**OilPerm™ FMMs -- Formation Fluid Mobility Modifiers**

*Custom Designed Chemistry Optimizes the Treatment Fluid Flowback and Hydrocarbon Production*

OilPerm™ FMMs are a suite of Formation Fluid Mobility Modifiers custom designed to promote quick recovery of fracturing fluids and provide enhanced reservoir hydrocarbon production following fracture stimulation treatments.

OilPerm FMM blends are custom designed to work in tight formations where they penetrate into the formation along with the fracturing fluid to provide:

- Enhanced mobilization of liquid hydrocarbons resulting in improved oil production rate and ultimate recovery, thereby helping reduce the cost per barrel of oil equivalent (BOE)
- Reservoir surface – fracture network interface treatment resulting in an optimized relative permeability to oil
- Reduced capillary pressure enabling rapid onset of gas production, enhanced production rates and maximized ultimate recovery
- Rapid recovery of the aqueous fracture treatment fluids from the fracture system resulting in reduced time for frac cleanup with maximized frac fluid recovery and reduced time before production
- Compatible with most fracturing fluid systems including PermStim™, SilverStim™, and Hybor G™ systems as well as WaterFrac™ systems and linear gel systems.

### OilPerm FMM blends

<table>
<thead>
<tr>
<th>OilPerm Blend</th>
<th>Charge</th>
<th>Contact Angle (Degree)*</th>
<th>Surface Tension (Dynes/cm)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMM-1</td>
<td>Non-ionic</td>
<td>20.2</td>
<td>32.5</td>
</tr>
<tr>
<td>FMM-2</td>
<td>Cationic</td>
<td>26.2</td>
<td>34.7</td>
</tr>
<tr>
<td>FMM-3</td>
<td>Non-ionic</td>
<td>15.2</td>
<td>28.0</td>
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<tr>
<td>FMM-4</td>
<td>Anionic</td>
<td>17.2</td>
<td>30.3</td>
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<td>FMM-5</td>
<td>Anionic</td>
<td>12.5</td>
<td>34.7</td>
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<tr>
<td>FMM-6</td>
<td>Non-ionic</td>
<td>22.0</td>
<td>28.8</td>
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<tr>
<td>FMM-7</td>
<td>Non-ionic</td>
<td>25.0</td>
<td>31.0</td>
</tr>
<tr>
<td>FMM-8</td>
<td>Anionic</td>
<td>15.5</td>
<td>31.1</td>
</tr>
</tbody>
</table>

* * diluted to 1 gpt and measured on glass substrate
** ** diluted to 1 gpt and measured using the Wilhelmy Plate method

OilPerm FMMs are blends of solvents, wetting agents and non-emulsifiers carefully selected and optimized for specific formation types through extensive laboratory interfacial chemical testing. These blends are provided as stable, easy to use materials that are safe and sensitive to local environmental needs.

OilPerm FMM treatment design parameters are optimized for specific well conditions to help prevent overtreatment and minimize cost using Halliburton’s RockPerm™ service.

RockPerm service is used to fine tune the selection and application of OilPerm FMMs to the individual formation and frac fluid system. This is accomplished by a series of laboratory analyses performed by local area Halliburton field laboratories. Some of the testing performed includes:

- Emulsion screening and tendency
- Fracturing fluid system compatibility
- Fracturing/formation water compatibility
- Offset oil/and condensate compatibility
- Effect on aqueous fluid recovery using formation cuttings and proppant
- Effect on oil productivity using formation cuttings and proppant

OilPerm FMM blends are optimized to provide maximum performance with respect to reservoir mineralogy which may vary from silicate to carbonate and as oil compositions vary from gas and condensate to heavy paraffinic or asphaltic oils.
Nano Technology is Key for Unconventional Reservoirs

Nano technology is used in formulating OilPerm FMM blends which results in products with greatly improved properties such as stability, penetration into the fracture network and reduced adsorption losses permitting deeper penetration into the formation and fracture network. All these properties lead to improved performance and economic benefits.

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Capillary pressure has a critical effect on aqueous and hydrocarbon fluid mobility following a fracture treatment. Reservoir drawdown pressure must exceed the capillary pressure in order to initiate fluid flow. OilPerm FMMs provide optimum reduction in capillary pressure enabling rapid well cleanup and enhanced hydrocarbon production.

OilPerm FMM blends Increase Relative Oil Permeability

In laboratory testing, the interfacial tension between oil and broken frac fluid, and oil and produced water decreased dramatically with the use of OilPerm FMMs. Reducing the interfacial tension means brine is displaced more effectively resulting in lower water saturation and a higher relative permeability to oil. Ultimately, more oil is released from contacted surfaces.

OilPerm FMM blends are optimized to precisely meet the individual reservoir and fluid characteristics thus providing rapid well cleanup, enhanced productivity and maximized ultimate recovery following fracture stimulation treatments.

Loss of efficacy caused by adsorption is demonstrated by flowing frac fluid with either OilPerm FMM or a conventional product through a pack of proppant with crushed formation material. The low interfacial tension generated by OilPerm FMM shows that adsorption is minimized while the conventional product lost most of its effect in the first pore volume injected.

Case Study – Proven Technology

The value of OilPerm FMMs is proven in operations by direct comparison to conventional products. In this field study, the average cumulative production for 9 wells treated with OilPerm FMM technology was compared to 12 offset wells treated with other conventional products. After 1 year of production, the average increase in oil produced per well was 35% while the gas produced per well was increased by 290%.

For more information about how OilPerm FMMs can help reduce your cost per BOE, contact your local Halliburton representative or email stimulation@Halliburton.com.

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