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AN ANALYSIS OF WATER REINJECTION AT
THE NILAND GEOTHERMAL TEST SITE

MASTER

BY: R. M. JORDA
COMPLETION TECHNOLOGY COMPANY

With Contributions By:

Leonard E. Baker, Sandia Laboratories
Mark Voss, Champion Chemicals, Inc.
David C. Williams, Champion Chemicals, Inc.

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Sandia Laboratories

CTC

COMPLETION TECHNOLOGY COMPANY

4200 WESTHEIMER RD., SUITE 211 • HOUSTON, TEXAS 77027

713/961-5011 • TELEX: 775781

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	Page
Table of Contents	i
List of Illustrations	ii
List of Tables.	iv
Abstract	v

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TABLE OF CONTENTS

	Page
Scope of the Report	1
Summary of the Report Contents	1
The Injection System Water Treating Plant	2
The Reinjection Well	6
The Injection Well Performance Analysis	10
The Character and Apparent Distribution of Suspended Solids in Magmamax #3	12
The Eimco Sludge-Bed Clarifier Performance	18
The Clarifier Performance with Sludge-Assist Chemicals	20
The LLL Mixed Media Filter Performance	23
Preliminary Investigation of Silica Resolubiliza- tion at Elevated Temperatures	37
A Proposed Explanation of Continued Favorable Reinjection in Magmamax #3	45
Recommended Additional Tests and Data Requirements. .	46
References	48
Appendix 1 - Champion Chemicals, Inc. Data, Houston, and Los Angeles Offices	50
Appendix 2 - Correlation Curves for membrane filter tests at 40 psi and 80 psi differential pressures	78
Appendix 3 - Millipore filter data recorded during periods of apparent upsets in the Niland injec- tion water treating system	81

LIST OF ILLUSTRATIONS

	Page
Figure 1 - The Niland Test Site Location	3
Figure 2 - The Water Plant Flow Sheet	5
Figure 3 - The Reinjection Well Schematic	7
Figure 4 - A Saraband Log (portion)	9
Figure 5 - The IWPA for Magmamax #3	11
Figure 6 - Millipore Filter Test (MFT) - Magmamax #3 Well Head	13
Figure 7 - MFT - No. 6 Surge Tank (injection water) .	15
Figure 8 - MFT - No. 6 Surge Tank (injection water) .	16
Figure 9 - Region 1, 2 and 3 Solids Distribution Map .	17
Figure 10 - Half-Life Calculation for Magmamax #3 Using Settling Tank Water	19
Figure 11 - The Damage Collar Concept	21
Figure 12 - A Sludge-Bed Clarifier	22
Figure 13 - MFT - Clarifier Inlet	24
Figure 14 - MFT - Clarifier Inlet	25
Figure 15 - MFT - Clarifier Outlet, Natural Sludge-Bed.	26
Figure 16 - MFT - Clarifier Outlet, Natural Sludge-Bed.	27
Figure 17 - MFT - Clarifier Outlet, Natural Sludge-Bed.	28
Figure 18 - MFT - Clarifier Outlet, Natural Sludge-Bed.	29
Figure 19 - MFT - Clarifier Inlet	31
Figure 20 - MFT - Clarifier Outlet with Sludge-Assist Chemicals	32
Figure 21 - MFT - Clarifier Outlet with Sludge-Assist Chemicals	33
Figure 22 - MFT - Clarifier Outlet - Partial Feed of Chemicals	34

	Page
Figure 23 - MFT - Clarifier Outlet - Partial Feed of Chemicals	35
Figure 24 - A Mixed Media and Uniform Bed Filter .	36
Figure 25 - MFT - LLL Mixed Media Filtrate	39
Figure 26 - MFT - LLL Mixed Media Filtrate	40
Figure 27 - Half-Life Calculations for LLL Filtrate	41
Figure 28 - The High-Temperature MFT Apparatus Used to Examine Silica Resolubilization	43

LIST OF TABLES

	Page
Table 1 - General Filtration Data	38
Table 2 - Partially Normalized Emission Spectro- graph Analysis of Niland Injection Water Suspended Solids, HCl Insoluble Portion .	42
Table 3 - Partially Normalized Emission Spectro- graph Analysis of Niland Injection Water Suspended Solids After Heating the Water to 300°F for 24 Hours, HCl Insoluble Portion	44

AN ANALYSIS OF WATER REINJECTION AT THE NILAND GEOTHERMAL TEST SITE

Abstract

The problems associated with reinjecting spent geothermal brines are currently under investigation. This effort has included field tests of injection water to evaluate treating equipment effectiveness at the Niland Geothermal Test Loop.

Using Champion Chemical, Inc., personnel and equipment under the direction of Sandia and CTC personnel, membrane filter tests were conducted on fluids from the settling tanks, from the test loop, from the clarifier and at the injection well head (Maggamax #3). From this and other information concerning the injection interval, pressure, temperature and well history, an attempt to predict a well half life was made. The results of these calculations were not in agreement with observed well performance.

An attempt with some apparent success has been made to understand the possible source of these discrepancies. The cyclic nature of the injection history dictated by need for descaling the test loop, followed by apparent partial recovery of injection acceptance, has led to a theory that is under investigation concerning effect of reheating the injection fluid containing amorphous particulate silica by the reservoir rock and fluid during well shut-in. Preliminary tests indicate some of this finely divided silica may be redissolving with consequent reduction in reservoir damage, and that two widely spaced injection wells in an alternating mode may provide low-cost, long-life injection capacity at Niland and similar geothermal projects.

AN ANALYSIS OF WATER REINJECTION AT THE NILAND GEOTHERMAL TEST SITE

Scope of the Report

An examination of the Imperial Magma-San Diego Gas and Electric Geothermal Experimental Test Site water reinjection system, near Niland, California, was conducted during March and April, 1978. The purpose of the study was to analyze the overall reinjection system performance, including specific pilot-size water treating equipment; to attempt to explain the observed favorable injection of poor quality injection water; and to specify test procedures which might lead to a better technical understanding of certain phenomena which exhibit an apparent contradictory nature.

The principle investigators for this study were Sandia Laboratories, Completion Technology Company, and Champion Chemicals, Inc. Assistance was provided by personnel from Imperial Magma, San Diego Gas and Electric, and the Lawrence Livermore Laboratories.

This report contains all of the test data acquired at the test site, and the data from additional tests conducted at Champion Chemicals' Houston Laboratory under the direction of Sandia Laboratories and Completion Technology Company.

Summary of the Report Contents

This report contains:

- (1) A performance analysis of the injection well, and a description

- of the apparent behavior of the injection system.
- (2) An analysis of the effect and distribution of the suspended solids contained in the injection water.
 - (3) An evaluation of the effectiveness of an Eimco pilot clarifier using a natural sludge bed composed of suspended solids contained in the injection water.
 - (4) An evaluation of the Eimco clarifier when selected sludge-assist chemicals are used.
 - (5) An assessment of injection performance using LLL mixed-media filtered water as the injectant.
 - (6) Results of tests designed to investigate high-temperature resolubilization of precipitated amorphous silica.
 - (7) A proposed explanation, the status of which may be conjectural, of why water containing high suspended solids can be injected at a high specific injection rate without any apparent well impairment or injectivity decline.
 - (8) A recommended series of tests to delineate certain system parameters and behavior characteristics which are currently either speculative or poorly defined.

The Injection System Water Treating Plant

The Imperial Magma - SDG&E Geothermal Experimental Site is located in the Imperial Valley, California, southwest of Niland, in a Federally designated KGRA (Figure 1). The project consists of a source well, Magma #1, producing through a 5± KW flash type pilot heat extraction plant.⁽¹⁾ The post-flash liquid averages about 17,000 barrels per day (500 U.S. gallons per minute) of water containing over 200,000 parts per million of total dissolved solids, specific gravity 1.16 (water = 1.0).

IMPERIAL VALLEY OF CALIFORNIA, 100 MILES EAST OF SAN DIEGO. KGRAs ARE FEDERALLY DESIGNATED KNOWN GEOTHERMAL RESOURCE AREAS.

The water is piped to a treating plant near the Magmamax #3 reinjection well. The water flows through a series of open-top settling tanks where gravity separation of precipitated solids produces a tank water effluent ranging from about 70-150 ppm suspended solids (Figure 2). These solids average more than 50 weight per cent amorphous silica, with metallic carbonates and oxides constituting the major remaining portion of the solids. (Appendix 1 contains detailed analyses of hydrochloric acid insoluble solids found in the injection water during April and May, 1978.) The oxides are predominately corrosion products, and the carbonates are mineral scales and corrosion products.⁽¹⁾ The silica is an iron-rich amorphous, metastable compound. The source of the silica is thought to be the solubilization of quartz (crystalline) in the producing horizon reservoir rock. When the produced water is cooled, the dissolved silica does not precipitate to its crystalline (stable) form, but occurs as the metastable amorphous form.^(1,2)

Water solubility of the metastable amorphous silica is greater than the solubility of the quartz. In relatively pure systems, the solubility of metastable silica is about 320 ppm at the injection well head temperature of 180°F, compared to quartz solubility of about 25 ppm at 180°F.

Silica solubility at the producing well head temperature (about 425°F) is in the range 500 ppm, which indicates that some 400 ppm of silica is being removed in the settling tanks (about 1.4 tons per day). The remainder (about 700 pounds per day) is injected with the water into the reservoir in which Magmamax #3 is completed.

The Magmamax #3 stabilized surface injection pressure is about 300 psig at an injection rate of 17,000 b/d.

A side stream of about 1000 b/d (30 gpm) is treated through an Eimco

THE FLOW DIAGRAM FOR THE WATER INJECTION SYSTEM
AT THE SDG & E SITE, NILAND.

FIGURE 2

sludge-bed clarifier in parallel with the settling tanks (Figure 2) during selected test periods. Also available for pilot testing is a mixed media pressure filter at the LLL test facility, located adjacent to the water treating plant (this is not shown on Figure 2).

The ReInjection Well

Magmamax #3 is completed to a total vertical depth of 3076 feet. The well is cased with a 9-5/8 inch combination string,^(3,4) and is cemented from 2618 feet using a cementing basket (Figure 3). The casing was slotted with saw-cut, 2 inch long, 80 mesh axial slots, 32 slots per foot, prior to being run. Two-inch (nominal) tubing is run to near bottom, and water is injected through the tubing-casing annulus, which leaves the tubing available for wire-line surveys and back-scuttling clean-out. Static pressures of 1310 psi and temperatures of 540°-570°F ($\approx$ 280°-300°C) have been measured prior to the start of injection.

Formation permeabilities in the range of 150-250 millidarcies have been reported from DST interpretations of several intervals during well tests.⁽⁵⁾ Further, lithologic variations in the Magmamax #3 injection interval have been observed which indicate that natural fractures may exist in the lower section of the interval. J.D. Tewhey⁽⁶⁾ states, "Drill cuttings and core samples indicate that the reservoir rocks in the geothermal field have been extensively fractured. The width of filled fractures varies from a few microns to a centimeter. Whereas the primary intergranular porosity in reservoir rocks is subject to irreversible self-sealing due to hydrothermal alteration, fractures can be considered as 'renewable' porosity in that they can be reopened after having been sealed."

Some data suggest that Magmamax #3 may have been hydraulically fractured

THE GENERAL COMPLETION CONFIGURATION OF MAGAMAX 3# INJECTION WELL, SHOWING THE "COMBINATION STRING", i.e., AN INTEGRAL CASING-LINER. WATER IS INJECTED THROUGH THE TUBING-CASING ANNULUS.

FIGURE 3

shortly after its completion.⁽⁵⁾ Any such fractures, however, would most likely close because no proppant was reported to have been used.

Permeability data used throughout this report have been obtained from a Saraband analysis of electric logs run in Magmamax #3. An example of the plotted Saraband analysis appears in Figure 4. Because the Magmamax #3 log is proprietary to Imperial Magma, no portions of the log have been reproduced in this text. The section of the log in Figure 4 is from a nearby well, and is shown to illustrate the nature of the Saraband data and the general pattern of sand/shale layering which occurs in Imperial Valley reservoirs similar to the Magmamax #3 injection interval.

In the analysis of the Magmamax #3 injection interval, only sands having a permeability of $k \geq 10 \pm$ millidarcies are considered as being capable of receiving injection water (logic appears later in this report). On this basis, the interval is assessed as having 169 feet of net injection sands, with the average permeability $k = 45$ md, and porosity $\phi = 0.2$, with a permeability range of $k = 8$ md to $k = 300$ md.

To further evaluate the properties of the injection interval, the Magmamax #2 Saraband log was interpreted in the interval corresponding to the injection section of Magmamax #3, because the two logs correlated very well. In Magmamax #2, the net corresponding interval was 172 feet, with an average permeability $k = 70$ md, and $\phi = 0.2$ with a permeability range similar to that found in Magmamax #3.

Because of the logarithmic character of portions of the Saraband analytical methods, averaging of k values when good well-to-well correlations are observed is a technique often used to normalize the Saraband data.⁽⁷⁾ Averaging the two permeability values results in an average formation permeability $k = 58$ md.

An example Saraband well log in its trace form. Numerical data are also calculated and furnished (not shown).

The Injection Well Performance Analysis

A technique developed for injection well analysis⁽⁸⁾ was applied to Magmamax #3. Input parameters are:

Well head pressure = 300 psig

Well bore hydrostatic pressure at mid-interval = 1432 psia

Hazen-Williams friction factor $C = 90$

Reservoir static pressure = 1310 psia

Well bore radius = 6 inches

Drainage/interference radius = 1000 feet

Water viscosity, average through drainage/interference radius =
0.2 Centipoise^{(9)*}

Flowing bottom hole temperature = 183°F**

Equivalent radius for annular injection = 6.14 inches

Net injection interval height = 169 feet

Formation permeability = 46 millidarcies (one case)

Formation permeability = 58 millidarcies (second case)

The IWPA for both permeabilities appears in Figure 5. The triangle marker on Figure 5 indicates the present operating condition of $q = 17,000$ b/d at a surface pressure $P_w = 300$ psig. This point falls just about on the IWPA for $k_f = 58$ md.

This can be interpreted as meaning that Magmamax #3 is behaving as if it were unimpaired (since P_w is about the same value from day-to-day), and as if the kh of the well is about 9800 millidarcy-feet ($k_f = 58$ md, $h = 169$ feet).

* Water viscosity is about $\mu = 0.4$ cp at $t = 180^\circ\text{F}$, and about $\mu = 0.11$ cp at $t = 540^\circ\text{F}$. A steady-state "reflected" value of about $\mu = 0.2$ cp represents a weighted average viscosity in the cylinder of water mobility.

** Measured by LLL test station at the Niland facility, and calculated using methods in reference (8).

IWPA CURVES DEFINING THE APPARENT BEHAVIOR OF MAGMAMAX #3 REINJECTION WELL, AT TWO k_f VALUES DISCUSSED IN THE TEXT.

FIGURE 5

This assumption is valid only if the water is actually being injected in the completion interval, and not escaping around the cement shoe to another, higher sand (some one and two Darcy sands overlie the present completion interval). Whether the injected water is confined to the interval 2618 feet - 3078 feet has not been verified at this writing. The conclusion of this report recommends test procedures for investigating this important injection parameter.

The Character and Apparent Distribution of Suspended Solids in Magmamax #3

Why the apparent k_h is about 9800 md/ft is not entirely clear. Millipore filter tests ^(8,9) on the injection water show that the permeability of filter cakes formed by suspended solids in the injection water ranges from $k_c = 0.29$ md, $k_c = 0.35$ md (Figures 6, 7, 8). Suspended solids for these tests ranged from about 234 ppm to about 104 ppm. The negative "y" axis intercepts of the slope indicate that colloids are not present in the water. ⁽¹⁰⁾ Analysis of one residue (Figure 8) shows that the solids are 19.9 weight per cent soluble in 1:4 glacial acetic acid, 14.1 weight per cent soluble in 15 weight per cent hydrochloric acid and 66 weight per cent HCl insoluble. This is a generally accepted oil industry means of identifying carbonates (HAc soluble), iron compounds - except magnetite - (HCl soluble) and silica compounds, barium sulfate, calcium sulfate, etc. (HCl insoluble).*

The k_c values provide an insight as to the distribution of the particles within the injection system. Figure 9 shows the Region 1, 2 and 3 relationships described in reference 8, updated to show the spread in the division between the Region 1 and Region 2, which has been further refined by Saucier ⁽¹¹⁾ and Abrams. ^(12, 13)

Figure 9 indicates that the suspended solids in the injection water

* This field test correlation was developed over many years of experience, but is not regarded as a substitute for the various other rigorous quantitative analyses.

Date 3/28/78 Water temp 175 °F

Differential pressure _____ p.s.i.

Sample point & pertinent data MagmaMax #3 injection
stream from LLL panel. Stream about 90% tank water and 10%

Eimco treated water, natural sludge bed. Filter ID No. GP-16.

Time
minutes

1
2
4
6
9
12
16
20

Cum. Vol.
cu. cm.

640
960
1395
1740
2170
2525
2930

CALCULATION

1. Volume at 16 minutes 2930 cc
2. Volume at 9 minutes 2170 cc
3. Difference (slope) 760 cc/√min (1-2)
4. Water quality ratio 800 ppm/md (from graph)
5. Solids content 233.7 ppm
6. Cake permeability 0.29 md (5+4)
7. HAC soluble ND % HCl soluble ND % Insoluble ND %

FIGURE 6

will invade formations where k_f values are in the range $k_f \geq 10$ to 30 md. Sections of the reservoir having lower permeabilities will cause surface filtration to occur. From the Saraband analysis data, most of the formation will be invaded by the particulates.

Figure 9 does not provide any quantitative indications of the depth of any invasion which might occur.

A Barkman-Davidson analysis for well bore narrowing or shallow invasion where $k_c/k_f < 0.05$ (Figure 10) indicates a well half-life of much less than 0.1 year, which contradicts observed well performance. Dr. D. H. Davidson was consulted for his interpretation of the data on Magmamax #3, and he expressed these views:

1. The Barkman-Davidson prediction techniques are most reliable when permeability variations throughout the injection interval are lower than those found in Magmamax #3.
2. When half-life predictions unquestionably contradict observed performance, deep invasion of particles is assumed to be taking place.
3. The correlation shown in Figure 10 applies to invasion depths less than five well bore radii.
4. Attention should be directed to the following portion of SPE #3543; "If particulate matter in the injection water can be transported great distances from the well bore, deposition will occur in a region of low pressure gradient and the rate of impairment will be small".

The specific injection rate of Magmamax #3 is about 100 barrels per day per net foot of sand. Deep invasion of solids in wells with specific injection rates greater than 30 occurs frequently in oil field brine disposal wells (reference 8, pp 14-16). If the injection water is confined to the

Date 9/10/78 Water temp 170 °F

Differential pressure 40 p.s.i.

Sample point & pertinent data No. 6 Surge tank
effluent (injection water). Cake color tan, thick slabs.

Filter ID #7.

Time
minutes

1
2
4
6
9
12
16
20

Cum. Vol.
cu. cm.

600
880
1330
1700
1980
2520
2980
3410

CALCULATION

1. Volume at 16 minutes 2980 cc
2. Volume at 9 minutes 1980 cc
3. Difference (slope) 1000 cc/ $\sqrt{\text{min}}$ (1-2)
4. Water quality ratio 315 ppm/md (from graph)
5. Solids content 108.4 ppm
6. Cake permeability 0.34 md (5+4)
7. HAc soluble nd % HCl soluble nd % Insoluble nd %

FIGURE 7

Date: 4/10/78 Water temp 170 °F
 Differential pressure 40 p.s.i.
 Sample point & pertinent data No. 6 Surge tank
effluent (injection water) Cake color tan. thick slabs.
Filter ID #8.

Time minutes	Cum. Vol. cu. cm.
1	580
2	840
4	1300
6	1650
9	1940
12	2450
16	2900
20	3310

CALCULATION

1. Volume at 16 minutes 2900 cc
2. Volume at 9 minutes 1940 cc
3. Difference (slope) 960 cc/√min (1-2)
4. Water quality ratio 300 ppm/md (from graph)
5. Solids content 104.3 ppm
6. Cake permeability 0.35 md (5+4)
7. HAc soluble 19.9 % HCl soluble 14.1 % Insoluble 66.0 %

FIGURE 8

THE RELATIONSHIP BETWEEN k_c AND k_f IN THE FLOW OF PARTICLE - LADEN FLUID THROUGH POROUS MEDIA. THE SPOTTED CORRIDOR DEPICTS THE TRANSITION ZONE BETWEEN SURFACE AND DEEP - BED FILTRATION.

FIGURE 9

interval 2618-3076 feet, deep invasion of solids appears to account for the favorable injection performance of Magmamax #3. Continued deep bed invasion can cause a "damage collar" to form, that is, a zone in which suspended solids collect when water velocity at some distance from the well bore no longer carries particulates away from the well (Figure 11). Back-building of an internal filter cake follows, and injectivity declines rapidly when this occurs (reference 8, pp 14-16). Damage collars often can be identified from pressure fall-off tests,⁽¹⁴⁾ where they indicate the presence of nearby faulting in wells where faulting is known not to exist. One possible explanation of why a damage collar has not apparently been generated appears later in this report.

The Eimco Sludge-Bed Clarifier Performance

A 30± gpm sludge bed clarifier* has been tested using settling tank inlet water as the feed stream. The clarifier (manufacturer, Eimco) uses a sludge bed composed of the suspended solids in the water to act as a fluidized filter and to provide a source of surface area to lower any supersaturation of silica (and other dissolved solids in the water). A schematic of a sludge-bed clarifier appears in Figure 12. (The Eimco unit has a metal shell; Figure 12 has a better cut-away drawing to illustrate the clarifier components.) Inlet water is forced to flow through a sludge bed which is maintained in the center cylinder of the clarifier. The water then passes through the cylinder-cone skirt annulus where additional gravity separation can take place, and the water then flows through the cone skirt-outer shell annulus to an overflow collector.

* Installed on the recommendation of Mr. John Featherstone, Imperial Magma, Engineering Dept.

THE CORRELATION FOR PREDICTING HALF - LIFE OF AN INJECTION WELL WHEN WELL BORE NARROWING OR SHALLOW (< 5 WELL RADIUS) INVASION IS TAKING PLACE, WITH LOW PERMEABILITY FILTER CAKE VALUES.

THE CENTER OF THE HATCHED CIRCLE SHOWS THE HALF LIFE USING SETTLING TANK WATER, ASSUMING THAT SHALLOW INVASION IS TAKING PLACE.

FIGURE 10

The dissolved silica in the clarifier feed water averages over 200 ppm, and dissolved silica in the effluent has been measured at levels of 170-180 ppm, so silica supersaturation appears to be removed in the vessel.

Figures 13 and 14 are millipore test data for the clarifier feed stream. Average suspended solids content for the two tests is about 254 ppm, and the filter cake permeability, k_c , is 0.29 md. Figures 15, 16, 17, and 18 show test data for the clarifier outlet, and suspended solids average about 124 ppm, indicating that the clarifier removed just over 50 per cent of the suspended solids. The k_c values for the solids in the effluent average 0.125 md, which indicates that the mean particle size of the effluent solids was about 34 per cent smaller than the mean particle size of the particles in the feed stream. The HAc-HCl analysis of the filter cakes (Figures 13, 16) indicate a reduced HCl insoluble solids content in the effluent particulates.

The principle benefits to be derived from treating the water with a natural sludge bed clarifier appear to be:

- (1) Produce a (silica?) undersaturated effluent and minimize scale-up of the injection well and injection reservoir.
- (2) Reduce the solids loading of the injection well and increase the time before which a damage collar forms.
- (3) Reduce filter loading in the event that sand (or other) filtration of the injection water becomes necessary.

The Clarifier Performance with Sludge-Assist Chemicals

One alternate to natural sludge bed operation is the use of ionic materials, clays, etc. to improve the effectiveness of solids removal. Under

A CONCEPTUAL VIEW OF A "DAMAGE COLLAR" CAUSED BY THE LOCALIZATION OF PARTICLES WITHIN A REGION AROUND AN INJECTION WELL WHERE DRAG FORCES ON THE PARTICLES ARE NO LONGER CAPABLE OF SUSTAINING RADIAL OUTWARD PARTICLE MOVEMENT.

FIGURE 11

An example industrial sludge - bed clarifier. (Courtesy CE Natco)

the supervision of Imperial Magma, three chemicals were selected for test in the clarifier, Calgon CAT FLOC T, C-35 clay, and M-580 polymer. Figure 19 shows the results of a millipore test on the date of the sludge-assist test. The inlet solids content was 147 ppm, with k_c calculated to be 0.11 md. Two tests of the effluent (Figures 20, 21) report a suspended solids content averaging 44.6 ppm, which suggests almost 70 percent removal of suspended solids. However, the percent of HCl insoluble solids in the discharged suspended solids was higher than that observed when the natural sludge bed was used.

It was necessary to discontinue the M-580 polymer feed and continue the test with only the CAT FLOC T and C-35 clay. This caused the system efficiency to deteriorate to the point where suspended solids removal was only about 40 per cent (Figures 22, 23), and the increased k_c values indicate that the mean particle size of the solids increased to about 1.6 times the mean particle size when all three sludge-assist chemicals were in use.

These test results, although somewhat sparse, suggest that solids removal efficiency can be increased with selected additives, but any conclusions beyond this preliminary assessment should be based on additional test data and on the explicit cost-effectiveness of the addition of any chemicals.

The LLL Mixed Media Filter Performance

A small scale mixed media filter was installed at the LLL testing facility for performance evaluation with the Niland brine systems. LLL will be issuing a complete report on this process unit. A mixed media filter and a uniform bed filter are shown in Figure 24. These are down flow

Date 3/29/78 Water temp 180 °F
 Differential pressure 80 p.s.i.
 Sample point & pertinent data Clarifier inlet taken
from settling tank valve. Filter ID # GP-22

Time minutes	Cum. Vol. cu. cm.
1	520
2	785
4	1165
6	1480
9	1875
12	2280
16	2635
20	

CALCULATION

1. Volume at 16 minutes 2635 cc
2. Volume at 9 minutes 1875 cc
3. Difference (slope) 760 cc/√min (1-2)
4. Water quality ratio 800 ppm/md (from graph)
5. Solids content 230.5 ppm
6. Cake permeability 0.29 md (5+4)
7. HAc soluble 22.7 % HCl soluble 21.2 % Insoluble 56.1 %

FIGURE 13

Date 3/28/78 Water temp 175 °F

Differential pressure 80 p.s.i.

Sample point & pertinent data Clarifier inlet,
test for solids content only. Silica in solution 270 ppm.

Filter ID No. GP-13

Time
minutes

Cum. Vol.
cu. cm.

1

2

4

6

9

12

16

20

CALCULATION

1. Volume at 16 minutes _____ cc

2. Volume at 9 minutes _____ cc

3. Difference (slope) _____ cc/√min (1-2)

4. Water quality ratio _____ ppm/md (from graph)

5. Solids content 276.5 ppm

6. Cake permeability _____ md (5÷4)

7. HAc soluble 38.7 % HCl soluble 8.7 % Insoluble 52.6 %

FIGURE 14

Date 3/28/78 Water temp 175 °F

Differential pressure 80 p.s.i.

Sample point & pertinent data Clarifier outlet.

Cake color dark grey. Natural sludge bed. Filter ID No. GP-9

Silica in solution = 170 ppm.

Time
minutes

Cum. Vol.
cu. cm.

1

1150

2

1830

4

2810

6

3565

9

12

16

20

CALCULATION

1. Volume at 16 minutes 3565 cc

2. Volume at 9 minutes 1830 cc

3. Difference (slope) 1675 cc/√min (1-2)

4. Water quality ratio 14 ppm/md (from graph)

5. Solids content 116.1 ppm

6. Cake permeability 0.12 md (5+4)

7. HAc soluble nd % HCl soluble nd % Insoluble nd %

FIGURE 15

Date 3/28/78 Water temp 175 °F
 Differential pressure 80 p.s.i.
 Sample point & pertinent data Einco outlet.
Cake color grey, natural sludge bed. Filter ID No. GP-10.

Time minutes	Cum. Vol. cu. cm.
1	1145
2	1810
4	2775
6	3510
9	4385
12	5140
16	6005
20	6740

CALCULATION

1. Volume at 16 minutes 6005 cc
2. Volume at 9 minutes 4385 cc
3. Difference (slope) 1620 cc/√min (1-2)
4. Water quality ratio 13 ppm/md (from graph)
5. Solids content 124.2 ppm
6. Cake permeability 0.104 md (5+4)
7. HAc soluble 41.6 % HCl soluble 16.5 % Insoluble 41.9 %

FIGURE 16

Date 3/28/78 Water temp 175 °F
 Differential pressure 80 p.s.i.
 Sample point & pertinent data Clarifier outlet
Cake color grey, natural sludge bed. Filter ID No. GP-11.

Time minutes	Cum. Vol. cu. cm.
1	1100
2	1710
4	2615
6	3310
9	4140
12	4855
16	5655
20	6365

CALCULATION

1. Volume at 16 minutes 5655 cc
2. Volume at 9 minutes 4140 cc
3. Difference (slope) 1515 cc/√min (1-2)
4. Water quality ratio 20 ppm/md (from graph)
5. Solids content 129.5 ppm
6. Cake permeability 0.15 md (5÷4)
7. HAc soluble nd % HCl soluble nd % Insoluble nd %

FIGURE 17

Date 3/28/78 Water temp 175°F
 Differential pressure 80 p.s.i.
 Sample point & pertinent data Clarifier outlet,
test for solids content only. Natural sludge bed. Filter
ID No. GP-12.

Time minutes	Cum. Vol. cu. cm.
1	_____
2	_____
4	_____
6	_____
9	_____
12	_____
16	_____
20	_____

CALCULATION

1. Volume at 16 minutes _____ cc
2. Volume at 9 minutes _____ cc
3. Difference (slope) _____ cc/ $\sqrt{\text{min}}$ (1-2)
4. Water quality ratio _____ ppm/md (from graph)
5. Solids content 124.2 ppm
6. Cake permeability _____ md (5+4)
7. HAc soluble nd % HCl soluble nd % Insoluble nd %

FIGURE 18

rapid filters often found in water treating systems.

Table I contains general filtration data for several types of filters, including the rapid mixed media (or graded bed) filters. It is important to note the maximum inlet suspended solids limits on the filters in Table I, because clarifier output should be within the limits shown.

Two millipore tests were run on the LLL pilot unit (Figures 25, 26). The suspended solids content of the filtrate averaged 2 ppm, and a $k_c \approx 0.1$ md was calculated. The HCl insoluble portion of the filtered material was less than 30 per cent, indicating a maximum possible silica content of the solids in the filtrate of 0.6 ppm. Although a complete evaluation is required before assessing the performance of the mixed media filter, initial results are encouraging.

The $k_c \approx 0.1$ md value suggests that surface filtration will take place on sands of $k_f \geq 3$ md to $k_f \geq 10$ md. Deep bed filtration of most of the solids in the filtrate will most likely occur. Presently, about 700 pounds of solids are being injected into Magmamax #3 (at 500 gpm, 100 ppm average suspended solids content). The mixed media filter would be capable of reducing this to about 2 pounds per day.

If all of the solids were being filtered on the sand face of a well with a specific injection rate of 100 barrels per day per vertical foot of sand, the well half-life would be about 3-4 years (Figure 27). Calculating a half-life for shallow invasion with the mixed media filtrate would be meaningless for Magmamax #3.

The combination of sludge-bed clarifier in series with rapid mechanical filters has the potential of providing water of high quality so that high-rate injection into wells of varying reservoir geometries will be possible and practical. This is in keeping with observed performance of

Date 4/10/78 Water temp 185 °F
 Differential pressure 40 p.s.i.
 Sample point & pertinent data Clarifier inlet
through 4 inch line. Cake color light grey, flaky texture.
 Filter ID NO. 9

Time minutes	Cum. Vol. cu. cm.
1	220
2	360
4	560
6	680
9	820
12	1040
16	1230
20	1390

CALCULATION

1. Volume at 16 minutes 1230 cc
2. Volume at 9 minutes 820 cc
3. Difference (slope) 410 cc/√min (1-2)
4. Water quality ratio 1400 ppm/md (from graph)
5. Solids content 147.1 ppm
6. Cake permeability 0.11 md (5+4)
7. HAc soluble nd % HCl soluble nd % Insoluble nd %

FIGURE 19

Date 4/10/78 Water temp 175 °F
 Differential pressure 80 p.s.i.
 Sample point & pertinent data Clarifier outlet,
with Calgon CAT FLOC T, C-35 Clay and M-580 polymer added
to sludge bed. Cake color grey, flaky. Filter ID No. 1.

Time minutes	Cum. Vol. cu. cm.
1	1100
2	1720
4	2610
6	3310
9	3900
12	
16	
20	

CALCULATION

1. Volume at 16 minutes 5250 (est) cc
2. Volume at 9 minutes 3900 cc
3. Difference (slope) 1350 cc/√min (1-2)
4. Water quality ratio 300 ppm/md (from graph)
5. Solids content 38.8 ppm
6. Cake permeability 0.13 md (5+4)
7. HAc soluble nd % HCl soluble nd % Insoluble nd %

FIGURE 20

Date 4/10/78 Water temp 175 °F
 Differential pressure 80 p.s.i.
 Sample point & pertinent data Clarifier effluent
with Calgon CAT FLOC T, C-35 Clay and M-580. Filter ID No.
2.

Time minutes	Cum. Vol. cu. cm.
1	1100
2	1700
4	2510
6	3150
9	3700
12	
16	
20	

CALCULATION

1. Volume at 16 minutes 5200 (est) cc
2. Volume at 9 minutes 3700 cc
3. Difference (slope) 1500 cc/√min (1-2)
4. Water quality ratio 280 ppm/md (from graph)
5. Solids content 50.3 ppm
6. Cake permeability 0.18 md (5+4)
7. HAc soluble 4.2 % HCl soluble 13.5 % Insoluble 82.3 %

FIGURE 21

Date 4/10/78 Water temp 175 °F
 Differential pressure 40 p.s.i.
 Sample point & pertinent data Clarifier outlet
with CAT FLOC T and C-35 clay only. Filter color grey,
thick slabs. Filter ID No. 3

Time minutes	Cum. Vol. cu. cm.
1	800
2	1240
4	1880
6	2370
9	2800
12	3540
16	3850
20	

CALCULATION

1. Volume at 16 minutes 3850 cc
2. Volume at 9 minutes 2800 cc
3. Difference (slope) 1050 cc/√min (1-2)
4. Water quality ratio 230 ppm/md (from graph)
5. Solids content 93.9 ppm
6. Cake permeability 0.41 md (5+4)
7. HAc soluble nd % HCl soluble nd % Insoluble nd %

FIGURE 22

Date 4/10/78 Water temp 175 °F
 Differential pressure 40 p.s.i.
 Sample point & pertinent data Clarifier outlet
with CAT FLOC T and C-35 Clay only. Filter color grey,
thick slabs. Filter ID No. 4

Time minutes	Cum. Vol. cu. cm.
1	630
2	1170
4	1790
6	2310
9	2780
12	3580
16	3920
20	

CALCULATION

1. Volume at 16 minutes 3920 cc
2. Volume at 9 minutes 2780 cc
3. Difference (slope) 1140 cc/√min (1-2)
4. Water quality ratio 210 ppm/md (from graph)
5. Solids content 81.8 ppm
6. Cake permeability 0.39 md (5+4)
7. HAc soluble nd % HCl soluble nd % Insoluble nd %

FIGURE 23

A mixed media filter (left) and uniform bed filter (right). Both are down flow filters, with up flow backwashing. (Courtesy CE Natco)

FIGURE 24

similar systems in oil fields. A large pilot test, or full scale test of such a system would provide valuable information for other geothermal re-injection systems, and consideration of such an installation appears warranted unless the current tests produce unfavorable performance data.

Preliminary Investigation of Silica Resolubilization at Elevated Temperatures

Discussions between Sandia and CTC staff* following the Niland field tests generated a possible explanation of why Magmamax #3 tolerated high specific injection rates of poor quality water with little, if any, signs of injectivity decline. One explanation involved the possibility that precipitated amorphous silica (and other solids which were previously in solution at $\approx 500^{\circ}\text{F}$) would redissolve if the injected water were reheated in the injection reservoir. A water sample from the Magmamax #3 injection stream was examined at Champion Chemicals' Houston laboratory. The solids collected on a 0.45 micron millipore (about 600 ppm) at 70°F were washed in 15 per cent HCl, and the acid-insoluble residue was examined using an emission spectrograph. The analysis, partially normalized, appears in Table 2, and indicates that the residue contained some 408-464 ppm** of SiO_2 .

A sample of the water was placed in a stainless steel cylinder and heated to 300°F for 24 hours (Figure 28). The hot water was passed through a 0.45 micron millipore. The liquid flashed after passing through a choke positioned downstream of the millipore holder and the vapors were condensed so that total filtrate volume could be measured. Total HCl-insoluble suspended solids on the millipore were measured to be 540 ppm.

An emission spectrographic analysis of HCl-insoluble residue (Table 3) showed that the SiO_2 collected on the membrane was 113-131 ppm.**

* Specifically, Mr. L.E. Baker, Sandia Laboratories, and Mr. R.M. Jorda, CTC.

** The author wishes to thank Dr. R.J. Grabowski for his assistance in interpreting the e-spec data.

TABLE I
FILTRATION DATA*

Type Filter	Design Flow Rate Per Sq.Ft. Filter Area	Maximum Inlet PPM Suspended Solids- Filter Will Handle	PPM Oil in Water- Filter Will Handle	Average PPM of Suspended Solids After Filtering	Average Operating Cost of Filters
Rapid Sand Graded Bed	3 gpm**	100	3	1	0.75 Mils/bbl
Anthracite	3 gpm	100	75	3	1.1 Mils/bbl
Cartridge (10" x 2½")	2-1/2 gpm per cartridge	10-15	3	0.5	4.5 Mils/bbl
Diatomaceous Earth-Rotary Leaf	1/2 gpm	20-40	10	0.2	11.5 Mils/bbl
Microfloc	3 gpm - 6 gpm	100	<10	1	0.8 Mils/bbl
Upflow/poly	3 gpm - 6 gpm	400	2-3	1	5.1 Mils/bbl***

* Based on 5000 bpd Plant - 1974-1975 Cost Data, subject to local conditions

** U.S. gallons per minute

*** Based on average polyelectrolyte feeds experience to date

The cost = cost of polyelectrolyte per barrel + 0.6 mils per barrel (1 mil = 0.001).

Date 4/10/78 Water temp 169 °F
 Differential pressure 40 p.s.i.
 Sample point & pertinent data III mixed media
filtrate. Cake color tan, grainy. Filter ID No. 5

Time minutes	Cum. Vol. cu. cm.
1	920
2	1900
4	3780
6	_____
9	_____
12	_____
16	_____
20	_____

CALCULATION

1. Volume at 4 minutes 3780 cc
2. Volume at 2 minutes 1900 cc
3. Difference (slope) 3209 cc/√min
4. Water quality ratio 22 ppm/md (from graph)
5. Solids content 1.9 ppm
6. Cake permeability 0.09 md (5+4)
7. HAc soluble nd % HCl soluble nd % Insoluble nd %

FIGURE 25

Date 4/10/78 Water temp 169 °F
 Differential pressure 40 p.s.i.
 Sample point & pertinent data III mixed media
filtrate. Cake color tan, grainy. Filter ID No. 6

Time minutes	Cum. Vol. cu. cm.
1	880
2	1900
4	3800
6	
9	
12	
16	
20	

CALCULATION

1. Volume at 4 minutes 3800 cc
2. Volume at 2 minutes 1900 cc
3. Difference (slope) 3244 cc/√min
4. Water quality ratio 21 ppm/md (from graph)
5. Solids content 2.1 ppm
6. Cake permeability 0.1 md (5+4)
7. HAc soluble 52.4 % HCl soluble 19.0 % Insoluble 28.6 %

FIGURE 26

THE CORRELATION FOR PREDICTING HALF - LIFE OF AN INJECTION WELL WHERE WELL BORE NARROWING IS TAKING PLACE, WITH HIGH FILTER CAKE PERMEABILITY VALUES.

THE CENTER OF THE HATCHED CIRCLE SHOWS THE HALF LIFE USING MIXED MEDIA FILTRATE, ASSUMING THAT SURFACE FILTRATION IS TAKING PLACE.

FIGURE 27

TABLE 2

Emission Spectrograph Analysis of Millipore HCl-insoluble residue from Magmamax #3 Injection Water Sample. The water contained 600 ppm acid-insoluble suspended solids.

<u>Element</u>	<u>E-spec per cent</u>	<u>Multiplier</u>	<u>Wt. per cent</u>
Al	3.0	3.8	11.4
Ba	1.0	1.7	1.7
Ca	0.6	2.5	1.5
Cl	0.6	---	0.6
Cu	0.04	---	0.04
Fe	2.0	1.9	3.8
Pb	0.1	---	0.1
Mg	0.1	---	0.1
Mn	0.04	---	0.04
K	0.1	1.2	0.12
Si	32.0	2.14	68.48
Sr	0.05	---	0.05
S	0.2	---	0.2
Sn	0.07	---	0.07
Zn	0.01	---	0.01
$\Sigma = 39.91$		$\Sigma = 88.48$	

Silica (SiO_2) is in the range 408-464 ppm as a suspended solid in the unheated water.

THE APPARATUS USED TO RUN HIGH TEMPERATURE
MILLIPORE TESTS FOR EXAMINING SILICA SOLUBILITY

FIGURE 28

TABLE 3

Emission Spectrographic Analysis of HCl-insoluble residue from Magmamax #3 Injection Water sample after heating to 300°F for 24 hours. The water contained 540 ppm acid-insoluble suspended solids after heating.

<u>Element</u>	<u>E-spec Per Cent</u>	<u>Multiplier</u>	<u>Wt. Per Cent</u>
As	0.3	1.4	0.42
Ba	0.1	1.7	0.17
Ca	0.1	2.5	0.25
Cl	0.2	---	0.2
Cr	5.0	1.4	7.0
Cu	0.1	---	0.1
Fe	30.0	1.9	57.0
Mg	0.1	---	0.1
Mn	0.1	---	0.1
Mb	0.2	---	0.2
Ni	0.5	---	0.5
Si	10.0	2.14	21.4
Na	0.6	---	0.6
S	0.2	---	0.2
Zn	0.1	---	0.1
$\Sigma = 47.6$			$\Sigma = 88.34$

Silica (SiO₂) is in the range 113-131 ppm as a suspended solid in the heated injection water.

The other solids were primarily corrosion products from the test cell, identified as magnetite. Inspection of the vessel showed a considerable amount of corrosion damage (also note the high chromium content of the residue, Table 3).

These data indicate that substantial silica resolubilization occurred at 300°F. The filtrates of the cold and hot tests were examined colorimetrically, and the hot filtrate was found to contain about 380 ppm more silica than the cold filtrate, further indicating that silica had been dissolved in the heated brine.

A second test at 300°F, in which a nitrogen blanket was used to minimize corrosion, produced suspended solids after 24 hours of heating in the amount of 264 ppm, of which 116-124 ppm were silica, and the remainder corrosion products, primarily magnetite.*

There is a need for more sophisticated tests to investigate possible silica resolubilization at elevated temperatures. And with the ionic complexity of the Niland water, actual water samples (as opposed to synthesized brines) should be used in any such tests.

A Proposed Explanation of Continued Favorable ReInjection in Magmamax #3

If the water is being contained within the interval 2618-3076 feet, and not going elsewhere, and if precipitated silica and other solids are redissolving at high temperatures, it is possible that the injected suspended solids solubilize during the periods when Magmamax #3 is shut in. The injection well normally is in use for about 1000 hours (about 42 days), after which the well is shut in for periods of 2-4 weeks while portions of the heat extraction plant equipment are overhauled for scale removal, etc. During this 2-4 week period, the injection zone, which had been cooled during sustained injection,⁽⁹⁾ can re-heat to static reservoir temperature.⁽¹⁶⁾ (Static reservoir temperature is $\approx$ 540-570°F.) Any soluble components of a "damage collar" would go into solution. If a large portion of solids were

*Further testing was suspended because of the corrosion damage to the equipment.

to redissolve, the formation of a damage collar capable of causing significant impairment would be unlikely.

If this were indeed the case, one possible means of low-cost reinjection would center around a plant having minimal surface water treating facilities, i.e., settling tanks, and using two widely-spaced reinjection wells in an alternating mode. Such a system would also minimize the amount of surface wastes, the disposal of which is parasitic to the overall generation cost of electric power.

Just how much heating of the water takes place at any distance from the well while injecting needs to be assessed. One model⁽¹⁵⁾ provides a means of estimating cylindrical isotherms around an injection well, but the model assumes constant specific injection rates into an injection zone 505 feet thick. The injection zone in Magmamax #3 grosses 458 feet, but nets about 170 feet, and is heavily layered with sections which do not accept any appreciable amounts of injected water. Thus, the information from the model in reference (15) provides good insight, but the dissimilarities between the model and Magmamax #3 preclude any quantitative use of the data.

The solubilization explanation must be viewed as being conjectural at this time; a good part of the rationale depends on knowing exactly where the water is being injected, which is currently subject to speculation.

Recommended Additional Tests and Data Requirements

Several items in the Magmamax #3 reinjection system are either speculative or poorly defined. In order to solidify the study of this system, the following procedures are recommended:

- (1) Run a continuous temperature survey, top to bottom, of Magmamax #3 at intervals of 1, 4, 8 and 24 hours after shut-in following a

period of sustained injection to define the water injection zones.

- (or) (2) Inject radio-tagged water (viz, iodine isotope) and run a radio tracer log while injecting, from top to bottom, to define the water injection zones.
- (3) Run a pressure fall-off test⁽¹⁴⁾ to determine the apparent kh of the injection well.
- (4) Prepare a detailed histogram of Magmamax #3 to see if any injectivity improvement has been observed after periods of sustained shut-in.
- (5) Run stabilized injection tests at rates higher and lower (Ca 10,000 b/d, 20,000 b/d) to see if the rate-pressure points at these rates agree with the IWPA data.
- (6) Initiate a laboratory study of silica (et.al.) resolubilization at temperatures up to about 550°F, using waters from the Magmamax #3 system.

If the procedures above are authorized and implemented, a more precise evaluation of the Magmamax #3 water treating and injection system can be provided.

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APPENDIX 1

**Champion Chemicals, Inc. Data,
Houston and Los Angeles Offices**

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

April 24, 1978

Mr. Bob Jorda
Completion Technology Company
4200 Westheimer Road
Suite 211
Houston, Texas 77027

Dear Bob:

Attached is a copy of data accumulated at the Magma water test facility we visited March 28 and 29. Also find analysis of millipores, bacteria culture tests, x-ray diffraction and Spectrographic data.

Enclosed please find a similar report from Dave Williams resulting from his work of April 10, 1978 at the same location.

Respectfully,

A handwritten signature in dark ink, appearing to read "Mark Voss", is written over a light background.

Mark Voss

MV/mld
Enclosures

cc: Ben Davis
Dave Williams

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 3-28-78

SAMPLE LOCATION: Clarifier Outlet

FILTER IDENTIFICATION: GP-9

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	1150
2	1830
4	2810
6	3565
6.5	3850
12	
16	
20	

CAKE COLOR:

TOTAL CUMULATIVE VOLUME: 3850 cc

TOTAL SUSPENDED SOLIDS: 116.1 mg/l

COMMENTS:

MILLIPORE FILTER FLOW RATE

DATE: 3-28-78

SAMPLE LOCATION: Clarifier Outlet

FILTER IDENTIFICATION: GP-10

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	1145
2	1810
4	2775
6	3510
9	4385
12	5140
16	6005
20	6740

CAKE COLOR:

TOTAL CUMULATIVE VOLUME: 6740 cc

TOTAL SUSPENDED SOLIDS: 124.2 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 3-28-78

SAMPLE LOCATION: Clarifier Outlet

FILTER IDENTIFICATION: GP-12

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	
2	
4	
6	
9	
12	
16	
20	

CAKE COLOR:

TOTAL CUMULATIVE VOLUME: 3750 cc

TOTAL SUSPENDED SOLIDS: 124.2 mg/l.

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 3-28-78

SAMPLE LOCATION: Clarifier Inlet

FILTER IDENTIFICATION: GP-13

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	
2	
4	
6	
9	
12	
16	
20	

CAKE COLOR:

TOTAL CUMULATIVE VOLUME: 1305 cc

TOTAL SUSPENDED SOLIDS: 276.5 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 3-28-78

SAMPLE LOCATION: Clarifier Outlet

FILTER IDENTIFICATION: GP-11

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	1100
2	1710
4	2615
6	3310
9	4140
12	4855
16	5655
20	6365

CAKE COLOR:

TOTAL CUMULATIVE VOLUME: 6365 cc

TOTAL SUSPENDED SOLIDS: 129.5 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 3-28-78

SAMPLE LOCATION: Wellhead

FILTER IDENTIFICATION: GP-15

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	275
2	440
4	695
6	910
8 ⁴	1180
12	1410
16	1685
20	1945

CAKE COLOR:

TOTAL CUMULATIVE VOLUME: 1945 cc

TOTAL SUSPENDED SOLIDS: 1036.8 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 3-28-78

SAMPLE LOCATION: Wellhead LLL Panel

FILTER IDENTIFICATION: GP-16

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	640
2	960
4	1395
6	1740
9	2170
12	2525
16	2930
20	

CAKE COLOR:

TOTAL CUMULATIVE VOLUME: 2930 cc

TOTAL SUSPENDED SOLIDS: 233.7 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 3-28-78

SAMPLE LOCATION: Wellhead LLL Filter Holder

FILTER IDENTIFICATION: GP-18

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	265
2	425
4	635
6	800
9	1010
12	1185
16	1385
20	

CAKE COLOR:

TOTAL CUMULATIVE VOLUME: 1385 cc

TOTAL SUSPENDED SOLIDS: 2422.5 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 3-29-78

SAMPLE LOCATION: Tank Output

FILTER IDENTIFICATION: GP-19

TEMPERATURE: 180° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	450
2	650
4	945
6	1185
9	1470
12	1710
16	1985
20	

CAKE COLOR:

TOTAL CUMULATIVE VOLUME: 1985 cc

TOTAL SUSPENDED SOLIDS: 876.5 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 3-29-78

SAMPLE LOCATION: Tank Valve

FILTER IDENTIFICATION: GP-22

TEMPERATURE: 180° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	520
2	785
4	1165
6	1480
9	1875
12	2280
16	2635
20	

CAKE COLOR:

TOTAL CUMULATIVE VOLUME: 2635 cc

TOTAL SUSPENDED SOLIDS: 230.5 mg/l

COMMENTS:

GEOHERMAL REINJECTION WELL - SITE M-3

FILTER NO.	SAMPLE LOCATION	(ppm)	% CARBONATES	% IRON COMPOUNDS	% INSOLUBLES
		TOTAL SOLIDS			
GP- 9	Clarifier Outlet	116.1			
GP-10	Clarifier Outlet	124.2	41.6	16.5	41.9
GP-11	Clarifier Outlet	129.5			
GP-12	Clarifier Outlet	124.2			
GP-13	Clarifier Inlet	276.5	38.7	8.7	52.6
GP-15 *	Wellhead	1036.8	28.2	26.5	45.3
GP-15 **					
GP-16	Wellhead LLL Panel	233.7			
GP-18	Wellhead LLL Filter Holder	2422.5			
GP-19	Tank Output	876.5			
GP-22 *	Tank Valve	230.5	22.7	21.2	56.1

* Emission Spectrograph

** X-ray Diffraction

CHAMPION CHEMICALS, INC.

Service Engineer: Mark Voss Date: April 4, 1978

GEOHERMAL TEST FACILITY

Site M-3

Calipatria, California

SULFATE REDUCING BACTERIA COUNT
(Incubated 5 Days)

<u>BOTTLE NUMBER</u>	<u>BACTERIA/ML.</u>	<u>REACTION</u>
1-6	Clarifier Inlet	Negative
1-6	Clarifier Outlet	Negative

Negative results for sulfate reducers are tentative. They will be incubated 28 days. If any results at that time differ from those shown above, they will be reported to you.

Respectfully submitted,

CHAMPION CHEMICALS, INC.

Mark Voss, Chemist

SCR

Spectro-Chemical Research Laboratory, Inc.

4800 West 34th, Suite A-12 Houston, Texas 77092

(713) 682-6738 (713) 682-6739

April 12, 1978

TO: Champion Chemicals, Inc.
P. O. Box 45509
Houston, Texas 77045

ATTENTION: Mr. Richard A. Davis

LABORATORY REPORT NO.: 7513 P. O. No.: Letter of 4-4-78

SAMPLE DESCRIPTION: Samples on millipore filters, RAD 3-123-2,
RAD 3-123-3.

X-ray Diffraction Analysis

Filter ID No GP-15

RAD 3-123-2	Amorphous NaCl	(non-crystalline) 1%±	Major
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April 12, 1978

Spectrographic Analysis (Semi-quantitative)

<u>Element</u>	<u>Wt. %, dry basis</u>	
	<u>RAD 3-123-2</u>	<u>RAD 3-123-3</u>
	(GP-15)	(GP-22)
Barium	.05	-
Calcium	1.	.8
Chloride	4.	3.
Copper	.06	.02
Iron	2.	2.
Lead	.2	.2
Magnesium	<.1	<.1
Manganese	.04	.04
Potassium	.04	.04
Silicon	28.	31.
Sodium	.4	<.1
Strontium	.03	.01
Sulfur	.1	.1
Tin	.07	.05
Zinc	.03	.02

Respectfully submitted,

M. E. Foster
Vice President Spectro-Chemical Research Laboratory, Inc.4800 West 34th, Suite A-12
Houston, Texas 77092

CHAMPION CHEMICALS, INC.

INTER-OFFICE CORRESPONDENCE

To: Ben Davis

Date: April 19, 1978

From: David C. Williams

Subject: Millipore Test Results-
Magma Geothermal Water
Clarification Pilot Unit

Millipore water quality tests were performed on April 10, 1978 at the Magma water clarification test facility near El Centro, California. The tests were performed in accordance with the procedure detailed by Mr. R. M. Jorda. With the approval of Mr. Jorda, the test pressure was decreased to 40 psig to enable the use of a single four-liter reservoir. In addition to duplicate millipore tests of the Eimco clarifier influent, Eimco clarifier effluent, surge tank effluent (setting tank #6), and Livermore mixed-media filter effluent waters, a semi-quantitative metal analysis of the Eimco influent suspended solids was performed (Pacific Spectrographic Labs-emission spectrograph) to identify the chemical nature of the geothermal plant waste water. Test results are attached in tabular form.

Respectfully,

David C. Williams

David C. Williams
Chemist/Technical Services

DCW/mo

Enclosures

cc: Bob Taylor
Mark Voss

RECEIVED

CHAMPION CHEMICALS, INC.
LAWSON, TEXAS

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 4-10-78

SAMPLE LOCATION: Eimco Effluent

FILTER IDENTIFICATION: 1

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	1100
2	1720
4	2610
6	3310
9	3900
12	
16	
20	

CAKE COLOR: gray (flaky)

TOTAL CUMULATIVE VOLUME: 3900 cc

TOTAL SUSPENDED SOLIDS: 38.8 mg/l

COMMENTS: Treatment

5 ppm. Calgon CAT FLOC T

C-35 Clay

0.4 ppm. M-580 (Calgon anionic polymer)

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 4-10-78

SAMPLE LOCATION: Eimco Effluent

FILTER IDENTIFICATION: 2

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 80 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	1100
2	1700
4	2510
6	3150
9	3700
12	
16	
20	

CAKE COLOR: gray (flaky)

TOTAL CUMULATIVE VOLUME: 3700 cc

TOTAL SUSPENDED SOLIDS: 50.3 mg/l

COMMENTS:

Treatment

5 ppm. Calgon CAT FLOC T

C-35 Clay

0.4 ppm. M-580 (Calgon anionic polymer)

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 4-10-78

SAMPLE LOCATION: Eimco Effluent

FILTER IDENTIFICATION: 3

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 40 psig

TIME (min.)	CUMULATIVE VOLUME (cc)
1	800
2	1240
4	1880
6	2370
9	2800
12	3540
16	3850
20	

CAKE COLOR: gray (thick slabs)

TOTAL CUMULATIVE VOLUME: 3850 cc

TOTAL SUSPENDED SOLIDS: 93.9 mg/l

COMMENTS: Treatment
5 ppm. Calgon CAT FLOC T
C-35 Clay

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 4-10-78

SAMPLE LOCATION: Eimco Effluent

FILTER IDENTIFICATION: 4

TEMPERATURE: 175° F

DIFFERENTIAL PRESSURE: 40 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	630
2	1170
4	1790
6	2310
9	2780
12	3580
16	3920
20	

CAKE COLOR: gray (thick slabs)

TOTAL CUMULATIVE VOLUME: 3920

TOTAL SUSPENDED SOLIDS: 81.8 mg/l

COMMENTS: Treatment
5 ppm. Calgon CAT FLOC T
C-35 Clay

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 4-10-78

SAMPLE LOCATION: Livermore Mixed Media Filter Effluent

FILTER IDENTIFICATION: 5

TEMPERATURE: 169° F

DIFFERENTIAL PRESSURE: 40 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	920
2	1900
4	3780
6	
9	
12	
16	
20	

CAKE COLOR: tan (grain)

TOTAL CUMULATIVE VOLUME: 4000 cc

TOTAL SUSPENDED SOLIDS: 1.9 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 4-10-78

SAMPLE LOCATION: Livermore Mixed Media Effluent

FILTER IDENTIFICATION: 6

TEMPERATURE: 169° F

DIFFERENTIAL PRESSURE: 40 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	880
2	1900
4	3800
6	
9	
12	
16	
20	

CAKE COLOR: tan (grain)

TOTAL CUMULATIVE VOLUME: 4000 cc

TOTAL SUSPENDED SOLIDS: 2.1 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 4-10-78

SAMPLE LOCATION: #6 Surge Tank (inj. H₂O) Effluent

FILTER IDENTIFICATION: 7

TEMPERATURE: 170° F

DIFFERENTIAL PRESSURE: 40 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	600
2	880
4	1330
6	1700
9	1980
12	2520
16	2980
20	3410

CAKE COLOR: tan (thick slabs)

TOTAL CUMULATIVE VOLUME: 3410

TOTAL SUSPENDED SOLIDS: 108.4 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 4-10-78

SAMPLE LOCATION: #6 Surge Tank (inj. H₂O) Effluent

FILTER IDENTIFICATION: 8

TEMPERATURE: 170° F

DIFFERENTIAL PRESSURE: 40 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	580
2	840
4	1300
6	1650
9	1940
12	2450
16	2900
20	3310

CAKE COLOR: tan (thick slabs)

TOTAL CUMULATIVE VOLUME: 3310

TOTAL SUSPENDED SOLIDS: 104.3 mg/l

COMMENTS:

P.O. BOX 45509
HOUSTON, TEXAS 77045

(713) 431-2561
Telex 762-012

MILLIPORE FILTER FLOW RATE

DATE: 4-10-78

SAMPLE LOCATION: Eimco Clarifier Influent (4" line)

FILTER IDENTIFICATION: 9

TEMPERATURE: 185° F

DIFFERENTIAL PRESSURE: 40 psig

<u>TIME (min.)</u>	<u>CUMULATIVE VOLUME (cc)</u>
1	220
2	360
4	560
6	680
9	820
12	1040
16	1230
20	1390

CAKE COLOR: gray - white (flake)

TOTAL CUMULATIVE VOLUME: 1390 cc

TOTAL SUSPENDED SOLIDS: 147.1 mg/l

COMMENTS:

GEOTHERMAL REINJECTION WELL - SITE M-3

FILTER NO.	SAMPLE LOCATION	(ppm)	% CARBONATES	% IRON COMPOUNDS	% INSOLUBLES
		TOTAL SOLIDS			
1	Eimco Effluent	38.8			
2	Eimco Effluent	50.3	4.2	13.5	82.3
3	Eimco Effluent	93.9			
4	Eimco Effluent	81.8			
5	Livermore Mixed Media Filter Effluent	1.9			
6	Livermore Mixed Media Filter Effluent	2.1	52.4	19.0	28.6
7	#6 Surge Tank (inj. H ₂ O) Effluent	108.4			
8	#6 Surge Tank (inj. H ₂ O) Effluent	104.3	19.9	14.1	66.0
9	Eimco Clarifier Influent	147.1			

Champion Chemical Inc.
1604 Missile Way
Anaheim, California 92801

Pacific Spectrochemical Laboratory, Inc.
Chemical and Spectrographic Analysis

2558 Overland Avenue
Los Angeles, California 90064

April 18, 1978

PURCHASE ORDER NO. 1177
DW

SEMIQUANTITATIVE ANALYSIS

	<u>#9</u>
Si-	25.%
K-	2.3
Na-	8.3
Ca-	8.8
Cu-	0.11
Be-	0.0026
B-	0.047
Mn-	0.11
Fe-	0.27
Pb-	0.61
Mg-	0.030
Ga-	0.0031
Al-	0.11
Li-	0.11
Ag-	0.017
Sr-	0.069
Cr-	0.0026
Other elements	nil
Total Ash Wt.	0.3710 gms.

Respectfully submitted,

PACIFIC SPECTROCHEMICAL LABORATORY, INC.

APPENDIX 2

Correlation Curves for membrane filter
tests at 40 psi and 80 psi differential pressures

CALIBRATION CURVES FOR FINDING w/k_c AT 40 PSI DIFFERENTIAL PRESSURE ACROSS MEMBRANE

CALIBRATION CURVES FOR FINDING w/k_c AT 80 PSI DIFFERENTIAL ACROSS MEMBRANE

APPENDIX 3

Millipore filter data recorded during periods of apparent
upsets in the Niland injection water treating system

Date 3/28/78 Water temp 175 °F

Differential pressure 80 p.s.i.

Sample point & pertinent data MagmaMax #3

Injection well head. Stream about 90 per cent water
from settling tanks, 10 per cent Eimco treated water,

Natural sludge bed. Filter ID No. GP-15. System
apparently upset.

Time
minutes

Cum. Vol.
cu. cm.

1	275
2	440
4	695
6	910
9	1180
12	1410
16	1685
20	1945

CALCULATION

1. Volume at 16 minutes 1685 cc
2. Volume at 9 minutes 1180 cc
3. Difference (slope) 505 cc/√min (1-2)
4. Water quality ratio 2500 ppm/md (from graph)
5. Solids content 1036.8 ppm
6. Cake permeability 0.41 md (5+4)
7. HAC soluble 28.2 % HCl soluble 26.5 % Insoluble 45.3 %

Date 3/28/78 Water temp 175 °F

Differential pressure 80 p.s.i.

Sample point & pertinent data Magmamax #3.

Injection well stream, LLL panel and filter holder.

Stream about 90 per cent tank water, 10 percent Eimco

treated water, natural sludge. Filter ID No. GP-18

System apparently upset.

Time
minutes

Cum. Vol.
cu. cm.

1

265

2

425

4

635

6

800

9

1010

12

1185

16

1385

20

CALCULATION

1. Volume at 16 minutes 1385 cc

2. Volume at 9 minutes 1010 cc

3. Difference (slope) 375 cc/√min (1-2)

4. Water quality ratio 4000 ppm/md (from graph)

5. Solids content 2422.5 ppm

6. Cake permeability 0.61 md (5+4)

7. HAc soluble ND % HCl soluble ND % Insoluble ND %

Date 3/29/78 Water temp 180 °F

Differential pressure 80 p.s.i.

Sample point & pertinent data Settling tank
output. Cake color brown. System apparently upset.

Filter ID No. GP-19.

Time
minutes

Cum. Vol.
cu. cm.

1

450

2

650

4

945

6

1185

9

1470

12

1710

16

1985

20

CALCULATION

1. Volume at 16 minutes 1985 cc
2. Volume at 9 minutes 1470 cc
3. Difference (slope) 515 cc/ $\sqrt{\text{min}}$ (1-2)
4. Water quality ratio 2500 ppm/md (from graph)
5. Solids content 876.5 ppm
6. Cake permeability 0.35 md (5+4)
7. HAc soluble ND % HCl soluble ND % Insoluble ND %