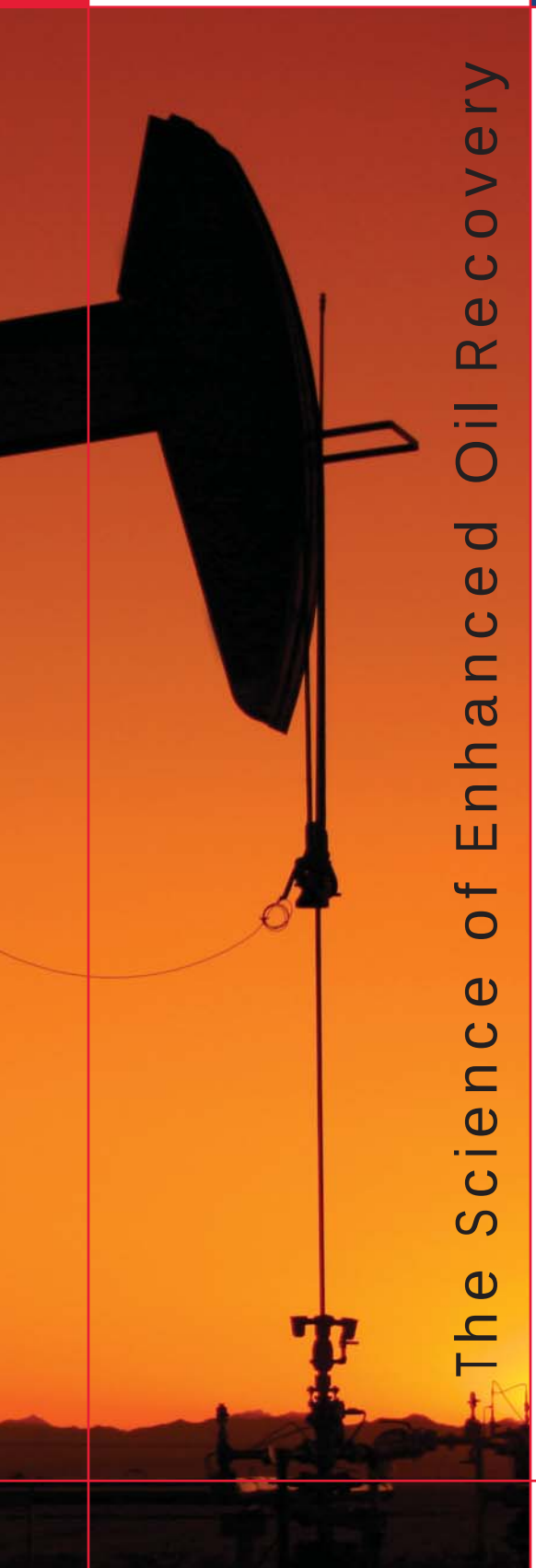
TIORCO
A NALCO & STEPAN COMPANY

Technology Products Summary



CONFORMANCE IMPROVEMENT AND WATER SHUT-OFF

MARCIT

Marathon's MARCIT gel polymer technology was a welcomed R&D breakthrough as a means to produce in-situ bulk polymer gels that are used to block high permeability fractures and channels in both injection well and producing well applications.

The MARCIT-CT gel science offers greatly improved gel quality and reduced health risk from the chrome cross-linking reagent. Most notable are simplified chemical processing and field implementation procedures that assure proper gel strength, creation and placement.

Applying the gel treatments to selected injection wells within an aging waterflood project diverts water drive away from developed channels and into oil-bearing rock. Applied to high water-cut producing wells, the gel slug preferentially enters the strongest water flow paths and blocks water intrusion. This allows the producer to be produced in a 'pumped-off' condition that reduces static head pressure on the oil bearing matrix rock.

MARCIT gel is formulated with crosslinked medium molecular weight anionic polymer designed to reduce water flow in fractured or very high permeability (>750 md) formations. MARCIT reduces permeability to water in cases of:

- Water coning
- High permeability channels and fractures in communication with water injection wells
- Fractures and channels connected to active bottom water-drive zones

After insitu gelling occurs, water in-flow to the well is usually reduced to less than 25% of pre-treatment production rates. This reduction to water permeability increases oil permeability and allows the oil-rich matrix to flow oil more easily to the wellbore. The beneficial effects on operating cost are many fold, including less water to pump; replacing expensive-to-operate electric submersible pumps with rod pumps; increased oil production due to improved reservoir draw-down, and fewer well workovers.

CONFORMANCE IMPROVEMENT AND WATER SHUT-OFF IN HIGH TEMPERATURE APPLICATIONS

UNOGEL

Extremely hot reservoirs (above about 220°F) have traditionally been difficult to work with because the high temperatures cause premature gel formation, making placement of large gel treatments difficult. UNOGEL technology allows gel to be placed in high temperature formations, and was developed by UNOCAL.

UNOGEL employs a special organic crosslinking system that forms gels more slowly at high temperatures. In fact, the system is so slow at room temperature that gelation will not occur. At high temperatures, the gels form slowly enough to allow placement of large volumes. Using UNOGEL with regular partially hydrolyzed polyacrylamides, reservoirs up to 300°F can now be treated. The temperature limit can be pushed even higher by working with special polymers.

STABILIZING SWELLING AND MIGRATING CLAYS

TIOR-KOH®
The effects of clays may be subtle, causing loss in injectivity over time, or in the extreme, causing the formation to "lock up" soon after initiating water injection.

Many low permeability sandstone reservoirs contain clays that swell and migrate upon flooding with fresh water. Montmorillonites swell upon contact with fresh water, plugging pore throats and reducing permeability to water injection. Migrating clays, including kaolinites and illites, reduce permeability as they become trapped in pore throat openings. When this happens, damage to the near wellbore area occurs and the injection of the drive fluid is restricted. Thus, waterflood efficiency is greatly reduced and present worth value of the reservoir decreases because oil production rate is proportional to water injection rate.

Most available technologies to stabilize clays are temporary. The TIOR-KOH process reacts with the near well-bore rock of the injection well to permanently stabilize the clays, rendering them immobile and non-swelling. In effect, the treatment increases the injection well radius, allowing higher injectivity to be maintained for a longer time.

Additionally, imbibition chemicals added continuously to the injection water work synergistically to enhance water penetration into the tightest oil bearing rock. TIORCO® 535 reduces the contact angle of injection water to the reservoir rock, thus permitting water to enter pore throats that are normally restricted to water intrusion. Thus, even more oil bearing rock is swept for measurable recovery of incremental oil.

Case history data from treated and un-treated injection wells in the same field attest to the long term effect of increased water injection rates produced by the TIOR-KOH process - faster reservoir fill-up, re-establishment of reservoir pressure, and increased fluid production.

VOLUMETRIC SWEEP IMPROVEMENT

BrightWater®
TIORCO® now offers a technology that promises to maximize your production: BrightWater chemical and application technology. Co-developed by Nalco, BP and Chevron, BrightWater is a sub-micron particulate chemistry that is injected downhole with flood water during a seconday recovery process.

BrightWater has been designed to activate at a pre-determined "in-depth" location within the reservoir. Upon activation, the BrightWater particles expand to many times their original volume, blocking pore throats and directing injection water into untapped, oil-rich zones. This deep reservoir profile modification causes additional oil to be swept toward the producing wells.

Over time, production begins to improve. With a simple treatment, you stand to recover up to an additional 10 percent of the original oil-in-place. This would translate to millions of dollars in value being added to your asset.

Various grades of BrightWater chemistry have been designed to target injection water thief zones at a range of reservoir temperatures and salinities. The latest generation of BrightWater currently tested for some North Sea fields will expand and set at less than 50°C. At this temperature, the technology promises to not only improve sweep efficiency, but also to minimize the volume of chemical plug required.

Colloidal Dispersion Gels
Colloidal dispersion gel (CDG) technology evolved from layered aluminum citrate gel technology in the mid-1980s when it was discovered that small amounts of aluminum citrate mixed directly with low concentrations of polymer resulted in solutions that had a much higher resistance to flow than uncrosslinked polymer.

The CDG process has several advantages over layered aluminum citrate gels:

- The process provides a higher RRF
- It is simpler to inject and control than layered gels
- The process is more economical because less aluminum is needed
- Laboratory design of optimum gel strength is much simpler

Oil producing reservoirs contemplated for secondary recovery must be studied prior to waterflooding to characterize the rock properties and determine how efficiently the reservoir will flood. Many exhibit a non-uniform permeability contrast that results in rapid water breakthrough at the offset producing well(s), with resulting inefficient oil recovery. If a reservoir shows a Dykstra-Parsons factor greater than 0.55, then a long-term injection side application of colloidal dispersion polymer gel should be considered early in the life of the waterflood to improve flood efficiency.

Colloidal Dispersion Gels (CDGs) are a specialized polyacrylamide gel that forms deep in the reservoir within the most permeable flow paths. These gels are formed from low concentration of polymer and are capable of entering matrix

rock and flowing in-depth, while being adsorbed onto the rock surfaces. Thus, high permeability flow paths are physically altered to reduce permeability. This makes the reservoir more uniform to the drive fluid resulting in more of the low permeability oil bearing rock being contacted. Case history data indicates one may expect recovery improvements up to 10% of original-oil-in-place, with less water injected over a shorter flood life.

Insitu Foam
In this approach, which is suitable for immiscible gas injection projects such as Nitrogen, surfactant solution in water is pumped into the reservoir followed by the immiscible gas injection. This causes formation of foam that blocks off high permeability zones and forces the nitrogen/CO_2 to sweep the low permeability zones. This approach is feasible with nitrogen, steam or CO_2 at low pressure. This approach is called Surfactant Alternating Gas (SAG) and variations of this are also know - Foam Alternating Gas (FAG) and Foam Alternating Water Alternating Gas (FAWAG).

Foam for Mobility Control
In situations where polymer usage is not suitable, foam can also be used as a mobility control agent to replace polymer in a surfactant project.

WATER SHUT-OFF IN GAS WELLS

UNOGAS
While polymer gels have been used successfully to shut off water or gas in oil wells, shutting off water in gas wells has not been very successful until the introduction of the UNOGAS technology. The problem lies in gel placement. In oil wells, gels tend to follow the high perm water or gas flow paths, so that maximum perm reduction is in the desired flow paths, and minimum damage is done to desirable oil producing zones. With a gas well, it is difficult to get good gel placement primarily in water zones without damaging gas production. Many attempts to shut off water in gas wells have therefore resulted in total shut-off of both gas and water.

The UNOGAS technology is a strategy that results in gas flow paths staying open during gel placement. This is done by injecting stages of gas between stages of gelant to maintain the gas flow paths. This strategy can be used with any of TIORCO's WATER-CUT gel systems, with the specific gel system selected based on reservoir characteristics. TIORCO has already combined the UNOGAS technology with MARCIT gel technology in recent gas well treatments.

TOTAL ZONE ISOLATION AND SHUT-OFF

MARASEAL
MARASEAL gel is formulated with high concentrations of crosslinked low molecular weight anionic polymer that penetrates into matrix rock for complete shut-off of the contacted area. MARASEAL can isolate producing wells from water in-flux due to:

- Channels and fractures behind pipe
- Failure of the cement bond
- Perforation into water zone

Unlike cement squeezes, MARASEAL penetrates into the rock matrix pores and the smallest fractures to completely shut off fluid flow from the treated interval by reducing permeability. The gel forms as a dense rubber-like compound that is stable in the harshest of downhole environments. MARASEAL has been demonstrated to be strong enough to resist differential pressures exceeding 2,000 PSI (13,790 kPa).

MARASEAL gel can be mixed and placed with normal oil field chemical and additive pump trucks. TIORCO designs the treatment and supplies the proper WATER-CUT chemicals to take into account individual well characteristics, bottom-hole temperature and desired gel time. Typical treatment sizes vary from 1 to 6 BBL per foot (0.5 to 3 m^3 per meter) of perforated interval. For complete shut-off of a zone, the gel is designed to penetrate from 3 to 10 feet (1 to 3 meters) into the matrix rock.

MARASEAL exhibits proven long-life robustness. It can be placed in the presence of H_2S, CO_2, and into a wide range of pH environments. Two versions of the gel system are available for low temperature, less than 141°F (61°C), and high temperature applications, 141 to 260°F (61 to 127°C). The working time of the gel is easily adjusted to meet exact well conditions and control the gelation time.

RESIDUAL OIL RECOVERY

A/SP
Primary and Secondary Recovery techniques together are able to recover only about 35-50% of oil from the reservoir. This leaves a significant amount of oil remaining in the reservoir. Chemical flooding (using surfactants) is one of the available technologies that can be used to recover up to an additional 35%.

Surfactant flooding is a well known concept that has been practiced in the field for many decades. Current technology is a progressive and gradual development of technologies and ideas that have existed for a long time. The key difference is the amount of surfactant used in projects today is much lower due to high purity.

Surfactant flooding is usually carried out after a waterflood. There are two main types of surfactant flooding – Alkaline Surfactant Polymer or Surfactant Polymer Flooding. All components are injected together into the reservoir as an ASP "slug" and it is not a sequential injection. Typically, the (A)SP slug is injected at about 0.3-0.4 PV for effective performance. The alkaline component reacts with the acidic compounds that exist in the oil creating natural soap and also helps with reducing the adsorption of the surfactant on the rock. Surfactants help in releasing the oil from the rock and reducing the interfacial tension between water and oil, while the polymer (typically, partially hydrolyzed polyacrylamide) acts as the viscosity modifier and helps mobilize the oil. Typically, a (A)SP flood is followed up with an equivalent pore volume injection of a polymer "push" solution. This helps reduce the oil recovery decline and helps extend the production for a longer period of time.

Imbibition / Wettability Alteration

Surfactants can be used in chemical EOR to change the wettability of the reservoir rock – in this approach, reservoir rock that is predominantly oil wet can be altered to become water wet, which releases the oil from the rock.

For more information on these and other products and services offered, contact your TIORCO sales representative.

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The Science of
Enhanced Oil Recovery

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