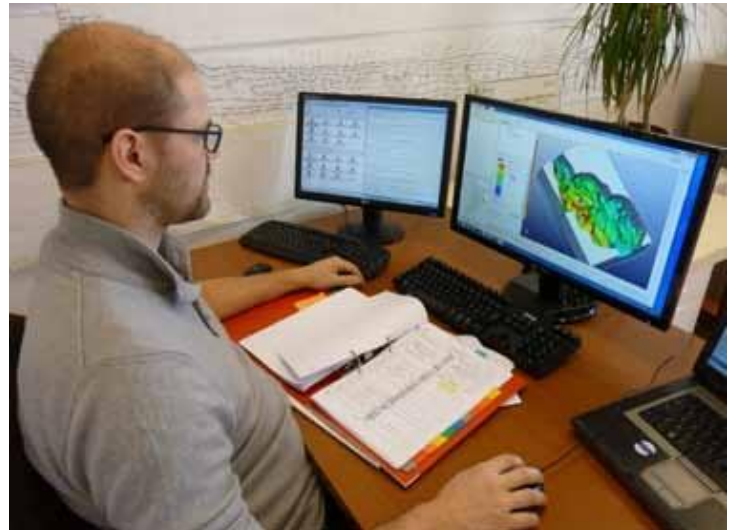




POLYMER WELL TECHNOLOGY

Tailor-made solutions



EOR, WSO, Conformance, Sand Control

POWELTEC

An Independent Service Company

POWELSAND

Sand Control by polymers

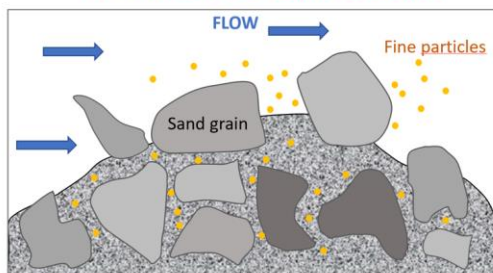
POWELTEC

In sandstone reservoirs, operators often face sand production problems due to the degradation of reservoir rock around the wellbore under high-velocity fluid flow. In many cases, **the sand consists of fines** which are not retained by stand-alone screens or gravel packs. The production of sand induces several problems such as **the degradation of surface facilities** (valves, pipe, pumping unit,...) and **the accumulation of sand in the wellbore**. The operators often choke the well and limit its production rate, which, in addition to frequent sand cleaning jobs, affects operational costs.

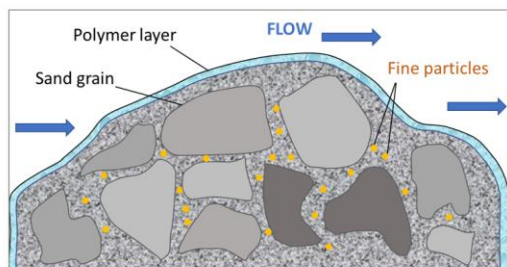
The degradation process starts with the erosion of the cement of the rock, with a production of fines. When the erosion of the rock is advanced, a production of large quantities of sand occurs together with sand accumulation in the wellbore. The principle of **the polymer sand control technology consists of the formation of a polymeric film on pore walls**, which stabilizes the rock around the wellbore and thus stops the erosion process. Such a film has to be strong enough to resist wash out by production fluids under high- velocity flow.

Principle of Powelsand

Without Powelsand



With Powelsand



The technology is based on the adsorption of an «environmentally friendly» water-based polymeric film onto the pore walls, which can efficiently prevent the erosion of the cement of the rock under high flow rates.

POWELSAND™: polymeric products are specifically designed to stick onto the pore walls and prevent the erosion of the rock with almost no impact on oil or gas flow.

During the past 10 years, remarkable results have been obtained in the treatment of Underground Gas Storage wells. Treatment efficiency lasts at least 4 years, saving the cost of regular well interventions such as coil tubing sand cleaning jobs. Re-treatments have also been performed successfully.

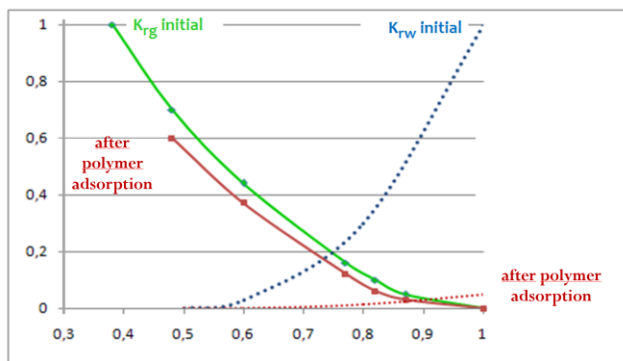
Combined Water Shut-Off & Sand Control treatments can be designed on request.

Treatment mechanism

On the contrary of resin-based sand control treatments which consist of the formation of rigid material in the rock over 1-2 feet, POWELTEC technology is based on the formation of a soft polymeric film deeper in the formation (about 3 to 6 meters).

POWELSAND™ products can be bullheaded into the whole open interval of the well, without specific tools for placement. The risk of well impairment is minimized by the use of Relative Permeability Modifiers.

The risk of well impairment is minimized through the a relative permeability modifiers effect



Kh core = 210mD

POWELSAND Applications

- **Gas wells**
- **Oil wells**
- **Underground Gas storage wells**
- **Water injection wells**

Powelsand specifications

Temperature (°C)	Up to 130
Salinity (g/l)	Up to 300
Permeability range (mD)	10 – 10 000
Shut in time (hours)	6
Regained permeability %	>80

Treatment design

Treatment design consists of laboratory flocculation tests to screen the polymer having the highest adsorption on produced sand. A full range of product is already available that have been evaluated through flocculation tests and coreflood experiments. Injectivity, dynamic adsorption, mobility reduction and oil/gas return permeability are the main parameters

Laboratory test - flocculation of reservoir sand

without polymer



Fine particles



with polymer



Agglomeration through polymer adsorption



Product delivery and field assistance

POWELTEC delivers the products and sends a technical team to support the operation manager, supervise the chemicals preparation and check the quality of the solutions prepared on site.

POWELTEC can also assist the operator in post-treatment monitoring.



References

Treatment of underground gas storage wells

- SPE 121291

Treatment of offshore gas wells

- SPE 179825

Treatment of oil well

- SPE IPTC 21171, SPE 210731

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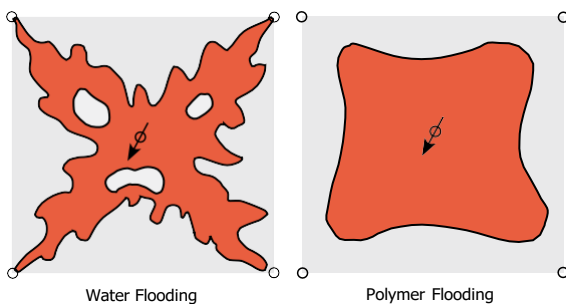
<https://www.poweltec.com/contact>

POLYMER FLOODING AND CHEMICAL EOR

Study & design



Scope



Principles of Polymer Flooding

Currently, about 60% of the reservoirs are submitted to water injection to sustain reservoir pressure and improve the sweep efficiency. However, due to reservoir heterogeneity and viscosity contrast between oil and water, water has a natural tendency to travel through preferential pathways thus leaving significant amounts of unswept oil behind. According the International Energy Agency 2009 report, an increase of 1% of the oil recovery factor could generate two or three years of additional oil resources. Thus, improving reservoir sweep efficiency appears as a major challenge for the oil industry.

Different EOR technologies can be implemented to reach this goal. Among them, polymer flooding consists in increasing the viscosity of injected water to correct the mobility ratio between oil and water and improve significantly reservoir sweep efficiency. Compared to other EOR technologies, polymer flooding can be implemented with relatively low assets investment.

PoWELTEC background

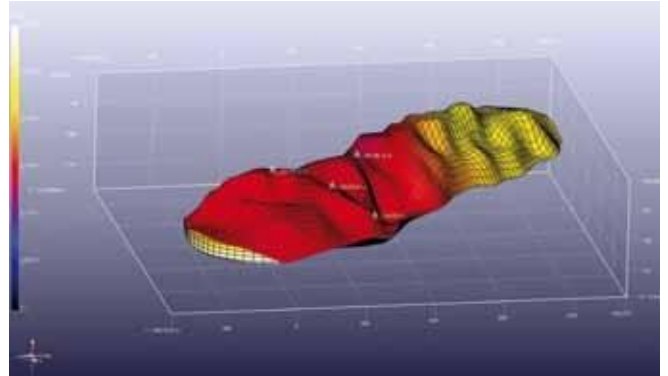
POWELTEC personnel has been involved in all the major breakthroughs realized in polymer EOR during the last decades, i.e., design of the first polymer flood pilot in Daqing (largest polymer flood project worldwide), Pelican Lake (first heavy-oil horizontal well polymer flood), Dalia (first deep offshore polymer flood). POWELTEC participates to R&D programs in cooperation with universities, research centers, chemical manufacturers and field operators. The most recent POWELTEC outcomes concern the development of EOR polymers for high temperature reservoirs (up to 120°C).

POWELTEC integrated services

POWELTEC proposes integrated services including laboratory studies, reservoir simulations, surface facilities design, field support for pilot launching, and pilot survey.

Laboratory study

POWELTEC offers more than 5000 square feet of laboratory facilities including six coreflood units and 2 deoxygenation ramps for long term stability tests according to API standards. The main goals of the laboratory study are to screen out the best-dedicated polymer to fit the reservoir conditions and determine polymer performances in reservoir rock types. Coreflood data are used as polymer input for reservoir simulations.



Reservoir simulations

Reservoir simulation studies are performed using PumaFlow™ software which includes a pertinent polymer module. The simulation program includes the following steps:

- Building of reservoir model with the pilot pattern
- History matching and model adjustments
- Simulation of injection scenarios, sensitivity study to polymer concentration, slug size and injection rate
- Definition of the best scenario with performance and economic forecasts

Surface facility design and pilot assistance

POWELTEC experts assist the operator in surface facilities design. POWELTEC team usually participates to the launching of the pilot, performing QC measurements on site. Pilot monitoring is achieved via the update of the reservoir model.

SP and ASP

As independent expert, POWELTEC evaluates the performances of SP and ASP formulations proposed by service companies and chemical manufacturers.

LABORATORY STUDIES



POWELTEC lab capabilities

POWELTEC has 5000 square feet of laboratory facilities including:

- 6 Coreflood rigs (for 1.5" cores and 1" cores)
- 1 Formation Damage rig
- 2 Deoxygenation ramps (API standard)
- 2 Rheometers and 2 viscometers
- 1 Filtration unit (API standard)
- 1 Mechanical degradation unit (API standard)
- Different Analyzers (Carbon analyzers, UV and light scattering spectrophotometers)





POWELTEC laboratory services

EOR Studies	EOR Polymer Independent Evaluation	WSO/Conformance & Sand Control	SCAL Services
Independent polymer/chemical expertise		Own dedicated product line	
Brine compatibility tests Bulk screening Filtration tests Long-term stability test in reservoir conditions Mechanical stability test Hydrodynamic properties in reservoir rocks (injectivity, Mobility & Permeability Reductions, dynamic adsorption, set of relative permeability curves before and after polymer injection) Data set for reservoir simulations			
	Field expertise	Flocculation test Gel kinetics Gel strength	

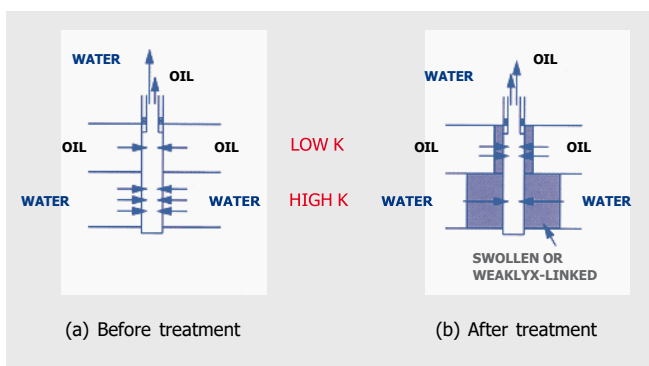
WATER SHUT OFF & CONFORMANCE CONTROL



Scope

Reducing water production from mature oil & gas fields represents a major challenge. Excessive water induces additional costs of lifting, separation, fluid treatments and disposal, as well as problems such as scales, corrosion, emulsion, bacteria development and sand production. Furthermore, water overtakes oil production in heterogeneous reservoirs. Water control becomes thus a major issue for the operators.

POWELTEC WSO/Conformance processes have been successfully applied in more than 100 field cases worldwide, i.e., gas wells, multi-layer water-flooded wells, heavy-oil horizontal wells, fractured reservoirs, sandstone and carbonate reservoirs.



Principles of Water Shut-off by polymers



POWELTEC WSO/Conformance technology

Different families of products with low environmental impact have been designed for both Water Shut-Off & Conformance Control:

- POWELGEL™: Delayed gel tailored to fit a broad range of reservoir conditions. Gel consistency can be adjusted from RPM (weak) gel to sealant (strong) gel.
- POWELSMART™: Size-controlled microgel specifically designed to penetrate deeply in the reservoir and selectively reduce water relative permeability vs oil or gas relative permeability (RPM products). Microgels withstand high salinity, severe shearing, high temperature and aggressive compounds (H₂S).
- POWELTHERM™: Bio-sourced thermo-thickening polymers designed to gel at a given temperature. Sealant gel for zone isolation and in-depth conformance control.

The products are environmentally friendly. They can be used up to 120°C and 260 g/L TDS salinity. For further details, refer to technical sheets.



Treatment design

Although the products can be used as sealant components for zonal isolation (with high consistency), a particular emphasis has been put on RPM systems (Relative Permeability Modifiers). In their RPM option, the products behave as weak gels and can strongly reduce the relative permeability to water without affecting the relative permeability to oil or to gas. They can thus be bullheaded into the whole open interval without requiring placement tools.

Treatment design combines laboratory study and near-wellbore reservoir simulations.

The laboratory study consists in product screening, (viscosity and stability tests) and core flooding. Coreflood experiments aim at measuring the polymer data set to be used in reservoir simulations (injectivity, dynamic adsorption, mobility and permeability reductions, RPM behavior and gel strength).

The reservoir simulation study consists in:

- building a representative model of the treated well or pattern constrained by history matching;
- evaluating different treatment scenarios;
- sizing the treatment and;
- predicting the benefits to be expected.

Product delivery and field assistance

POWELTEC defines the surface handling facilities and the operational program.

POWELTEC can deliver the products and send a technical team to assist the operation manager, supervise the chemicals preparation and perform Quality Control measurements on site.

After treatment, POWELTEC can provide post-treatment monitoring.



POWELGEL

Water Control by Gels

Powelgel Gel™ is a technology using crosslinked gels with different consistency, which is now proposed on the market by POWELTEC. The main domains of applications are:

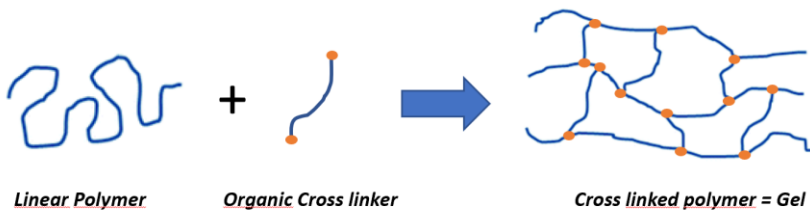
- Water Shutoff
- Profile Control
- Well or layer abandonment

The process uses water-soluble polymers which are mixed with organic crosslinkers to form gels with controlled gel time and gel consistency. Different gel chemistries have been designed, each one covering a given window of reservoir temperature. Products have thus been optimized for the following windows of temperatures: 15-50°C, 45-85°C, 80-120°C, 115-140°C, 140-165°C.

Gel time is adjustable to obtain delay from few hours to 4 weeks, with chemical additives. Gel consistency can be also adjusted, from weak RPM gels to strong sealing gels.

POWELGEL-GEL™ products are environmentally friendly, avoiding the use of hazardous agents such as heavy metal ions

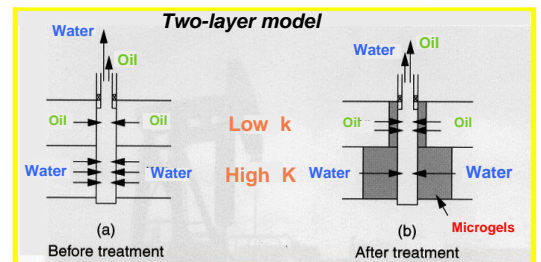
Chemistry of Gels



POWELGEL-GEL™ is a gel technology which has been developed by POWELTEC for Water Shut-off and Profile Control purposes. It combines polymer and crosslinker (usually with some additives) that form a gel after a certain time and in certain conditions (temperature, salinity). The polymers are synthetic water-soluble copolymers and the crosslinkers are organic crosslinkers. All products are environmentally friendly and can be deployed without restriction.

Applications

The main target is high-water-cut multi-layer production wells. In this type of well, frequently, water is mainly produced from high-permeability layer and overtakes oil production from lower permeability layer. To solve the problem, two approaches can be considered. (1) A strong gel can be spot to seal and block all production from a given layer. (2) A weak gel can be bullheaded into the whole open interval, which will reduce water influx from the high-permeability layer, while maintaining production from the low-permeability layer (Fig. 2). Approach 1 is generally preferred when water zone is clearly identified and well completion enables selective placement. Approach 2 is more risky but is easy to deploy at low cost. It does not require selective placement. To mitigate invasion of gels in oil production zone, a unique strategy has been developed by Poweltec called hybrid technology (see here below).



Sealing Gel (1)

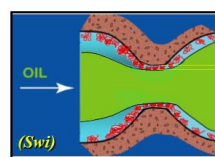
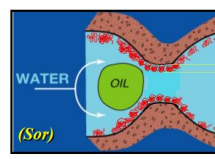


Weak Gel (2)

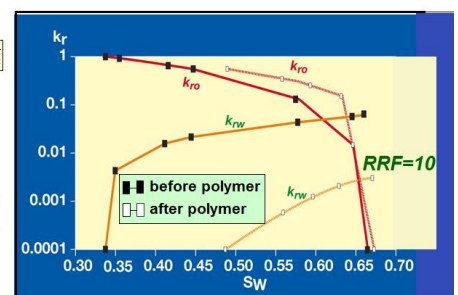
RPM - weak gels

For Water Shut Off application, weak gels are squeezed into the formation surrounding the wellbore at a depth of several meters from wellbore. The result is a selective reduction of the relative permeability to water, with low impact on the relative permeability to oil or to gas (RPM effect).

The risk of well impairment is minimized through a relative permeability modifiers effect.



Adsorbed polymer or microgels



Relative permeability modification after Microgel adsorption

POWELGEL Applications

- **Water Shut Off in Oil and Gas wells**
- **Conformance control for water injection wells**

Powelsand specifications

Temperature (°C)	Up to 120
Salinity (g/l)	Up to 300
Permeability range (mD)	10 – 10 000
Shut in time (hours)	7 to 15 days
Regained permeability to oil %	>80

Treatment design

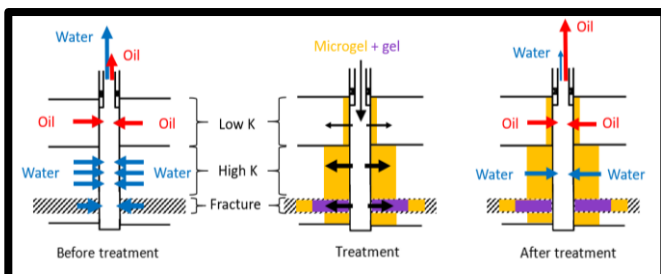
- Evaluation of candidate well according to analysis of pertinent data (a Check List is delivered on request),
- On request - Laboratory study to optimize microgel composition (bulk tests and coreflood experiments),
- On request - Numerical simulations with PumaFlow reservoir software using laboratory coreflood results as input data, to size up the treatment and predict performances,
- Product delivery / On-field assistance
- Post-treatment evaluation.

Specific design – Hybrid technology

Poweltec offers Microgel and Gels for WSO. These technologies can be combined as hybrid technology especially when the zone to be treated cannot be isolated. It also avoids the need of work over and coil tubing.

This technology applies especially to treat reservoir with fractures (example : horizontal well, fractured carbonate with strong bottom aquifer SPE 203394 and SPE 217009).

A Microgel slug is injected before and after the Gel sequence. With such hybrid strategy, by simple bullheading, the placement of the gel occurs in the high-permeability zones only. By avoiding the coil tubing to inject/squeeze the Gel in the formation, it reduces the cost of the treatment



Product delivery and field assistance

POWELTEC delivers the products and send a technical team to support the operation manager, supervise the chemicals preparation and check the quality of the solutions prepared on site.

POWELTEC can also assist the operator in post-treatment monitoring.



References

Treatment of Heavy Oil Reservoirs

- SPE 24661, SPE 177914, SPE 206333

Treatment of fractured carbonate wells

- SPE 56740, SPE 203394, SPE 217009

Treatment for conformance

- SPE 207850, SPE 208070, SPE 211430, SPE 211446

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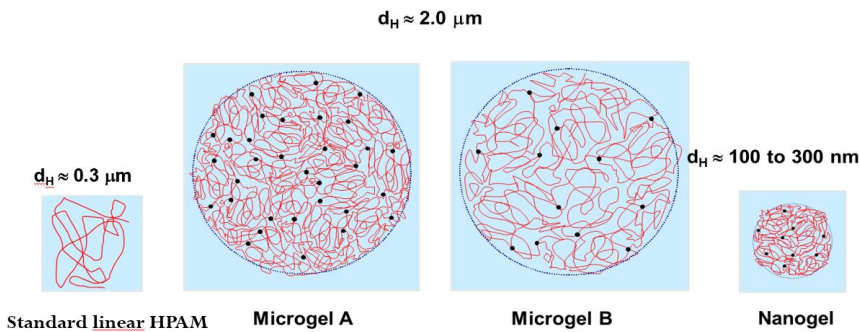
POWELSMART Water Control by Microgels

POWELSMART™ is a technology using microgels with different sizes, which is proposed on the market by POWELTEC. The main domains of applications are:

- Water Shutoff / Conformance Control
- Sand Control

The process uses preformed water-soluble microgels, produced in the plant and delivered under liquid (emulsion) or powder form. POWELSMART™ microgels have a remarkable thermal (up to 165°C), shear and chemical stability, a narrow size distribution and are environmentally friendly (some have been qualified for offshore North Sea applications). When injected into a formation, POWELSMART™ microgels adsorb strongly on the rock, thus forming a thick and continuous gel-like layer on pore walls, which improves rock stability and induces RPM effects (Relative Permeability Modification). Actually, POWELSMART™ microgels can strongly reduce the relative permeability to water, while affecting very little the relative permeability to oil or to gas. They can thus be bullheaded into the whole open interval surrounding the wellbore, with very little risk of well impairment.

Chemistry of Microgels

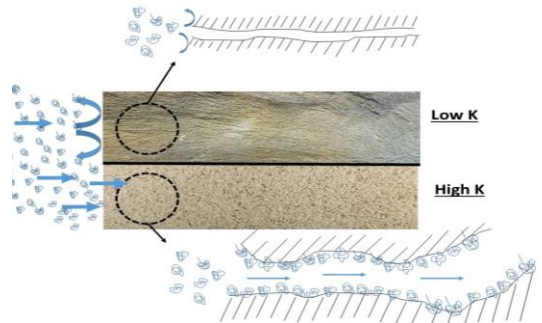


The Small Microgels (SMG) are a **Patented Technology** owned by Poweltec. Microgels are polymer particles that have rock adsorption capacities and that provide a Relative Permeability Modification (RPM) effect. The proposed Microgels by Poweltec are available in a broad range of sizes from **0.1 μm to 2μm**, with various chemical compositions, in order to be adapted to most reservoir conditions and reservoir rock qualities.

Placement of microgel through size exclusion process

For a given application, the size of the Microgel is chosen in such a manner as to penetrate easily the high-permeability parts of the reservoir while invading very little the other zones by a phenomenon of size exclusion. The placement is thus favored in the high-permeability streaks where water encroachment occurs.

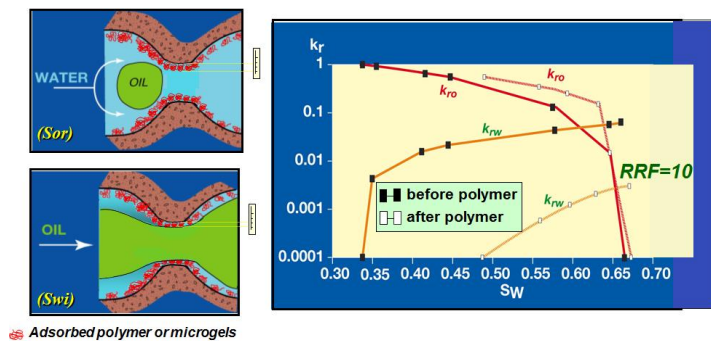
The risk of low permeability layer impairment is minimized through a size exclusion phenomenon



Treatment mechanism

For Water Shut Off application, Microgels are squeezed into the formation surrounding the wellbore at a depth of several meters from wellbore. The product adsorbs on the surface of the rock, resulting in a selective reduction of the relative permeability to water, with low impact on the relative permeability to oil or to gas (RPM effect).

The risk of well impairment is minimized through a relative permeability modifiers effect



Relative permeability modification after Microgel adsorption

POWELSMART Applications

- **Sand control in Oil and Gaz wells**
- **Water Shut Off in Oil and Gaz wells**
- **Conformance control for water injection wells**

Powelsmart specifications

Temperature (°C)	Up to 120
Salinity (g/l)	Up to 300
Permeability range (mD)	10 – 10 000
Shut in time (hours)	No
Regained permeability to oil %	>80

Treatment design

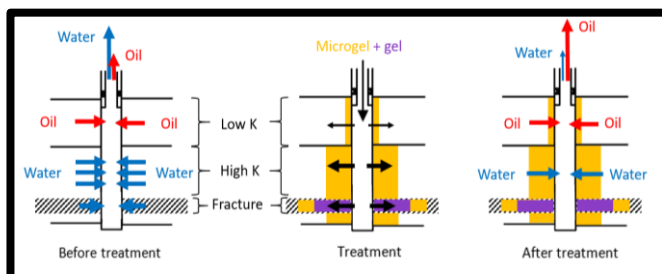
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Product delivery and field assistance

POWELTEC delivers the products and send a technical team to support the operation manager, supervise the chemicals preparation and check the quality of the solutions prepared on site.

POWELTEC can also assist the operator in post-treatment monitoring.



References

Treatment of underground gas storage wells

- SPE 71525, SPE 106042

Treatment of Heavy Oil Reservoirs

- SPE 24661, SPE 177914, SPE 206333

Treatment of fractured carbonate wells

- SPE 203394, SPE 217009

Treatment for conformance

- SPE 185864, SPE 179765, SPE 211446

Treatment of carbonate wells

- SPE 188871

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