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Development and Field Application of a Low pH, Efficient Fracturing Fluid for Tight Gas Fields in the Greater Green River Basin, Wyoming

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Abstract

Hydraulic fracturing has proven to be one of the best technologies to improve productivity from tight gas wells. In such low-permeability reservoirs, careful consideration must be given to fracturing fluid selection. Some reservoirs are under-pressured and require the use of energized fluids, while others are sensitive to water-based fluids due to clay swelling and migration.

Proppant pack damage due to gel residue is one the primary causes of low production rates after hydraulic fracturing treatments. To minimize the damage and therefore maximize production, a new premium highly efficient fracturing fluid was developed. This premium system incorporates low polymer loading carboxymethyl guar polymer and a zirconium-based crosslinker. An adjustable crosslink delay makes the fluid ideal for deep well fracturing and coiled tubing treatment as frictional pressure losses can be minimized. The system can be energized or foamed with carbon dioxide (CO_2) and nitrogen (N_2) or may also be used in binary foam systems.

This paper will provide details on the new fracturing fluid system, in terms of proppant pack cleanup, rheological properties and fluid loss as well as other parameters. Various rheological evaluations using high-pressure, high-temperature rheometers as well as a foam loop; fluid leak-off testing; and proppant pack conductivity and regain permeability evaluations are presented.

Field case histories will evaluate fracturing treatments using new fracturing fluid and comparable treatments using conventional fluid. Normalized production data of the treated wells of both systems are also compared.

Introduction

Water based fracturing fluids are the most common stimulation fluid used for hydraulic fracturing in the industry today. The water-based fluids can range from plain water with a friction reducer to a complex crosslinked polymer fluid with a variety of additives. Modern fluids can be pumped in batch-mix or continuous-mix modes. Rheological properties (viscosity, for example) can be adjusted as desired very easily by varying polymer or additive loading (either in stages or continuously) during the job if required. Crosslinking is the most cost-effective way of increasing the viscosity of the fluid. Water-based fluids can be crosslinked at high or low-pH conditions. To achieve the same viscosity at higher reservoir temperatures, one can use an order of magnitude less polymer by crosslinking than with linear polymer in aqueous solutions. Historically, these fluids typically required polymer loading from 40 to 80 pounds per thousand gallons (ppt). However, with the higher-yielding more efficient polymers and with better crosslinking technology, the loadings have dropped to as low as 12 ppt on the low end and as high as 35 ppt on the high end for most applications (Dawson, et al., 1998). Most common crosslinked fluids used in the industry are in the high pH range. These include most borate and zirconate crosslinked fluids.

The low polymer, highly efficient systems are particularly suited for tight gas formations where minimal conductivity impairment is required. Many low permeability formations also tend to have clays. Over the last three decades, there have been several papers published on the need for low pH fluids in low permeability sandstones. Simon, et al. presented a paper in 1976 detailing the effect of pH on relatively non-swelling clay minerals, Kaolinite, chlorite and illite as well as the more highly water sensitive clays mixed layer and montmorillonite. They concluded that formation rock samples were more compatible with low pH fluids than with high pH fluids. Coulter, et al. in 1983 contradicted this observation and concluded that fluids in the pH range of 4.7 to 11.5 caused no damage. In 2002, Gdanski came to the conclusion that high pH fluids have potentially two different mechanisms for interaction with clays: neutralization of the natural clay acidity and the attack of hydroxide on clays which can cause instability of certain clays, for example smectite. There seems to be general agreement that low-pH fluids tend to cause less permeability damage to low-permeability sandstones. Low pH can also assist in