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ASSESSMENT OF THE INJECTABILITY OF BRINES PRODUCED BY GEOPRESSURED-GEOTHERMAL RESOURCES OF THE GULF COAST

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ABSTRACT

A mobile, field test system has been developed for on-line evaluation of geopressured brine injectability at elevated pressures and temperatures. The apparatus consists of a flow system that is connected directly to the well-site brine-handling equipment. The system permits injectability assessment on the basis of standard membrane filtration tests and an examination of the effects of brine aging by means of incubation tests. Auxiliary instrumentation are used to characterize the brine suspended solids. The test system is being used to diagnose water quality at the design wells of the U.S. Department of Energy.

INTRODUCTION

Disposal of the spent brine is one of the most important aspects of the utilization of geopressured-geothermal resources. Typical geopressured wells are expected to produce in excess of 20,000 barrels of brine per day, and subsurface injection of such large quantities of fluid will require careful monitoring to ensure high brine quality (i.e., low suspended solids levels), especially if scale- and corrosion-inhibitor programs are employed.

The objective of the work reported here was to develop a state-of-the-art system for injectability testing and apply the system in conjunction with flow tests at appropriate geopressured-geothermal wells to assess the fluid quality. The primary measurement is an adaptation of standard membrane filtration tests (National Association of Corrosion Engineers, 1973), in which the permeability of a filter that is an analog of the injection formation is monitored. The permeability behavior, which is related to the properties of the solids cake that is formed on the filter, can be interpreted in terms of the characteristics of the disposal well to estimate its useful lifetime (Barkman and Davidson, 1972). These techniques are utilized routinely in the oil and gas industry, and more recently have been applied to geothermal effluents (Owen et al, 1977; Tewhey et al, 1978; Raber et al, 1979) and to brines at Strategic Petroleum Reserve sites (Owen and Quong, 1980).

In addition to injectivity testing components, an autoclave is incorporated into the flow system for capturing a sample of the brine and measuring changes in the fluid as a function of time. Fluids can be sampled at pressures up to 5000 psi and characterized at pressures up to 2000 psi. The maximum temperature of injectivity testing is determined by the material of the membrane filter: $\sim$140°C for polycarbonate and $\sim$200°C for Teflon. Instrumentation are also provided for precise, off-line measurement of brine turbidity and the particle size distribution of the suspended solids.

APPARATUS

Figure 1 is a simplified diagram of the flow system used to assess the injectability of the geopressured brines. The system is a refined and updated version of equipment that we have used previously (Owen et al, 1977; Netherton and Owen, 1978; Hasbrouck and Owen, 1979; Owen et al, 1980). The principal improvements in this system are a wide-range, high-resolution, non-invasive mass flowmeter (Micro-Motion model B12AF), a high-resolution transducer/indicator for differential pressure measurement (Validyne model CD223), a Teflon-lined, stirred autoclave (Berghof cat. no. 7400), and a high-pressure sight glass (Penberthy model 1TU1) for visual observation of the flow of brine into the system. All wetted parts of the system are stainless steel, glass, or Teflon; all tubing is either Inconel 600 or Hastelloy C-276. Included in the flow system is a cartridge filter assembly that can be used to prefilter the test brine to establish the potential benefits of prefiltering spent brine before subsurface disposal.

The principal mechanical and electronic components are housed in a 6-ton Chevrolet step van that is equipped with an auxiliary gasoline-operated AC generator for remote field operation. A portion of the van is devoted to a rudimentary chemical laboratory; major equipment is a Cahn model 21 electrobalance, a Hach model 18900 ratio turbidimeter, a Spectrex model ILI1000 laser particle counter with particle-profile attachment, and an Orion model 301 pH meter.

Portable apparatus is also provided for use outside the van for pumping and filtration of cooling water from local ponds, and for temporary collection and disposal of spent brine from the test system. A small gas/liquid separator was also designed for use in sampling brine at pressures higher than 2000 psi (such as at production wellheads) or when entrained gas, which interferes with the injectivity measurements, is encountered in the brine. This vessel has a capacity of 1 liter and, together with a throttling valve, can supply $\sim$2 gpm gas-free brine to the experiment while discharging the free methane and surplus fluid into a bypass loop.

METHODOLOGY

Injectability tests were carried out either at constant differential pressure across the filter membrane (the standard method) or at constant flow rate. In the standard method, downstream valves are used to maintain the differential pressure, and the cumulative mass flow is measured as a function of time. In the constant flow rate method, the rise in differential pressure across the membrane is recorded. Flow in the brine discard loop (see Figure 1) is used to maintain the system input temperature at the pipeline value. Upstream valves are kept wide-open to prevent flashing and to ensure that the total input pressure is the

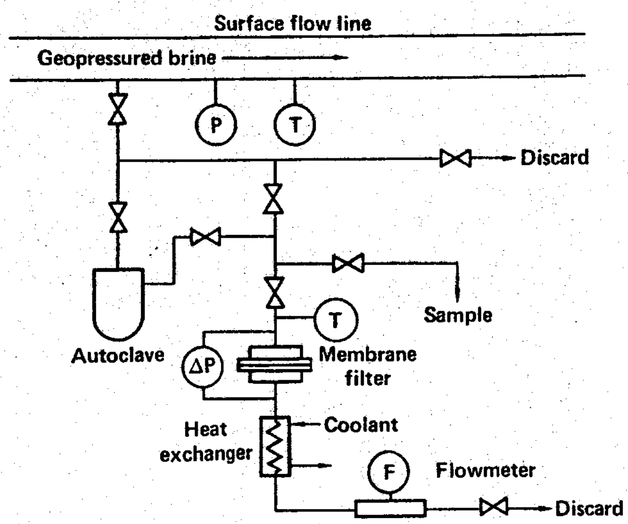

Fig. 1. Simplified schematic diagram of injectability testing system. Transducers: P-pressure, T-temperature, F-flow.

same as that of the pipeline. Suspended solids concentrations are determined in conjunction with the injectivity tests by weighing the filters before and after the experiments.

To capture a sample of brine in the autoclave, the heating mantle is preheated to the brine temperature, brine is flowed through it for further equilibration, all of the gas is bled from the top of the autoclave to minimize the headspace, and then the valves are closed to trap a sample of the brine. A thermoregulator then maintains the brine at its original temperature. Fluid is removed from the autoclave by pressurization with nitrogen.

RESULTS OF TESTS AT PLEASANT BAYOU WELL

The injectability characteristics of the fluids at the Pleasant Bayou No. 2 well (Brazoria County, Texas) have been measured during two phases of well flow tests. During the Phase I tests in September-October, 1980, the well was flowed at an average rate of 19,200 bbl/d; and, because calcite scaling was found initially, a scale inhibitor was metered continuously into the produced brine. The scale inhibitor (a proprietary mixture of the phosphonate/polyacrylate-polymer type) concentration in the brine was 50 mg/l (ppm), and it was injected into the brine near the production wellhead. Injectability tests were performed and suspended solids concentrations were measured on brine from three points in the brine processing system: the production wellhead, downstream of the choke (∿800 psi), and the injection line (∿400 psi). When testing at the wellhead, the pressure (∿3800 psi) was dropped to lower values before entry into the test system.

During Phase II of the Pleasant Bayou well tests commencing in July, 1981, the well was flowed at 29,000 bbl/d, the initial wellhead pressure was ∿2000 psi, and two separators were operated in parallel to handle the brine flow. Two inhibitors were metered into the brine this time: the same scale inhibitor as used previously, at 12 mg/l concentration, and a diamine-type corrosion inhibitor at a level of 25 mg/l. Our initial injectivity tests were performed on brine that was sampled near the disposal wellhead at a pressure of ∿400 psi.

Table 1 lists some representative results of the measurements of suspended solids levels in the brines during the two phases of well flow tests. The data reveal that the solids levels in the untreated brine are very low, but are increased significantly by the addition of the scale control agents. Chemical analyses of the solids indicate that this is caused by the well-known precipitation of the phosphonate by the calcium of the brine. The higher concentrations of suspended solids in the untreated brine during Phase II compared to Phase I was due to presence of sand, which in turn was caused by the higher well flow rate.

Figure 2 shows the flow behavior of the geopressured brine under various conditions as it is passed through membrane filters. Here also there is a marked contrast between the untreated and inhibitor-treated brine. These

Table 1. Concentrations of Suspended Solids in Brine at Pleasant Bayou No. 2 Well.

Pressure (psi)	Temp. °C	Scale Inhibitor Conc. (mg/l)	Filter Pore Size (μm)	Conc. of Susp. Solids mg/l
Phase I Flow Test - 19,200 bbl/day				
1500	130	50	10	0.41
1000	130	0	10	0.026
1000	130	50	0.4	0.69
800	130	50	10	11.8
370	130	50	10	8.7
400	130	0	10	0.021
360	130	50	0.4	14.8
Phase II Flow Test - 29,000 bbl/day				
435	138	12	10	0.89
377	137	12	10[a]	1.7
400	135	12	0.4	1.6
377	142	0	10[a]	0.22
377	140	0	0.4	0.18
400	142	12[b]	10	0.016

[a]Teflon membrane
[b]Brine prefiltered through 1-μm Cuno filter

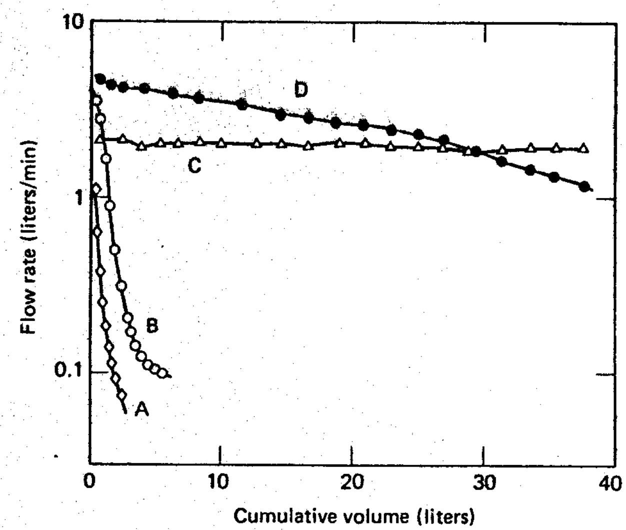

Fig. 2. Water quality curves for Pleasant Bayou brine. 10 μm membrane filters. Curve A - 50 mg/l scale inhibitor, ΔP = 50 psi; Curve B - 12 mg/l inhibitor, ΔP = 50 psi; Curve C - 12 mg/l inhibitor with brine prefiltered through 1 μm Cuno filter, ΔP = 5 psi; Curve D - no inhibitors and no pre-filtering.

flow data and data obtained at constant flow rate have been analyzed together with the parameters of the injection well (Pleasant Bayou No. 1) to give estimates of the rates of impairment under various brine conditions. Based on the constant-flow measurements, estimates of the sizes of suspended particles, and a methodology outlined in a recent paper by Davidson (Davidson, 1979), it appears that deep invasion of the particulates into the formation would occur. The calculations show that, at inhibitor levels of 12 mg/l, there would be a significant reduction in effective injection formation permeability in times of the order of a few months. In contrast, the untreated brine is highly injectable and predicted well lifetimes are in excess of 20 years.

In conclusion, the results of these measurements illustrate the utility of water quality and injectability testing in conjunction with the flow tests of new wells. Further investigations are underway at Pleasant Bayou to optimize the concentrations of chemical inhibitors with respect to both scale abatement and brine injectability.

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