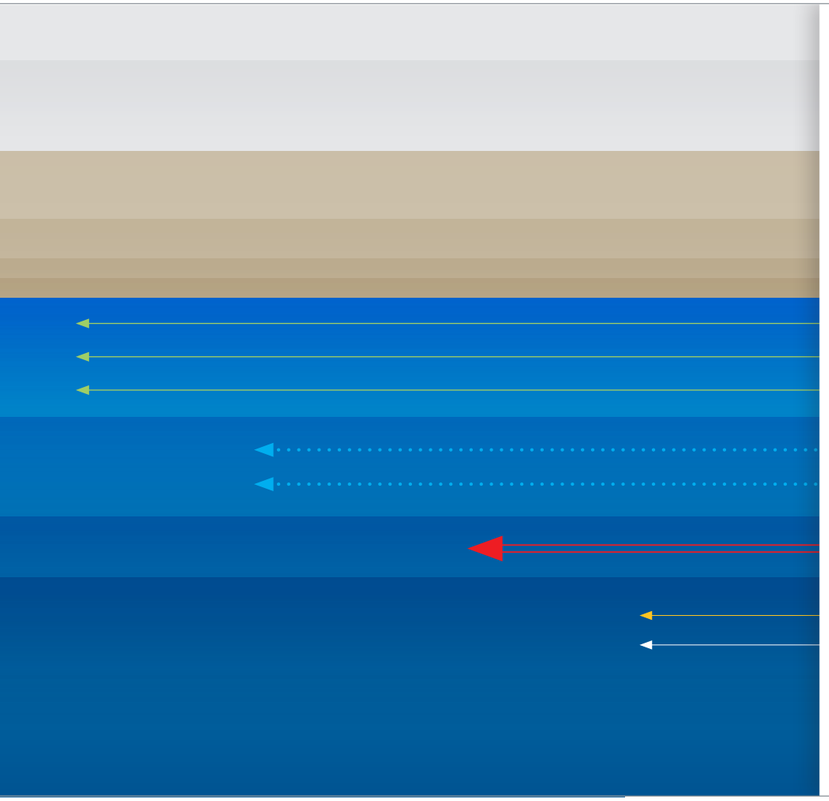
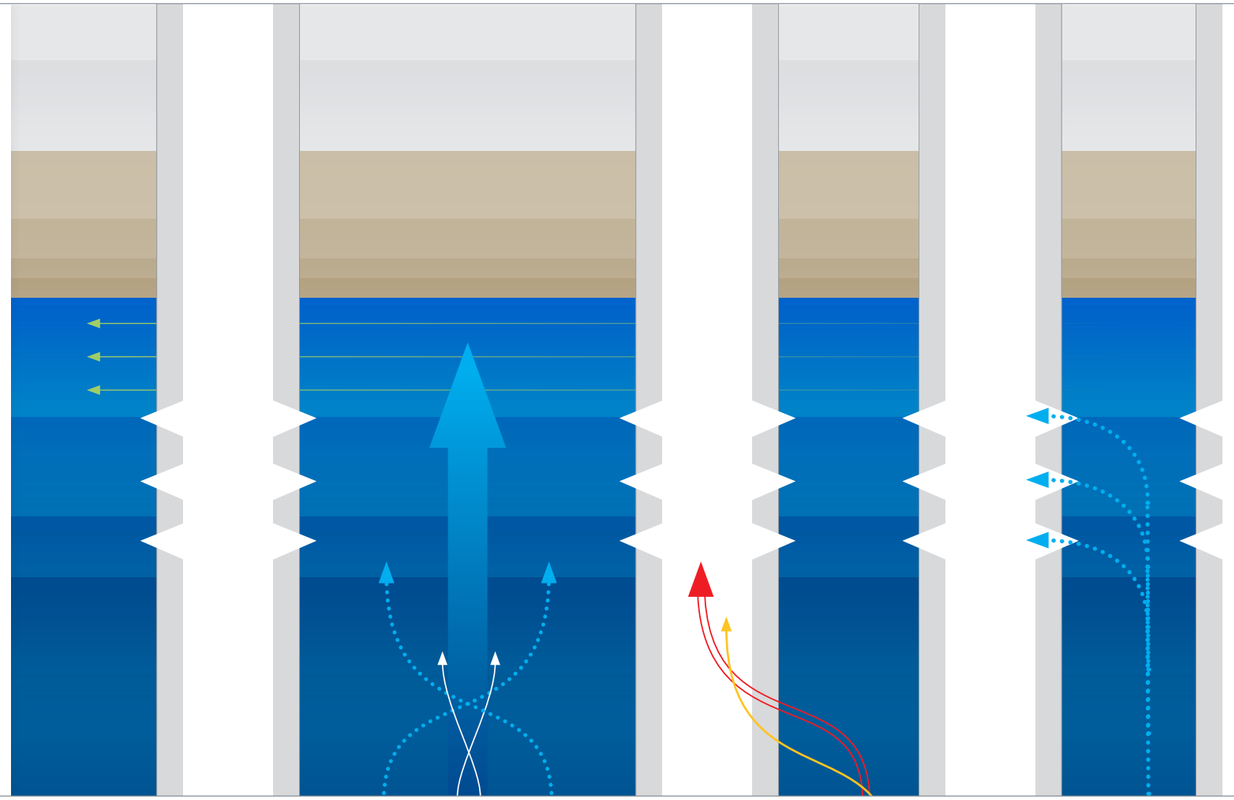
Schlumberger



The Schlumberger integrated solution to control both gas and water while maintaining or increasing productivity and recoverable reserves provides comprehensive conformance control—from candidate recognition through treatment design and execution to results evaluation. Schlumberger offers the experience and technologies to help you unlock the potential of your reservoir.



Gas and Water Control in the Bay of Campeche

Gas and Water Control in the Bay of Campeche

From candidate diagnosis to treatment execution

www.slb.com/watercontrol

Schlumberger

CONTROLLING WATER AND GAS PRODUCTION IN THE BAY OF CAMPECHE

Oil production in the Bay of Campeche is declining at a rapid rate, especially in the Cantarell field. These reservoirs are naturally fractured, with gas and water flowing through the natural fractures, leaving oil trapped in the matrix. Controlling gas and water production is critical to prevent unwanted fluid from reaching the wellbore.

In some wells in the Cantarell field, the combined progression of gas and water has reduced the oil window to as little as 40 m in some wells. The loss of zonal isolation as a result of cement sheath failure has compounded the problem, resulting in heavy losses while drilling and cementing wells in the field.

As oil and gas fields mature, excess water production often threatens the economic viability of wells. Excess gas or water production often results in increased production costs and decreased productivity.

Field-Proven Technologies and Expertise

Water Control and Interval Isolation

Challenge
- Control water production
- Abandon interval
- Perforate a new interval at a higher section within the same formation

Solution
- OrganoSEAL* F flowing gel to flow through natural fractures and reduce water invasion at the reservoir level
- Mechanical plug to isolate the interval

Results
- Achieved zonal isolation
- Reduced water cut by more than 90% in the new interval

Water Control and Interval Isolation with Coiled Tubing

Challenge
- Control water production
- Abandon interval
- Perforate a new interval at a higher section within the same formation

Solution
- OrganoSEAL F flowing gel to flow through natural fractures and reduce water invasion at reservoir level
- Mechanical plug to isolate the interval

Results
- Achieved zonal isolation
- Reduced water cut by up to 90% in the new interval

Gas Shutoff and Zone Abandonment

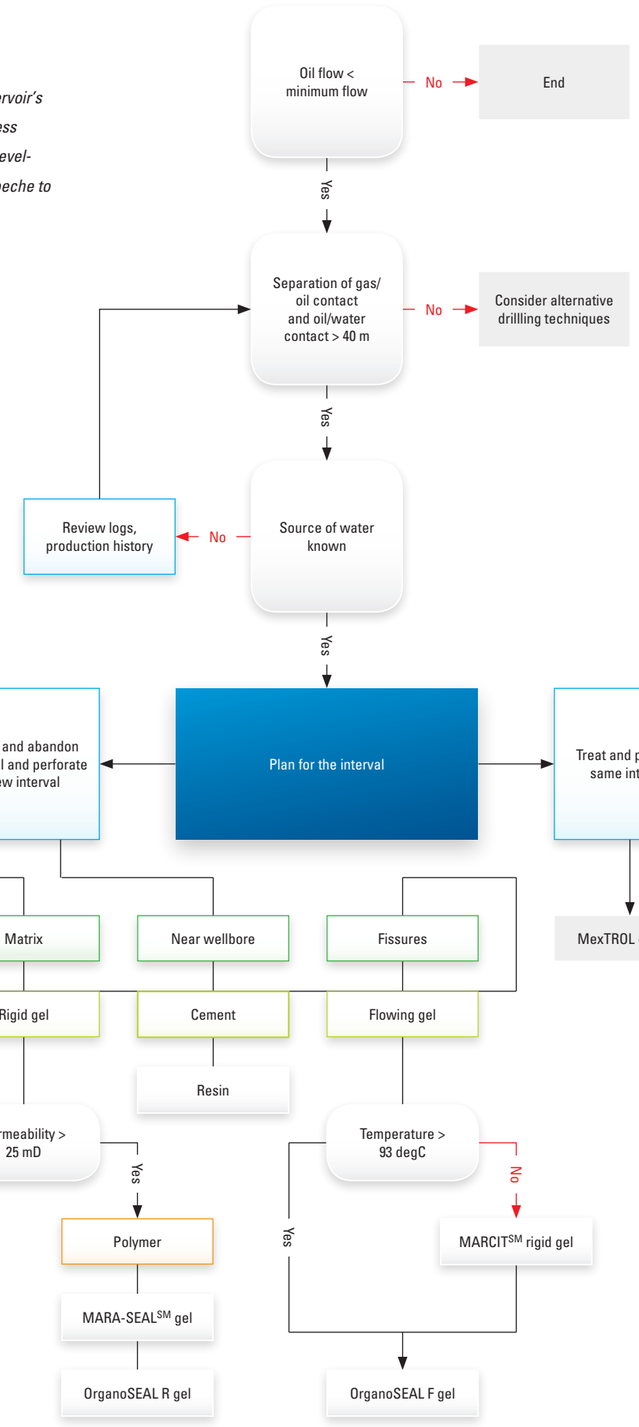
Challenge
- Improve cement placement for zone abandonment when gas invasion and total losses are observed
- Achieve complete isolation to continue drilling operations and produce from a deeper zone

Solution
- OrganoSEAL R rigid gel to penetrate the matrix and reduce losses
- GASBLOK* gas migration control cement system to seal the interval

Results
- Achieved complete zonal isolation and gas shutoff
- Allowed continuation of drilling

Conformance Control Decision Chart

Conformance control is manipulating the reservoir's external fluid drive to push out more oil and less water. This conformance control chart was developed specifically for wells in the Bay of Campeche to help maximize hydrocarbon production.



Complexity

What are the types of water control problems?

CASING, TUBING, OR PACKER LEAKS
Water can flow through a damaged section of the casing or through leaks in the completion equipment.

FLOW BEHIND CASING
A defective cement sheath can cause water to flow up to the producing interval.

MOVING OIL/ WATER CONTACT

FRACTURES FROM A WATER LAYER
Water can flow through natural fractures connecting a water zone to the perforated interval, a common situation in the Bay of Campeche.

CONING OR CUSPING
Because of the differences in the mobility of water and oil and the pressure drawdown applied at the wellbore, a preferential water movement can be created.

Complexity

What are the types of gas control problems?

CASING, TUBING, OR PACKER LEAKS
Gas can flow through a damaged section of the casing or through leaks in the completion equipment.

FLOW BEHIND CASING
A defective cement sheath can cause gas to flow down to the producing interval.

FRACTURES FROM A GAS LAYER
Gas can flow through natural fractures connecting a gas zone to the perforated interval, a common situation in the Bay of Campeche.

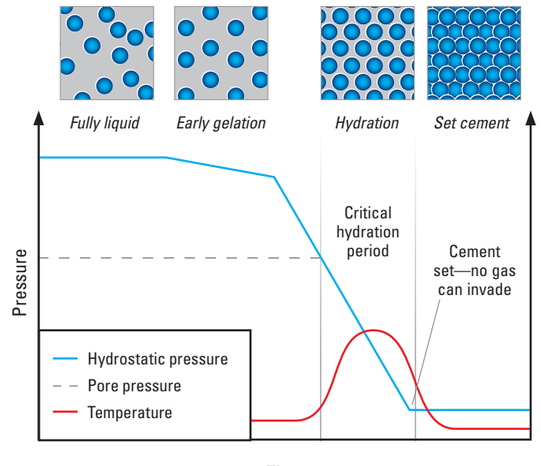
CONING OR CUSPING
Because of the differences in the mobility of gas and oil and the pressure drawdown applied at the wellbore, a preferential gas movement can be created.

Water Control

Services and field-proven results

GASBLOK

Gas migration control cement system



Hydrostatic pressure changes as the cement sets.

Controlling formation fluid migration during workover operations is a key factor in successful offshore cementing operations. The GASBLOK* portfolio of slurries, which was developed to cover a range of bottomhole temperatures and all cement slurry densities, ensures tight slurry design. The GasMigrationAdvisor* software advisor to evaluate the risk of gas migration in well cementing helps in designing these tight slurries by

- determining the formation fluid risk
- recommending a solution based on bottomhole circulating temperatures (BHCTs).

SlurryDesigner* cement blend and slurry design software is a power slurry design tool that uses solid volume fraction to determine the GASBLOK requirements.

GASBLOK TECHNOLOGY

GASBLOK cement additives create an impermeable barrier to prevent annular gas migration into the cement slurry during the critical hydration period. The microgels form an impermeable cement filtercake that blocks gas flow. The ability of the slurry to stop gas migration is directly related to additive concentration, which depends on BHCT and slurry solid volume fraction.

The D500 GASBLOK LT cement additive, a suspension of polymeric microgels, can be used in applications from 0 to 71 degC [32 to 160 degF] BHCT and in slurries of any density. When migration is imminent, the microgels coalesce in the pore spaces of the slurry, creating a barrier.

The D600G GASBLOK gas migration control cement additive for temperatures ranging from 66 to 149 degC [150 to 300 degF] BHCT is an aqueous dispersion of latex particles with surfactants that improve dispersion and add stability. When formation gas enters the cement slurry, the latex particles form a coherent, low-permeability plastic film that blocks migration. The additive also improves cement bonding to the casing and formation interfaces.

The D700 GASBLOK HT cement additive can be used in severe applications from 121 to 177 degC [250 to 350 degF] BHCT and in slurries at any density. The D700 GASBLOK HT additive also controls gas migration by improving cement bonding to casing and formation interfaces and by creating a thin, low-permeability filtercake to reduce fluid loss from the cement slurry.

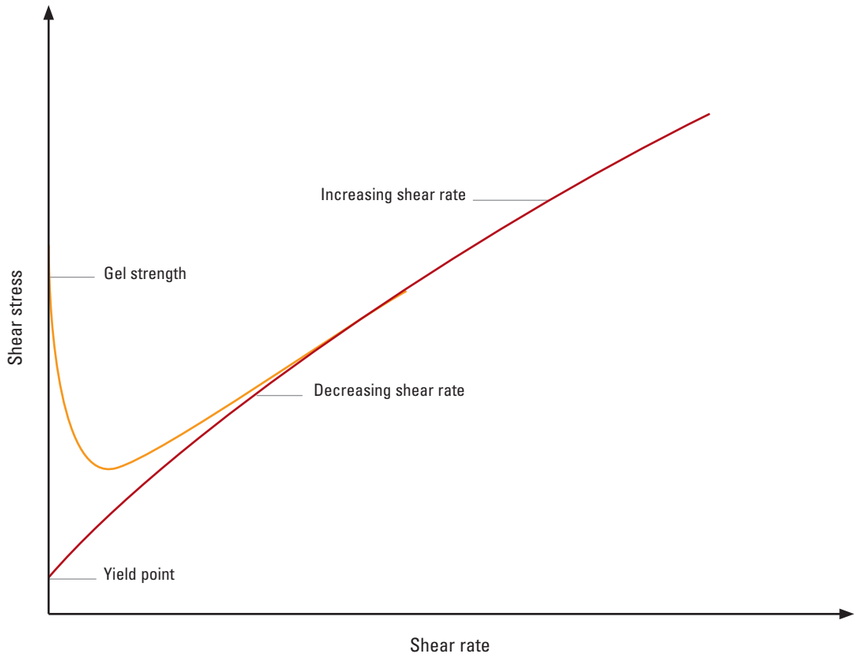
Thixotropic Cement Slurries

A solution for your workover operations

Thixotropic slurries are thin and fluid during mixing and displacement, but rapidly form a rigid, self-supporting gel structure when pumping stops. When reagitated, the gel structure breaks and the slurry regains fluidity. Then, upon cessation of shear, the gel structure reappears and the slurry returns to a self-supporting state. Thixotropic systems are used for workover operations

- to repair split or corroded casing
- as lead slurries for remedial cementing when obtaining a squeeze pressure is difficult
- as a group to quickly immobilize the slurry
- to prevent gas migration in combination with GASBLOK additives
- to meet lost circulation challenges.

After each static-dynamic cycle, the gel strength and yield point increase, providing a measure of the degree of thixotrophy of the slurry. Because thixotropic slurries can be designed to be pumped through coiled tubing, they allow for more accurate placement.



Thixotropic slurry has higher gel strength at static conditions.

MARA-SEAL

Rigid gel

APPLICATIONS

- Water/gas shutoff in near-wellbore area
- Zone abandonment
- Injector well shutoff in high-matrix-permeability thief zones
- Openhole sealing for short-radius horizontal reentries (liquid liner applications)

BENEFITS

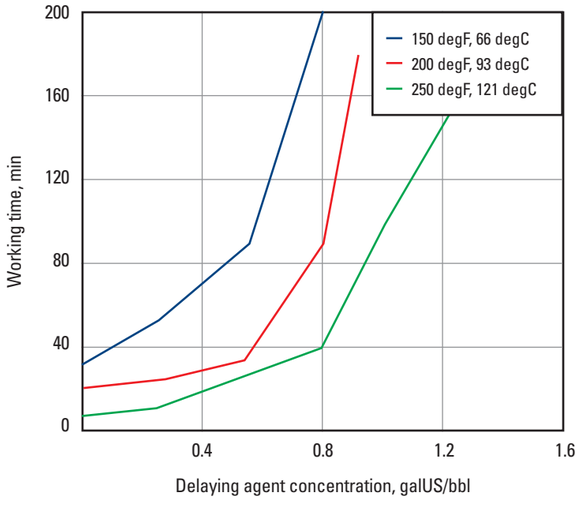
- Penetration into matrix pore spaces for complete shutoff squeeze treatment
- Permanent blocking of interval

FEATURES

- Temperature range below 150 degC [302 degF]
- Effective permeability reduction
- Low molecular weight polymer that facilitates small-pore penetration
- Resistance to degradation of solution by polymer chain breakage

MARA-SEAL[SM] gel is a field-proven fluid to shut off the near-wellbore area and control water production. Controllable, delayed crosslinking allows the fluid to be injected into the rock matrix as a clear solution that forms a rigid “ringing” gel. This permits complete shutoff of the perforations, behind-casing voids, and the near-wellbore formation. The technology has been applied in many reservoirs worldwide to control water from

- near-wellbore channeling
- high-permeability channeling where vertical flow barriers exist.



TECHNOLOGY

MARA-SEAL gel is formulated with a low-molecular-weight synthetic polymer (polyacrylamide) and an organometallic crosslinker. The low molecular weight facilitates materials handling by reducing hydration time and lowering tubular friction pressures at high polymer loadings. Matrix injectivity is substantially improved over high molecular weight materials. Working time can be closely controlled, so that treatments can be performed to completion without long shut-in times.

GEL STRENGTH

The excellent gel strength of MARA-SEAL gel results from the adhesive nature of the polymer and the strong intermolecular crosslink bonds. The polymer coats the matrix materials and adheres strongly. Subsequent in-situ crosslinking achieves a rigid, continuous gel phase. In-matrix performance is demonstrated in a 2-in length of 200-mesh sand invaded with a 5% MARA-SEAL gel. At 66 degC (158 degF), the sandpack showed zero permeability to brine. Even at 700 psi injection pressure, the permeability was reduced from the original 1.1 D to 0.2 mD, a reduction of more than 99.9%.

MARA-SEAL gel’s bulk gel strength has been characterized in several ways. Dynamic oscillatory rheometry has been used to study the crosslinking kinetics and resulting gel strength. At temperature, a typical MARA-SEAL gel will have storage moduli and complex viscosities several orders of magnitude higher than a well-formed, 40 lbm/1,000 galUS borate-crosslinked guar.

In addition to core testing, gel extrusion tests indicative of in-situ performance have been performed in 500-micron capillaries. After gelation, brine is pumped against the gel at slowly increasing pressures until breakdown occurs due to extrusion. Failure pressures are measured in thousands of psi, demonstrating the superior bulk strength and wall adhesion performance of the MARA-SEAL gels.

DGS

Delayed gelation system

APPLICATIONS

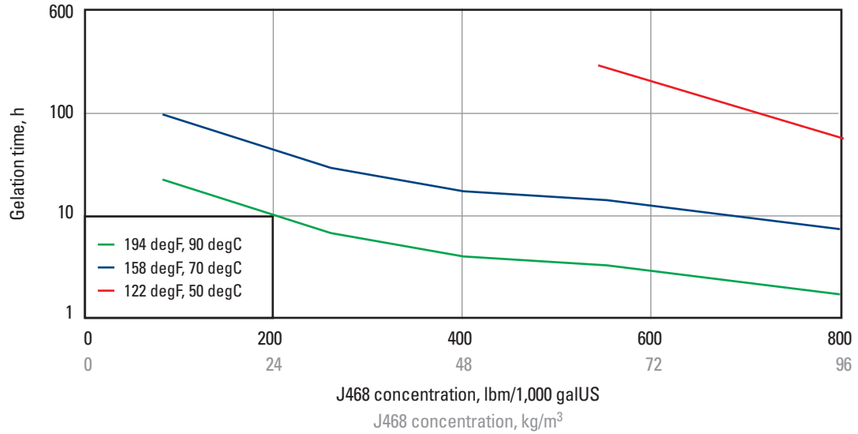
- Water/gas shutoff deep into the formation
- Zone abandonment
- Injector well shutoff in high-matrix-permeability thief zones

BENEFITS

- Penetration into matrix pore spaces for complete shutoff squeeze treatment
- Permanent blocking of interval

FEATURES

- Easily controlled gelation time up to 121 degC [250 degF]
- Fresh or brackish mix water
- Low-viscosity, solids-free fluid
- Consilicate, nonpolymeric system
- Acid removal of freshly formed gel



DGS J468 concentrations versus gel time.

The DGS* delayed gelation system is a patented, field-proven fluid designed to eliminate

- water coning during production
- water production through high-permeability channels
- injection and sweep inefficiency caused by high-permeability channels.

DGS fluid is capable of penetrating deep into the formation, where it gels to drastically reduce permeability. Gel that is formed in situ reduces permeability by more than 97%. The gel time can be adjusted from a few hours to several days over a wide temperature range. Gelation is not affected by contamination from Ca+ and Fe+3.

DGS fluid is composed of a plugging agent and an activator that can be mixed in water, seawater, or most oilfield brines. The DGS solution does not develop viscosity until the activator thermally decomposes, causing the system to form a rigid gel. Before the gel time is reached, the fluid is insensitive to shear and can, therefore, be pumped at any rate and filtered after mixing. Gelation is not affected.

The system is thermally activated and creates a consistent permeability barrier wherever it is placed.

Permeability Reductions Measured After 3,000 Pore Volumes of Flow Through Cores

Core Type	Temperature, degF [degC]	Original Fluid Permeability, mD	After DGS Fluid Permeability, mD	Decrease, %
Sandpack	149 [65]	2,360	49.0	97.9
Sandpack	122 [50]	3,124	31.0	99.0
Sandstone	149 [65]	3,630	65.0	98.5
Sandstone	212 [100]	100	3.3	96.7
Carbonate	104 [40]	910	18.0	98.0
Carbonate	176 [80]	506	8.5	98.3

MARCIT

Flowing gel for fracture shutoff

APPLICATIONS

- Fissured formation shutoff where flow selectivity favors the fissures and the high-molecular-weight polymer limits matrix penetration
- Conductive fault shutoff
- Injector well shutoff where thief zones communicate with producers

BENEFITS

- Maximization of reservoir productivity where high water cut is attributed to production through fissures
- Maximization of well longevity by shutting off unwanted fluids

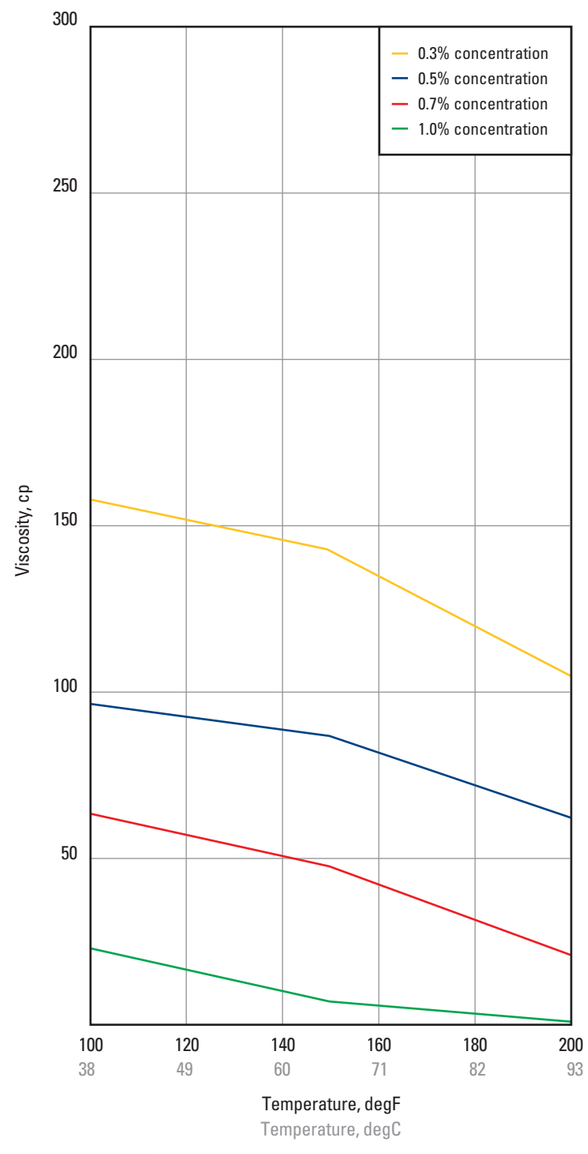
FEATURES

- Temperatures below 93 degC [199 degF]
- Flow reduction in fractures without entering the matrix
- Low matrix leakoff losses

MARCIT[SM] gel is a crosslinked synthetic polymer (polyacrylamide) gel designed for water control in naturally fractured reservoirs. MARCIT treatments can be applied to both injectors and producers when a high water cut is attributed to production through fissures.

Polymers used in this treatment have high molecular weights, which limits leakoff into the matrix and results in greater viscosities per polymer concentration. Crosslinking occurs relatively early in the treatment process, further aiding in reducing leakoff and increasing fissure penetration efficiency. The crosslinked material is a flowing gel that maintains the ability to penetrate natural fractures.

MARCIT gel is applied primarily in formations where water is produced through fractures or fissures that are in contact with an aquifer or an injection system. The fluid can be bullheaded without coiled tubing, and continuous mixing allows the fluid composition to be customized based on injectivity interpretation during placement.



MARCIT linear gel viscosity at elevated temperature.

OrganoSEAL R

Organic crosslinked gel

APPLICATIONS

- Water/gas shutoff in near-wellbore area
- Zone abandonment
- Injector well shutoff in high-matrix-permeability thief zones
- Openhole sealing for short-radius horizontal reentries (liquid liner applications)
- High-temperature formations
- Areas where environmental regulations prohibit use of heavy metal crosslinkers

BENEFITS

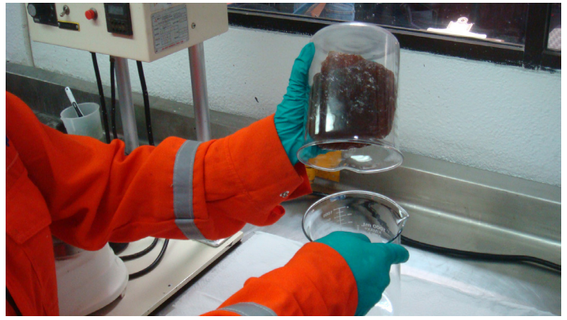
- Control of unwanted products from near-wellbore or high-permeability channeling
- Permanent interval blocking without cement

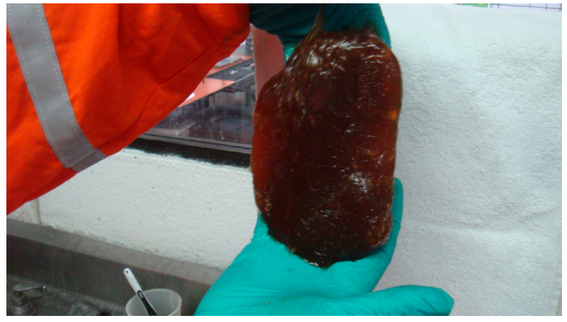
FEATURES

- Temperatures below 163 degC [325 degF]
- Mix water salt tolerance
- Resistance to degradation of solution by polymer chain breakage

Rigid OrganoSEAL* R gel technology produces a high-strength, crosslinked synthetic polymer gel that is capable of penetrating the matrix prior to gelation. OrganoSEAL R gel is primarily used for water shutoff, but it can be used in place of cement squeeze for casing bond failures and for sealing the openhole sections during vertical or short-radius horizontal recompletions.

OrganoSEAL R gel is especially useful for treating production problems in the near wellbore where complete blockage is required.





OrganoSEAL F

Organic crosslinked gel

APPLICATIONS

- Fissured formation shutoff where flow selectivity favors the fissures and high-molecular-weight polymers limit matrix penetration
- Conductive fault shutoff
- Injector well shutoff where thief zones communicate with producers
- Openhole sealing for short-radius horizontal reentries (liquid liner applications)
- High-temperature formations
- Areas where environmental regulations prohibit use of heavy metal crosslinkers

BENEFITS

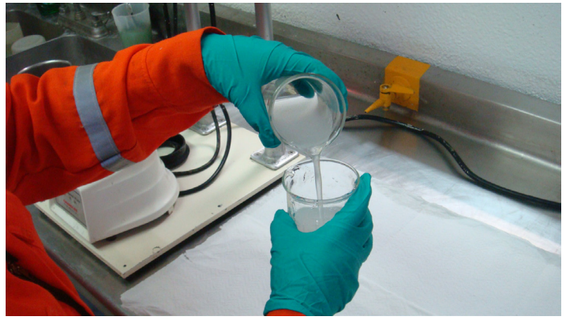
- Maximization of reservoir productivity with high water cut from production through fissures
- Maximization of well longevity

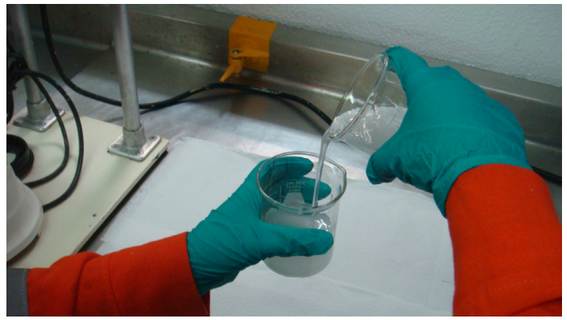
FEATURES

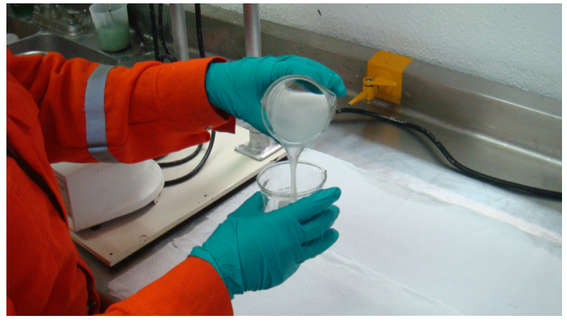
- Temperature range below 163 degC [325 degF]
- Mix water salt tolerance
- Reduced permeability
- Low matrix leakoff losses

OrganoSEAL* F organic crosslinked gel is an aqueous-based gel formed from synthetic polymers and organic crosslinkers. It is used for water control in naturally fractured reservoirs, and treatments are applicable in both injector wells and producing wells where a high water cut is attributed to production through fissures.

Polymers used in this treatment have high molecular weight, which limits leakoff into the matrix and results in greater viscosities per polymer concentration. The crosslinked material is a flowing gel that can penetrate natural fractures. The crosslinkers are released from a thermally activated breakdown of J525 and J524 primary OrganoSEAL crosslinkers at elevated temperatures. The gel and the crosslinker combine to form the polymer.







MexTROL

Coiled tubing–placeable waterless well cement

APPLICATIONS

- High-water-cut wells or other difficult placement situations

BENEFITS

- Improves cement placement because of the use of coiled tubing (CT)
- Saves money and improves environmental safety by making oil-base and diesel-base solvent preflushes unnecessary

FEATURES

- Waterless cement formulation
- Adjustable rheology
- Adjustable thickening time
- Fast compressive strength development
- Placement through CT equipped with the ACTive* family of services

High water production in oil and gas wells is a common and expensive concern on mature fields due to water-disposal costs, environmental issues, and reduced oil and gas production. The success of every water control treatment relies on proper problem identification, selected fluid properties, and an adequate placement technique.

Because it can be selectively placed using CT, MexTROL waterless cement is a technically suitable option to overcome high-water-cut issues.

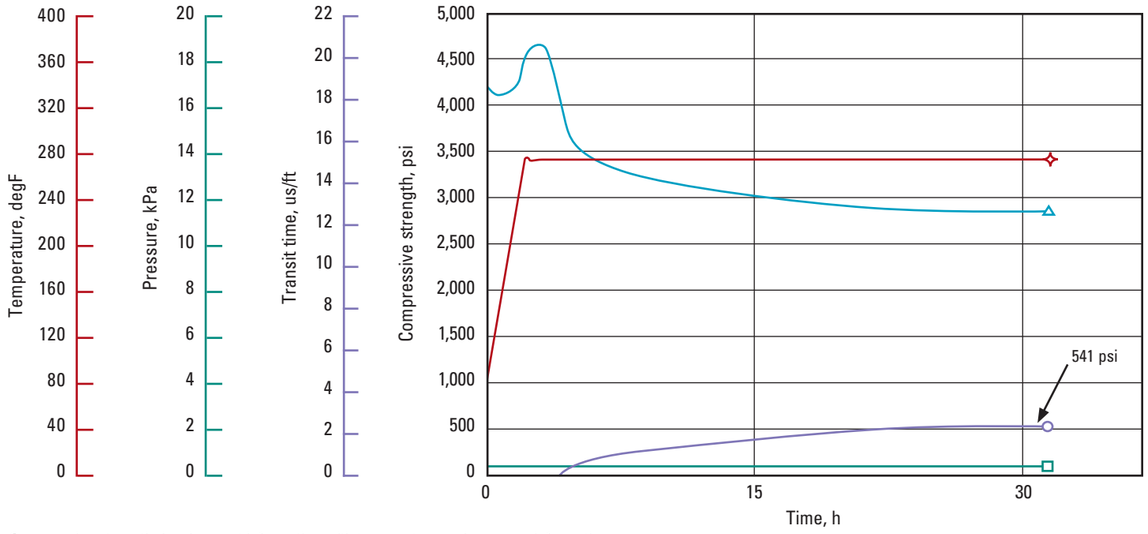
OPERATIONAL CONSIDERATIONS

Typically, waterless cement slurry placements are preceded by large volumes of oil-based preflushes, such as diesel and solvents, to displace the existing water around the production casing and near-wellbore area to avoid unwanted premature cement set. However, low water content in the matrix can reduce the treatment effectiveness. MexTROL cement has been developed taking into account these placement considerations.

This cement can be effectively placed by coiled tubing because of its low friction rheology, reducing contamination and avoiding large preflushes. Additionally, the ability to select different cement particle sizes allows efficient invasion into the formation matrix and fissures to seal the water flow paths.

MexTROL technology has been developed based on a combination of highly reactive cement, surfactants, and solvents to allow fast setting in contact with water, with adjustable parameters.

- Range of density: 1.50 sg to 1.60 g/sg
- Adjustable rheologies: can be set as low as plastic viscosity of 40 cP and yield point = 10 lbf/100 ft^2, ideal for CT applications
- Thickening time: Adjustable up to 6 hours based on expected water contamination. In all cases, MexTROL cement develops a right angle set behavior.
- Fast compressive strength development



Compressive strength development information with temperature and pressure information.

Water Control and Interval Isolation Reduce Water Cut by 90%

Case study: Pumping OrganoSEAL F flowing gel through coiled tubing optimizes treatment placement in Mexico's Caan field

Challenge

Control water production in a naturally fractured reservoir by isolating and abandoning the old interval and perforating a new interval at a higher section within the same formation.

Solution

Use OrganoSEAL* F flowing gel to flow through natural fractures and reduce water invasion at the reservoir level, followed by a mechanical plug to isolate the interval.

Results

Achieved zonal isolation and reduced water cut by 90% in the newly perforated interval.

Water production in the Bay of Campeche

The Caan field, Bay of Campeche, is one of the main oil reservoirs offshore Mexico. Yet, oil is declining at a rapid rate in this naturally fractured reservoir because of excessive water production. Gas and water flow through the natural fractures, leaving oil trapped in the matrix. Controlling gas and water production is critical to prevent unwanted fluid from reaching the wellbore.

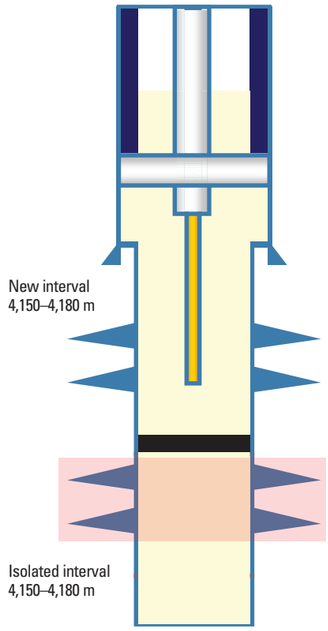
To increase productivity and improve economic efficiency, the operator contacted Schlumberger to design a treatment plan.

Isolation of a newly perforated interval

OrganoSEAL F flowing gel was used to block water flow through the natural fractures. A 100-bbl preflush treatment was pumped while pressure and temperature were monitored. The preflush was followed with 270 bbl of OrganoSEAL F gel and displaced with seawater. After 24 hours of activation time, a cleanup operation was performed through coiled tubing using the Jet Blaster* jetting scale removal service. Placing a plug and cement provided a mechanical restriction that isolated the old interval from the new interval.

Zonal isolation and water cut reduction

Using the Schlumberger solution, the operator achieved the desired zonal isolation and reduced water cut in the newly perforated interval by 90%.



Post-treatment wellbore diagram.

Water Control and Interval Isolation Reduce Water Cut by More Than 90%

Case study: OrganoSEAL F flowing gel, plug, and cement placement provide mechanical restriction to perforate new interval in Mexico's Caan field

Challenge

Control water production in a naturally fractured reservoir by isolating and abandoning the old interval and perforating a new interval at a higher section within the same formation.

Solution

Use OrganoSEAL* F flowing gel to flow through natural fractures and reduce water invasion at the reservoir level, followed by a mechanical plug to isolate the interval.

Results

Achieved zonal isolation and reduced water cut by more than 90% in the newly perforated interval.

Water production in the Bay of Campeche

The Caan field, Bay of Campeche, is one of the main oil reservoirs offshore Mexico. Yet, oil is declining at a rapid rate in this naturally fractured reservoir because of excessive water production. Gas and water flow through the natural fractures, leaving oil trapped in the matrix. Controlling gas and water production is critical to prevent unwanted fluid from reaching the wellbore.

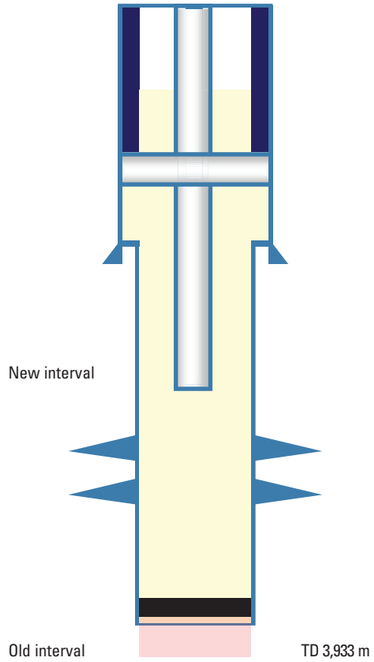
To increase productivity and improve economic efficiency, the operator contacted Schlumberger to design a treatment plan.

Creation of a mechanical restriction

OrganoSEAL F flowing gel was used to block water flow through the natural fractures. A 200-bbl preflush treatment was pumped while pressure and temperature were monitored. The preflush was followed with 550 bbl of OrganoSEAL F gel and displaced with seawater. After 24 hours of activation time, a mechanical plug was set, followed by cement to perforate a new interval.

Zonal isolation and 97% water cut reduction

Using the Schlumberger solution, the operator achieved the desired zonal isolation and reduced water cut in the newly perforated interval by 97%. The OrganoSEAL F treatment blocked water flow through the natural fractures, and placing a plug and cement provided a mechanical restriction that isolated the old interval from the new interval.



Post-treatment wellbore diagram.

Effective Treatment Provides Conformance Control for Drilling to Continue in Bay of Campeche

Case study: OrganoSEAL R rigid gel and GASBLOK slurry penetrate matrix and seal off interval for complete zonal isolation

Challenge

Improve cement placement for zone abandonment when gas invasion and total losses occur and achieve complete zonal isolation to continue drilling operations and produce from a deeper zone.

Solution

Use OrganoSEAL* R rigid gel to penetrate the matrix and reduce losses. Used GASBLOK* gas migration control cement system to seal the interval.

Results

Achieved complete zonal isolation and gas shutoff, allowing continuation of drilling.

Conformance control in the Bay of Campeche

The Cantarell field, Bay of Campeche, is a large carbonate reservoir in Mexico. Yet, oil is declining at a rapid rate in this naturally fractured reservoir because of excessive water production. Gas and water flow through the natural fractures, leaving oil trapped in the matrix.

Conformance control—manipulating the reservoir's external fluid drive to push out more oil and less water—was presenting a challenge for the operator. Because gas invasion in the producing interval was changing the oil/gas contact, the operator decided to abandon the interval to continue drilling operations and produce from a deeper zone. To achieve this objective, the operator contacted Schlumberger to design a treatment plan.

Treatment to block the matrix and near-wellbore area

Because cement would not provide the necessary seal, OrganoSEAL R rigid gel was chosen as a lead with the GASBLOK cement slurry acting as a cap to block the matrix and near-wellbore area. The OrganoSEAL R treatment was pumped in two stages to develop a rigid gel in the near-wellbore area. Then, GASBLOK cement slurry was pumped, which acted as a cap. After the activation time for the treatment was completed, the cement plug was successfully pressure-tested at 500 psi.

Post-treatment wellbore diagram.

Complete zonal isolation and continuation of drilling

The successful application of the OrganoSEAL R and GASBLOK treatments blocked the matrix and near-wellbore area, allowing the cement to work as an efficient seal and completely block the zone. The cement plug was milled without any circulation losses, which allowed drilling operations to continue.