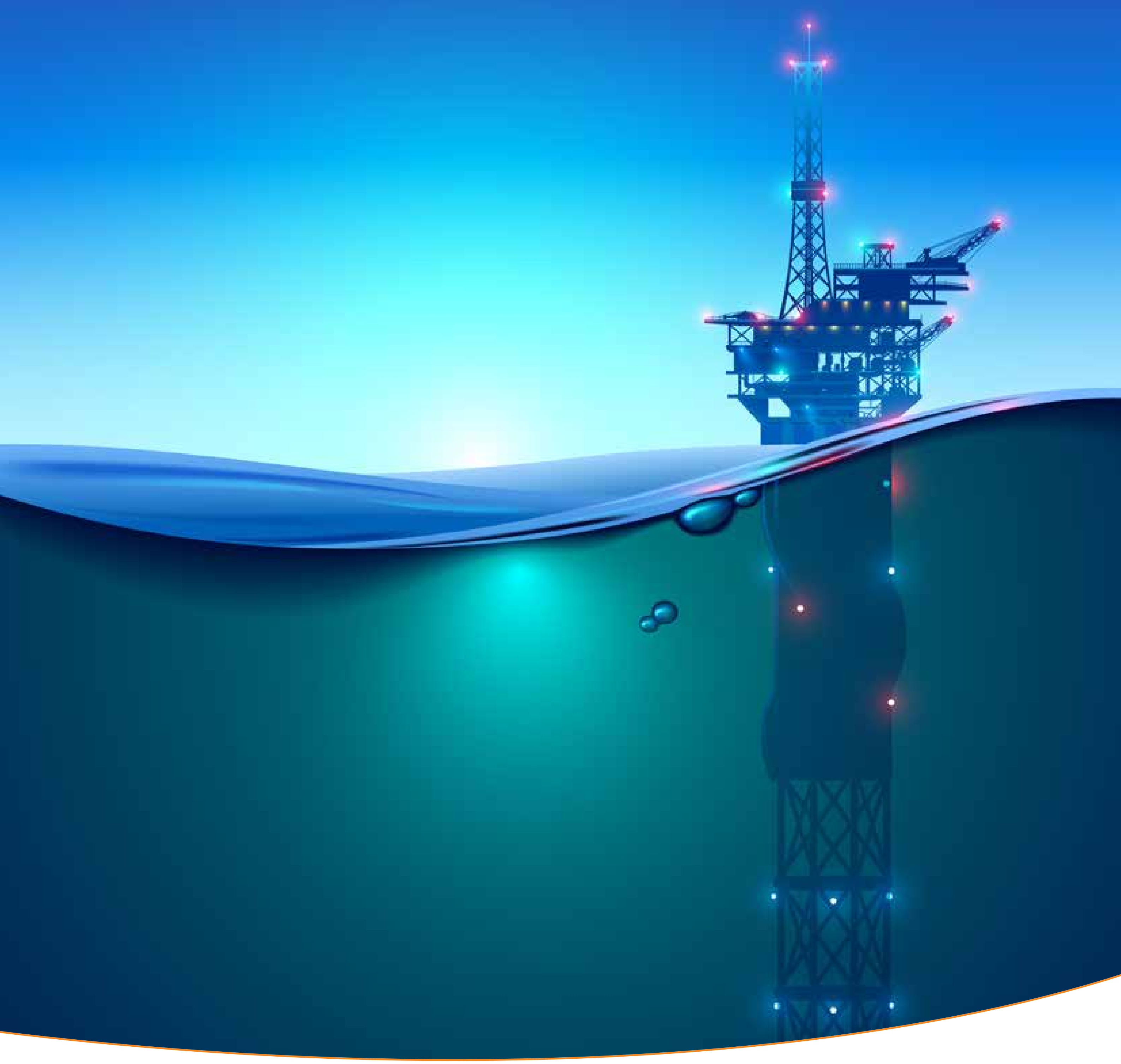


High performance viscoelastic surfactant portfolio

Nouryon

Viscoelastic surfactant portfolio

Nouryon viscoelastic surfactants (VES), due to their unique chemical structures, can exhibit different characteristics depending on the type of environment they are exposed to. They can generate highly temperature-stable foams, impart excellent IFT reduction and create a non-damaging and reversible viscous gel-structure that can also reduce friction and have a positive impact on overall lubricity of the fluid.

The unique behavior of viscoelastic surfactants to generate viscosity when exposed to saline environments in addition to their rheopectic properties along with temperature induced-viscoelasticity make these surfactants highly advantageous for a variety of oilfield applications when compared with standard polymer-type viscosifiers. Some of these applications include:

Stimulation applications

- In-situ diversion used in HCl acidizing for carbonate reservoirs
- Diversion pads when used in sandstone acidizing operations
- Non-damaging viscosifiers in hydraulic fracturing applications

Drilling and completion applications

- Non-damaging viscosifiers for use in gravel packing and completion fluid applications
- High temperature lubricants for use in non-damaging drill-in fluids
- Non-damaging viscous pad to prevent leak-off and fluid losses

Viscoelasticity

VES are termed as such because they are capable of imparting shear-thinning and elastic viscosities based on the environment that they are exposed to. This is unlike most conventional polymers used today that rely on swelling to viscosify fluids.

When exposed to solutions containing low concentrations of cationics, these surfactants typically maintain a spherical micellular structure (with little or no viscosity).

However, when immersed in solutions containing a higher concentration of ions and with the effect of temperature, these spherical micelles elongate into rod-like micelles that form a cross-linked gel structure thus giving viscosity to the fluid.

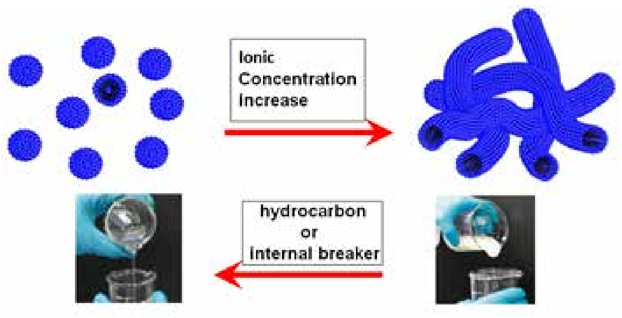


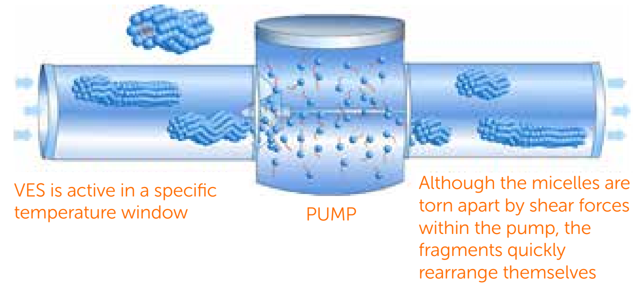
Image from Paper
Yu et al. SPE 121715; Nasr-El-Din et al. SPE 89418

Rapid viscosity breaking

The addition of unipolar solvents or VES-breaking surfactants, causes the rod-like VES micelles return to a spherical structure which results in a rapid breaking of the fluid viscosity.

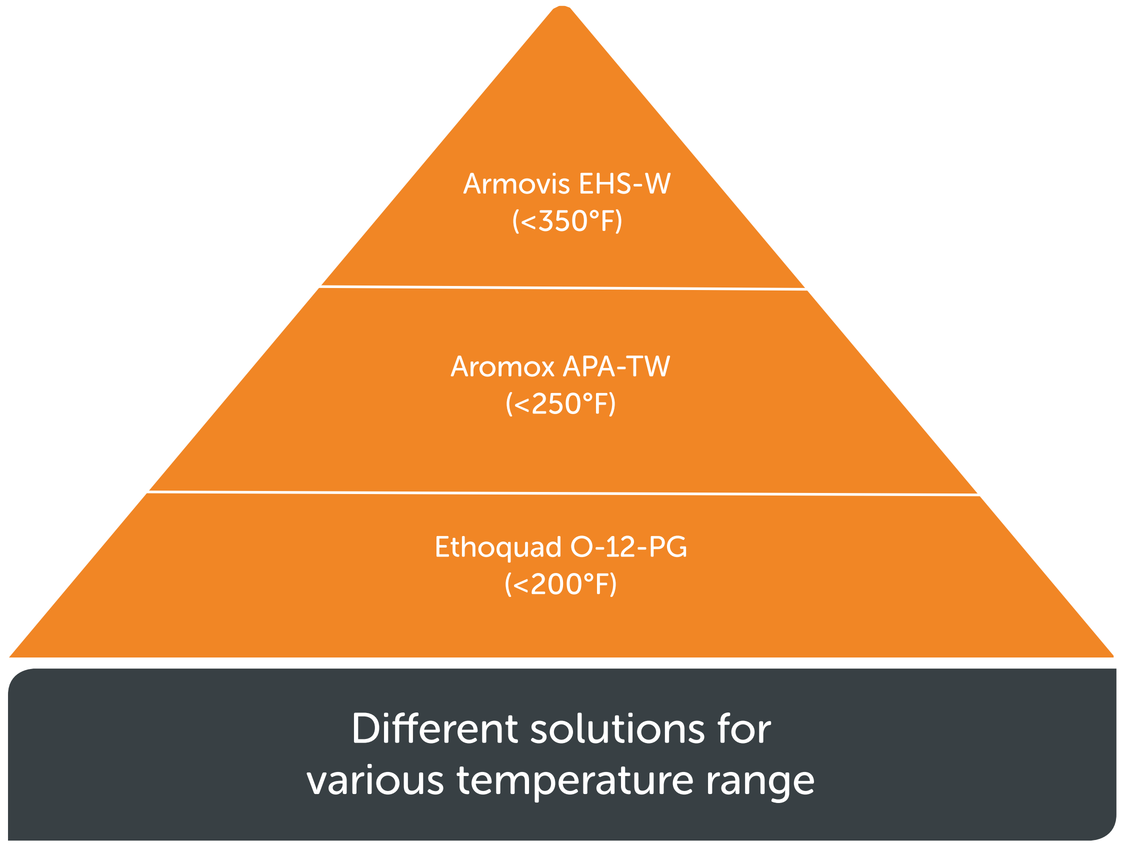
Shear-thinning and elastic behavior

Allows for lower pump pressure and excellent proppant carriage as compared to polymers.



Viscoelastic surfactant products

Nouryons commercial viscoelastic range of products allow for a broad range of applications based on temperatures ranging from 75°F up to 350°F.



Viscoelastic surfactant viscosity data

The distinctive mechanism through which VES micelles cross-link to impart viscosity allows for a wider range of operation and enhanced thermal stability.

Temperature

The Nouryon viscoelastic range of surfactants allows for applications over a wide-range of temperatures (100-350°F).

Each grade of viscoelastic surfactant chemistry can be easily piloted to suit the application at hand based on the temperature requirements.

Factors that affect the viscosity of VES fluids include:

- Temperature
- Concentration and type of surfactant
- Concentration and type of brine
- Compatibility of other additives in the fluid

6% VES in 30% $CaCl_2$

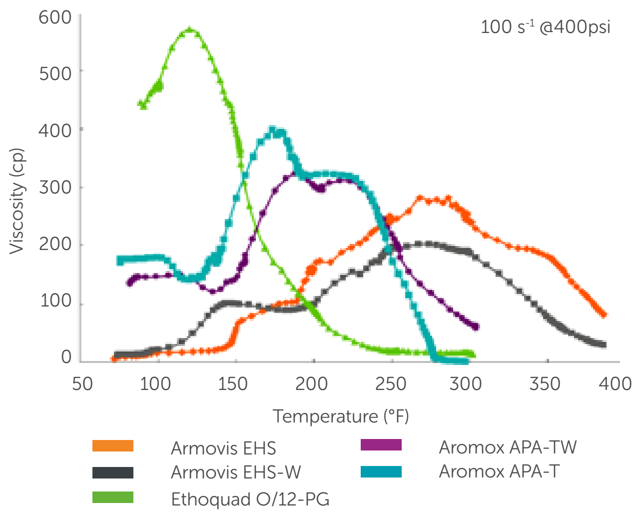


Fig. 1 Viscosity vs. Temperature functionality of Nouryon VES portfolio

Thermal stability

Viscoelastic surfactants exhibit an excellent thermal stability as compared to polymer-based viscosifiers.

- Non-damaging and reversible viscosity when used with internal breakers and/or post-flush breaking fluids
- Unlike polymers, consistent viscosity over extended periods of time
- Resistant to thermal degradation over time at temperatures below 350°F
- Temperature stability tests have shown stable viscosities over periods of up to 14 days

6% EHS (2457-73-3) in 30 wt% $CaCl_2$

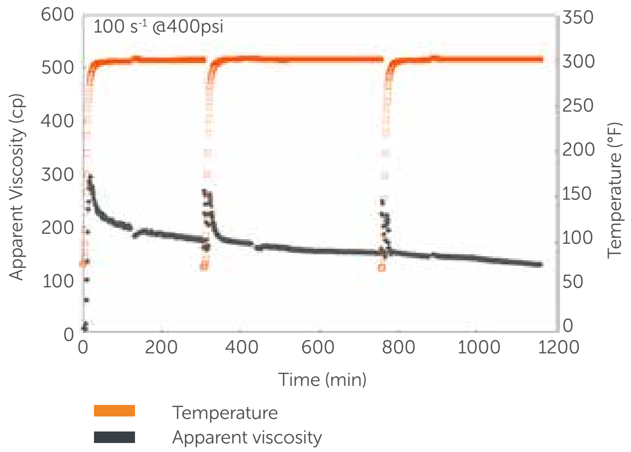


Fig.2 Thermal Stability of Armovis EHS in depleted acid (20% HCl -> 30% $CaCl_2$ brine) at 300°F

Viscoelastic surfactants are soluble in well-bore fluids, leaving no residue which makes them non-damaging to the formation.

VES breaking

Through the use of mutual solvents or hydrocarbons as a post-flush, the gel structure of VES fluids can be rapidly broken down resulting in no formation damage as compared to polymeric viscosifiers.

Hexane as Breaker for Armovis EHS at 6% in 30% $CaCl_2$

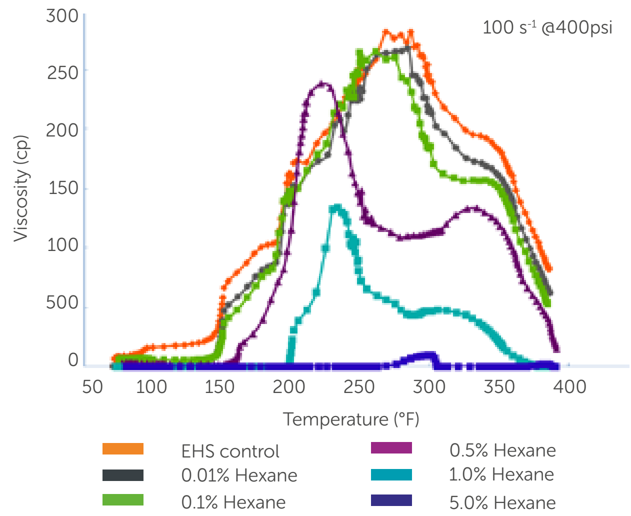


Fig. 3 Breaking effect of VES Gel through the use of Hexane

Delayed internal breaking

Based on the type and concentration of breaker used, VES fluids can be piloted to break in a set amount of time.
Developed internal breakers can also be used for different applications to pilot the breaking time.

EHS and EGMBE in 30% $CaCl_2$ at 300°F

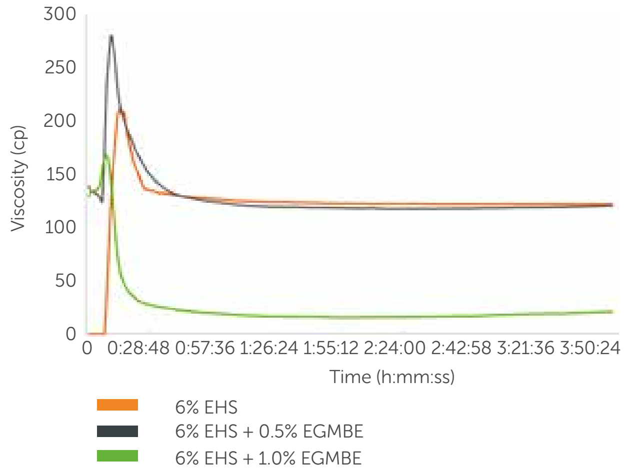


Fig.4 Breaking effect of VES GEL through EGMBE as a mutual solvent post-flush

Conclusions

The Nouryon VES range offers significant advances in a variety of applications and temperature profiles.

- Viscosification of fluids at bottom-hole temperatures at up to 170°C/350°F
- Viscoelastic properties that can deliver better diversion and proppant placement
- Shear-thinning properties allow for lower surface pump pressures
- Lubricity and friction reducing effect of gel
- Improved ecotoxicity over current VES chemistries
- Effective and controllable breaking of gels to enhance reservoir productivity
- Non-damaging characteristics over polymer chemistries
- Excellent iron and other contaminant tolerance over current chemistries

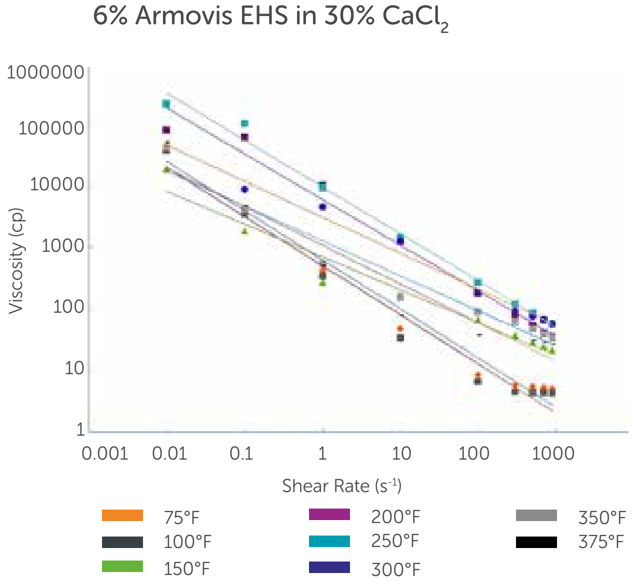


Fig. 5 Example of shear-thinning viscosity of VES fluids

Excellent shear recovery characteristics

Unlike polymeric viscosifiers that degrade on shear and require a cross-linker to activate a higher viscosity during pumping, Viscoelastic surfactants show almost complete recovery of viscosity after being exposed to high shear conditions.

This allows for much more effective proppant carriage and placement into the well-bore when considered for fracturing applications.

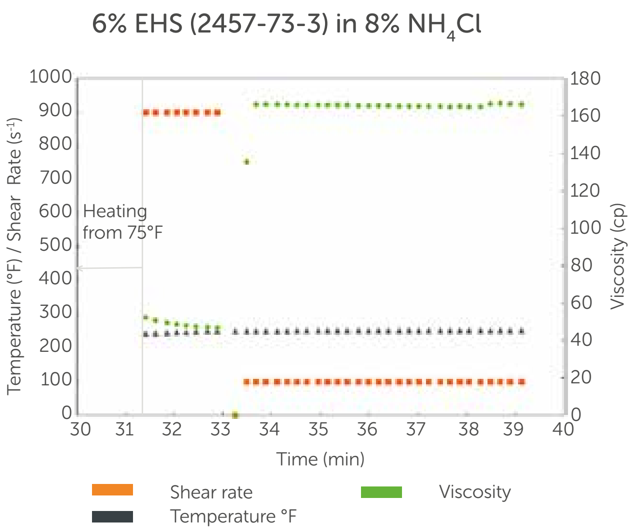


Fig.6 Example of viscoelastic properties of VES fluids (6% VES in NH_4Cl brine)

Product	Temp stability	Chemistry	Flash point	Pour point	Activity	REACH	Biodegradability data
Ethoquad O/12 PG	200°F	Oleyl methyl ammonium chloride + 2 EO	104°C	nd	69% (in PG)	No	Not readily biodegradable
Aromox APA-T	250°F	Tallow amidoamine oxide	>100°C	4°C (mp)	50%	No	To be tested
Aromox APA-TW	250°F	Tallow amidoamine oxide	>100°C	<0°C (from PDS)	42%	No	To be tested
Armovis EHS	350°F	Zwitterionic surfactant	25°C	12°C	42%	No	20%<x<60%; OECD 306 (seawater) screening
Armovis EHS-W	350°F	Zwitterionic surfactant	>23°C	-15°C	42%	No	20%<x<60%; OECD 306 (seawater) screening

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