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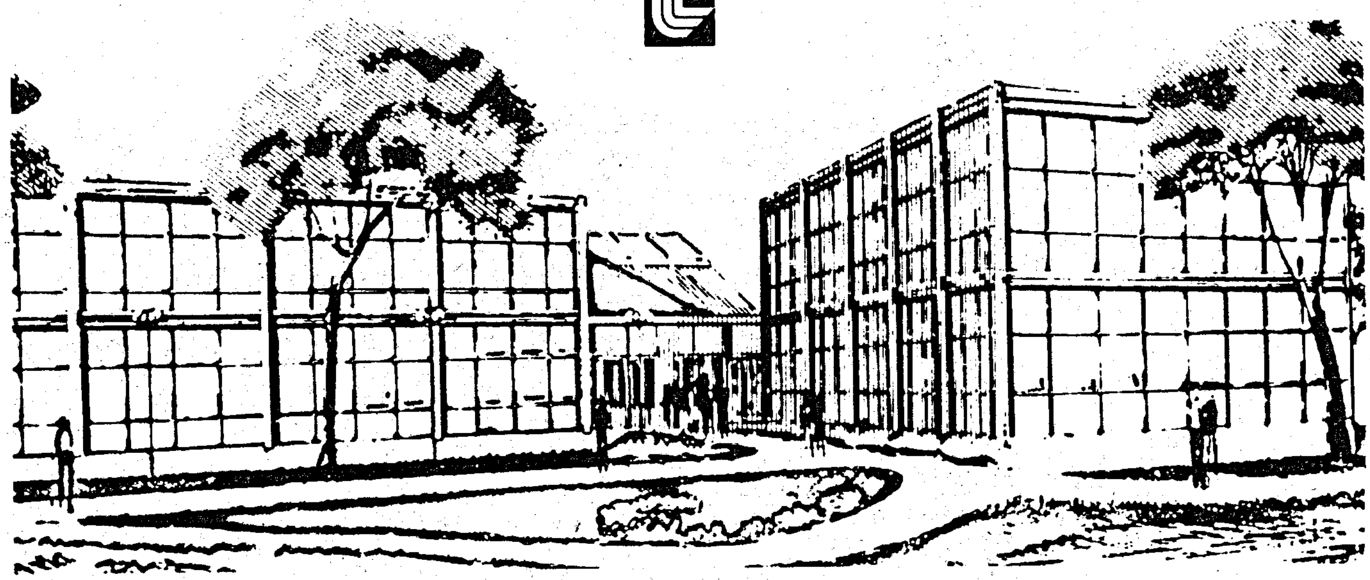

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PROCESSING OF GEOTHERMAL BRINE EFFLUENTS FOR INJECTION

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ABSTRACT

The handling and disposal of brine effluents is a critical part of any geothermal conversion process. Brine effluents from the San Diego Gas & Electric/Department of Energy - Geothermal Loop Experimental Facility were characterized for particulate concentration and chemical composition. Bench scale tests were conducted with inorganic and organic coagulants as a means of enhancing the sedimentation process for separation and removal of suspended solids, principally amorphous silica. The effects of temperature, retention time, and pH on the precipitation of supersaturated silica, subsequent floc settling properties, and supernatant clarity were also determined. A design of a pilot scale clarifier, now undergoing testing is also described.

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Introduction

An important consideration in geothermal development projects is the handling and disposal of spent brine effluents. At the SDG&E/DOE Geothermal Loop Experimental Facility (GLEF) located in the Imperial Valley, California, spent brine is discharged from the 4-stage flash process and injected back into the formation via an injection well, Magmamax #3.

In the GLEF process, brine containing 20% total dissolved solids is flashed successively from a reservoir temperature of 300°C to the process exit temperature of 90°C. Evolution of the steam phase concentrates the brine by ~ 25%, while evolved CO_2 gas elevates the brine pH to ~ 5.5 All of these factors contribute to producing a supersaturated brine in metal sulfides, carbonates, and amorphous silica. The resultant solids precipitation has reduced considerably the injectivity of the injection well. Extensive rework of the well has been required. (Nugent & Vick; SDG&E bimonthly reports).

Effluent Solids Characterization

The actual concentration and chemical composition of the particulates depend on the method of steam condensate disposal for a given brine (Table 1). In previous measurements suspended solids concentrations in brine effluents in combination with high pH condensate were found to be as high as 480 ppm (Quong, Bishop, and Hill). Prior to recombination, if the pH of the steam condensate is lowered to pH 5 from pH 6.7 in the first stage and as high as pH 9-10 in the 4th stage, the production of suspended solids can be significantly reduced (Table 1). However, brine effluent injection without condensate is now the preferred mode of operation. This best simulates large scale operation in which cooling water makeup becomes a critical requirement, which can be satisfied through use of steam condensate.

The principal constituent in the brine effluents without condesate recombination is amorphous silica. Initially, silica concentration in Magmamax #1 brine is 500 ppm. This drops to ~ 300 ppm after the flash process and the transit time to the injection wellhead. Brine effluent in open containers without agitation collected at the injection wellhead and held at 90°C will continue to precipitate silica, reaching an equilibrium concentration of roughly 200 ppm in 2-3 hours. The necessary steps for effluent treatment become reasonably clear - namely separate and remove the particulates and produce a fluid that is not supersaturated in any species which would precipitate in the formation and impair injection longevity.

Coagulants and Coagulant Aids

An integral part of a process for removal of colloidal solids is the use of chemical coagulants. The role of these additives is to: 1) destabilize the colloids through neutralization of surface charge. By reducing mutual repulsive forces, particles can approach sufficiently close to allow attractive forces to become effective for particle agglomeration. 2) adsorb and attach onto colloidal particles. This bridging action is an important factor in particle destabilization and aggregation.

The most commonly used coagulants are inorganic: $FeCl_3$, $Fe_2(SO_4)_3$, MgO, and $Al_2(SO_4)_3$. Organic polymers or polyelectrolytes are also used with greater frequency and success. In general these compounds have been used or developed primarily for removal of turbidity and colloidially dispersed solids from ambient temperature, low

TABLE 1

Chemical Composition, Concentration, and Mineralogy of
Suspended Solids in Brine Effluent -
GLEF Operation with Magmamax #1 Brine

ELEMENT[(a)]	NO CONDENSATE COMBINATION (CONCENTRATION, %)	ACIDIFIED CONDENSATE AND COMBINATION (CONCENTRATION, %)
Si	40.5	14
S	0.2	5.7
Pb	0.14	40.0
K	0.2	0.7
Ca	0.65	1.9
Mn	0.06	-
Fe	4.0	4.6
Cu	0.15	3.3
Zn	0.15	-
Suspended Solids Concentration, ppm	178	25
Mineralogy[(b)]	Amorphous Silica	Amorphous silica Galena, PbS possibly - Pb(OH)Cl $Pb_3(Co_3)_2(OH)_2$

(a) by X-ray fluorescence analysis, R. W. Ryon (LLL)

(b) by X-ray diffraction analysis, M. A. Chan (LLL)

salinity waters that are commonly encountered in municipal water and sewage systems. Their effectiveness in the higher temperature, high salinity Niland brines is virtually unknown.

As a result, commercially available inorganic and organic coagulants were tested individually and in combination at different concentrations, pH, and temperatures in GLEF effluent. Time was also a factor since silica precipitates continuously. Testing was conducted with conventional jar testing apparatus. The data acquired to date lead to the following conclusions.

Control Samples (pH ~ 5.5, Temp 85°C), without additive
- Agitation significantly aids coagulation and flocculation of colloidal solids in spent geothermal brines.

Effect of Temperature
- Temperature in the range of 40°C to 85°C does not appear to benefit or impair the effectiveness of a coagulant.

Post precipitation
- At brine pH of 5.5 without aging, supernatants remain supersaturated, and cloud with silica post precipitation. Coagulants do not help to increase the rate of removal of dissolved silica.

Effect of Aging
- Retention of brine for 2 hours reduces silica concentration nearly to saturation levels, but does not improve ultimate floc characteristics.

Effect of pH
- Elevating the brine pH to 5.9 drops silica concentration rapidly to saturation levels (Table 2). Floc particles settle well. Supernatant clouds with $Fe(OH)_3$ post precipitation.

TABLE 2

Effect of NaOH Addition on
Silica Concentration in Brine
Effluent from the GLEF

NaOH Added ppm	pH	SiO_2 concentration, ppm, in supernatant @ 30 minutes
0	5.5	236
25	5.9	199
75	6.0	185
125	6.2	162

Polyelectrolytes
- Organic coagulants, particularly cationic are somewhat beneficial. Effectiveness is significantly improved when used in combination with sludge recycle. Approximately 10 ppm of the polymer is sufficent.

Inorganic Coagulants
- These are slightly beneficial. $Fe_2(SO_4)_3$ at ~ 100 ppm does the best job among the inorganic additives. Again, improvement is found when used with sludge recycle.

These tests have provided us with significant insight into the benefits and limitations of chemical additives. At the present, a pilot scale clarifier is being tested as a means of removing suspended solids from the brine effluent (Figure 1). The process includes one or a combination of: addition of coagulant, pH adjustment, sludge recycle, and flow through the sludge layer or "blanket." Tests with an 11 ft^2 precoat pressure filtration unit with backwash indicate technical feasibility for polishing the clarifier overflow stream to 1 ppm residual solids. The economic feasibility will be compared with mixed media sand filters when the data is acquired.

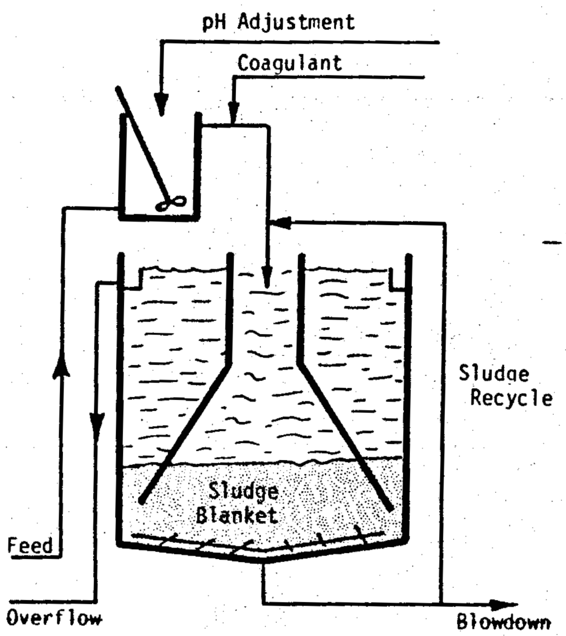

Figure 1. Schematic of Pilot Scale Clarifier Under Test For Removal of Suspended Solids From Niland Brine Effluents

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