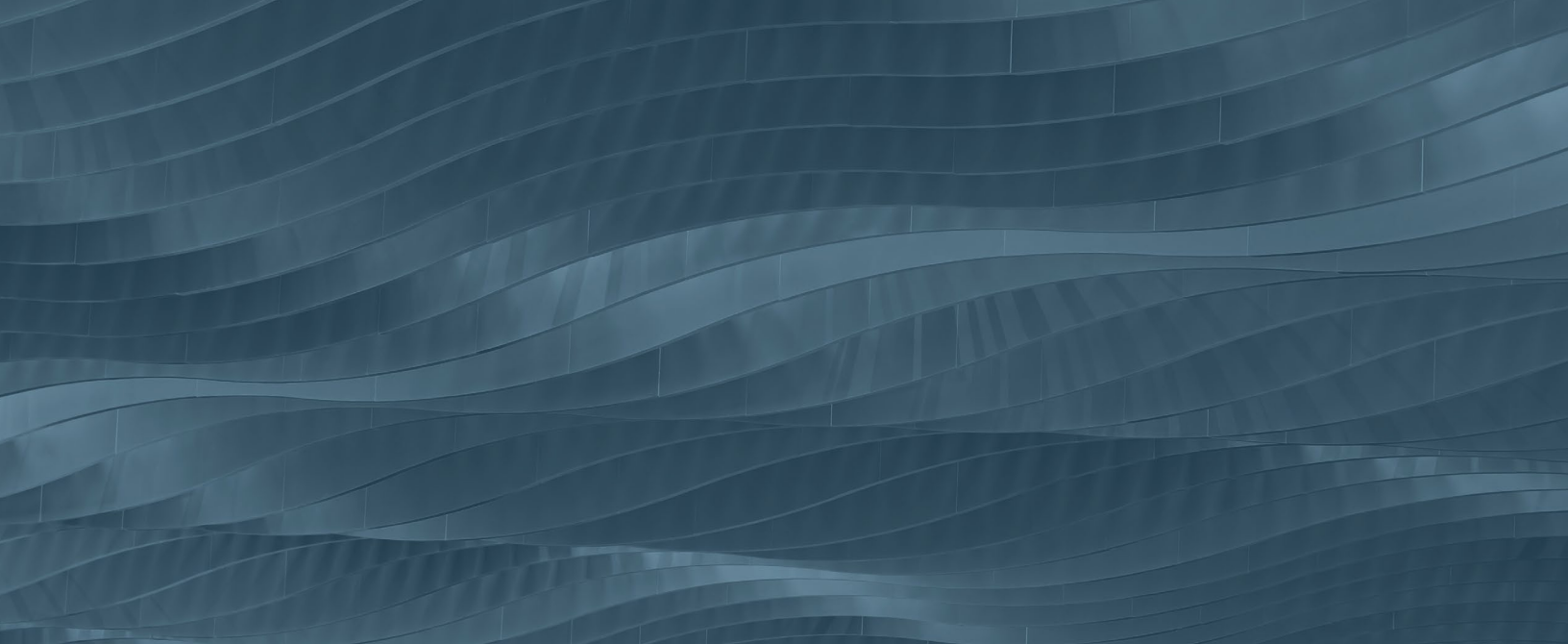


Unlock more oil with fewer chemicals

Dow additives for chemical
enhanced oil recovery





Achieve more with less

With a significant amount of oil remaining in a reservoir after primary and secondary recovery, operators continue to hunt for cost-effective ways to increase recovery without drilling new wells. Since many fields already use water flooding, chemical enhancements to water flooding are a natural evolution in the production of a well. Chemical enhanced oil recovery (CEOR) techniques such as wettability alteration, polymer flooding, surfactant flooding or combinations of each are all options to boost production in mature reservoirs.

Many reservoirs, such as mixed wet sandstone and oil wet carbonates, trap a significant amount of oil at the large rock surface area. This oil is bound tightly and is difficult to remove by traditional water flooding methods. Creating more water wet conditions on the rock releases significant amounts of oil and allows water to imbibe into the rock through capillary action. Wettability can be changed through the use of surfactants.

The most effective improvement to water flooding is achieved through individual design of a CEOR method. After evaluating a reservoir, a combination of alkalis (A), surfactants (S) and polymers (P) can be used to increase oil recovery. While there are many different combinations (ASP, SP, P, AP), one of the most difficult tasks is to find a stable surfactant formulation for a given oil and brine mixture.

With an extensive background and experience in polymer chemistry and surfactants for use in oil production, Dow is at the forefront of the CEOR evolution. We offer a broad portfolio of solvents, surfactants, and chelants along with the expertise to fine-tune these solutions to individual field conditions to help producers get the most out of their assets.

Dow's broad CEOR portfolio

- **ELEVATE™ WA Surfactants** – A broad range of anionic and non-ionic surfactants that can increase oil recovery by lowering surface tension between oil and the reservoir rock. They offer excellent wetting, emulsifying and dispersing properties in a range of oilfield chemicals.
- **ELEVATE™ SF Surfactants** – Anionic and non-ionic surfactants that work in synergy with the primary surfactant to offer ultralow interfacial tension (ULIFT).

- **DOWANOL™, CELLOSOLVE™, CARBITOL™ and alcohol Co-Solvents** – Effective glycol ether and alcohol co-solvents for formulating a variety of complex surfactant/co-surfactant/co-solvent mixtures that are suitable for a system's specific needs.

In addition, Dow has a significant co-solvent portfolio with solvents that are very hydrophilic to very hydrophobic. Given the variability in reservoir conditions that AP and ASP floods can be applied, their tunability can provide a competitive advantage in terms of formulation optimization.

- **VERSENE™ and VERSENEX™ Chelants** – Chelants used to manage water quality, particularly divalent ions, to allow easier formulation of surfactant brine solutions.

ELEVATE™ chemical EOR solutions

Better performance

ELEVATE™ chemical EOR products encompass a **broad portfolio of surfactants, solvents, and chelants** that have proved resilient to harsh reservoir conditions in the field application of ASP.

High actives, winterization

Additives have high actives concentration which **enables savings in logistics** and storage. Winterization down to -40 °C available with environmentally friendly solvents (percentage actives between 20-40%).

Sustainable impact

Injection of Dow's additives to ASP floods **increase production efficiency of reservoirs** (hence reduce GHG impact). Dow offers products that are biodegradable, pose no bioaccumulation, and have low to no toxicity.

Product stability and safety

Additives are design to not generate stable emulsions when back-produced and have no negative effects on corrosion or elastomer stability, posing **no risk to surface facilities**. Additives are also safe to handle and load/unload under normal PPE protection.

Common CEOR methods

After water flooding chemical techniques are often used to improve oil recovery after water flooding. One of the most cost-effective techniques is the use of surfactants to provide reservoir rock. Oil or mixed water reservoir rock can be changed to a water wet state, allowing increased water injectivity and more oil to be recovered. In carbonate reservoirs where permeabilities are low, a traditional ASP flood may be difficult to implement.

Surfactant-induced wettability alteration significantly increases water injectivity and recovery rates in carbonate systems. Easy to implement in the field, these tuned surfactant systems are injected directly into the water flooding system, and imbibe deep into the matrix, releasing oil and improving flow pathways. Dow's experts can tailor an effective wettability solution for your reservoir using state-of-the-art core floods.

Alkaline-surfactant-polymer flooding

While wettability alteration is a cost-effective approach, much higher recovery rates are afforded by other CEOR methods. The most effective CEOR operations in sandstone reservoirs involve flooding a reservoir with either an alkali-surfactant-polymer (ASP) combination or an alkali-polymer-only (AP) injection. These chemical injections interact with water remaining from the secondary recovery stage, freeing the trapped oil and making it recoverable.

ASP chemical enhanced oil recovery

A properly formulated ASP flood combines the best of three chemical components to optimize recovery:

- **Alkali:** reduces surfactant adsorption on reservoir rock and helps reduce oil-water interfacial tension by interacting with the crude oil to form natural soaps.
- **Surfactant:** reduces interfacial tension between oil and water to extremely low levels (ULIFT), which makes it easier to displace the oil and drive it to the production well.
- **Polymer:** increases the drive water viscosity, which improves sweep efficiency and mobility control.

Often, using only a single surfactant in the ASP can lead to the formation of undesired viscous emulsions, necessitating the addition of a co-surfactant or co-solvent to generate the desired ULIFT. Dow's ELEVATE co-solvents and co-surfactants enable ULIFT formulations by providing:

- Improved phase stability
- Lower injection slug viscosity compared to viscous emulsions that can cause high pressure gradients
- Increased residual oil recovery rate compared to formulations that form viscous emulsions which tend to move slowly through the reservoir

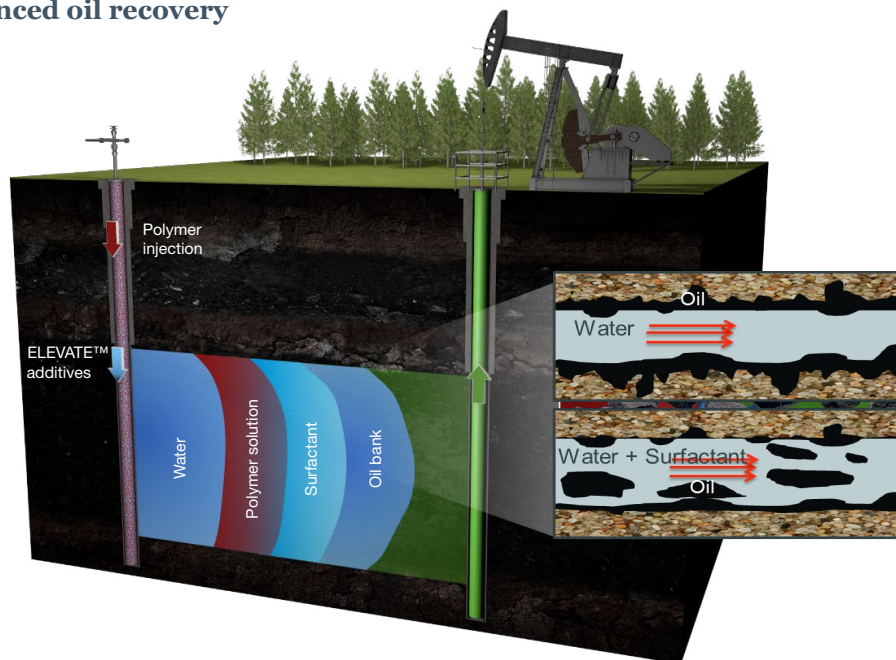


Figure 1. ASP flooding example, with flooding in one wells to drive oil to a single production well.

Let Dow help you select the optimal approach

CEOR design and implementation is a very sophisticated process. Selecting the components for the full formulation depends on many factors, including reservoir temperature, pressure, depth, reservoir geology, and salinity. Each oilfield is different and has to be characterized before the most effective solution can be modeled and produced.

Dow's team of experts possesses a thorough understanding of the dynamic relationship between oil and brine, as well as the intricacies of geology and the mechanics of oil extraction. That expertise allows us to help evaluate the feasibility of a CEOR plan using various surfactants and co-solvents. We will fully formulate and flood-test a surfactant-oil-brine system for your well that matches both reservoir brine salinity and temperature, one of the most critical factors of a successful CEOR operation.

In addition, Dow can help implement novel solutions for wettability alteration through additives and design of water for injection, further increasing efficiency. This collaboration allows us to customize and fine-tune solutions of high purity and specificity at relatively low cost to optimize operations.

Testing capabilities minimize risk, maximize yield

Dow has developed laboratory evaluation and reservoir simulation capabilities to support field implementation to help customers get more out of previously inaccessible reserves. Dow's EOR lab features extensive capabilities to test multiple core flood set-ups (formation response testers) using PVT cells, phase behavior equipment and interfacial tension measurement equipment. All of our testing is done under actual reservoir conditions to determine the best option for your operation and to allow fine-tuning to meet the precise reservoir pressure, temperature and brine concentrations.

Optimizing formulations with Winsor phase experiments

Winsor phase experiments are widely used in screening and optimizing formulations whose salinity matches the reservoir brine salinity and temperature. Aqueous surfactant solutions and oil are mixed and allowed to coalesce with time, and the phase progression from Winsor Type I (oil-in-water microemulsion) to Winsor Type III (middle phase microemulsion) to Winsor Type II (water-in-oil microemulsion) is observed. This progression occurs by varying formulation components (e.g., hydrophobe length or co-solvent/co-surfactant concentration) or experimental conditions (e.g., salinity, temperature, oil type and pressure).

For CEOR applications, it is typically the salinity that is varied in these experiments, and the salinity at which the lowest IFT is obtained is termed the optimal salinity. The optimal salinity corresponds to where an equal amount of water and oil are solubilized in the Type III middle phase microemulsion.

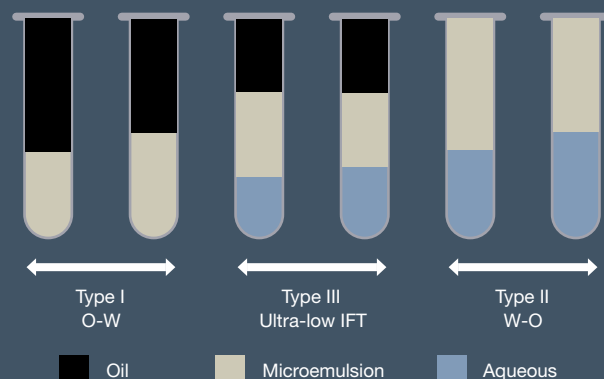


Figure 2. Progression of microemulsion behavior in Winsor phase experiments.

Name	Type	Active %	Use
ELEVATE™ SF106	Anionic	<=46%	Workhorse co-surfactant agent for use as coupling agent and compatibilizer.
ELEVATE™ SF108*	Anionic	70%	Very hydrophilic co-surfactant for emulsion stability in the presence of brine
ELEVATE™ SF110	Anionic	45-47%	Co-surfactant agent for use as coupling agent and compatibilizer. Higher emulsion stability power than SF106.
ELEVATE™ SF120	Anionic	46%	Co-surfactant agent for use as coupling agent and compatibilizer. Higher emulsion stability power than SF110.
ELEVATE™ SF160	Anionic	35-37%	High temperature stable co-surfactant for emulsion stability. Very stable in wide pH range.
ELEVATE™ SF144	Anionic	>=75%	Very hydrophilic co-surfactant for emulsion stability in the presence of brine.
ELEVATE™ SF600	Non-ionic	50%	Environmentally friendly co-surfactant with high cloud point, very stable at basic conditions.
ELEVATE™ SF601	Non-ionic	70%	Environmentally friendly co-surfactant with high cloud point, very stable at basic conditions.

This list of Dow surfactants contains 6 anionic and 2 non-ionic offerings with wide range of properties. Dow offers more products that can be tailored to enhance performance over offerings.

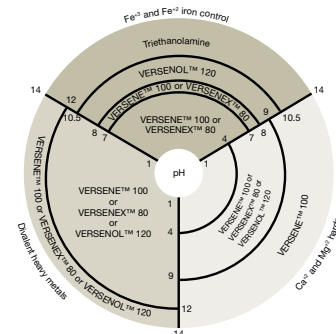
* Not currently register for commercial use in North America or Europe

Name	Type	Active %	Use
iso- Propanol	Alcohol	100%	Workhorse solvent, multipurpose.
iso- Butanol	Alcohol	100%	Workhorse solvent, multipurpose.
Butyl CELLOSOLVE™	Glycol ethers	>99%	Workhorse solvent, fast evaporating, good hydrophilic/hydrophobic balance. Water soluble.
Butyl CARBITOL™	Glycol ethers	>99%	Workhorse solvent, higher molecular weight, lower evaporation rate, and more water soluble than butyl CELLOSOLVE™.
ELEVATE™ SL103	Glycol ethers	90-100%	Lower evaporation rate, and more water soluble than butyl CARBITOL™.
ELEVATE™ SL404	Glycol ethers	50-100%	Lower evaporation rate, and more water soluble than butyl CARBITOL™. Higher molecular weight than Elevate SL103.
DOWANOL™ DPnB	Glycol ethers	>98.5%	Excellent solvent to address formulation viscosity. Recommend to use blended with CELLOSOLVE™ or CARBITOL™.

This list of Dow solvents are mostly targeted to be used as co-solvents in the chemical EOR industry. Dow offers more products that can be tailored to enhance performance over offerings.

Name	Type	Active %	Use
VERSENE™ 100	EDTA	37-39%	Most widely used chelant, hexadentate.
VERSENOL™ 120	HEDTA	38%	Most soluble chelant at low pH conditions, pentadentate.
VERSENEX™ 80	DTPA	38-40%	Most resistant to harsh conditions, octadentate.

This list of Dow chelants mostly targeted at sequestering di-valent ions at specific pH ranges. Products available in liquid and powder form. Dow chelants are water soluble and stable up to 200°C.





Dow's commitment to sustainability

Dow's commitment to sustainability is infused into the very DNA of our Company. In 2006, we launched our 2015 Sustainability Goals, which focused not only on the Company's footprint in our own operations but also our handprint through the positive impact of Dow products and their role in global sustainable development. Now we have introduced our 2025 Sustainability Goals. With these Goals, Dow seeks to advance the wellbeing of humanity by helping lead the transition to a sustainable planet and society. The seven commitments that comprise the 2025 Sustainability Goals represent the next step in our long-term strategic journey. For more information on how sustainability is integrated into all aspects of our business and operations, please visit [dow.com/sustainability](https://www.dow.com/sustainability).



More EOR solutions from Dow

Dow has additional EOR solutions that can be customized for different EOR strategies. Our ELEVATE™ brand covers additives to improve conformance in miscible gas floods in conventional and unconventional floods, as well as improve formulations and phase stability for chemical EOR floods such as ASPs. EOR techniques often lead to water treatment issues including mineral scaling, unresolved emulsions and water cleanup. Dow can work with you to find the optimal solution to water treatment needs for EOR.

Product stewardship and safety

Dow has a fundamental concern for all who make, distribute, and use its products, and for the environment in which we live. This concern is the basis for our product stewardship philosophy by which we assess the safety, health, and environmental information on our products and then take appropriate steps to protect employee and public health and our environment. The success of our product stewardship program rests with each and every individual involved with Dow products – from the initial concept and research, to manufacture, use, sale, disposal, and recycle of each product.

Dow strongly encourages its customers to review both their manufacturing processes and their applications of Dow products from the standpoint of human health and environmental quality to ensure that Dow products are not used in ways for which they are not intended or tested. Dow personnel are available to answer your questions and to provide reasonable technical support. Dow product literature, including safety data sheets, should be consulted prior to use of Dow products. Current safety data sheets are available from Dow.

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