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An Assessment of the Injectability of Conditioned Brine Produced by a Reaction Clarification -- Gravity Filtration System in Operation at the Salton Sea Geothermal Field, Southern California.

L. B. Owen, E. Raber, C. Otto, R. Netherton, R. Neurath, and L. Allen

November 28, 1979

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An Assessment of the Injectability of Conditioned Brine
Produced by a Reaction Clarification -- Gravity Filtration System
in Operation at the Salton Sea Geothermal Field, Southern California

L.B. Owen, E. Raber, C. Otto, R. Netherton, R. Neurath and L. Allen

ABSTRACT

A Demonstration Reaction Clarifier -- Gravity Filtration System with a 1600 GPM throughput capability was in operation at the joint DOE-SDG&E-MAGMA test facility located in the Salton Sea Geothermal Field, Southern California, during the summer of 1979. The system, which was designed to condition spent effluent from a 10 MWe-size geothermal power plant, removes supersaturated dissolved species and residual suspended solids from brine prior to subsurface brine disposal via injection wells. We established the post-processing chemical stability of conditioned effluents by means of anaerobic incubation tests at 90°C. The effect of residual dissolved polymer, that might be used for the purpose of scale control in upstream power plant components on the efficiency of reaction clarification, was also evaluated. Membrane filtration and core tests were used to assess the injectability of processed brine.

We found that the clarifier-filter operational procedures and system design permitted oxygenation of the brine by air intrusion. This resulted in partial stabilization of dissolved silica and precipitation of oxides of iron. As a consequence, conditioned brine injectability was poor. However, elimination of the air intrusion problem would result in a substantial improvement in brine quality. Residual amounts of dissolved polyamino-ethylene (20 ppm, by weight), a powerful antsilica precipitant, in brine was shown, by means of bench-scale tests carried out at ~90°C, to improve the efficiency of the clarification process where the additive appears to function as a flocculant.

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Introduction

An assessment of the injectability of conditioned effluents produced by a 10 MWe-sized demonstration reaction clarification-gravity filtration system was carried out under the auspices of the LLL Geothermal Project's Industrial Support Program. The brine conditioning system, located at the Salton Sea Geothermal Field (SSGF), Southern California, pretreats spent brine effluent from the Geothermal Loop Experimental Facility (GLEF) jointly operated by DOE, San Diego Gas and Electric Co (SDG&E), and Magma Power Co. Brine conditioning is required to prevent impairment of injection wells caused by precipitation of solids and/or deposition of suspended solids in the wellbore or within the injection formation. The brine conditioning system began operation during the summer of 1979.

The clarification process removes supersaturated dissolved species from brine by a process based on sludge contact^{1,2}. The sludge consists of freshly precipitated solids. The clarifier also removes the bulk of suspended particulates from brine by a combined process consisting of sludge-blanket filtration and settling. Dual media gravity filters (sand plus anthracite) are used as polishing filters to remove residual suspended solids present in the overflow from the clarifier. We assessed the injectability of processed effluent by means of isothermal brine incubation tests (90°C), membrane filtration and core tests. The incubation tests were conducted under anerobic conditions to establish the chemical stability of processed effluents. Membrane filtration and core test results were used to estimate the useful life of injection wells receiving processed effluents. The core tests were particularly useful in evaluating the potential detrimental effect of brine-rock interactions that can occur when effluents enter the injection formation.

A considerable effort was expended during FY-1979 in the field evaluation of organic compounds that might be useful as silica scale inhibitors. One compound, the HCl salt of polyaminoethylene (PAE·HCl), was found to significantly affect scaling rates at temperatures of 125°C or less³. The polymer works by stabilizing colloidal silica. We performed additional incubation tests and a bench-scale sludge contact experiment to establish the effect of anti-scaling polymer additions on clarifier performance.

CLARIFIER OPERATIONAL PROCEDURES

The clarifier was sized for 1600 GPM throughput, which is adequate to process full flow from two production wells. During the evaluation period, it was not possible for the GLEF operators to maintain two well flow because of difficulties with the Woolsey No. 1 well. As a consequence, the clarifier initially was operated at 50% of its design capacity and, as a result, effluent quality was significantly degraded. The major difficulty was attributed to partial collapse of the sludge blanket.

As an expedient remedial measure, 50 to 60 percent of the clarifier overflow was recycled to boost the average throughput rate in the unit. This procedure resulted in oxygenation of the brine due to air intrusion. Other sources of brine aeration were also subsequently identified. The result of air contamination was precipitation of ferric iron in the form of a hydroxide:

The formation of ferric iron is followed by the hydrolysis reaction:

The net effect is formation of a light flocculant iron-rich precipitate and reduction of brine pH. The pH decrease in turn causes partial stabilization of dissolved silica. Therefore, brine aeration not only results in production of new precipitates but also interferes with the ability of the reaction clarifier to reduce dissolved silica to saturation at the processing temperature.

Experimental

Incubation Tests. Brine incubation tests were carried out under anerobic and isothermal conditions to establish the potential for post processing formation of new suspended solids. Three types of samples were evaluated; clarifier influent, clarifier effluent and gravity filter effluent. Samples were collected in an insulated container and then transferred to 50 ml bottles for incubation at 86-90°C. Following incubation for periods ranging from 15 minutes to 48 hours, samples were filtered through 1.0 μ m Nucleopore membrane filters. The filtrate was stabilized with 1% HCl and then analyzed for total dissolved silica by atomic absorbtion. Suspended solids concentration was obtained by noting the weight change of the membrane filters. Composition of suspended solids was obtained by subsequent analysis of the filtered solids.

Polymer Experiments

The effect of 20 ppm (by weight) of PAE·HCl polymer on dissolved silica in clarifier influent was established by incubation tests at 90°C. A jar testing apparatus was used to study the effect of 20 ppm PAE·HCl polymer on clarifier performance. Brine samples containing the polymer, while maintained at 86-90°C, were mixed at a constant speed of 100 RPM in the presence of 10 volume percent sludge obtained from the clarifier. Aliquots of the mixture were then removed, over a time interval ranging from five minutes to one hour, for subsequent analysis of total dissolved silica by the atomic absorbtion method described earlier.

Brine Injectability Tests

A newly developed automated system for membrane filter and core testing was used to obtain data on spent brine injectability⁴. Effluent from the gravity filtration system at 101°C and at 500 PSI was fed into a specially equipped air-conditioned van. Initial filter tests were performed with 0.4, 1.0 and 8.0 μ m pore size nucleopore membrane filters on as received brine. Additional tests using 0.4 and 8.0 μ m membrane filters were also performed with an 1.0 μ m pore size Cuno cartridge filter inserted in the sampling line upstream of the membrane filters. All membrane filter tests were carried

out at constant differential pressure. The 0.4 and 1.0 μm membrane filter were operated at 50 psi differential pressure and the 8 μm membrane filter tests were run at 10 psi differential pressure. The duration of all filter tests was one-half hour.

For the core test, a one-inch (OD) diameter by four-inch long right circular cylinder of Kayenta sandstone was exposed to brine at 101°C and 20 psi differential pressure. Kayenta sandstone is a reasonably good analog of typical upper SSGF reservoir sands. The permeability and porosity of the core were 1050 md and 20 percent, respectively. A confining pressure of 500 psi was applied to the core via a heated (100°C) oil bath. The first 1500 pore volumes (1PV $\approx$ 10 ml) of flow through the core was prefiltered with a 1 μm pore size Cuno cartridge filter. The remainder of the flow to the core was not prefiltered.

In general, our automated membrane filter and core test apparatus control system functioned exceedingly well. All system parameters were maintained within ± 2 percent of their set points. Schematic diagrams of the test apparatus are shown in Figures 1-3. A detailed description of the digital control and data acquisition system is provided by Hasbrouck et al⁴.

RESULTS

Incubation tests - As shown in Figure 1, clarifier influent is chemically unstable and appreciable amounts of silica precipitate over a period of 48 hours. Quasi-equilibrium solubility of dissolved silica is 153 ppm (by weight). Although the influent temperature was 101°C, we completed the incubation test at 90°C to avoid the need for more complex autoclave-type experimental apparatus. Since the solubility of silica increases with increasing temperature, it would be desirable to correct the 90°C solubility data to yield the actual silica solubility at 101°C. A complication arises, however, because the solubility of silica is also inversely proportional to brine salinity. We attempted to convert the silica solubility value measured at 90°C to the corresponding value at 101°C using data provided by Harrar et al^{5,6}.

Figure 3. Schematic Diagram of Auxillary System Used to Maintain Constant Confining Pressure on Core Samples. Core Temperature is Maintained via a Heating Rod and Temperature Sensor Inserted into the Oil-Filled Pressure Vessel. Both Confining Pressure and Core Temperature are Maintained by a Digital Controller.

Data for the temperature dependence of silica solubility in Woolsey No. 1 brine (4.10 M Cl; $\rho = 1.666 \text{ g/cm}^3$) over the interval 50 to 90°C was fit by least squares⁵. The best line through six data points is given by:

$$\text{Dissolved Silica (mg/Kg)} = (1.938)(^{\circ}\text{C}) - 14.79 \quad (1)$$

The regression coefficient (r^2) was 0.96. Application of equation (1) indicates that an increase in brine temperature from 90 to 101°C will cause a corresponding increase in silica solubility from 159.6 to 181 mg/Kg (12 percent).

Data for the salinity dependence of silica solubility in Magmamax No. 1 and Magmamax No. 2 brine were also fit by least squares⁶. The corresponding relationships between dissolved silica, brine density and brine chloride content at 90°C are summarized in equations (2) and (3):

$$\text{Dissolved Silica (mg/Kg)}_{90^{\circ}\text{C}} = (-910.88)(-\text{g/cm}^3) + 1226.62; r^2 = 0.54 \quad (2)$$

$$\text{Dissolved Silica (mg/Kg)}_{90^{\circ}\text{C}} = (-9.97)(\text{Cl-Moles/litre}) + 204.08; r^2 = 0.39 \quad (3)$$

For a measured Cl concentration of 4.28M, application of equation (3) leads to an estimated value for dissolved silica at 90°C of 161.4 ppm. The calculated silica solubility is within 5 percent of the measured value of 153 ppm from the incubation test. Applying the 12 percent temperature-correction factor leads to an estimate for dissolved silica in 4.28M brine at 101°C of 176 ± 5 ppm.

The effect of the clarification process on dissolved silica and on the chemical stability of the effluent is shown in Figure 5. A quasi-equilibrium for dissolved silica has been established at 198 ppm. Suspended solids concentration has also been stabilized at between 70-80 ppm, a value equivalent to the nominal concentration of total particulates in the clarifier overflow. We conclude, based on our previous assessment of silica solubility in clarifier influent, that the clarifier effluent remains slightly supersaturated in silica. The apparent stability of the effluent is an artifact resulting from oxygenation of brine caused by recirculation of 50-60 percent of the clarifier overflow and precipitation of ferric iron.

An assessment of the gravity filter effluent, shown in Figure 6, indicates that dissolved silica is still slightly supersaturated (198 ppm). In addition, a new precipitate, consisting primarily of acid soluble iron oxides, forms over a 24-hour period. We were able to detect precipitation of iron because the bulk of the silica-rich particulates were removed by the gravity-filters. Since the brine was weakly acidic, additional precipitation of silica did not contribute significant amounts of suspended solids during the 24-hour incubation period. However, additional silica would eventually precipitate from solution.

Polymer Experiments - A considerable effort has been devoted to an assessment of potential silica scale inhibitors by LLL geothermal project personnel. One concern relative to the use of silica-inhibitors involves the potential for interference with the subsequent brine clarification process. We have already seen how a potent silica antiscalent like hydrochloric acid (in this case produced indirectly by oxidation of ferrous iron) can interfere with the clarification process. We therefore selected the most potent organic silica antiscalent compound identified to date for evaluation of its effect on sludge-contact removal of silica. Silica precipitation from clarifier influent (at 90°C) treated with 20 ppm of the hydrochloride salt of polyaminoethylene (PAE·HCl) is significantly retarded (Figure 7). Results of our bench-scale evaluation of sludge-contact destabilization of dissolved silica (90°C) in clarifier influent are summarized in Figure 8. Sludge-contact reduces dissolved silica in brine to near equilibrium in one hour while silica in untreated brine requires about 24 hours to reach the same level.

The effect of 20 ppm of the polymer PAE·HCl on the sludge-contact destabilization of silica is summarized in Figure 9. Silica in polymer-treated brine is more rapidly removed relative to the nominal rate of silica removal in raw brine contacted with sludge. The accelerating rate of silica precipitation in polymer-treated brine probably results from flocculation of "large" silica particulates by residual dissolved polymer. Thus, we can conclude, at least in the case of PAE·HCl, that polymer treatment of brine for scale control purposes also has the potential for improving the efficiency of the subsequent clarification process.

Brine Injectability Tests

A modified version of a method described by Barkman and Davidson for assessing fluid injectability, based on membrane filtration or core data, was employed to evaluate the injectability of processed effluent⁷. In the Barkman and Davidson method, 0.45 μm pore size membrane filters or core samples are exposed to fluid at constant differential pressure. The hydraulic properties of the surface or internal cake formed by deposition of suspended solids or scaling of the porous structure under test are measured and then used to estimate fluid injectability. Analytic models are presented for use in calculating an injection well half-life for various assumed impairment mechanisms. The half-life is defined as the time required for the injection rate to fall to one-half of its initial rate at constant pressure. The most useful impairment models for this geothermal application are wellbore narrowing, which accounts for deposition of solids on the sandface in the injection interval, and invasion which accounts for migration of suspended solids into the injection formation to distances greater than five wellbore radii from the injection well.

In the case of a geothermal reservoir with high porosity ($\geq 20\%$) and primary and secondary permeability, it is obvious that a 0.45 μm membrane filter cannot be used as a realistic analog of an injection interval. We employed a method described by Champlin et al. to estimate the average pore diameter of a porous matrix with 20 percent porosity and 500 md permeability⁸. According to Champlin et al., the largest diameter particle capable of passing through a given porous medium is about 25 percent smaller than the average pore size given by:

$$M = 4 \left[\frac{1 - \phi}{\left(\frac{\phi \times 10^3}{5K} \right)^{\frac{1}{2}}} \right] \quad \text{Eq. (4)}$$

where M is the mean Pore diameter, (μm), ϕ is the fractional porosity and K is the permeability (Md).

We calculated a mean Pore diameter for the injection zone into which pretreated brine was injected of 11.3 μm based on a formation porosity and permeability of 20 percent and 500 md, respectively. Using the 25 percent criteria, we selected 8.0 μm membrane filters as conservative analogs of the injection interval. However, additional tests were run with 0.4 μm membrane filters in order to produce comparative data and to obtain data on total suspended solids in the gravity filter effluent. The assumptions used to calculate injection well half-lives are summarized in Table 1.

Table 1. Basis for Half-life Calculations

Density filter cake	2.0 g/cc
Density brine	1.17 g/cc
Density filter cake/density brine	1.71
X-sectional area of membrane filter	9.62 cm^2
X-sectional area of core	5.07 cm^2
Radius well	0.325 ft
Radius core	0.0417 ft
Brine viscosity	0.5 cp
Injection interval	400 ft
Injection rate	41,143 BLD
Core flow rate	0.679 BLD
Formation permeability	500 MD
Core permeability	1050 MD

Half-life Calculations - The half-life is computed as the product:

$$T_{1/2} = F \times G_{1/2} \quad \text{Eq. (5)}$$

where F is proportional to the time required to fill one wellbore volume with solids and $G_{1/2}$ is an adjustment factor related to the impairment mechanism. F is independent of the impairment process and is defined as:

$$F \text{ sec} = \frac{r_w^2 \cdot h \cdot P_c/P_w}{i_o \cdot w} \quad \text{Eq. (6)}$$

where: r_w = radius of wellbore (m)
 h = injection interval length (m)
 P_c = density of filter cake (g/cm^3)
 P_w = density of water (g/cm^3)
 i_o = injection rate (m^3/sec)
 w = concentration suspended solids (g/g)

$$\text{invasion: } G_{\frac{1}{2}} = 3 \phi^2 (Kc/Kf) (ra/rw)^2 (\ln re/rw) \quad \text{Eq. (10)}$$

where:

ϕ = fractional formation porosity

ra = invasion radius

We used the following forms of equations 7-10 to evaluate our experimental data:

$$F \text{ yrs} = 2.489/W(\mu\text{g/g}) \quad \text{Eq (11)}$$

$$\frac{W}{Kc} = \frac{2.584 \times 10^6 \cdot \Delta P_t \text{ (PSI)}}{S^2} \quad \text{Eq (12)}$$

$$\frac{W}{Kc} = \frac{7.170 \times 10^5 \cdot \Delta P_t \text{ (PSI)}}{S^2} \quad \text{Eq (13)}$$

$$G_{\frac{1}{2}} \approx 22.13 (Kc/Kf) \quad \text{Eq (14)}$$

$$G_{\frac{1}{2}} \approx 906.6 (Kc/Kf) \quad \text{Eq (15)}$$

Equation 12 and 13 were used for the analysis of membrane filter and core data respectively. Equation 14 was used for the case of wellbore narrowing and equation 15 accounted for invasion. In the case of invasion, we assumed a radius of effect of 500 feet and an invasion radius of 10 feet.

Membrane Filtration Test Results - In general, the quality of effluent produced by the large gravity filtration system was poor. It was not possible to pass more than about 10 litres of brine through 0.4, 1.0 or 8.0 μm membrane filters during a 30 minute test interval (Figures 11-12). The 0.4 and 1.0 μm membrane filters performed in essentially identical fashion, but a significantly smaller volume was passed through the 8.0 μm filter. The use of a 1 μm pore size cartridge filter upstream of the membrane filters substantially improved brine quality. Suspended solids data and half-life calculations derived from the membrane filter tests are summarized in Table 2.

The quality of brine produced by the gravity filters is poor because of a relatively high concentration of suspended particulates in the filter effluent (5-10 ppm) and a tendency for precipitation of iron from the conditioned brine. The estimated half-life of a typical injection well receiving conditioned brine at a rate of 41,143 BD based on the 8 μm membrane filtration test, is about two months. The use of a cartridge prefilter improves the 8 μm -based half-life estimate by an order of magnitude (2 years). If we assume that the fine particulates passing through the cartridge filter would invade the injection zone to a distance of 10 feet from the wellbore, the half-life estimate increases by another order of magnitude to more than 80 years. As noted earlier, the poor performance of the brine conditioning system is a result of inadvertent oxygenation of the brine. If the conditioning system were operating at its design optimum, the injectability of the brine would be equivalent to the effluent produced by our small 1 μm pore size cartridge filter.

Core Test Results - The 8 μm membrane filter test data suggested that effluent from the gravity filters would impair a core sample by deposition of suspended solids and precipitation of iron and silica. We anticipated additional silica precipitation would occur when the weakly acidic silica supersaturated effluent was partially neutralized by reaction with

carbonate-rich minerals in the core sample. The core was, therefore, initially feed 1 μm cartridge prefiltered brine. As shown in Figure 13, core permeability remains constant for the first 1550 litres of throughput. Core permeability then began to rapidly decline. The cartridge prefilter was bypassed after about 2600 pore volumes had been passed. At that time, the system was shut-in for less than an hour while the gravity filters were backwashed. When flow resumed, we observed a partial recovery of core permeability. However, permeability rapidly declined. We observed a similar partial recovery of permeability after the core had been shut-in, (at about 3200 pore volumes) for another gravity filter backwashing cycle. Permeability again declined rapidly with resumption of flow. The reason for the apparent recovery of permeability after gravity filter backwashing cycles is not known. Possibly, the quality of filtered brine substantially improves immediately following a backwash cycle.

The core test results are summarized in Table 2. A pH change was observed across the core. Influent pH was usually about 5.0. The core effluent pH increased to 5.2 - 5.3. For the purposes of half-life calculations, a suspended solids concentration of 0.03 ppm was assumed for the influent. This value for suspended solids was based on results of our 0.4 μm membrane filtration test of prefiltered brine. The calculated half-life was about two months. A second calculation based on the first 1500 pore volumes of core throughput yield a half-life in excess of 60 years.

Post mortums on the core established that impairment resulted from deposition of iron- and silica-rich solids on the sandface. The deposits did not penetrate more than an inch into the core. As shown in Figure 14, no deposits were present on the perforated disc placed on the inlet surface of the core as an analog of a slotted liner.

Conclusions

The quality of brine effluent produced by a 1600 GPM-capacity demonstration reaction clarifier-gravity filtration system was significantly degraded by operational procedures that caused partial oxygenation of the brine. Resulting oxidation of ferrous iron caused a decrease in brine pH and partial stabilization of dissolved silica. The slow formation of flocculant iron-rich precipitates increased the impairment potential of the brine. Our incubation, membrane filtration and core test results suggest that elimination of brine oxygenation would result in production of a highly injectable effluent. The application of organic polymer compounds, such as PAE·HCl, for the purposes of scale inhibition may result in significant improvements in the efficiency of the sludge-contact process for removal of supersaturated silica from brine.

A more convenient form of equation 6 is:

$$F \text{ yrs} = \frac{1533 \cdot r^2 \cdot h \cdot P_c/P_w}{i_o \cdot W} \quad \text{Eq. (7)}$$

where r and h are in feet and i_o is in barrels per day.

The permeability of the filter cake formed by deposition of suspended solids or scaling must be known in order to calculate the $G_{\frac{1}{2}}$ -factor. Filter cake permeability is obtained from a measurement of the water quality ratio. The water quality ratio (W/K_c) is defined as:

$$\frac{W}{K_c} = \frac{1.20 \times 10^5}{S^2} \frac{(\rho_c/\rho_w) \cdot A_c^2 \cdot \Delta P_t}{\mu} \quad \text{Eq. (8)}$$

where:

- w = concentration suspended solids ($\mu\text{g/g}$)
- K_c = permeability of filter cake (Md)
- ρ_c = density of filter cake (g/cm^3)
- ρ_w = density of water (g/cm^3)
- ΔP_t = pressure drop across membrane filter or core (Atm)
- A_c = area of membrane filter or core exposed to brine (cm^2)
- S = slope of linear portion of filtration curve ($\text{Ml}/\sqrt{\text{min}}$)
- μ = water viscosity (cp)

S is obtained by regression of the linear portion of the filtration curve plotted in coordinates of cumulative flow (ordinate) vs $(\text{time})^{\frac{1}{2}}$. An example of a typical filtration curve is provided in Figure 10. The sign of the intercept formed by extrapolation of the linear portion of the filtration curve indicates whether the porous medium under test has been invaded by fine particulates (positive intercept) or whether solids have formed a surface cake (negative intercept).

We calculated $G_{\frac{1}{2}}$ for the case of wellbore narrowing and invasion:

$$\text{wellbore narrowing: } G_{\frac{1}{2}} = 3 \cdot (K_c/K_f) \cdot \ln(r_e/r_w) \quad \text{Eq. (9)}$$

where:

- K_f = formation permeability (md)
- r_e = radius of effect
- r_w = radius of well

Table 2. Results of membrane filtration and core tests of gravity filter effluent

Filter Size (μm)	1 μm Cuno cartridge prefilter	ΔP (PSI)	Suspended solids (mg/l)	Slope ¹ (L/min)	Intercept (L)	W/Kc (ppm/Md)	Kc (Md)	F (yrs)	$G_{1/2}$	$T_{1/2}$ (Yrs)
0.4	no	50	9.09	2.275	-1.636	24.963	0.364	0.274	0.0161	0.004
1.0	no	50	5.21	2.394	-1.902	22.543	0.231	0.478	0.0102	0.005
0.14	yes	50	0.03	11.907	-17.408	0.911	0.033	82.97	0.0015	0.12
8.0	no	10	8.03	1.033	0.673	24.214	0.332	0.310	0.602	0.19
8.0	yes	10	0.10	21.725	-41.008	0.055	0.182	248.90 248.90	0.0081 0.330	2.01 82.1 ²
Kayenta Sandstone core	yes	20	0.03 ³	0.718	10.590	27.816 0.073	0.001 0.410	82.97 82.97	0.0020 0.743	0.17 ⁴ 61.7 ⁵

1 Linear regression "goodness of fit" R^2 factor 1.00 for all runs.

2 Assumes 10 foot invasion radius.

3 Assumed concentration of suspended solids.

4 Half-life based on first 2500 pore volumes through core.

5 Half-life based on first 1500 pore volumes through core.

CLARIFIER INFLUENT INCUBATION TEST RESULTS (90C)
AUGUST 1, 1967

Figure 4

CLARIFIER EFFLUENT INCUBATION TEST RESULTS (86-88C)
AUGUST 1, 1979

Figure 5

GRAVITY FILTER EFFLUENT INCUBATION TEST RESULTS (86-88C)
AUGUST 1, 1979

Figure 6

EFFECT OF POLYMER ON STABILITY OF CLARIFIER INFLUENT (85-90C)
AUGUST 1-2, 1979

Figure 7

SLUDGE CONTACT DESTABILIZATION OF SILICA IN CLARIFIER INFLUENT (85-90C)
AUGUST 1-2, 1979

Figure 8

EFFECT OF POLYMER ON SLUDGE CONTACT DESTABILIZATION OF SILICA (85-90C)
AUGUST 1-2, 1979

Figure 9

BARKMAN AND DAVIDSON-TYPE FILTRATION CURVE
FOR KAYENTA SANDSTONE SHOWING INVASION

Figure 10

MEMBRANE FILTRATION TESTS OF CONDITIONED BRINE
MAGMA POWER CLARIFIER-FILTRATION SYSTEM
AUGUST 8, 1979

BRINE DIRECTLY FROM MAGMA FILTERS

PREFILTERED BRINE FROM MAGMA FILTERS

0.4 MICRON: ---
1.0 MICRON: -O-

0.4 MICRON: -*-

Figure 11

8 MICRON MEMBRANE FILTRATION TEST RESULTS
FOR CONDITIONED BRINE FROM MAGMA POWER'S
CLARIFIER-FILTER SYSTEM
(AUGUST 8, 1979)

Figure 12

PERMEABILITY OF KAYENTA SANDSTONE TO CONDITIONED BRINE FROM
THE MAGMA POWER CLARIFIER-FILTRATION SYSTEM

Figure 13

Figure 14. Core Sample Exposed to Conditioned Brine Produced by the 10 MWe Clarifier-Filtration System.

The core was plugged by a deposit of iron and silica-rich solids that formed on its upper surface. The solids did not form scale on the steel perforated disc placed on the upper surface of the core. The disc was used as an analog of a downhole injection well completion liner.

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