# NOTICE CONCERNING COPYRIGHT RESTRICTIONS

This document may contain copyrighted materials. These materials have been made available for use in research, teaching, and private study, but may not be used for any commercial purpose. Users may not otherwise copy, reproduce, retransmit, distribute, publish, commercially exploit or otherwise transfer any material.

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material.

Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specific conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

This institution reserves the right to refuse to accept a copying order if, in its judgment, fulfillment of the order would involve violation of copyright law.

HIGH SALINITY GEOTHERMAL ENERGY CONVERSION BASED UPON THE OPERATING EXPERIENCE AT THE SAN DIEGO GAS & ELECTRIC-DOE GEOTHERMAL LOOP EXPERIMENTAL FACILITY LOCATED AT THE NILAND RESERVOIR, IMPERIAL VALLEY, CALIFORNIA, U.S.A.

### Presented By George Anastas

Research at the Geothermal Loop Experimental Facility (GLEF), co-funded by San Diego Gas & Electric (SDG&E) and the U.S. Department of Energy (DOE), was successfully concluded in September of 1979. In 13,000 hours of operation during a three and one-half year period, the nominal 10 megawatt electrical-equivalent GLEF provided engineers and researchers from SDG&E, national laboratories, government agencies and industry the opportunity to identify problems in working with highly saline geothermal fluids and to develop solutions that could be applied to a commercial geothermal power plant producing electricity.

Figure 1 shows the location of the site of the GLEF in relation to the other geothermal anomolies in the Imperial Valley. Figure 2 sets forth, in a concise fashion, the history of the GLEF.

The Niland Reservoir, which supplied fluid to the facility, has a high total dissolved solids (TDS) content of about two hundred fifty thousand (250,000) parts per million (ppm), but has a high downhole temperature between 500-600°F.

Figure 3 shows the constituents of the solids in the brine. Note that the silica content is approximately 200 ppm and that the chloride concentration is well over 100,000 ppm. Figure 4 shows a generalized range of non-condensable gas content of the brine that was used at the facility.

During the period 1976-1977, the facility was operated in a four-stage, flash binary cycle operation. The Final Report of the Geothermal Loop Experimental Facility discusses the operation of the facility in this manner. However, in 1978-1979, the facility was operated in a two-stage flash cycle

若らえい

configuration is shown in Figure 5. Figure 6 is an aerial photograph of the facility at the time the effluent brine clarifier filter was being constructed.

One of the largest obstacles to constructing a power plant at the Niland Reservoir is related to the reservoir brine. The solids that precipitate from the brine upon cooling not only form scale in the brine piping, but most of the solids are carried through the plant and are injected into the reservoir. This causes the reinjection capability of the wells to decline.

In February, 1978, Imperial Magma and Lawrence Livermore Laboratory began conducting a separate series of tests of equipment to remove suspended solids efficiently from the effluent brine prior to injection. One of the problems that had to be overcome was the relatively slow evolution rate of the silica in solution in the brine. This dissolved silica precipitated so slowly that quick removal of suspended solids from the effluent brine was not sufficient to preclude the brine from containing a degree of silica supersaturation. This silica tended to precipitate in the injection well or in the reservoir itself, causing potentially irreparable damage to the well or the reservoir.

The process that was decided upon and extensively tested by Imperial Magma (with the cooperation of the Envirotech Corporation) is similar to that used in water and sewage treatment industries. To verify the pilot test on a larger scale, the decision was made in mid-1978 to build a fullscale treatment facility at the GLEF, based on this process. The system consists of a reactor clarifier (Figure 7), media sand filter (Figure 8) and thickener (Figure 9). The period of operation of the clarifier/filter system was limited to less than 1000 hours, prior to project termination. Figures 10 and 11 are schematic representations of the operation of the clarifier filter system. Important conclusions derived from the GLEF Project are summarized as follows:

- Supersaturation of silica in the effluent brine can be quickly removed by a reactor/clarifier.
  - Most of the resulting suspended solids can be removed by settling/filtering.
  - Oxygen must be carefully excluded in order to prevent further reaction and generation of suspended solids.
  - Solid waste, predominantly silica, separated via the filter press, is readily transportable.

-2-

- The clarification process is relatively stable.
- Injection capability of the processed brine appears feasible if atmospheric oxygen can be excluded from the process.
- Reservoir injection capability and production evaluations were accomplished and the reservoir appears to be capable of supporting commercial power production.
- No induced subsidence was detected.
- Steam of acceptable quality, with further treatment, can be produced (See Figures 12 and 13).





313

-3-

#### **1972 WELL FLOW TESTS GLEF CONSTRUCTION &** MODIFICATION TO TWO STAGE BY MAGMA/NARCO START UP FLASH CYCLE • PURPOSE: TO DETERMINE: HIGH AMBIENT TEMPERATURES GLEF MODIFIED TO STIMULATE BRINE HANDLING AND HIGH WATER TABLE PORTIONS OF TWO STAGE FLASH CYCLE - FLOW CHARACTERISTICS HAMPERED CONSTRUCTION EXISTING EQUIPMENT UTILIZED WHERE POSSIBLE - TEMPERATURE STABILITY START - UP WAS CONDUCTED USING TO SAVE MONEY - MINERAL CONTENT WATER IN THE BINARY LOOP INSTEAD OF ISOBUTANE CONCLUSIONS: DUE TO BRINE HANDLING PROBLEMS - FLUID CHARACTERIZED **GLEF OPERATION** ENCOUNTERED, BINARY LOOP - RESERVOIR APPEARED CAPABLE (TWO STAGE FLASH CYCLE) REMAINED CHARGED WITH WATER OF SUPPORTING DEVELOPMENT 1978 – 1979 GLEF TEST PROGRAM - TEST FACILITY REQUIRED TO DEVELOPED FROM RISKS IDEN-DEVELOP ENERGY CONVERSION CYCLE TIFIED IN THE FEASIBILITY STUDY **GLEF OPERATION** MISCELLANEOUS TESTING CON-(FOUR STAGE FLASH/BINARY) DUCTED IN AREAS OUTSIDE THE SCOPE OF THE TEST PROGRAM 1976 – 1977 GLEF TEST PROGRAM DEVELOPED TO PROVIDE INFORMATION FOR DESIGN AND OPERATION STUDY PERFORMED ON METHODS. GLEF DESIGN OF CONTROLLING BRINE FLOW OF POWER PLANT SURGES HEAT EXCHANGER TESTING IN 1973 SHOWED SEVERE OPERATIONAL PROBLEMS THAT HAMPERED TEST TUBE FOULING OCCURRED WHEN LIQUID BRINE IS COOLED PROGRAM: STEAM SEPARATOR AND HEAT EXCHANGER TESTING IN - UNSTABLE CONTROL OF PROCESS CLARIFIER/FILTER INSTALLATION 1974 SHOWED STEAM COULD BE PRODUCED AND ITS HEAT - INSTRUMENTATION FAILURE SYSTEM INSTALLED TO TREAT TRANSFERRED TO A SECOND FLUID WITHOUT SIGNIFICANT ENTIRE GLEF BRINE FLOW 1976 – 1977 GLEF TEST PROGRAM TERMINATED AND **TUBE FOULING** A FEASIBILITY STUDY STARTED TO REASSESS EFFECTIVELY ELIMINATED SCALE ABOVE TEST LED TO DEVELOPMENT OF 4 STAGE FLASH/ **OBSTACLES TO COMMERCIAL DEVELOPMENT AND** FORMING TENDENCY OF INJEC-BINARY CYCLE WITH ISOBUTANE IN BINARY LOOP THE ENERGY CONVERSION CYCLE TION BRINE AND REMOVED SUS-PENDED SOLIDS FEASIBILITY STUDY CONCLUDED THAT A TWO STAGE FLASH CYCLE WOULD BE BEST AT FULL - SCALE SYSTEM YIELDED THIS RESERVOIR AND IDENTIFIED RISKS OF MUCH DESIGN INFORMATION COMMERCIAL DEVELOPMENT **RESERVOIR OPERATION PILOT CLARIFIER & FILTER TESTING** INJECTION WELL PLUGGING SERIES OF PILOT SCALE TESTS EXPERIENCED CONDUCTED BY IMPERIAL MAGMA METHODS OF REMOVING IN COOPERATION WITH VENDORS SUSPENDED SOLIDS PRIOR REACTOR CLARIFIER, DUAL MEDIA TO INJECTION STUDIED **GRAVITY FILTER, AND FILTER** SEVERAL TECHNIQUES TRIED. PRESS CHOSEN FOR TREATMENT CLARIFIER/FILTER SYSTEM SYSTEM FAVORED 1972 1973 1974 1975 1976 1977 1978 1979

Fig. 2. GLEF history.

.

 $\mathbf{O}$ 

ELEMENT	HIGH	LOW	AVERAGE
CI	146,000	94,000	121,000
Na	54,600	29,600	42,700
Ca	28,300	16,700	22,900
κ	14,100	5,830	10,200
Mn	903	498	718
Sr	472	292	382
Zn	313	172	256
Si	236	152	204
Ba	195	79	142
ំំុំរដ្ឋ ផ្លូវដំណ	197	122	162
Fe	320	152	236
Mg	116	67	87
Pb	68	24	49
Note: All measureme	nts are ppm		

Fig. 3. Elemental range for generalized brine.

	DECEMBER 1 % OF TOTAL 0	976 A 3AS % (	UGUST 1979 DF TOTAL GAS
CO 2	98.14		98.92
CH 4	0.68		0.51
N 2	0.02		0.57
02	*ND		*ND
H <sub>2</sub>	*ND		*ND

\*ND implies none detected

Fig. 4. Generalized range of noncondensable gases in brine.





 $(1,1,1) \in \mathbb{R}^{n+1} \times \mathbb{R}^{$ 



Fig. 6. Aerial photograph of Geothermal Loop Experimental Facility (GLEF).



## Fig. 7. V-17 Reactor/Clarifier.

 $\mathbf{C}$ 

318



### Fig. 8. V-18 SVG Sand filter.



Fig. 9. V-22 Thickener.



Fig. 11. GLEF process flow diagram.

	CI-	Na+	Ca++	к+	Fe++	Si
Steam entering 1st stage scrubber	37.1	7.5	3.4	1.3	0.1	*ND
Steam leaving 1st stage scrubber	17.2	1.8	0.6	0.4	0.1	*ND
Steam entering 2nd stage scrubber	342	171	63.6	32.7	3.4	1.5
Steam leaving 2nd stage scrubber	131	51.7	21.5	12.0	0.4	0.1
Combined Condensate	89.5	22.0	10.0	5.1	0.2	*ND

\*ND implies none detected

Fig. 12. Average ionic concentrations (ppm) in the steam for Magmamax No. 1 fluid (Nov.1978-Dec.1978).

	C1-	Na+	Ca++	к+	Fe++	Si
Steam entering 1st stage scrubber	60.8	18.7	9.3	4.7	0.7	*ND
Steam leaving 1st stage scrubber	17.7	1.5	0.3	*ND	0.1	*ND
Steam entering.2nd stage scrubber	408	160	61.1	20.7	0.5	2.5
Steam leaving 2nd stage scrubber	447	136	67.3	25.7	0.9	*ND
Combined Condensate	225	78.2	30.0	14.0	0.7	*ND

\*ND implies none detected

Fig. 13. Average ionic concentrations (ppm) in the steam for the Woolsey No. 1 fluid (Jan.1979-Mar.1979).