Fracturing Fluid Systems

Broad Variety of Systems Enables Customizing the Treatment Fluid to Reservoir Requirements

Since Halliburton performed the first commercial fracturing treatment in 1949, the development of specialized fracturing fluid systems has been a constant research and development focus. The fluid systems are designed to implement a treatment according to design in order to help increase production and improve the Operator's return on investment. Designs are based on these key parameters:

- Fluid type
- Viscosity requirements
- Fluid rheology
- Economics of fluid
- Experience with local formations
- Laboratory data on the formation
- Material availability
- Proppant selection

Fluid systems optimized to these parameters can result in minimized formation and fracture face damage for maximized results. Fluid systems may be linear gels, crosslinked gels, foam or friction-reduced water.

Linear Gel Fluids

Linear gel fracturing fluids are formulated with a wide array of different polymers in an aqueous base. Polymers that are commonly used to formulate these linear gels include guar, hydroxypropyl guar (HPG), carboxymethyl HPG (CMHPG), and hydroxyethyl cellulose (HEC). These polymers are dry powders that hydrate or swell when mixed with an aqueous solution and form a viscous gel.

Crosslinked Gel Fluids

Borate Crosslinked Gel Fluids

- Good proppant transport
- Stable fluid rheology at temperatures as high as 300°F
- Low fluid loss properties
- Good cleanup properties

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Since performing the first commercial fracturing treatment in 1949 (bottom photo), fracturing fluid development has been a constant focus of Halliburton's research and development efforts. Equipment and techniques are constantly evolving as more is learned.

Borate crosslinked gel fracturing fluids utilize borate ions to crosslink the hydrated polymers and provide increased viscosity. The polymers most often used in these fluids are guar and HPG. The crosslink obtained by using borate is reversible and is triggered by altering the pH of the fluid system. The reversible characteristic of the crosslink in borate fluids helps them clean up more effectively, resulting in good regained permeability and conductivity. Borate crosslinked fluids have proved to be highly effective in both low and high permeability formations.

Organometallic Crosslinked Fluids

Organometallic crosslinked fluids are the most popular class of fracturing fluids. Primary fluids that are widely used are zirconate and titanate complexes of guar, hydroxypropyl guar (HPG) and carboxymethyl-hydroxypropyl guar (CMHPG). Organometallic crosslinked fluids are routinely used to transport the proppant for treatments in tight gas sand formations that require extended fracture lengths. The organometallic crosslinked fluid can also be used in fracturing fluids containing carbon dioxide.

- Provides extreme stability at high temperatures - excellent proppant transport capabilities at temperatures from 60 to 400°F.
- Offers more predictable rheological and friction pressure properties.
- Provides better control of the crosslinking properties of the fluid.
- Allows job design in acidic, neutral, and alkaline pH fluid conditions.

Gelled Oil Fluids

The use of a viscous gelled oil system as a fracturing fluid minimizes the possibility of damage in certain formations such as particle migration resulting from water contacting clays. When used with Halliburton's My-T-Oil V™ system, gelled oil fluids rapidly develop a consistent gel viscosity which eliminates the need to pre-mix the gel. Also, gel viscosity can be controlled while the treatment is being pumped, enhancing job design flexibility. Gelled oil systems were the first type of high viscosity fluids used in hydraulic fracturing and have the major advantage of being compatible with almost any type of rock formation. And, gelled oil is more convenient in cold weather conditions when compared to water-based fluid systems.

Liquid Gel Concentrates

Liquid gel concentrates (LGC™) are concentrated liquid slurries prepared with the polymers. Since the concentrated polymers are in liquid form, the handling and mixing of dry, powdered material at the wellsite is eliminated. LGC technology also provides an efficient, precise method of varying the viscosity of the fracturing fluid during the fracturing treatment.

LGC can be added to an already hydrated gel to adjust the viscosity of an existing gel. It can also be added to water and premixed as the fluid is being pumped, so the viscosity can be controlled while the treatment is being pumped. All Halliburton LGCs are now ultra clean and meet the requirements of the Energy Act of 2005 and the CleanWater Act.

ADP™ Dry Polymer Blender

Halliburton's ADP™ dry polymer blender enables any of Halliburton's fracturing fluid systems to be mixed from a dry powder. The advantages of mixing with a dry powder over using LGC slurries include:

- Significant reduction in the potential for transportation and storage incidents involving liquids.
- Conservation of petrochemical materials as the carrier fluid is no longer required.
- Reduction of combustion and greenhouse emissions due to reduced vehicle miles traveled transporting liquid gelled material.

LGC slurries were a large leap forward in efficiency over mixing the gelling agent into the total water supply. These liquid gel concentrates enabled adding the gelling agent "on demand" and reduced costs and HSE exposure.

The ADP blender enables mixing any of Halliburton fracturing fluid using a dry powder. This eliminates the need for all hydrocarbon-based carrier fluids.

However, LGC slurries often contain hydrocarbon-based carrier fluids. The carrier fluids started off as using diesel, and then switched to using mineral oil as part of a Halliburton commitment to remove diesel from hydraulic fracturing fluids. The ADP blender is the next evolutionally step in that it enables completely eliminating the hydrocarbon carrier fluids from the fracturing fluid process.

Foamed Fluids

As oil and gas producing reservoirs become pressure depleted, the use of foamed fracturing fluids provides energized gas for fluid recovery after the fracturing treatment. Foamed fracturing fluids contain the liquid phase of the fluid system (usually gelled), a foaming agent, and an internal phase of typically 60 to 80% of N_2 or CO_2. Foamed fluids can be applied to virtually all types of oil and gas wells, over a wide range of pressure, where it is important to minimize damage. The low liquid content of foams leaves less liquid to remove from the well. Foams produce very thin filter cake, yet have low fluid loss characteristics. The gel in foams can also be crosslinked for higher viscosity. N_2 is compatible with all crosslinked fluid systems, while CO_2 is compatible with the Pur-Gel™ III and pHaserFrac systems.

Choosing the Optimum Fluid System

Data used to determine the appropriate fluid system includes the following:

- Friction pressure determination of the various fluid systems.
- Fluid rheology at a variety of temperatures.
- Conductivity for the various fluid systems.
- Compatibility of the fluid with the formation.
- Compatibility of the fluid with the components.
- Environmental properties of the fluid systems.
- Gel break properties and conditions.

Fluid System Additives

Halliburton has a complete line of additives for use during fracturing to help optimize the various parameters of the fracturing fluid system. These additives include clay control agents, gel stabilizers, surfactants, foamers, gel breakers, fluid loss additives, friction reducers, scale inhibitors, biocides, and pH control additives.

Each of these has special chemicals that can be used to maximize certain characteristics. For example, foaming additives have been designed for different temperature conditions. Clay control additives have been developed for initial contact as well as for longer lasting protection. And, gel breakers have been developed for various temperature applications and for release-rate control.

Non-Guar and Low-Guar Polymer Technologies

Halliburton's latest efforts center around ways to reduce or eliminate the need for guar in situations where guar supply is limited. Because of the rapid expanse of hydraulic fracturing, the components of many fluid systems have had their demand rise meteorically. To ensure the continuation of peak performance, Halliburton has been and continues to innovate new fluid formulations and alternatives.

CleanStim℠ Service

CleanStim℠ fracturing service uses a new fracturing fluid formulation made with ingredients sourced from the food industry. CleanStim service is a major advance in fracturing fluid technology. In addition to environmental benefits, the CleanStim fluid system provides excellent performance in terms of pumpability, proppant transport and retained conductivity, Laboratory tests showed over 90% retained conductivity after 24 hr of flow. The system is applicable over a broad temperature range providing up to 30 minutes pumping time at 225°F (107°C).

PermStim℠ Service

PermStim™ fracturing fluid technology is centered on a guar-free fluid, relying on proven crosslinking reactions in which instant or delayed mechanisms are available. Utilizing Halliburton's wide-ranging crosslinker packages, precise viscosity control can be achieved based on both reservoir and operational needs.

PermStim fluid contains virtually no insoluble residue. The fluid system is applicable from 100°F (38°C) to 275°F (135°C). It can be used at higher temperatures when cool down effects are considered.

The benefits of PermStim fluid over traditional guar-based fluid systems include:

- Virtually no residue
- Improved well cleanup

- Enhanced proppant pack permeability
- Controllable viscosity

EZ-Stim℠ Service

EZ-Stim℠ service uses new polymeric borate crosslinking technology to provide the performance of a conventional top-tier borate crosslinked fluid but with much less guar. EZ-Stim fracturing service helps provide improved efficiency for hybrid treatments and for fracturing long horizontal wellbores. Using up to 60% less guar, the fluid system reduces wellhead pressures, requires less hydraulic horsepower, and reduces damaging guar gel residue.

Widely Used Water-Based Fluid Systems

In terms of volume pumped, the most widely used fracturing fluid systems include Delta Frac, Hybor, SilverStim fluids and friction-reduced water. Halliburton technologies include AquaStim service for friction-reduced water frac treatments, pHaserFrac service for compatibility with CO_2, Sirocco service for high temperatures and DeepQuest service that enables fracturing ultra deep reservoirs.

Delta Frac® Service

Delta Frac fluid is an optimized borate fracturing fluid system that provides high viscosity with low gel concentrations. In fact, Delta Frac service provides about the same viscosity as a conventional borate fracturing fluid, but uses up to 33% less gel. Reduced polymer loading can help reduce formation damage, improve retained conductivity, and reduce the amount of breaker required. This all translates to improved productivity and cost effectiveness.

- Helps reduce formation damage.
- Provides superior retained conductivity.
- Provides excellent proppant transport.
- Achieves clean, complete breaks.
- Simple to use system enhances quality and helps reduce time on location.

HPH™ breaker is an enzyme breaker solution that is especially effective in Delta Frac treatments up to about 140°F. It has high pH stability that is very effective and economical at pH 8 and above.

Fluid System	Polymer	Crosslinker	Maximum Temp °F
CleanStim	Non-Guar	Al	225
PermStim	Non-Guar	Zr, Al	275
EZ-Stim	G	B	160
Sirocco	CMHPG	Zr	400
DeepQuest	HPG CMHPG	B, Zr	325
Hybor	G, HPG	B	320
SeaQuest	HP	B/Ti	300
Pur-Gel III	CMHPG	Zr	275
pHaserFrac	CMHPG	Zr	275
Delta Frac	G, HPG	B	200
Silver Stim LT	G	B	100

For mid-temperature wells, Delta Frac service capitalizes on the advantages offered by oxidizing breakers. Activated ViCon™ NF breaker solution–a new, proprietary oxidizing breaker–is particularly suited for temperatures above 170°F.

Hybor℠ Fracturing Service

Hybor™ fluid is a delayed borate crosslinked fluid using guar or HPG gelling agent. Hybor fluid is recommended for wells with bottomhole static temperatures (BHST) of 125° to 300°F and provides these performance features:

- High viscosity fluid.
- Can be run semi continuously or batch mixed.
- Crosslinked fluid reheals after shearing.
- Crosslinked gel filter cake cleans up with water production.
- Filter cake can be broken with OptiFlo™ II and III agents.

SilverStim® LT Fracturing Service

SilverStim® LT fracturing service provides improved regained conductivity and environmental performance plus simplified fluid selection and pricing. It is designed for applications at 80°F to 180°F.

SilverStim LT fracturing service takes full advantage of Halliburton's knowledge of guar-based polymer chemistry and crosslinking reactions. The service includes a stabilized fluid system with built-in clay control and break mechanisms.

This comprehensive system provides important benefits:

- Reduced fracture damage due to efficient polymer breaks.
- Enhanced regained conductivity provided by optimized breaker packages. This can help achieve higher production and improve return on investment based on specific reservoir conditions
- Complete crosslinking system provides ease of pumping and improved quality control and assurance.
- Meets the requirements of the CleanWater Act
- One price covers gel, clay control additives and breakers.
- Improved pricing efficiency allows proposed and actual invoice prices to match, even if on-site design modifications are made.
- System packaging eliminates the need for individual chemical charges, reducing ticket review and validation.

pHaserFrac℠ Fracturing Service

pHaserFrac service features a derivatized guar polymer that is compatible with carbon dioxide and can be used with up to 7% potassium chloride (KCl) for maximum clay protection. The CMHPG gel in pHaserFrac™ fluid is crosslinked within the acidic pH range of CO_2, so there is no substantial change in gel characteristics when CO_2 is added. The addition of CO_2 to the frac fluid gives the fluid more energy (due to CO_2 expansion) to aid in flowback and formation cleanup after the fracture treatment.

Sirocco℠ Fracturing Service

This service extends the proven benefits of low polymer fracturing fluid to higher temperature wells with the added benefit of salt compatibility. Sirocco™ fluid provides the excellent proppant transport capabilities of conventional CMHPG fluid systems but uses less base polymer resulting in much higher regained conductivity.

- Can be used with 2% KCl water or KCl substitute as the base and does not suffer the almost total viscosity loss exhibited by CMG-based fluid systems.
- Provides very predictable viscosity and fluid efficiency. Sirocco fluid tends not to "thermally thin" as quickly as other widely-used fracturing fluids. Sirocco fluid can be customized to provide the optimum break based on reservoir requirements.

DeepQuest℠ Service

DeepQuest service enables fracpack and hydraulic stimulation of ultra-deep reservoirs without exceeding the safety limits of surface equipment, tubulars, and high-pressure manifolds. Vertical well depth in offshore and land environments can result in surface treating pressures exceeding 15,000 psi in a typical fracturing or FracPac℠ service on a 25,000-ft TVD well. DeepQuest™ weighted fluid can reduce surface treating pressure by 18%, bringing it under the 15,000 psi limit of the flexible hoses.

AquaStim℠ Service

AquaStim water frac service technologies are designed to help operators achieve better fracturing results from treatments using friction-reduced water including improved production and load recovery, and reduced fracture face damage.

AquaStim service includes the breakthrough GasPerm 1000℠ service technology. Other new technologies that can be components of AquaStim service for fracturing unconventional reservoirs include OptiKleen-WF™ viscosity reducing agent and FR-56™ friction reducer.

A new version of SandWedge® enhancer specially formulated for water frac treatments can be highly effective when used with AquaStim service to help maintain long term conductivity and control formation fines material flowback.

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Halliburton has designed a wide range of fracturing fluids for use in many different environments; including onshore, deepwater, high temperature, super long laterals, and more.

For more information, contact your local Halliburton representative or email stimulation@halliburton.com.

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