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METHANE EXTRACTION FROM GEOPRESSURED-GEOTHERMAL
BRINE AT WELLHEAD CONDITIONS

R. Quong, L. B. Owen*, F. E. Locke, C. H. Otto, R. Netherton and L. E. Lorensen

University of California
Lawrence Livermore Laboratory
Livermore, CA 94550

ABSTRACT

Disposal of geopressured-geothermal brine effluents by injection is expected to be costly, even into shallow aquifers. If injection into the production reservoir becomes necessary to maintain productivity and to minimize subsidence, the injection pumping costs can become overwhelming. An option aimed at reducing injection pump operating costs is to maintain a higher than normal pressure at the production wellhead to reduce the injection pumping work load. The crucial element, however, is that a significant portion of CH₄ remains in solution and must be recovered in order for the pressure maintenance option to be cost effective. A laboratory and field test capability has been established, and we are presently evaluating several methods for extracting dissolved CH₄ at high temperature and pressure. Solvent extraction and use of hydraulic motors or turbines coupled to CH₄ recovery systems are the leading candidate methods.

INTRODUCTION

The recovery of methane (CH₄) and the utilization of thermal energy from geopressured brines will require innovative developments which can substantially reduce the cost of fluid production and injection to achieve economic feasibility. These developments will be necessary unless energy prices rise significantly faster than production costs. Recent analyses of the economics of CH₄ recovery from geopressured aquifers located along the Gulf Coast of Louisiana and Texas indicate that in order to achieve profitability, a CH₄ selling price of roughly \$7.50-10/Mcf would be necessary given relatively optimistic reservoir parameters.^{1,2} A significant portion of the expenses is the cost of fluid disposal by subsurface injection.

* Present Address: TerraTek
420 Wakara Way
Salt Lake City, Utah 84108

The ratio of injection operating and maintenance (O&M) costs to the price of natural gas is plotted against injection pressure in Figure 1. A dissolved CH₄ concentration of 20 scf/bbl is consistent with some recent well test data.³ It is also consistent with the lower of two laboratory studies of CH₄ solubility in ~15 wt% NaCl solutions at pressures of 12,000 psi and temperatures of 150°C.^{4,5} For pure water, the upper limit in dissolved CH₄ concentration that can be expected at 150°C and 12,000 psi in geopressured waters is about 40 scf/bbl.

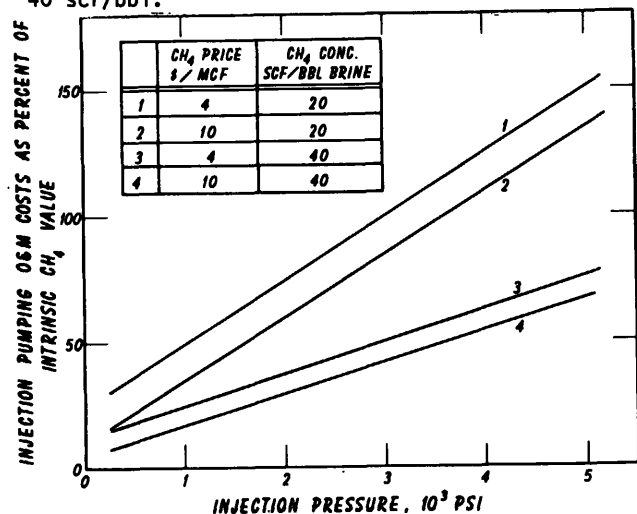


Figure 1. Relationship between injection pressure, CH₄ concentration, and pumping O&M costs (After Doscher et al., 1979)

At today's CH₄ price of ~\$4/Mcf and from indicated dissolved CH₄ concentrations of ~20 scf/bbl from well test data, the O&M pump costs alone for injection at pressures of 1000 psi into shallow hydrostatic aquifers would consume 50% of the recoverable CH₄ value. Injection pump O&M costs rise steeply with required injection pressure becoming prohibitively costly for geopressured waters with low CH₄ content.

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It is clear that measures which could reduce injection costs would contribute significantly to the economic viability of geopressured resource development. In the production of geopressured aquifers, sufficient pressure at the wellhead could be maintained to permit direct injection into shallow aquifers without pumping equipment. However, direct injection is advantageous only if the residual amount of CH₄ still dissolved is recoverable, and production rates are not significantly reduced. If it becomes necessary to inject into the production reservoir for pressure maintenance and subsidence control, injection pumping costs could easily exceed the value of the recoverable energy.⁶ A potential option is to maintain sufficient pressure at the production wellhead, at the expense of reduced production rates, to achieve an economic advantage by substantially lowering the injection pump work while recovering the dissolved methane.

We are presently investigating several methods designed to extract dissolved CH₄ in brine at high temperature and pressure. The methods include gas stripping, solvent extraction, and use of brine driven pumps and hydraulic turbines with provisions for CH₄ recovery. Conceptually, all of these methods are technically feasible and capable of near isothermal operation, to permit thermal energy recovery from the CH₄-depleted brine.

Gas Stripping - The basis of this process involves introducing a volatile agent into the brine which reduces the partial pressure of dissolved CH₄ sufficiently to cause CH₄ to evolve from the liquid phase. While CH₄ recovery by gas stripping, using nitrogen or Freon-114, appears to be technically feasible, the process is economically impractical due to substantial dissolution loss of the stripping agent in the brine at the anticipated process pressures, and the high energy requirements for the subsequent separation of the CH₄ from the stripping gas.

Solvent Extraction - Recovery of CH₄ by solvent extraction is conceptually quite simple. A high boiling solvent is contacted with the brine at temperature and pressure in an extraction tower. If the selectivity is sufficiently high, CH₄ is extracted and subsequently recovered in near pure form by depressurization of the extract. Paraffinic hydrocarbons generally have low solubilities in water.⁷ Hexadecane, in particular, is a promising candidate solvent, although definitive solubility of hexadecane in brine at 150°C is not available. Assuming hexadecane and brine are mutually insoluble and from data on CH₄ solubility in brine⁴ and CH₄ solubility in hexadecane⁸, about 3-4 transfer units were calculated, for a counter-current differential contactor with twice the minimum ratio of solvent to brine. We also plan to investigate the potential usefulness of diesel fuel as a solvent for CH₄ recovery, since diesel fuel contains significant amounts of Hexadecane and other paraffinic hydrocarbons.

Figure 2 illustrates relative flow rates for the solvent extraction process. An intriguing application is to utilize the available residence time and turbulent flow conditions in the production casing as a co-current extraction column. A major concern with the solvent extraction process is the formation and stability of emulsions which could seriously affect performance.

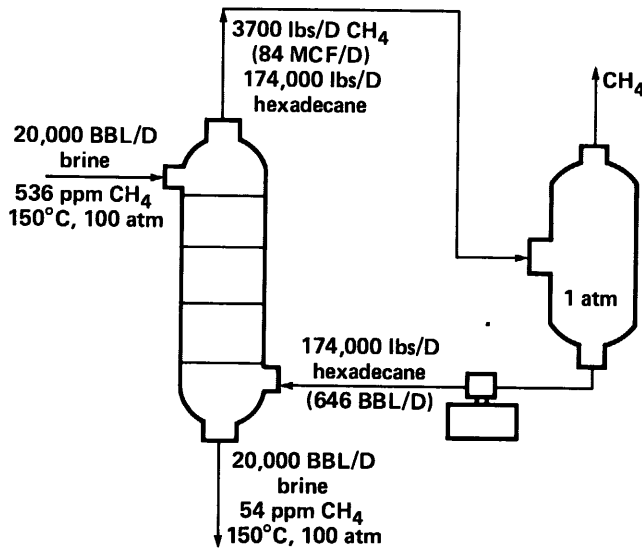


Figure 2. Conceptual design for a CH₄-solvent extraction process. The inventory of circulating solvent is approximately 3% of the daily cumulative brine production.

Hydraulic Energy Conversion Devices with Methane Recovery - If sufficient pressure is available at the production wellhead, the excess pressure can be utilized to help drive the injection operation through use of reciprocating positive displacement hydraulic motors (Figure 3) or

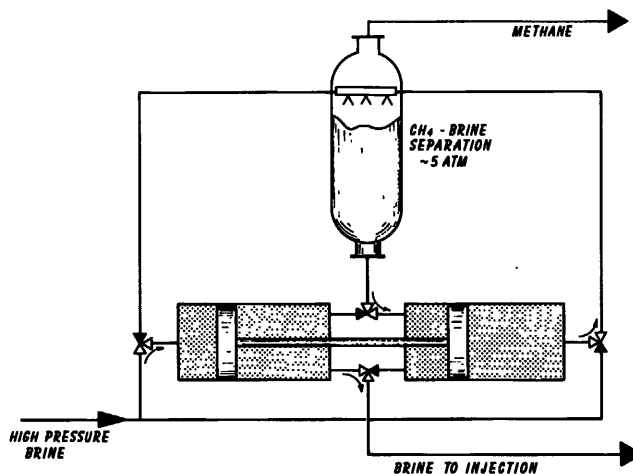


Figure 3. Reciprocating positive displacement hydraulic pump with a capability for evolution and removal of dissolved CH₄.

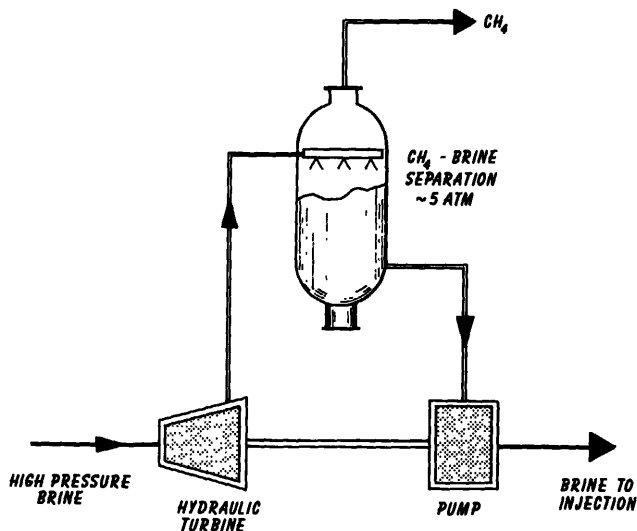


Figure 4. Hydraulic turbine with a capability for evolution and removal of dissolved methane.

hydraulic turbines (Figure 4) with special provisions to permit CH₄ recovery at the saturation pressure of brine at 150°C. Important considerations that will require analysis and test data include CH₄ exsolution rates, hydraulic and mechanical losses, pump cavitation, materials performance, and other issues such as brine chemistry (scaling, corrosion, etc.) that impact all CH₄ extraction methods.

Laboratory Test Facility - A facility has been established to permit test and evaluation of the previously mentioned methods for extracting CH₄ and converting geopressured fluid hydraulic energy to useful work. Test equipment are in various stages of design and construction.

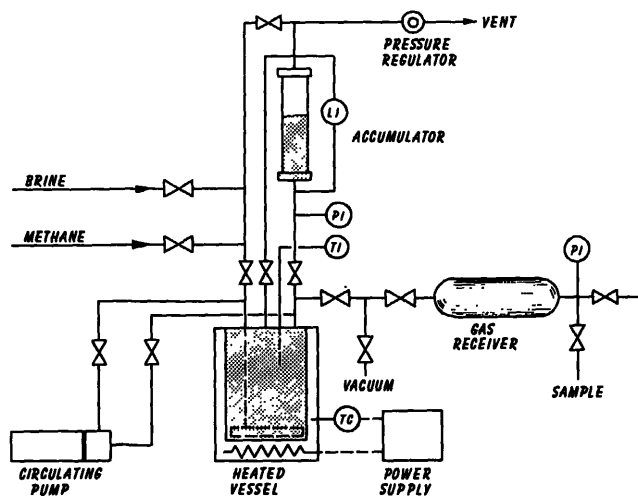


Figure 5. Static laboratory facility for the high temperature-pressure evaluation of CH₄ solubility in brine; CH₄ solubility in selected organic solvents; organic solvent solubility in brine.

Figure 5 depicts the apparatus which will be used to conduct phase equilibria measurements. It has the capability of operating at 150°C and up to 1500 psi. Initial measurements will include determinations of CH₄ solubility in brine and organic solvents, CH₄ exsolution rates, and mutual solubility of brine and organic solvents. To achieve rapid and complete gas-liquid equilibrium, gas is dispersed through the liquid continuously. Similarly, a magnetically driven liquid circulation pump is used to achieve interfacial contact for the liquid-liquid phase equilibria measurements. This apparatus will enable us to obtain solubility data which presently do not exist on specific compounds at elevated temperatures and pressures.

For laboratory scale process development studies, a continuous stream of CH₄-saturated brine is required. We have designed and are presently constructing such a system as depicted schematically in Figure 6. A brine solution is prepared and deaerated. The liquid feed is pumped up to the desired pressure (up to 1500 psi), brought to temperature (up to 150°C) in a heat exchanger, atomized, and passed through a pressured CH₄ atmosphere. CH₄ is also bubbled through the liquid in the CH₄ saturated vessel. A final heater (actually contained in a separate vessel) raises the temperature sufficiently to undersaturate the brine with respect to CH₄ to allow for pressure drop across the control valve without gas evolution. This brine feed system will provide 1 liter/min flow rates.

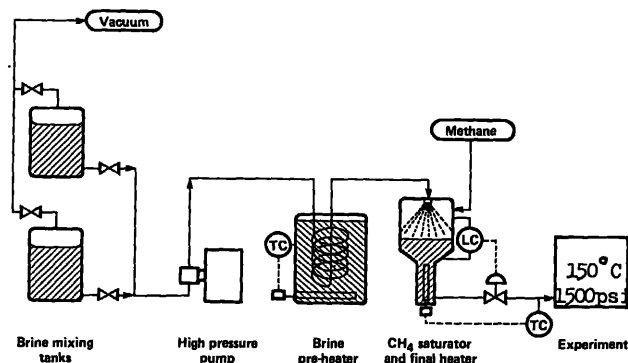


Figure 6. Dynamic laboratory facility for producing a liter/min flow of CH₄-saturated brine at temperatures and pressures up to 150°C and 1500 psi, respectively. The use of corrosion-resistant materials and Fluoroelastomer-coated low carbon steel pressure vessels permits testing brines with salinities up to 150,000 ppm total dissolved solids.

A laboratory sized continuous flow solvent extraction process will be tested in a system now under design (Figure 7). The extraction column is the main component. Initial tests will be conducted with the column operating as a continuous differential contactor. Spray tower and packed column operation will be studied.

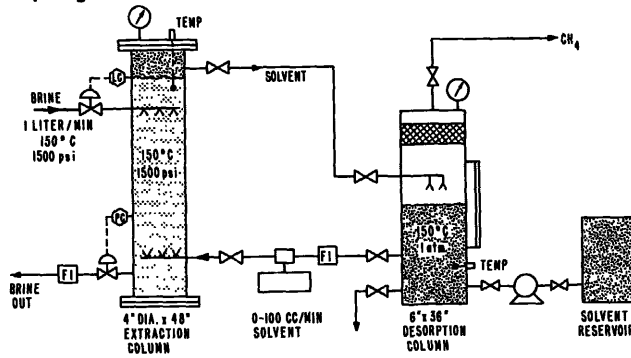


Figure 7. Dynamic laboratory facility for evaluating CH_4 -recovery by solvent extraction.

The major anticipated difficulty with fabrication and subsequent operation of the various laboratory test systems was the high corrosivity of the brine ($\leq 150,000$ ppm total dissolved solids). To minimize cost, we used thick wall type 316SS valves and type 316SS fittings, Inconel 600 tubing and VitonTM-coated low carbon steel pressure vessels. A liquid VitonTM fluoroelastomer coating (Type PLV-2000TM), obtained from PELMOR Laboratories, Inc., was applied to low carbon steel specimens and tested by immersion of the specimens in brine at 200°C for 48 hours. The coating exhibited excellent adhesion and resistance to the hot brine. Use of PLV-2000TM-coated low carbon steel in place of a corrosion resistant metallic material (i.e. Inconel 600; Hastelloy C-276), reduced the cost of a typical pressure vessel by a factor of four to five times.

In order to derive the full benefits of elevated pressure/temperature CH_4 extraction processes, spent brine injectability, at elevated pressure and temperature, must be high to eliminate the potential for premature impairment of injection wells. The primary concerns are impairment resulting from deposition of scale and suspended solids. We are evaluating this facet of the overall CH_4 extraction process by means of field injectability tests which involve flowing brine, at various temperature/pressure conditions, through membrane filters. The observed change in membrane filter permeability to brine can then be related, in a semi-quantitative way, to the injectability of the brine. We have modified existing designs for membrane filtration test apparatus to permit data collection at temperatures and pressures up to 150°C and 3000 psi, respectively.⁹⁻¹¹ The injectability tests will be carried out in conjunction with the DOE-sponsored evaluation of the Pleasant Bayou Geopressured Well No. 2, Brazoria County, Texas.

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