# VALUE ADDED TECHNOLOGY FOR STRIPPER OIL AND GAS WELL BRINES

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## Introduction

The Appalachian Basin oil and gas industry is composed primarily of independent producers operating stripper oil and gas wells in New York, Ohio, Pennsylvania and West Virginia. The wells operated by these independents produce very small quantities of crude oil and natural gas and small volumes of brine. This brine has historically been viewed as a waste product and proper disposal of it is a significant portion of the cost attendant to well operation. In many areas of the United States the brine is disposed of by injecting it into hydrocarbon and/or non-hydrocarbon bearing formations that are both porous and permeable. The Environment Protection Agency (EPA) regulates this subsurface disposal of brine using well injection. EPA categorizes these injection wells to be either Class I or Class II wells. Class I wells according to EPA guidelines[1] are considered to be "technically sophisticated wells that inject large volumes of hazardous and non-hazardous wastes into deep, isolated rock formations that are separated from the lowermost underground source of drinking water (USDW) by many layers of impermeable clay and rock." Class II wells inject fluids (brines) associated with oil and natural gas production. This category of injection wells includes wells that are used for enhanced recovery of oil and gas. The process of enhanced recovery amounts to the injection of fluids such as brine, gas or steam into hydrocarbon bearing zones and thereby recovering oil and gas that would otherwise be unrecoverable. The prerequisite for both Class I and II wells is a formation with adequate permeability and porosity. Permeability is the rock property that defines the rate at which fluid can be injected into a formation. In theory, higher-pressure differentials between the well bore and the formation result in higher injection rates. Limits with respect to pressure differential are imposed by regulations set forth by the EPA. Porosity is a measure of the capacity or voidage space of a rock and along with formation thickness and areal extent define the capacity of the formation. In many areas, there exist no formations that can be used with either Class I or Class II wells and as a consequence alternative methods of disposal are used.

One such alternative method is to treat produced brines in a wastewater treatment facility to remove suspended oils and greases, suspended solids, and heavy metals such as iron prior to discharge into surface water. Commercial brine treatment facilities[2] of the type located near Franklin, Pennsylvania, and Indiana, Pennsylvania, provide this service to local producers in southern New York and Central Pennsylvania. Transport of the brine to these facilities is by over-the-road tanker. This method of brine disposal is expensive and from an environmental management viewpoint, recovery of this resource is a more desirable alternative. For example, approval has been received to use these brines for stabilizing unpaved rural roads and in conjunction with State Transportation Departments, deicing[3]. There is no charge to the producer for the disposal of brines used in these applications. Efforts to find other uses for these brines that would result in at least a break-even proposition for producers are underway at The Pennsylvania State University.

## Use of Produced Water in Hydrofracturing

Hydrofracturing is a technique of stimulating oil and gas wells. Economides et al.[4] describes it as consisting of injecting fluid into the formation with such pressure that it induces the parting of the formation. After failure of the rock, the sustained application of the hydraulic pressure extends the fracture outward from the point of failure. Proppants are added to the fracturing fluid to hold open the created fracture after the hydraulic pressure used to generate the fracture is relieved. The fluid used in this process can be very simple or quite complex and the amount of fluid used in the process can vary from a 1,000-gallons to over a 500,000-gallons. Fluids commonly used include water, diesel oil and gases such as Nitrogen and Carbon Dioxide. Material used for propping the fracture include well-sorted sand and spheres composed of ceramic or Bauxite. The amount of proppant used depends on the formation to be fractured. The capability of the fluid to carry proppant is dependent upon the viscosity of the transport fluid. If the fluid used is water, a guar-derivative such as hydroxypropyl guar (HPG) or carboxymethylhydroxypropyl guar (CMHPG) is added to produce the appropriate viscosity. Other materials added to this fluid can include:

- Biocides – these materials are added to treatment water to control bacterial contamination. There are two types of microorganisms found in water base fluids: aerobic, which consume water base polymers during surface storage, and aerobic, sulfate reducing microorganism that destroy the polymer and produce hydrogen sulfide down hole.
- Gel breakers – used to chemically degrade the guar polymer and thereby reduce its viscosity.
- Surfactants – added to the fluid to reduce surface tension and capillary pressure in pore spaces.

The equipment necessary to hydrofracture a well is significant. Typically, positive displacement pumps capable of moving large volumes of fluid-sand slurries at high pressures are used. These pumps discharge the fluid-sand slurry into a network of high-strength steel piping that is attached to the wellhead. Additional equipment includes trucks to transport and feed the proppant. The capital, operating and maintenance costs associated with this equipment are significant. Consequently, the typical producer purchases the process and materials as a turnkey service.

A gas well drilled in the Appalachian basin penetrates multiple pay zones. These pay zones are Devonian age porous and permeable sandstones. Geologically, these sandstone reservoirs are separated by impermeable shale. The operator typically will select as many as five pay zones in each well for completion. Each pay zone is then isolated and hydrofractured as a separate unit. After drilling to the target depth, casing is run into the well and the annulus space between the casing and drilled hole is filled with cement. The casing adjacent to the zone to be completed is perforated. Perforating is accomplished by lowering into the well a perforator that fires electrically detonated shaped charges from the surface. Clean up of the perforation is accomplished by spearheading the hydrofracturing process with Hydrochloric acid.

The fluid of choice in the Appalachian basin for hydrofracturing is fresh water. Fresh water is used for economic reasons and generally; it is readily available from ponds, streams and/or rivers. Recently however, the Appalachian basin has experienced a regional drought. Independent producers have experimented with using untreated produced brine as a total substitute for fresh water or by mixing the fresh water with brine. Preliminary studies have indicated that it can be used as a replacement for freshwater and the results of the hydrofracturing have been positive.

There are significant questions with respect to the impact of the use of these brines on the productivity of formations. This is particularly true if the brine is used in repeated applications. It is reasonable to expect that the brines will reach a point where their effectiveness will be reduced and their use will result in significant damage to the formation where used.

**Mineralogy of Formations**

Numerous authors[5, 6,7] have investigated the impact of injected fluids on the clays contained in sandstones. The impact is negative in that it tends to reduce the native permeability of the formation. This reduction in permeability may result from clay swelling and/or mechanical breakdown. For this reason, Potassium Chloride is often added to fresh water before hydrofracturing. This procedure of adding Potassium Chloride was suggested by Black and Hower[6] and is commonly used in the Appalachian basin.

Clays are negatively charged. The density of negative charges can be measured by determining the number of positive charges required to neutralize the clay crystal. This is known as the cation exchange capacity (CEC) of the clay and is expressed in milliequivalents (ME) for 100-grams of clay. The table below lists the CEC of several clays[8]. The replacement of one cation by another on any clay is governed mainly by the

**Cation Exchange Capacity of Selected Clays and Sand**

| Clay | Range of Cation Exchange Capacity |
|---|---|
| Smectite | 80 to 150 |
| Illite | 10 to 40 |
| Kaolinite | 3 to 15 |
| Chlorite | 10 to 40 |
| Sand (2 to 62 microns) | 0.6 |

Law of mass action and the valence of the cation. Generally, where monovalent and divalent cations are present in the same concentration, the divalent cation will be preferentially attracted to the clay. The physical effect of this phenomenology is that the introduction of freshwater into a clay system will result in permeability damage and a reduction in production. For this reason, Potassium Chloride is added to the fresh water. Among common monovalent cations, potassium has been shown to be more effective than sodium as a method for mitigating clay swellage and damage.

The impact on the clay contained in these formations of using formation brine as the hydrofracturing fluid is not known. In other producing areas, hydrocarbon (oil and gas) and brine from one formation are produced to the surface. The brine is separated from the produced hydrocarbons and often used in drilling and completions effort. In the Appalachian basin, wells penetrating the Middle Devonian sandstones, the hydrocarbons and brines from multiple formations are produced as a commingled stream to the surface through a common well bore. The commingled brine stream is separated at the surface and stored in steel tanks. It is this brine that is used for stimulation purposes.

**Hydrofrácturing a Middle Devonian Well**

The brine used for Hydrofracturing a Middle Devonian well is delivered to the well to be stimulated by over the road tankers. It is pumped into an open-pit that has been lined with an impermeable plastic liner. A centrifugal pump is used to feed the suction side of the positive displacement pumps. The various chemicals and proppants are mixed and added to the brine and displaced into the well at volumetric flow rates of 800-1000 gallons/minute. At the completion of the first stage, the slurry is flowed back into the pit and the process repeated again using the same fluid. This fluid now contains a complex array of chemicals and "solid fines" that are made up of attrited proppants and shale. During each stage, additional chemicals are added and the amount of attrited proppants and shale increases.

**Investigation**

The purpose of the study is to determine the effect of using these brines in the stimulation process on the ultimate recovery of natural gas from Middle Devonian reservoirs located in the Appalachian basin. There are several questions that need to be answered concerning this procedure. These questions include:

- Given the fact that the mineralogy of each formation is unique, what is the impact of injecting commingled brine into these formations in terms of its impact on the clays contained therein?
- What damage to formation permeability results from the recycling of brine from one stage to the next?
- What damage to formation permeability results from the use of brine that contains micron size "solid fines"?
- What is the impact of this process on ultimate natural gas production and the economics of well development?

To answer these questions, a work plan was developed. The elements contained in the work plan are as follows:

- Five wells will be selected for the analysis. Prior to setting casing in the well bore, sidewall cores of the formations to be hydrofractured will be obtained. The mineralogy of these cores will be determined. Representative brine will be displaced through the cores and the effect on permeability of the brine evaluated.

- The flow-back from each hydrofracture stage will be collected and analyzed to determine changes in the brine given the addition of the chemicals used in hydrofracturing and the presence of solid fines.
- Historical production data will be analyzed to determine any measurable effects of stimulation on ultimate production.

It is expected that this study will be undertaken during the 2000-2001 drilling cycle. A final report is expected during the third quarter of 2001.

## Summary

The recent regional drought has created a situation where water necessary for stimulating gas wells was scarce. Independent producers in the Appalachian basin replaced the freshwater used for stimulation with brine that had been produced from existing production wells in the area. The results of this replacement procedure require an assessment to determine whether the procedure impacts ultimate recovery of the natural gas contained in these reservoirs. Moreover, an evaluation of the procedure needs to be undertaken to determine whether changes to it are in order. To accomplish this analysis, a systematic study has been proposed and will be undertaken. Elements of the study include analyses of the rock cores and hydrofracture fluids, and analysis of gas production data.

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