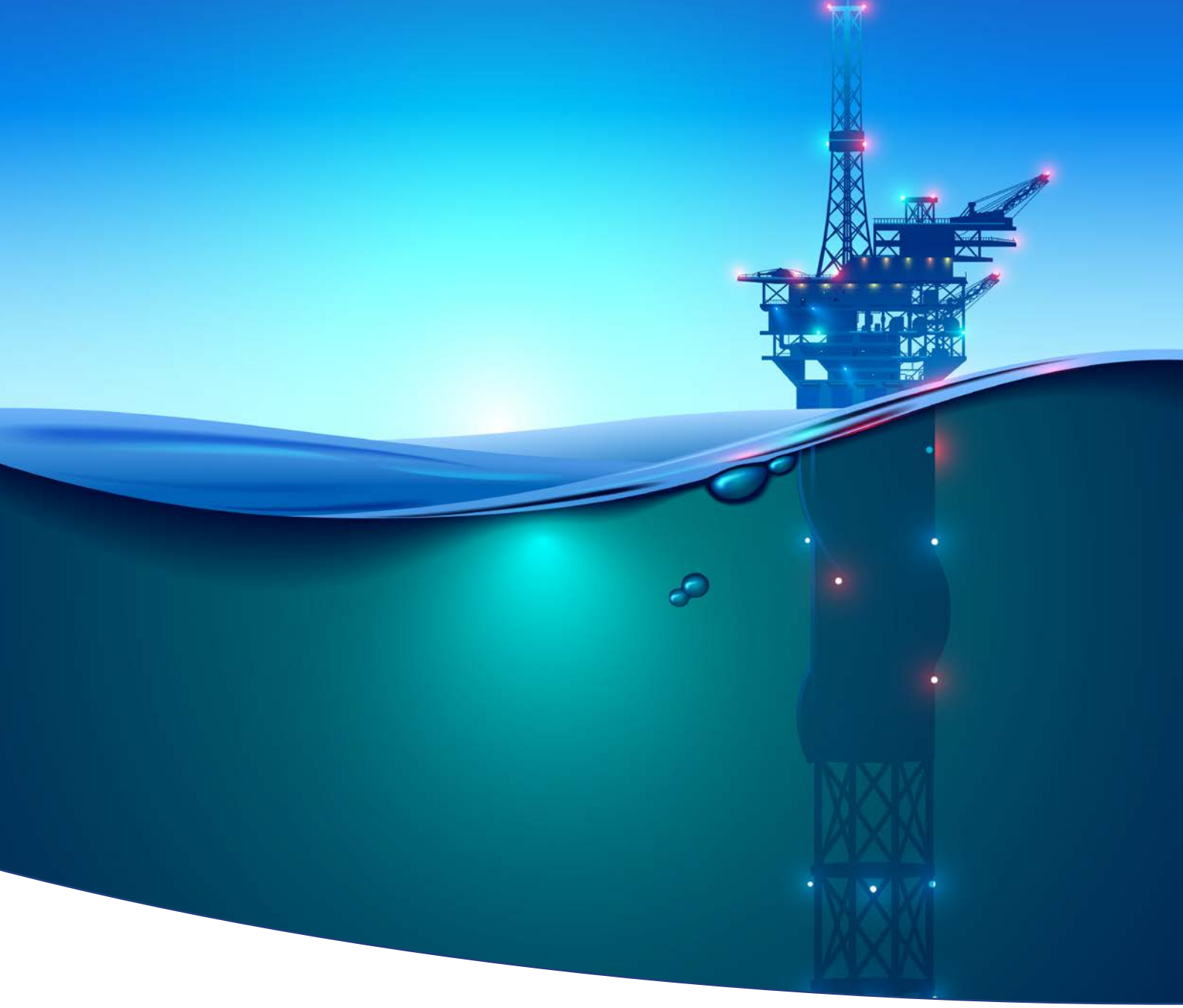


Viscoelastic surfactants

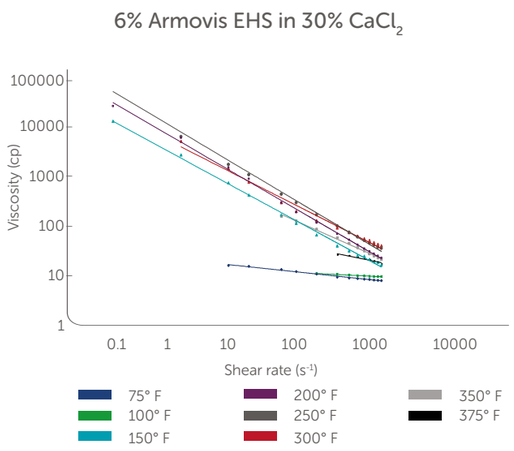
For oilfield stimulation, drilling and completion applications

Nouryon

Increase well productivity

Optimize well productivity or injectivity by adding our reliable, non-damaging viscoelastic surfactants as diverting agents or viscosifiers for oilfield stimulation, drilling and completion processes.

The unique behavior of viscoelastic surfactants (VES) to generate rheopectic and temperature-induced viscoelasticity when exposed to saline environments make them highly advantageous for a variety of oilfield applications in comparison to standard polymer-type viscosifiers.



Example of shear-thinning viscosity of VES fluids

- Non-damaging to formations versus polymer chemistries
- Lower toxicity than other VES chemistries
- Effective and controllable breaking of gels to enhance reservoir productivity
- Viscosification of fluids at high bottom-hole temperatures
- Facilitation of handling/mixing in extreme cold environment with winterized variants
- Viscoelastic properties for better diversion and proppant placement
- Shear-thinning properties for lower surface pump pressures
- Lubricity and friction reducing effect of injected fluids
- Higher iron and other contaminant tolerance than alternative VES chemistries

Ask us which VES fits your need:

- Armovis® EHS
- Armovis® EHS-W
- Aromox® APA-T
- Aromox® APA-TW
- Armovis® LT

website | nouryon.com/markets/oilfield
email | oilfield@nouryon.com

We believe good chemistry is key to a sustainable future and are dedicated to continually innovating and creating environmentally responsible solutions, allowing us to deliver enhanced productivity and improved sustainability performance.

Our viscoelastic surfactant solutions are specifically designed to meet the varying temperature demands of hydrocarbon-bearing reservoirs while maintaining a constant viscoelasticity and viscosity and to leave no residue in the formation. Additionally, we offer a selection of “winterized” VES for extremely cold surface temperatures (see “W” designation).

Stimulation applications

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

Drilling and completion applications

- Non-damaging viscosifiers in gravel packing and completion fluid applications
- High temperature lubricants in non-damaging drill-in fluids
- Non-damaging viscous pad in leak off and fluid loss prevention

Reliable VES performance

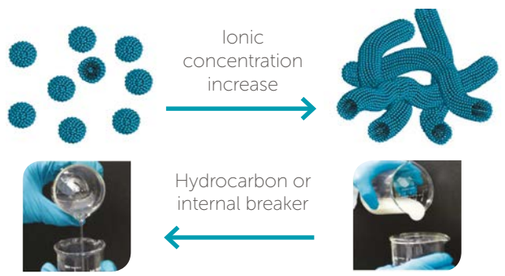
The distinctive mechanism through which VES micelles crosslink to maintain viscosity enhances thermal stability across a wider temperature range.

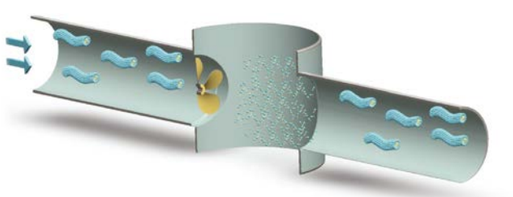
Viscoelasticity

When exposed to solutions containing low concentrations of electrolytes, VES typically take on a spherical micellular structure (with little or no viscosity).

However, when immersed in solutions having a higher concentration of electrolytes and within the optimal temperature range, the VES spherical micelles elongate to form rod-like micelles. This creates a cross-linked gel structure that increases fluid viscosity and allows the VES to reform after shearing.

In contrast to VES, most conventional polymers are unable to maintain viscosity and elasticity when stressed by their environment.





Reformation of micelles after shearing

What are viscoelastic surfactants?

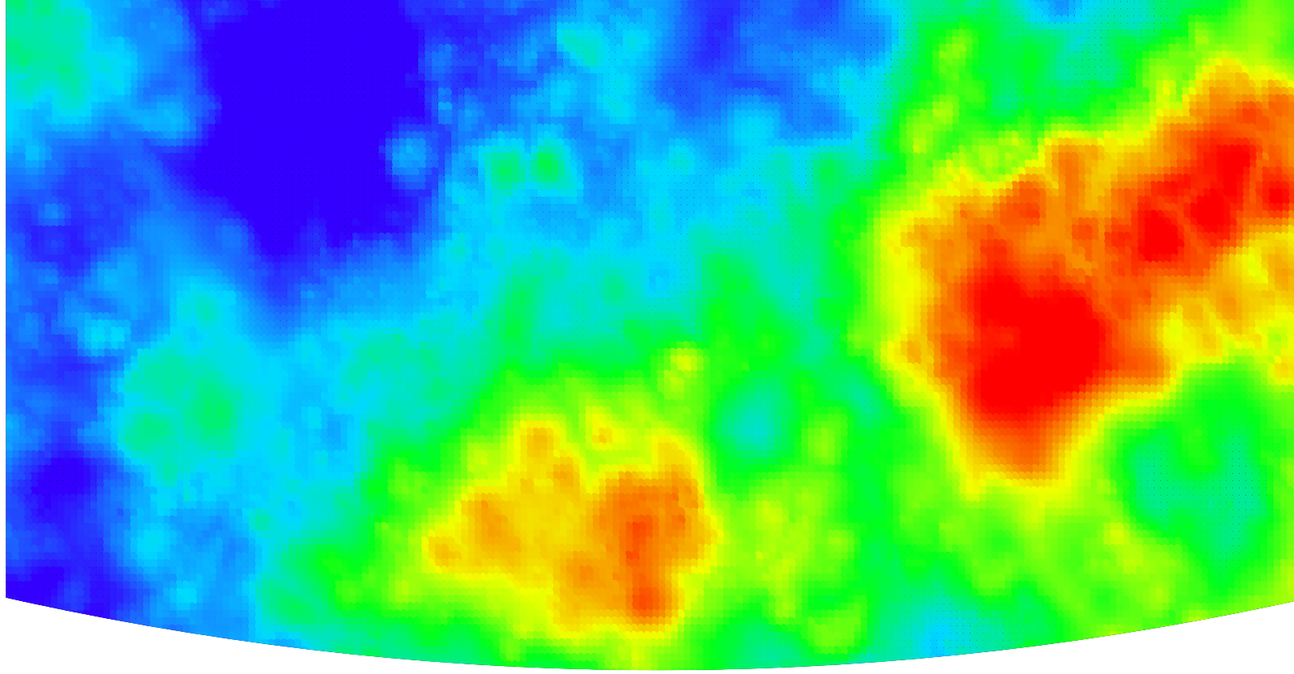
Viscoelastic surfactants (VES) are an ideal replacement for polymeric viscosifiers in oilfield processes. The properties of VES tend to remain more constant when exposed to different environments, such as variations in temperature and fluid salinity. VES are also soluble in wellbore fluids, leaving no residue behind resulting in no damage to the formation.

Shear-thinning and elastic behavior

In fracturing and completion applications, our VES can be mixed into the fluid as a concentrate and will develop viscoelasticity once fully blended with the brine.

When the fluid is added before a pump, it is exposed to high shear. Although the elongated rod-like micelles are sheared, they quickly reform after passing through the pump and regain viscoelasticity.

Fully developed viscoelastic surfactants decrease turbulence within the pump, allowing for lower pump pressure and excellent proppant carriage.



Temperature

Each grade of our viscoelastic surfactants can be easily piloted within many applications and across temperatures ranging from 75° F to 350° F (24° C to 177° C).

In addition to temperature, other factors that affect the viscosity of VES fluids include:

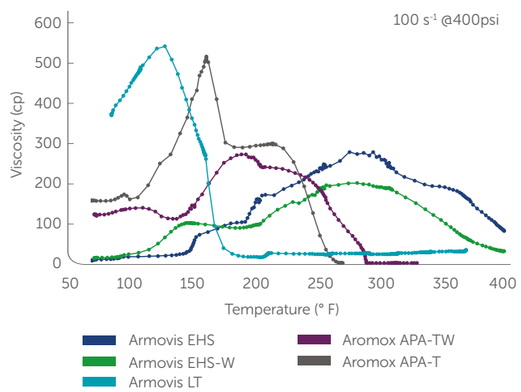
- Concentration and type of surfactant
- Concentration and type of brine
- Compatibility of other additives in the fluid

Thermal stability

Viscoelastic surfactants exhibit an excellent thermal stability.

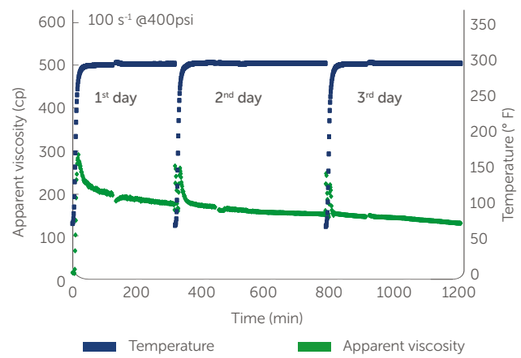
- Consistent viscosity over extended periods of time, unlike polymers
- Resistant to thermal degradation over time at temperatures below 350° F (177° C)
- Temperature stability tests have shown steady viscosities over periods of up to 14 days

6% VES in 30% $CaCl_2$



Viscosity vs. temperature functionality of our VES

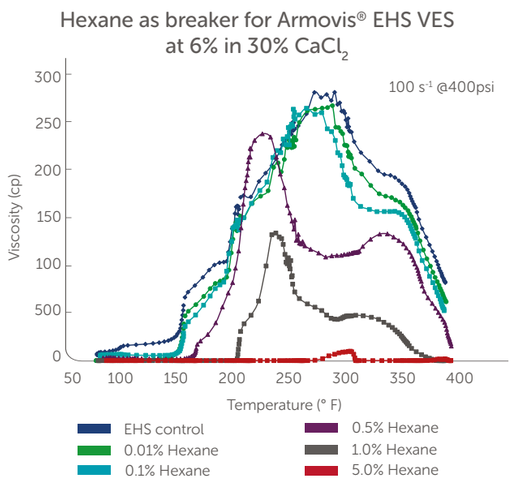
6% Armovis® EHS in 30 wt% $CaCl_2$



Thermal stability of Armovis® EHS VES in depleted acid (20% HCl -> 30% $CaCl_2$ brine) at 300° F (149° C)

VES breaking

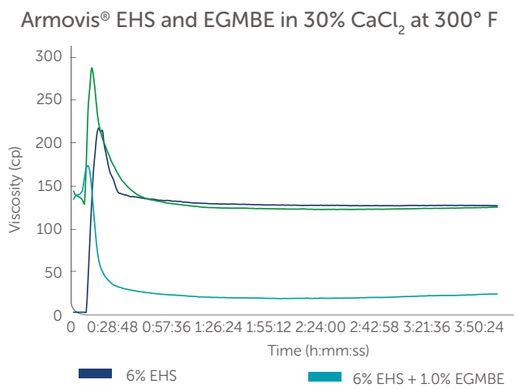
The gel structure of VES fluids can be rapidly broken-down during flow back once in contact with reservoir crude oil after treatment or by a post-flush stage containing mutual solvents or hydrocarbons. This allows VES to leave the formation undamaged compared to polymeric viscosifiers.



Breaking effect of VES gel using Hexane

Delayed internal breaking

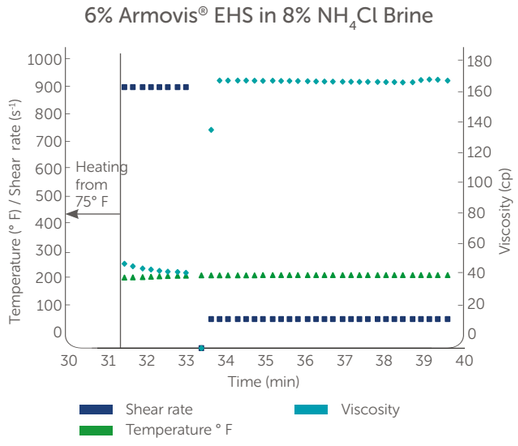
Based on the type and concentration of breaker used, VES fluids can be tailored to break in a set amount of time. Internal breakers can also be developed for different applications to evaluate the breaking time.



Breaking effect of VES gel through ethylene glycol monobutyl ether (EGMBE) as a mutual solvent post-flush

Shear recovery

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 wellbore when considered for fracturing applications.



Example of viscoelastic properties of Armovis® EHS VES fluids

VES portfolio

Our non-damaging viscoelastic surfactants are designed to meet the demanding temperatures of oilfield stimulation, drilling, and completion processes and to help optimize well productivity or injectivity.

When exposed to high downhole temperatures, our VES maintain constant viscoelasticity and viscosity. Winterized variants are also available to facilitate handling and mixing in extremely cold environments (see products with "W" label).

Product	Temp stability	Chemistry	Flash point	Pour point	Activity	EU REACH	Biodegradability data
Armovis® EHS	350° F (177° C)	Zwitterionic surfactant	77° F (25° C)	45° F (7° C)	42%	No	20%<x<60%; OECD 306 (seawater) screening
Armovis® EHS-W	350° F (177° C)	Zwitterionic surfactant	73° F (23° C)	5° F (-15° C)	42%	No	20%<x<60%; OECD 306 (seawater) screening
Aromox® APA-T	250° F (121° C)	Tallow amidoamine oxide	212° F (100° C)	39° F (4° C)	50%	No	To be tested
Aromox® APA-TW	250° F (121° C)	Tallow amidoamine oxide	212° F (100° C)	25° F (-4° C)	42%	No	To be tested
Armovis® LT	200° F (93° C)	Ethoxylated ammonium chloride	220° F (104° C)	21° F (-6° C)	69% (in PG)	No	Not readily biodegradable

Contact us for more details
website | nouryon.com/markets/oilfield
email | oilfield@nouryon.com

Nouryon

Nouryon is a global, specialty chemicals leader. Markets and consumers worldwide rely on our essential solutions to manufacture everyday products, such as personal care, cleaning goods, paints and coatings, agriculture and food, pharmaceuticals, and building products. Furthermore, the dedication of more than 7,900 employees with a shared commitment to our customers, business growth, safety, sustainability and innovation has resulted in a consistently strong financial performance. We operate in over 80 countries around the world with a portfolio of industry-leading brands. Visit our website and follow us @Nouryon and on LinkedIn.

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