And now the fourth stage. I am unable to compare this vessel with the previous inspection as the vessel had been used as a reservoir for pigging prior to the last inspection.

However, the rust on the ceiling appears to be progressing. The welds on the baffle are being reduced by rust. A new screen was placed and welded into the vessel. See drawing. Some of the welds on supports for this screen seem poor to me and I feel that they may fail and cause the screen to flap and possibly fall to cover the outlet line. I called this to the attention of Mr. DeLamarter and had him inspect the welds with me.

A. R. Gonzalez

ARG:kw

SAN DIEGO GAS & ELECTRIC COMPANY

INTERNAL CORRESPONDENCE

FORM 115-6143C

FROM A.R. Gonzalez
TO W.O. Jacobson / H.K. Bishop
SUBJECT Inspection of Flash Vessels
Shutdown date September 30, 1977

DATE October 11, 1977

FILE NUMBER

Operating time since last shutdown was 177 hours and 40 minutes.

During this run time, all vessels were treated equally with respect to operating time.

Brine source Woolsey 1 and Magmamax 1.

A.R. Gonzalez

ARG:raf

cc: K.K. Li, SDG&E (Original) ✓
R. Quong, LLL
N. Hodgdon
V. Jackson

First Stage A Flash Vessel

The water line appeared to be at 71 cm.. Scale above the water line was 0 - 1mm. thick and appeared to contain quite a bit of lead sulfide. Scale below the water line was less than 0.5 cm. thick. It appears to be falling away in sheets.

The vessel floor was covered with debris to a depth of 10-15 cm. for the entire length of the vessel. The drain pit contained debris to approximately one third its depth. This was probably caused by a blowing down of the drain line while draining the vessel. The Vortex breaker showed little indication of scale buildup. The water level indication stand pipe with a 2" line was closed to one-half inch.

First Stage B Flash Vessel

The water line appeared to be at 86 cm.. The scale on the vessel wall was 1-2mm falling away. There was a pile of granular debris at the inlet end of the vessel one meter long and 10cm deep. This pile appeared to be made up chiefly of lead sulfite. The Vortex breaker is in good condition. The drain pit was half full of water with 10cm of sludge in the bottom. The water level indication stand pipe was one fourth closed off.

Second Stage Flash Vessel

The water line appeared to be at 78 cm.. Scale below the water line was less than 1 cm thick falling away. Scale above the water line was limited and less than 1 mm thick. Horizontal weld still showing signs of rust. Scale formation throughout shows no change from previous inspections except that large chunks of scale previously noted around the inlet pipe had moved to the Vortex breaker and were waiting to jump in. New Vortex breaker in very good condition.

Third Stage Flash Vessel

The water level was at 76 cm. The scale above the water line was 1-2mm thick. Scale below the water line was 1-8mm thick and falling away. Debris was accumulated through the entire length of the vessel. Depth of debris varied from 10-20cm and formed a hard crust over the surface. The Vortex breaker had a formation of scale around the edge which was threatening to close off the outlet line. (Please see drawing on the following page.)

October 11, 1977

Vortex breaker
Scale buildup
only on plate
and outlet pipe
edge.

Fourth Stage Flash Vessel

The water line was at 81 cm at the inlet end and 122 cm at the outlet end. Scale above the water line was less than 2mm and appeared to contain large amounts of rust. Scale below the water line was less than 1 cm and hard black. Debris was approximately 5 cm deep and extended from the outlet to approximately half the vessel length. The baffel welds are undergoing rust attack.

Conclusions

Conclusions will be reserved until the next shutdown at which time a more thorough inspection will be accomplished.

A. R. Gonzalez
A. R. Gonzalez

ARG:rmf

APPENDIX C

SAN DIEGO GAS & ELECTRIC COMPANY

INTERNAL CORRESPONDENCE

FORM 115-6143C

FROM Fred DeLamarter

DATE August 29, 1977

TO Bill Jacobson

FILE NUMBER

SUBJECT Reinjection Line Report

Since the reinjection line was cleaned the plant has been in operation for 896 hours. During this time the magnetic disintegrator was in operation and a pig had been run down the reinjection line about every day. The plant was shut down on August 22, 1977 for routine inspection. The following openings on the reinjection line were opened:

1. Elbow above 1A separator was removed and found a layer of hard scale about 1/4" thick inside elbow, upstream and downstream of elbow. Scale was smooth.
2. Magnetic disintegrator was removed and found the bars inside almost all covered with a hard scale. The inlet and outlet line was also coated with scale. There was a small piece of pig covering on the bars. The inlet valve to the disintegrator would not close all the way due to scale in the guides. The inlet valve was cleaned up.
3. 1st test coupon - inside the test coupon the inlet and outlet, as far as can be seen, were very clean. This line has brine flow through it only during pigging operation.
4. Blanks on tees before all expansion loops were very clean as far back in as can be seen with a light. It even showed signs where the pig was scratching the bare metal where the pig made the bend. When reaching downstream towards the expansion loop you can feel some chunks of scale up to about 3/8" thick. This could have been there before. Blanks on all four expansion loops revealed the same condition.
5. Blank just before going under the road showed line to be very clean also. When reaching inside of elbow it also revealed the same chunks of scale.
6. Reinjection strainers - Magma personnel removed both strainers and found both strainers to be collapsed. Strainers had a lot of scale on them and also had chunks which were covered with more scale. They had some evidence of parts of pig on them.

Reinjection Line Report

-2-

8-29-77

Remarks: When the plant was shut down on the 22nd of August at 1200, P-2 had been running with hydrochloric acid going into the bearings 1/2 hour out of every two hours. At 1600 that day, P-2 was to be started up again to flush cooling water through the pump and reinjection line. At this time P-2 was frozen up. Pump was sent to machine shop for repairs.

Fred DeLamarter

FD:kw

cc: N.Hodgdon
V.Jackson

SAN DIEGO GAS & ELECTRIC COMPANY

INTERNAL CORRESPONDENCE

FORM 117-6143L

FROM J. R. Bricarello
TO W. O. Jacobson
SUBJECT Vessel and Reinjection Line Scale

DATE September 19, 1977

FILE NUMBER

Enclosed in this report are scale analyses of scales sampled between 8/24 to 8/26, 1977 deposited during the previous 896 hours of operation. During this operational period one several day shut down and daily pigging occurred. Condensate recombination in the fourth stage was the operational mode with some first stage condensate going for P-2 bearing purge. This bearing purge water was treated continuously or bi-hourly with inhibited 31% hydrochloric acid. The overall effect of the acid on the reinjection brine pH was negligible, however, its effect on scale is unknown. As always, the samples are prone to sampling bias, since they are taken only where the line or vessel has been exposed and access is available. The GLEF brine line venturies were not sampled this run because they were not removed.

Scale deposited below the water line in the vessels generally was less than 5 mm for the first through fourth stage. The scale tended to be porous, black and brittle. The fourth stage contained approximately 10-15 mm of scale on the walls. Floor debris had the same physical characteristics of the wall scale but was thicker. The increased thickness was caused by scale deposition on the wall side of the piece which fell from the wall. As found before, floor debris in the third stage had a black inner layer rich in iron.

Chemical trends appear to be consistent with what has been observed previously. A lead bearing scale high in sulfur was found in the first stage debris. Iron was a major constituent of the scale until the fourth stage (Table I). Silica generally increased until the fourth stage wall sample (Table I) where the scale was primarily a carbonate scale.

The presence of carbonate and barium rich scale are the two anomalies found for this 896 hour run. Prior to this operation, even with condensate recombination, carbonate scale was not usually found in the fourth stage. No exact explanation can be given, however, some supporting factors may be: lowered level, change in flow patterns, decreased temperature, refluxing on vessel baffle, diversion of first stage steam condensate away from the fourth stage, and recirculation of P-2 fluid through the vessel. The sudden appearance of a high barium scale, although to be expected with Woolsey's

9-19-77

sulfate concentration, seems odd. There must be some factor in the fourth stage which accelerates the growth and deposition of barium sulfate, since the barium concentration between the third and fourth stages goes from 0.80% to 4.65%. Any of the preceding hypotheses given for the carbonate scale could cause the enhanced deposition.

Reinjection line scale samples which were collected are unique in that they represent "almost" only one mode of operation and the pipes were clean prior to use. One drawback is the line was pigged during plant operation which undoubtedly disturbed the physical and chemical nature of the scale. Still, several trends are observable as the samples were collected at progressively greater distances from the plant. As one proceeds away from the plant, three chemical changes take place. The amount of carbonate type scale decreases, the silica content increases, and the lead content increases (see Table 2). Any theories regarding these changes must include the parameters of temperature, pressure, particle size and solubility. The silica increase may be attributed to the polymerization being delayed by the addition of condensate which dilutes the brine. As the polymerization progresses with time making silica available for scaling the carbonate, which formed in the fourth stage, would become displaced. Also, if the carbonate particles are conglomerating as they travel down the pipe they are less likely to deposit, since larger particles do not scale as readily. Assuming the lead deposits as a carbonate, its increase can be related to particle size and solubility. The solubility of lead carbonate is much less than that of calcium carbonate so it will form. However, since there is less lead available for particle flocculation the optimum deposition size may not be reached until further away from the plant.

In conclusion, the scale found during this operation appears to be similar to that previously produced with condensate recombination. Only the quantity seems reduced, possibly because Woolsey's lower scaling potential caused by a decrease in dissolved silica.

John Bricarello

JB:kw

Enclosures

TABLE 1

SCALE IN VESSELS

Vessel Location Thickness (mm) Element	1st Stage		2nd Stage		3rd Stage		4th Stage	
	Wall 2-5 Wt%	Floor 10-15 Wt%	Wall 2-5 Wt%	Floor 5-10 Wt%	Wall 10-15 Wt%	Floor 5-20 Wt%	Wall 10-15 Wt%	Floor 10-20 Wt%
Fe	26.00	22.00	28.65	25.65	21.00	23.00	10.00	3.70
Cu	0.36	1.50	0.46	0.23	0.30	0.79	0.29	0.13
Zn	0.52	0.16	0.24	0.12	0.13	0.23	0.77	0.13
Mn	1.69	1.44	4.06	2.08	1.56	1.62	5.30	0.69
Pb	1.62	11.90	0.74	1.14	0.46	2.16	1.28	0.21
Ca	1.35	0.67	0.81	1.35	0.67	0.54	12.15	1.35
Al	0.63	1.00	0.34	0.81	0.60	0.76	0.52	0.21
Si	14.90	14.45	13.15	17.55	18.85	16.25	8.35	23.70
Ba	0.19	1.10	0.16	0.65	0.95	0.80	4.65	10.00
Mg	0.78	0.76	0.26	0.49	0.25	0.39	0.11	0.11
Na	1.57	0.90	0.93	1.20	1.26	1.21	0.47	0.30
CO ₃	*ND	ND	ND	ND	ND	ND	24.8	2.10
S	0.94	2.46	0.21	0.43	0.72	1.40	1.52	2.85

*ND Implies None Detected

APPENDIX D

INTERNAL CORRESPONDENCE

FORM 118-6143C

FROM J. R. Bricarello

DATE September 20, 1977

TO W. O. Jacobson

FILE NUMBER

SUBJECT ReInjection Well Scale

Enclosed are analyses of scale removed from the two inch perforated pipe paralleling Magmamax # 3 reinjection well casing. The scale deposited represents a build up over approximately 900 hours of operation. Initial operation of plant was without condensate recombination. The thickness of the scale varied between 1-5 mm with the initial white layer (representing no condensate addition) being less than 0.5 mm. Samples were taken every 500 feet on the pipe and two samples representing accelerated build up on the perforations and downhole sludge are also included in Table I.

As can be seen in Table I, several chemical trends occur as samples are taken from deeper down the well. Generally, the carbonate like scale decreases with depth while the silica content increases. Iron content stays fairly consistent from sample to sample. Copper, zinc, manganese, and sulfur concentrations also stay constant. Silica concentrations are also consistent until 2800 feet where there is a slight increase. The most notable change is that of lead. As one goes deeper the lead concentration increases. The same is also true of barium. This may be relatable to the formation of $PbBaO_3$ which was found in a reinjection line sample submitted to the Bureau of Mines.

The perforation scale was primarily lead. It contained 33% Pb as opposed to 8% for the highest lead bearing pipe scale. This may imply some sort of flow or temperature effect determines the lead deposition. It should be investigated as to whether bare metal existed at the slots when they were cut or were coated with a preservative. If it was not coated an oxidized surface would be available for scale build up.

The sludge analyzed does not vary greatly from sediment found when the brine is allowed to cool. A high silica, barium sulfate, calcium carbonate solid is formed. Comparing this sludge with the scale we see all solids produced do not adhere evenly. Generally the barium sulfate, and carbonates scale preferentially to the silica.

In conclusion, we see a scale not too much different from reinjection line scale in the well. Lead and barium increase in the well while the carbonate scale decreases. Lead appears to deposit preferentially on the slots as opposed to on the pipe.

J.R. Bricarello

JB:kw

Enclosure

cc: N.C.Hodgdon, F.J.DeLamarter, R.Vick, H.K.Bishop, R. Quong, L. Brassfield

TABLE I

MAGMAX # 3 SCALE DEPOSITED ON TWO INCH PIPE TEST LENGTH

Depth	Surface	500'	1000'	1500'	2000'	2500'	2800'	2930'	Perf	Sludge
Element										
Fe	2.20%	1.66%	1.89%	2.71%	2.77%	3.50%	1.63%	2.62%	1.57%	7.85%
Cu	0.03%	0.03%	0.03%	0.17%	0.32%	0.02%	0.12%	0.13%	0.81%	0.24%
Zn	0.29%	0.30%	0.30%	0.24%	0.32%	0.35%	0.14%	0.11%	0.22%	0.13%
Mn	2.48%	2.48%	2.76%	2.62%	3.17%	3.59%	2.07%	1.56%	2.50%	0.42%
Pb	3.35%	2.10%	1.50%	4.12%	3.88%	3.10%	8.71%	7.29%	32.95%	5.18%
Ca	12.65%	10.90%	9.70%	8.95%	9.70%	11.45%	6.05%	5.07%	7.68%	1.16%
Al	0.05%	0.07%	0.07%	0.07%	0.05%	0.05%	*ND	ND	ND	0.37%
Si	8.60%	8.25%	8.95%	8.25%	7.60%	8.60%	9.30%	9.65%	6.90%	22.75%
Ba	8.40%	8.85%	7.30%	9.75%	8.05%	11.35%	10.45%	7.95%	5.90%	4.30%
Mg	0.03%	0.02%	0.02%	0.04%	0.05%	0.15%	0.02%	0.04%	0.04%	0.04%
Na	0.98%	0.98%	1.34%	0.93%	0.87%	1.28%	2.60%	3.63%	1.16%	0.09%
CO ₃	17.5%	15.1%	13.4%	12.4%	13.4%	16.1%	8.20%	7.00%	12.3%	1.65%
S	4.13%	5.22%	4.77%	4.34%	4.65%	4.61%	4.03%	3.76%	1.63%	3.41%

*ND implies none detected

APPENDIX E

SAN DIEGO GAS & ELECTRIC COMPANY

INTERNAL CORRESPONDENCE

FORM 115-6143C

FROM H. K. Bishop, Secretary
TO GLEF Program Evaluation Committee
SUBJECT Minutes of September 29, 1977 Meeting

DATE October 5, 1977

FILE NUMBER

This meeting was held in San Diego on September 29, 1977 to review the Geothermal Loop Experiental Facility (GLEF) program and determine the future activities at this facility.

I. Introduction

The meeting was opened by Rich Swanson, SDG&E's Geothermal Program Manager, who introduced the meeting participants (see attached list of attendees). Mr. Swanson reviewed the goals of the meeting which were to review the current status of the GLEF Program and recommend a direction for future activities. The specific goals of this meeting were to determine and recommend:

1. Whether further study of conversion cycles is necessary before continuation of testing a specific cycle.
2. Whether the current program with the flash/binary cycle should be continued.
3. Whether a modified GLEF Program should be established and, if so, the areas of emphasis for the Modified Program.

II. Review of GLEF Program and Results to Date

The GLEF Program, outlined in the program summary, was reviewed by Mr. Bill Jacobson, GLEF Project Manager. At the conclusion of the review, Mr. Jacobson asked if all significant areas of test data had been discussed.

Mr. Tom Hinrichs asked for additional comments on the reinjection problem. Mr. Jacobson agreed that the reinjection problem is a very significant one and described in some detail the past reinjection efforts. Mr. Hinrichs asked what the reason was for scale formation during the period the GLEF was operated in a cascade mode,

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that is, in a mode in which the condensate from the preceding stages were added to the successive stage. Mr. Jacobson suggested that scaling was a pH effect and that future plans to control the pH of the condensate may eliminate such scaling.

Dr. Roland Quong noted that steady state operation could not always be achieved. Bill Jacobson pointed out that slugging of the production fluid, probably due to the long run of pipe between the production well and the plant, was a major cause of plant instability. This may not be a problem if the plant is operated simply to produce power. However, it does create a severe problem in gathering data necessary to describe plant operation. Because of this, it is expected that this problem must be addressed in the future operations of the facility.

Mr. Roy Austin asked about suspended solid formation. Bill Jacobson responded that suspended solids appear to increase as the temperature of the geothermal fluid is reduced and that also it could be a cause of the injection problem. Mr. Martin Scheve asked about the variation in suspended solids from stage to stage. Bill Jacobson responded that this was not well established. Roland Quong indicated that in the first stage, suspended solid level was approximately 40 ppm increasing to 140 ppm at the injection well. Mr. Ken Mirk inquired as to the size of the suspended solids. Ronald Quong responded that they were normally less than 10 microns in diameter. Mr. A. Hutchinson noted that solids precipitation (scaling) is definitely not uniform throughout the plant.

Mr. Jim Kuwada asked that if the flow regime in the production lines were known and if it could be manipulated to reduce slugging. Bill Jacobson noted that the plant operation was very dependent upon the back pressure in the plant and any increase to control slugging would reduce the production well flow.

Roland Quong reiterated that the data presented was only for a single well flow. Bill Jacobson responded that two well flow had recently been achieved, however, the data was not yet complete.

Roy Austin asked if the cost of power could be established. Bill Jacobson was concerned that the need of a backup pump as well as the cost of other plant operations such as cleaning has not yet been established

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and that firm operating costs could not be determined at this time. Roy Austin emphasized the need in future tests to provide data for determining operating costs.

Jim Nugent commented that instrumentation is also a major problem. Ted Fick indicated that the instrumentation problem is not just due to lack of stability--scaling also seriously effects instrumentation accuracy.

Summary

Rich Swanson summarized the major concerns of the participants as follows:

1. Injection well problems
2. Instrumentation problems
3. Solids production problems
4. Slugging problems (instability)

These major concerns are in addition to those included in SDG&E's presentation.

III. Currently Planned GLEF Activities

The planned GLEF activities outlined in the meeting program were summarized by Bill Jacobson.

Roy Austin asked for a definition of "long and near term" testing. Bill Jacobson responded that near term testing was testing that would be accomplished within the next three months. Long term testing would be accomplished within the next 18 months.

Ken Mirk asked about the cleaning procedures that were proposed. Bill Jacobson responded that an acid or caustic soak followed by high pressure water and pigging would be evaluated. Roy Austin suggested that solids removal is an additional item to be included as a long term activity. Ben Holt would like to add evaluation of injection pumps. Bill Jacobson responded that this was covered in the reservoir plan.

IV. Evaluation of GLEF Program

The goals, objectives, major uncertainties, resulting tests and comparison of tests to the present plan outlined in the meeting program were reviewed by Bill Jacobson.

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Definition and Goals

Roland Quong asked if the definition of the GLEF was a four-stage flash/binary facility. Bill Jacobson responded that this was not yet established and that the goal of the GLEF program was to evaluate possible alternative cycles. Mr. Martin Scheve suggested that one of the goals of the current ERDA contract was to develop power on line as soon as possible and that the reason for this meeting was to define the best way to get power on line as soon as possible.

Objectives

Jim Nugent proposed the following objective: Establish design criteria for production and injection of brine and identify a development plan. This objective was accepted by the participants.

Uncertainties

Jim Kuwada proposed that the GLEF evaluate a pure binary system in which the brine is pumped through the plant without flashing. It was the general conclusion of the participants that pumps were not available at this time to handle the high temperature brines occurring in the Niland reservoir.

Mr. Dick Lindwall suggested that because cooling water is so important in the Imperial Valley, the GLEF should include evaluation of alternative cooling methods. George Tardiff indicated that LLL will try to evaluate the use of Salton Sea or agricultural waste water.

Dick Lindwall also was concerned that we may need to control hydrogen sulfide emissions. Ben Holt indicated that hydrogen sulfide control systems currently exist and perhaps it was not necessary to have the GLEF look at this particular specie. Ken Mirk would like to include the environmental concerns in a more general legal and institutional category. Tom Hinrichs believes that these are general problems for the entire geothermal industry and not specific to the GLEF.

Conversion Cycle Discussion

On the subject of cycle efficiency, Dick Lindwall indicated that the most efficient cycle for the current two production wells at Niland may not be the most efficient for other production wells and that perhaps it would be wise to test the simplest cycle. However,

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the participants still felt that it would be of value to try to determine the optimum cycle for the current production system.

Ben Holt indicated that a two-phase flash system promises to be one of the most efficient systems that could be applied to the Niland reservoir. A. J. Hutchinson suggested that the two-stage flash would allow a lower pressure in the first stage which would increase production rates.

Brine Handling

LLL stated that they believed both brine modification (acidification) and scale removal (cleaning) appear to be technically feasible. The effect of acidification on corrosion should be more fully investigated.

Program Evaluation Conclusions

These comments concluded the discussion of the program evaluation portion of the meeting. As a result, it was agreed to include all of the proposed goals, objectives and resulting tests with the addition of the following:

1. Establish design criteria for production and injection of brines and identify a development plan.
2. Include environmental considerations in the evaluation of alternative cycles.
3. Determine tasks which will provide information for evaluation of operating costs.

Martin Scheve indicated that a pure brinary system (pumped) is not feasible because of pumping problems. However, the several forms of flash/binary systems should be evaluated.

V. Recommendations

The recommendations for the modification of the GLEF program outlined in the attached program summary was reviewed by Bill Jacobson.

Conversion Cycle

George Tardiff asked what basis would be used to compare or evaluate various cycles. Bill Jacobson

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believed that this would be done on the basis of costs and commercial application. George Tardiff was concerned that this data was premature and that not enough data was available to determine which cycle would be best. Jim Kuwada suggested that it may not even be possible to utilize the flash cycle because of injection problems. Ben Holt suggested the final option be kept open and work be concentrated on brine handling. Bill Jacobson indicated that we were working on this now. Ken Mirk also believed that emphasis should be placed on demonstrating production and injection.

Larry Owens, Tom Hinrichs and Martin Sheve believe that a pure binary cycle is not possible at Niland at this time because of the scaling problems and because of the downhole temperatures which prohibit the use of a downhole pump. George Tardiff considered the flash/binary cycle to be feasible and that treatment of the brine injection fluid to control scaling can be developed.

Jim Kuwada articulated a concern that we should not only want to bring power on line quickly but power on line reliably. He is also concerned about the expressed differences between wells and wonders if we can build a plant that will operate reliably utilizing a number of different wells. Roy Austin proposed continuation of brine acidification tests and small scale prototype testing of double flash system. Martin Scheve suggested that examination of two-stage flash could be accomplished by LLL with their current facilities by simply eliminating the last two stages. Evan Hughes suggested that a parametric study be used to design a system around the production and injection parameters and also to try to put a cost on the production and injection parameters.

Rich Swanson summarized the conclusions of the Committee on the conversion cycle as follows:

1. Identify the data needed to make a determination on the optimum cycle. Do not include a pumped binary cycle for consideration.
2. Conduct small scale tests of both the flash and the flash/binary system (separate from the GLEF).
3. Convert the GLEF to the best cycle for continuation of a testing program.

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Brine Handling

Both brine modification (acidification) and scale removal (cleaning) appear to be technically feasible and both may be needed. Martin Scheve suggested that for this reason, both techniques should be evaluated.

Ben Holt suggested that steady state flow must be achieved in order to conduct any evaluation. This task was added to the Plant Operating Characteristics Section.

Reservoir Characteristics

The Committee suggested that Items 2 and 3, "Flow from Magmamax 2" and "Drilling New Wells" should be eliminated and the more general objective of "Obtaining data from additional wells" substituted. In response to Martin Scheve's question, Tom Hinrichs indicated that Magma does have plans to drill additional wells in order to define the reservoir. George Tardiff emphasized the need to evaluate long-term injectivity.

Isobutane Conversion

Martin Scheve discussed the Raft River 5 MW facility which will utilize isobutane cycle. He questioned whether the installation of the isobutane cycle at Niland would be worth the cost which might include substantial plant modifications. Ken Mirk was concerned that the installation of an isobutane system would slow down investigation of other problems because of the difficulty of subsequent plant modification. Rich Swanson suggested we should not eliminate isobutane at this time but depend upon the feasibility study to assess the magnitude of the problems suggested here. Rich Swanson also commented that the GLEF would be operated while the feasibility study was being conducted to acquire as much data as possible to assist in the identification of the most economical cycle.

Critical Components

One of the identified critical components is the injection pump. Martin Scheve asked if the cause of the injection pump problem had been identified. Present data indicates that scaling is the major cause of the current injection pump problem. Rich Swanson suggested that GLEF program include additional emphasis on development of improved injection pumps.

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VI. Final Summary

1. Review of GLEF Program to Date -

- a. Instrumentation problems
- b. Injection well problems
- c. Stability problems
- d. Solids production.

2. Currently Planned GLEF Activities -

Additional activities should include solids removal and effluent treatment.

3. Evaluation of GLEF Program -

a. Goals

Add: "To allow near-term implementation of a commercial scale plant at Niland".

b. Objectives

Add: "Establish design criteria for production and injection of brine and identify development plan".

c. Uncertainties

Amend the plant operation uncertainties to include costs.

4. Recommendations -

a. Conversion cycle

Identify additional data needed to determine optimum cycle. Do not consider pumped-binary cycle. Operate the GLEF in a manner to yield as much of the needed data as possible for flash and flash/binary cycle.

b. Reservoir Characteristics

Delete flow of Magmamax 2 and drilling new wells and add obtain data from additional wells.

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c. Plant Operating Characteristics

Additional emphasis on improving plant stability.

d. Critical Components

Add increased emphasis on injection pump development.

Schedule

The schedule attached to the program summary was reviewed by Bill Jacobson. Martin Scheve questioned whether at this time we can define a date, e.g., March 1979, at which a decision on a 50 MW plant can be made. It was agreed to delete this milestone. Martin Scheve also suggested that within the next month we must define what the schedule for the future GLEF program will be. Bill Jacobson indicated that the near-term portion of this plan is well defined. However, the longer term schedule for the program will need to await the results of the feasibility study. Ken Mirk suggested that an additional milestone be introduced which calls for reliably producing and injecting geothermal fluid, i.e., a reliable brine handling system. It was agreed that this milestone would be June 1978. Martin Scheve proposed a goal of December 1978 be established to assess whether a decision on a large-scale plant at the Niland reservoir can be made.

Adjournment

Rich Swanson expressed appreciation to all for participating in this meeting.

H. K. Bishop
H. K. Bishop

HKB:vbw