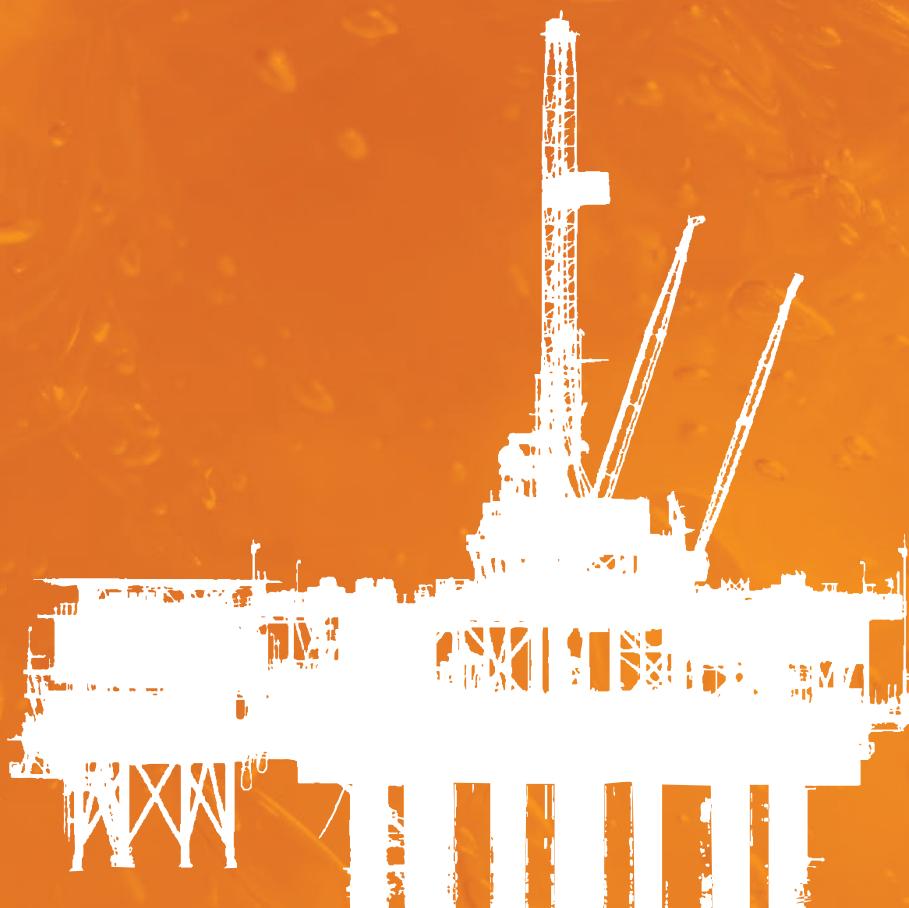




The Perfect Stimulation Solution™



AkzoNobel at a glance

AkzoNobel is proud to be one of the world's leading industrial companies. Headquartered in Amsterdam, the Netherlands, we are a Global Fortune 500 company and are consistently ranked as one of the leaders on the Dow Jones Sustainability Indexes.

As a major producer of specialty chemicals we supply industries and consumers worldwide with quality ingredients for life's essentials. We think about the future, but act in the present. We're passionate about introducing new ideas and developing sustainable answers for our customers. With Operations in more than 80 countries, our 50,000 people around the world are committed to delivering leading products and technologies to meet the growing demands of our fast changing world.

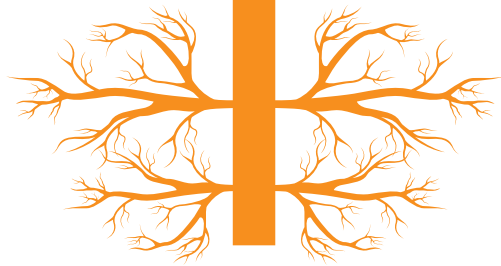
For more information please visit: www.akzonobel.com.



Dissolvine® StimWell™

The Perfect Stimulation Solution™

- 💧 For carbonate and sandstone formations
- 💧 Effective up to 400°F
- 💧 Very low corrosion
- 💧 No face dissolution
- 💧 Good iron control
- 💧 No sludge formation
- 💧 Minimum additives
- 💧 Biodegradable
- 💧 Non-toxic
- 💧 Safe to handle
- 💧 Cost effective
- 💧 Field Proven





1. Introduction

The production of oil and gas is being challenged by increasingly difficult conditions. Extreme temperatures and high pressure, expensive metallurgy of the tubular, extended reach wells and strict health, safety and environment regulations will dictate the future of the industry. In many cases, conventional technologies no longer meet the requirements of the oilfield engineer or regulatory bodies. AkzoNobel has developed a unique stimulation fluid with high thermal stability and low corrosion potential which is both effective and environmentally-friendly. This brochure introduces and explains the many distinct advantages of our Dissolvine® StimWell™ product.

Dissolvine® StimWell combines all the advantages of conventional stimulation technologies and avoids the disadvantages associated with these technologies. As a standalone fluid Dissolvine® StimWell improves the permeability of both carbonate and sandstone formations by dissolving calcium carbonate and controlling iron at the same time.

Dissolvine® StimWell:

- Effectively improves the permeability of the formation
- Causes no face dissolution
- Is compatible with clays
- Controls iron
- Prevents sludge formation
- Does not need many additives

In addition, and in contrast to currently used chemicals, Dissolvine® StimWell has excellent properties:

- High thermal stability
- Low corrosion potential
- Compatible with down-hole equipment
- Effective across wide flow rates
- Environmentally-friendly characteristics

Its biodegradation and eco-tox properties meet the requirements for on-shore and offshore application around the world. Overall, the combination of its unique properties and broad capabilities make Dissolvine® StimWell The Perfect Stimulation Solution™.



2. Conventional stimulation of oil and gas reservoirs

Stimulation with hydrochloric acid (HCl) is a well established technique to improve the production from a carbonate reservoir. HCl is effective in the dissolution of calcium carbonate, the reaction products are soluble, it is readily available and HCl in itself is cheap. At first sight, HCl seems an ideal stimulation fluid, but HCl has many limitations that become even more problematic at downhole temperatures exceeding 200°F. For example, HCl is corrosive, especially for chromium-based steel, it causes scale dissolution and cannot prevent iron or asphaltene precipitation. To solve these problems, the application of HCl requires large amounts of additives that make the treatment as a whole very costly and increases the risk of creating formation damage rather than removing it.

Organic acids – such as acetic, formic or citric acid – eliminate some of these drawbacks as they are less corrosive, give some iron control (citric acid) and reduce asphaltene sludge formation. On the other hand, thermal decomposition starts at 250°F and the solubility of the reaction products is limited, which reduces the concentration of the fluids. Since these are weak acids, the reaction with carbonate will never be fully completed and part of the acids will remain unreacted. As a consequence of these chemical properties, the volumes and reaction time of an organic acid-based stimulation job are significantly higher.

Chelating agents, such as ethylene diamine tetraacetic acid (EDTA), hydroxy ethyl ethylene diamine triacetic acid (HEDTA) and nitrilo triacetic acid (NTA) also have a low corrosion potential and can effectively dissolve calcium carbonate. But they have limited solubility and thermal stability under acidic conditions and suffer from slow biodegradability or an unfavorable toxicity profile. Many independent organizations have classified NTA as potentially carcinogenic for humans and regulatory bodies are putting restrictions on the use of NTA in (consumer) products.

Sandstone reservoirs are generally treated with hydrofluoric acid (HF) and HCl mixtures, also known as mud acid, to improve the permeability. Although highly corrosive and very toxic, HF is often used as it is the only chemical that can dissolve siliceous material. The HCl is added to dissolve any carbonate damage and to control the amount of damage due to numerous (re-)precipitation reactions that are triggered by the HF treatment. However, many sandstone formations contain clays – such as chlorite, kaolinite and illite – which are sensitive towards HCl. Illite in particular has a tendency to break-up into small particles that can block the pores of the formation, causing irreversible formation damage. As a consequence of the complex chemistry between the mud acid and the rock, many sandstone acidizing treatments are unsuccessful or even ruin the well totally.

3. The Perfect Stimulation Solution™: Dissolvine® StimWell™

Dissolvine® StimWell™ combines all the advantages of conventional stimulation technologies and avoids the disadvantages associated with these technologies.

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The stimulation of carbonate and sandstone formations has been extensively studied. Dissolvine® StimWell is able to improve the permeability of carbonate rock such as calcite and dolomite at temperatures ranging from 80°F to 400°F and at a wide range of injection rates.

Figure 1 shows a three-dimensional CT scan of an Indiana Limestone core which has been treated with Dissolvine® StimWell. The scan clearly shows that a wormhole has been formed which propagates throughout the entire length of the core, without showing face dissolution at the inlet of the core.

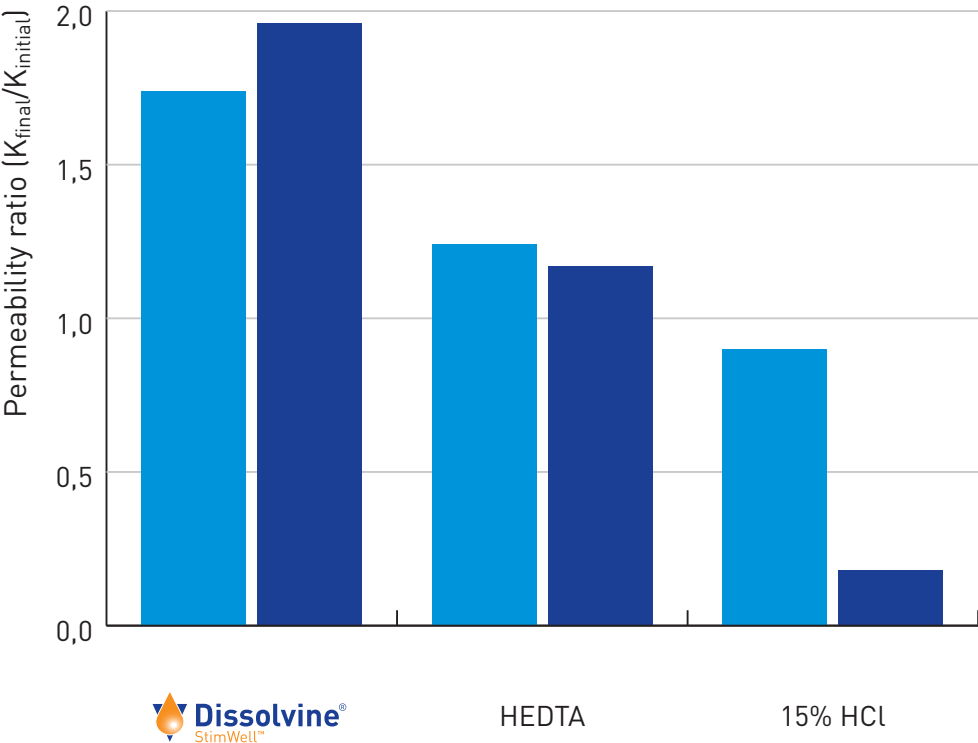
Figure 1: 3D CT scan of a 20-inch long Indiana Limestone core which has been treated with Dissolvine® StimWell at 1 cm³ per minute and 250°F.



The value of Dissolvine® StimWell as stimulation fluid is not limited to carbonate rock. Sandstone formations also benefit from the unique properties of our product. Figure 2 shows that Dissolvine® StimWell has superior performance compared with 15% HCl or HEDTA in improving the permeability of Berea and even illite-rich Bandera sandstone. Similar improvements in permeability have also been measured for sandstones with up to 18% illite. In contrast, HCl causes formation damage. The significant increase in permeability with Dissolvine® StimWell proves that no unwanted (re-)precipitation reactions were triggered, confirming its compatibility with clays.

Figure 2: The permeability change of Berea and illite-rich Bandera sandstone after treatments at 300°F and 5 cm³ per minute.

■ Berea
■ Bandera



	Berea	Bandera
Quartz	86	57
Dolomite	1	16
Calcite	2	-
Feldspar	3	-
Kaolinite	5	3
Illite	1	10
Chlorite	2	1
Plagioclase	-	12

3.1. No face dissolution

Face dissolution, or wash out, can be a serious problem when using HCl, especially at low injection rates and/or high temperatures, as illustrated by Figure 3 and Tables 1 and 2. In contrast to HCl and HEDTA, Dissolvine® StimWell causes no face dissolution even under the most challenging conditions. A substantial amount of HCl is wasted in the near wellbore area and does not contribute to the improvement of the oil or gas production. In addition to being a misuse of chemicals and money, a wash out can also be a troublesome passage for future coiled tubing operations.

Figure 3:
Left: The inlet side of a core after stimulation with Dissolvine® StimWell showing no face dissolution.
Right: The inlet side of a core after stimulation with 15% HCl showing severe face dissolution.

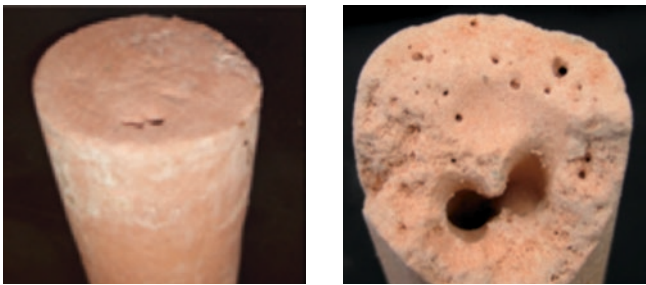


Table 1: 2D CT scans of six-inch long Pink Dessert calcite cores that have been treated with Dissolvine® StimWell or 15% HCl at 200°F and 1 cm³ per minute.

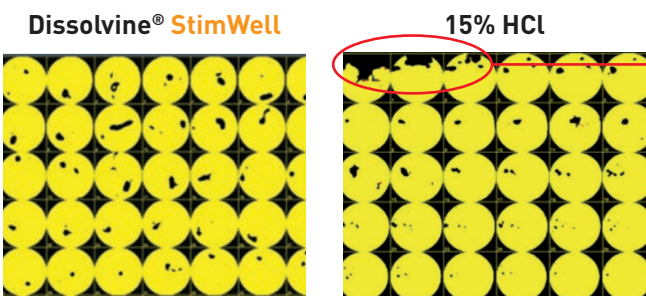
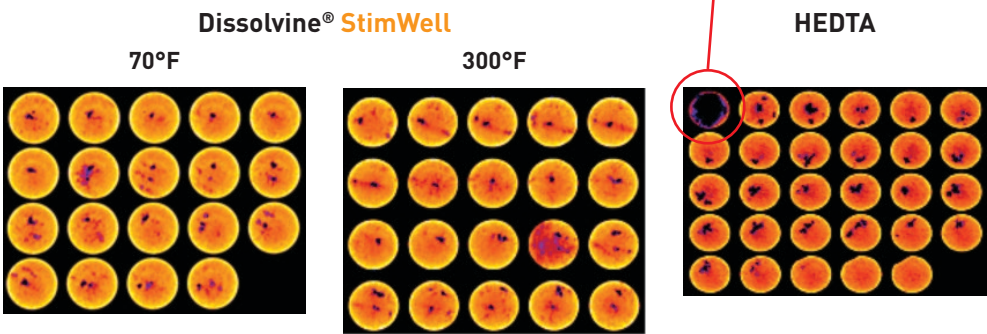


Table 2: 2D CT scans of six-inch long Indiana Limestone cores that have been treated with Dissolvine® StimWell or HEDTA at 0.5 cm³ per minute.



3.2. Stability and versatility at high temperatures

Figure 4 shows that high temperatures are even an advantage when acidizing with Dissolvine® StimWell. At elevated downhole temperatures of the well, a greater increase in permeability is achieved with less volume. Also, compared with other organic acids, Dissolvine® StimWell proves its excellent effectiveness by the smaller pore volume to breakthrough, as illustrated by Figure 5.

Figure 4: The influence of temperature on the increase in permeability and required pore volume to reach breakthrough of six-inch Indiana Limestone core treated with Dissolvine® StimWell at 2 cm³ per minute.

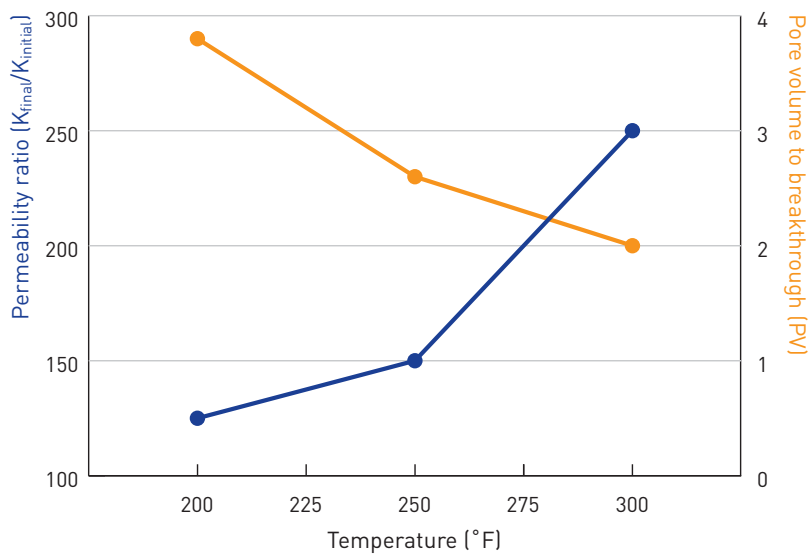
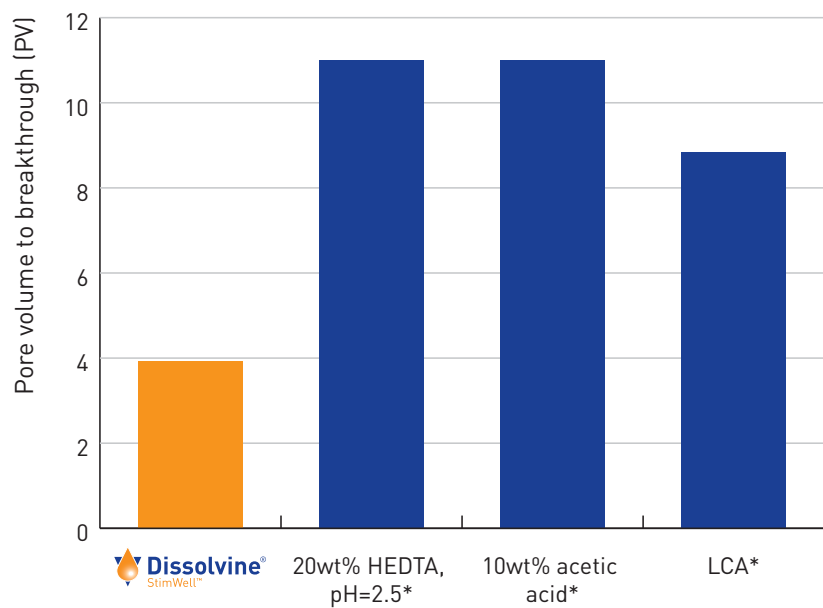


Figure 5: The effectiveness of Dissolvine® StimWell compared with other organic acids as measured by core flood tests with six-inch Indiana Limestone at 250°F and 2 cm³ per minute.
* data data for Long Chain Carboxylic Acid derived from Huang et al (2003) SPE 82268



3.3. Iron control

The presence of iron, especially ferric iron can cause numerous problems in and near the wellbore. Ferric iron can originate from the formation itself, or more likely from corroded tubular and even from contaminated stimulation fluids.

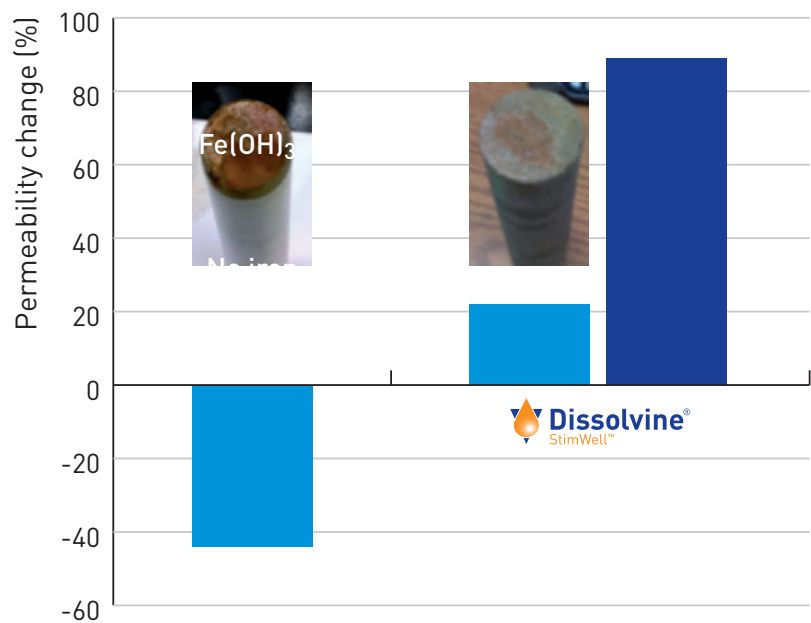
It forms insoluble iron hydroxide precipitates during acid treatments when the acid gets spent and when the pH rises above 2.5. Ferric iron also induces the precipitation of asphaltenes, resulting in asphaltic sludge which can block the formation and thus reduce the production from the well. In sour wells iron ions are even more challenging as they can form all sorts of insoluble iron sulfides, that – once formed – are

difficult to remove. To tackle this problem, iron control agents such as EDTA, NTA, etc. are often added to the stimulation fluid. However, most of these chelating agents have limited solubility in acids and consequently provide little protection against the detrimental effects of ferric iron. In contrast, Dissolvine® StimWell is highly soluble in most acids, as shown in Figure 16 (page 24), and being based on a chelating acid, it can effectively complex the ferric iron and keep the iron in solution. It can therefore be added as an iron control agent for most stimulation jobs.

Dissolvine® StimWell does more than just control iron alone. Figure 6 shows that the addition of Dissolvine® StimWell improves the stimulation of a carbonate formation, whereas a treatment with HCl alone caused a reduction in permeability of more than 40%, due to the precipitation of iron hydroxides. When Dissolvine® StimWell is used as a standalone fluid for the stimulation of carbonate or sandstone reservoirs, there is no need to add extra iron controlling agents as it can do both jobs at the same time.

Figure 6: The influence of Dissolvine® StimWell on the success of the limestone stimulation job with 5% HCl containing 10000ppm Fe.

200°F
300°F



3.4. Low corrosion

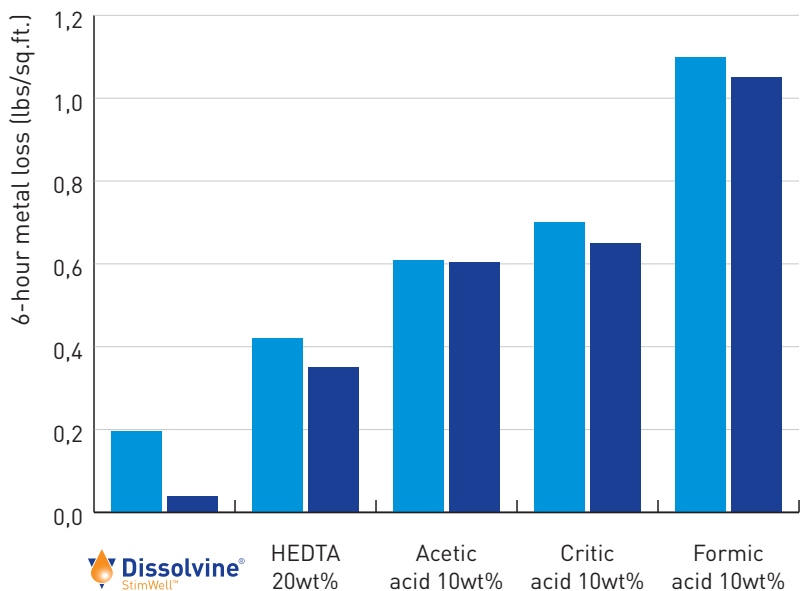
Compared with other acidizing fluids, Dissolvine® StimWell has a remarkably low corrosion potential for both carbon steel and chrome-based tubular. This helps to totally eliminate – or drastically reduce – the need for corrosion inhibitors from the overall acidizing program. Elimination of corrosion inhibitors will not only lead to significant cost reduction in the acidizing process, but also helps to avoid any formation damage induced by the corrosion inhibitors themselves, as well as significantly alleviating negative environmental impact of generally used inhibitors.

Low carbon steel

Figure 7 shows that with Dissolvine® StimWell, the corrosion of low carbon steel is kept below the generally accepted limit of 0.05 lbs/sq ft, with a fraction of the volume of corrosion inhibitor that is needed for other chelates and acids, including HCl. In addition, there is no need for expensive corrosion inhibitor intensifiers even beyond 350°F.

Figure 7: The corrosion potential of Dissolvine® StimWell and other traditional acids – with and without corrosion inhibitor - on L-80 carbon steel at 300°F and 1000 psi nitrogen start pressure.

■ No CI
■ 0.001v% CI



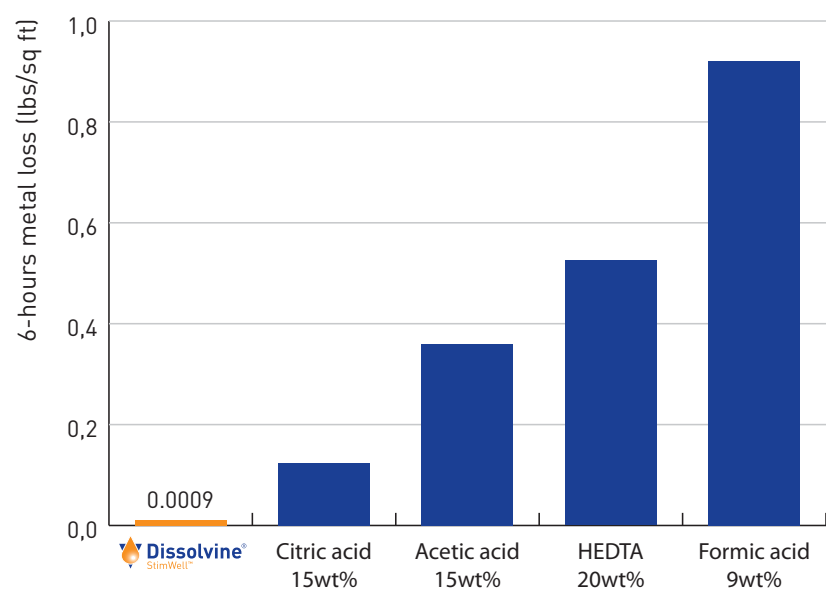


Figure 8: The corrosion potential of Dissolvevine® StimWell compared with other acidizing fluids measured during a six-hour corrosion test at 300°F with Cr-13 steel (UNS S41000) and a 1000 psi nitrogen start pressure.

Chromium steel

Compared with commonly used acidizing fluids, Dissolvevine® StimWell is extremely gentle for chromium-based tubular, as illustrated in Figure 8. At 300°F, Dissolvevine® StimWell is the only acidizing fluid that does not require a corrosion inhibitor to keep the corrosion rate over Cr-13 stainless steel below the maximum value of 0.05 lbs/sq ft.

No corrosion inhibitors

Extensive corrosion studies have proved that Dissolvevine® StimWell has a remarkably low corrosion potential for both low carbon steel and chromium-based tubular. Figure 9 shows that for some metallurgies, no inhibitors are required, even up to temperatures as high as 400°F.

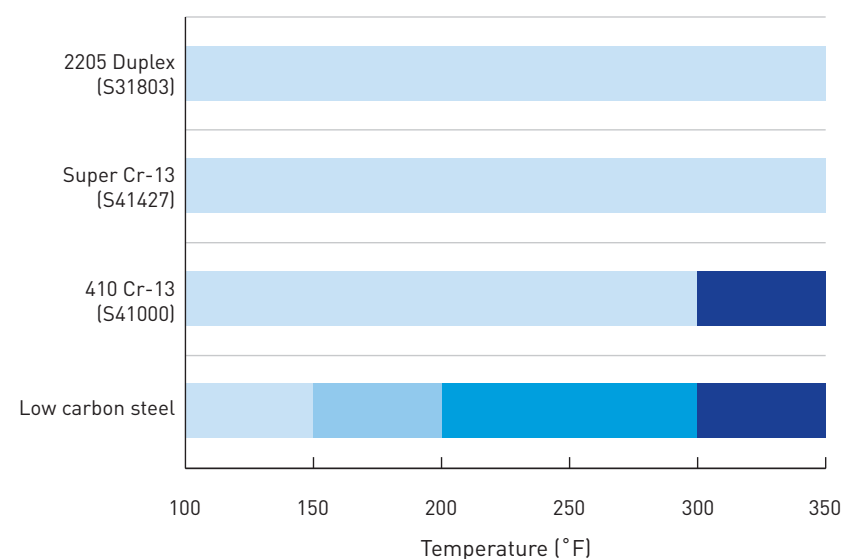


Figure 9: Corrosion inhibitor requirements for various metallurgies treated with Dissolvevine® StimWell. The temperature ranges reflect conditions with a corrosion rate <0.05lbs/sq ft during a six-hour corrosion test with a 1000 psi nitrogen start pressure.

3.5. Safe for people and planet

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Dissolvine® StimWell is registered and approved for offshore use, including in the North Sea

The effectiveness and convenience of using Dissolvine® StimWell is coupled with its environmentally-friendly profile. Dissolvine® StimWell has been extensively reviewed and studied for its impact on planet and people. The studies and regulatory reviews confirm its friendliness to plants, animals and humans.

The main component of Dissolvine® StimWell is based on natural and sustainable raw materials. The natural origin of Dissolvine® StimWell makes the product biodegradable, under both fresh and seawater conditions. This has been confirmed by the results obtained in several biodegradability studies and reviews conducted by certified third party laboratories.

Another major advantage of Dissolvine® StimWell is its excellent properties with regards to aquatic and human toxicity. Because of these very low toxicity levels, combined with its biodegradable characteristics, Dissolvine® StimWell is safe and is allowed for offshore use around

the world, including the North-East Atlantic (OSPAR recommendation 2010/3).

In contrast to other frequently used stimulation chemicals, Dissolvine® StimWell is not considered to be a hazardous chemical. It does not have any adverse hazard classifications and does not require any hazard labeling. Handling and transport can be done safely without the need for any extreme safety precautions.



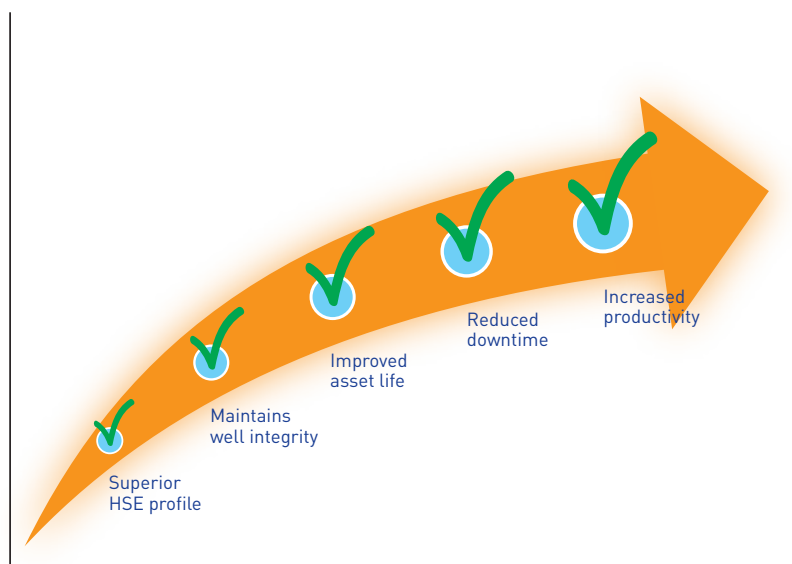


Figure 10: The many advantages which make Dissolvine® StimWell the Perfect Stimulation Solution™.

3.6. Cost effective

Dissolvine® StimWell is a shining example of a sustainable, innovative product which can help you meet some of your toughest stimulation challenges. It also offers added value from an economic perspective. Unlike conventional treatments, Dissolvine® StimWell needs minimum to no additives. Its inherently low corrosive nature means that the overall acidizing program can be executed without expensive additives such as corrosion inhibitors and intensifiers, even at high temperatures. Its natural iron binding ability means that the product does not need additional iron control or anti-sludge agents to be effective. Elimination of these types of commonly used additives translates into a simple, easy and less problematic treatment program. Furthermore, the overall chemical cost is significantly reduced per treatment.

In addition to the lower chemical cost, Dissolvine® StimWell offers additional economic benefits such as less rig time, reduced down time, less handling, etc. Dissolvine® StimWell requires no additional chemical treatment on flow back and

will not cause upset in production facilities. Whether it is low carbon steel or chrome-based tubular; whether it is 100°F or 400°F, Dissolvine® StimWell helps support durability of well tubular and equipment. The effectiveness of the product in keeping the reaction products in solution also means that there is less damage to the rock formation during or post-treatment.

Its ease of handling and ecological nature completes its economic attractiveness and makes Dissolvine® StimWell not only the Perfect Stimulation Solution™, but also an eco-premium stimulation solution.



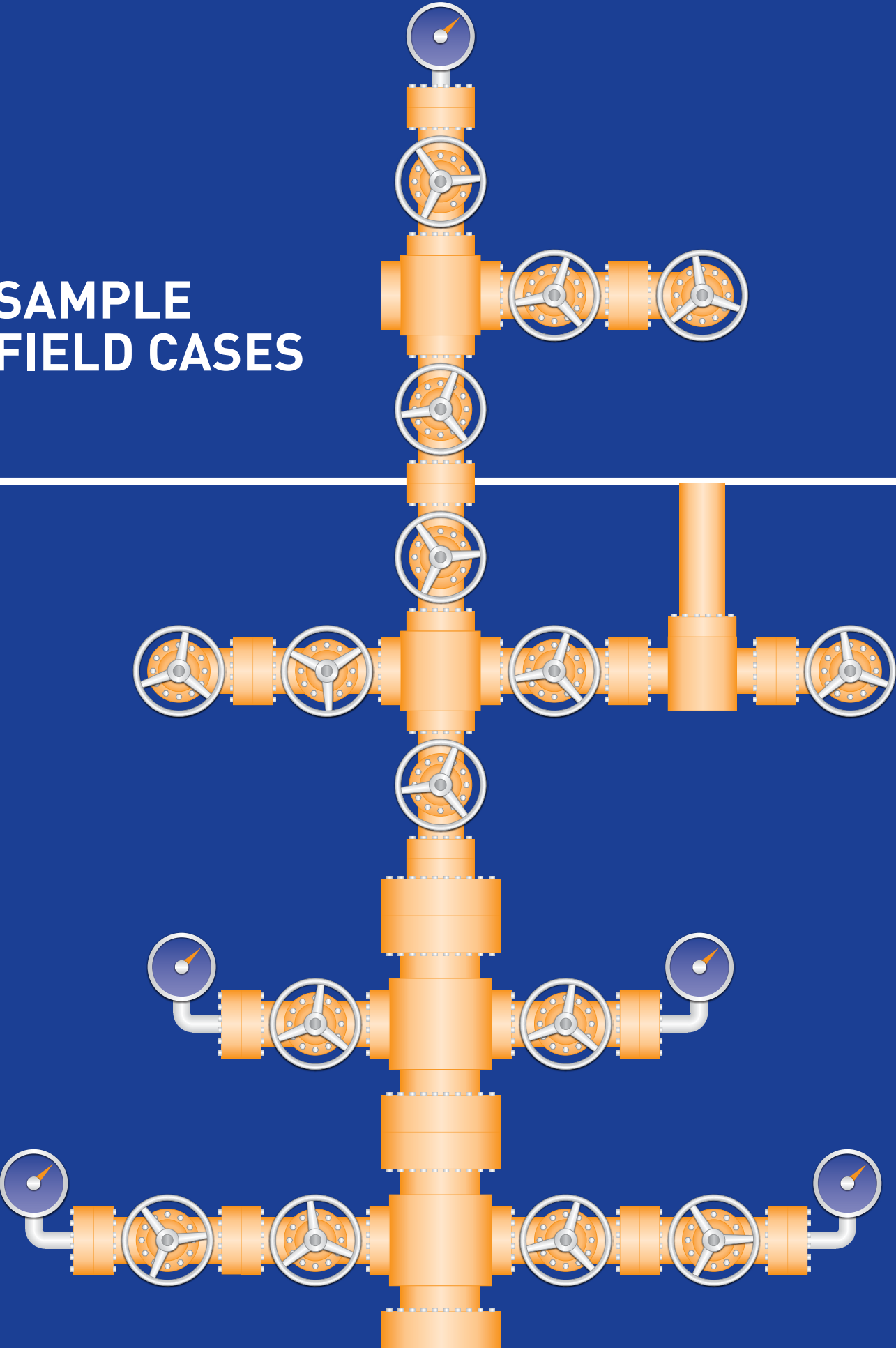
3.7. Worldwide supply and support

Dissolvine® StimWell is marketed through our regional centers in the US, the Netherlands, Singapore and China. The global spread of our manufacturing facilities in the US, the Netherlands and China ensures that Dissolvine® StimWell can be delivered easily to our customers in any part of the world. Thanks to our concerted research and development efforts, product quality and consistency are ensured.

Dissolvine® StimWell is available in various packaging and quantities, ranging from drums to tank cars to rail cars.

Dissolvine® StimWell can be easily applied in the field after further dilution with water for optimum performance. We can advise you on the process to establish the optimum dosage. To make the most of this technology, we can work with you to recommend a full acidizing program which has been optimized to meet your particular well conditions based on custom core-flood tests at our dedicated development center. Our intention is to ensure that you achieve the best stimulation results possible.

**SAMPLE
FIELD CASES**



1. Stimulation of high temperature gas well, in carbonate formation

A vertical gas well in a deep, sour carbonate reservoir was successfully treated using Dissolvine® StimWell. Previous matrix stimulation treatments with conventional acids in this high temperature well did not sustain production and fracturing was considered. However, this case clearly proves that matrix acidizing with Dissolvine® StimWell was the best choice in terms of gas production, well integrity, and environmental impact.

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The challenge

After a work-over, productivity at the well significantly reduced, and the well was shut-in for seven years. High temperatures -300°F- combined with corrosive gases -19% H₂S and 9% CO₂- and the presence of chrome-nickel based internals within the low carbon steel tubular made finding a suitable stimulation fluid difficult.

The solution

Dissolvine® StimWell was used as main treatment, as it is especially designed for the challenging reservoir conditions and strict environmental regulations. Less than 1% of a corrosion inhibitor was added to keep the corrosion rate below the 0.05 lbs/ft² limit. The Dissolvine® StimWell treatment was applied by bull-heading and production was re-started after six hours of soaking time.

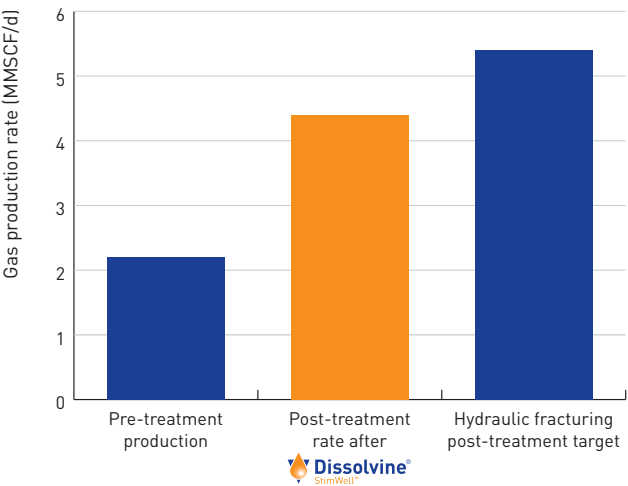


Figure 11: Measured gas production before and after treatment with Dissolvine® StimWell. For comparison the expected fracturing treatment result is given.

Results

After the treatment, the production rate increased by 110% compared to the well production rate seven years before, almost equaling the result expected from fracturing. Analysis of the flow back revealed that Dissolvine® StimWell dissolved large amounts of calcite and dolomite without any adverse effect on the well tubular. Over two years after the treatment, the well still produces gas without problems.

- Removes formation damage effectively
- Minimal impact on well metallurgy
- High compatibility with production fluids
- A viable alternative to fracturing systems.
- Only two components main treatment and much lower volume requirement compared to conventional acids.

2. Stimulation of high temperature oil well, in sandstone formation

An offshore, high temperature well that had been producing oil for over decades was successfully treated with Dissolvine® StimWell™. The hydrocarbon production in this well had fallen and water production increased over time – down to 200 BOPD, along with a 90% water cut.

This case clearly proves that Dissolvine® StimWell is also an excellent choice for matrix acidizing of sandstone formations. The treatment did not induce additional water or sand production, confirming that Dissolvine® StimWell targeted the right zones without causing formation destabilization. Analysis of the flow back revealed that Dissolvine® StimWell dissolved large amounts of calcite and dolomite, as well as iron scales in, and near, the wellbore without any adverse impact on tubular.

The challenge

Conventional acid treatments have been ruled-out in this well due to the presence of acid sensitive clays –mainly illite and kaolinite- in the sandstone formation and the high potential of corrosion. Protection of the tubular was especially challenging due to the aged low carbon steel tubular that had been exposed to high temperature -260 °F- and high concentration of corrosive gases -7% H₂S and 3% CO₂.

The solution

Dissolvine® StimWell mixed with a minimal concentration -0.25 %- of corrosion inhibitor was applied as the main treatment. A pre- and post-flush was utilized to prevent water blockage and improve well performance. The treatment was applied by bull-heading and flush back and production restart followed after seven hours of soaking.

Results

The Dissolvine® StimWell treatment increased the oil production to 310 STB/day few days after well stimulation. The long term production rate was later stabilized at 240 STB/day. An extra production of 2,400 barrels was achieved in the 60 days following the treatment.

- Uniform stimulation of sandstone formations with low risk of rock disintegration.
- Low corrosion risk to tubular at high temperatures. Viable treatment option even with ageing installations.
- Reduced equipment requirements mean smaller operational footprint.

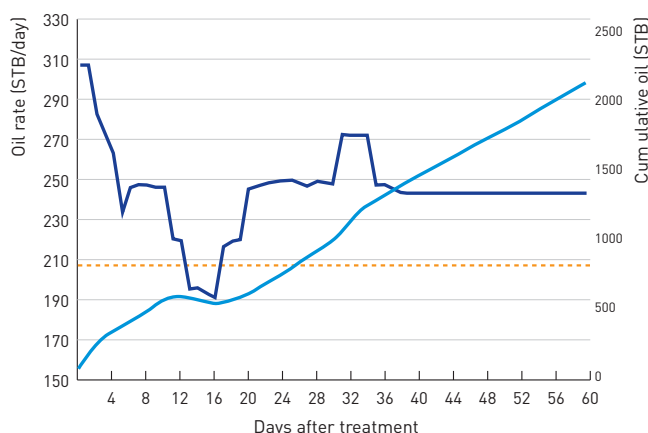


Figure 12: Improvement of well performance after treatment with Dissolvine® StimWell™

Oil rate (STB/day) Cumulative oil (STB)
Pre Acid Rate

3. De-scaling of well tubular, with ESP in place

Iron and carbonate scale in a vertical offshore single string oil producer equipped with ESP was successfully removed using Dissolvine® StimWell. In addition, the sandstone formation was mildly stimulated to increase the oil production. In 2010, the ESP has been destroyed by scale build-up and the operator wanted to remove the scale layer that was building up again on the new ESP before it was too late. Dissolvine® StimWell was chosen because of its efficiency in removing the scale and because it has a tested gentle corrosion profile for the ESP. As a result, retrieval of the ESP was not required.

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This case clearly proves that the combination of scale removal and matrix acidizing with Dissolvine® StimWell was the best choice resulting in complete scale removal, improved production, fully maintained integrity of the ESP and well tubular, and on top of that a low environmental impact.

The challenge

An off-shore oil well in a sandstone reservoir showed declining production due to scale build up on its tubular and electric submersible pump. Previous treatments with HCl had resulted in a short duration production increase followed by a sharp decline, due to the incompatibility of the acid with clays in the formation -illite, kaolinite and chlorite- and the build-up of yet more scale. Repeated scale build-up and acid treatments lead to frequent replacement of the ESP.

The Solution

Dissolvine® StimWell was applied as the main treatment to remove the scale, and perform a limited stimulation of the formation containing traces of calcite and dolomite. Dissolvine® StimWell was preceded and followed by a pre- and post-flush aimed to prevent water blockage and improve well performance. The treatment was applied by bull-heading. Production restart followed after 24 hours soaking time at a bottom hole temperature of 160°F.

Results

After the treatment, the oil production of the well increased from 400 to 512 bbl/day and the PI improvement sustained for 6 months. Extensive analysis of the flow back after the treatment indicated that large amounts of scales were dissolved without any adverse impact on the ESP or well tubular.

- Low corrosive character on tubular metallurgy, field elastomers and sensitive down-hole equipment such as ESPs.
- No need to retrieve the ESP during treatment.
- Compatible with various acid sensitive clays.

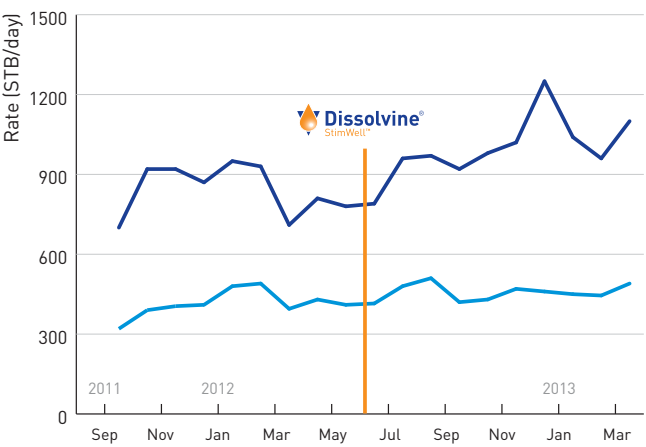


Figure 13: Improvement of well performance after treatment with Dissolvine® StimWell™

Oil rate (STB/day) Liquids rate (STB/day)

PRODUCT TECHNICAL INFORMATION



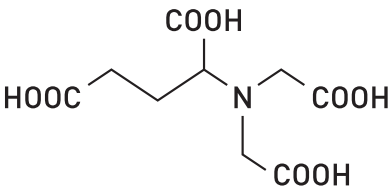
1. Product description

Dissolvine® **StimWell™** is based on the recently developed chelating agent glutamic acid diacetic acid (GLDA). As shown below, GLDA has four carboxylic acid groups, giving it a powerful acidic character, capable of dissolving calcium carbonate. In combination with the nitrogen atom, these acid groups can also form strong bonds with di- and trivalent metals, ensuring iron and other metal ion control.

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Table 3: Product properties

Chemical structure:



Chemical name: glutamic acid N, N-diacetic acid; GLDA
CAS No: 58976-65-1
Chemical formula: C₉H₁₃NO₈
Molecular weight: 263.2 g/mol

Dissolvine® **StimWell** HTF characteristics

Characteristic	Dissolvine® StimWell HTF ⁺	Dissolvine® StimWell (50 v/v%)*
Active ingredient	GLDA	GLDA
Physical form	Liquid	Liquid
Appearance	Clear liquid	Clear liquid
Color	Yellow-brown	Yellow
pH 10%	3.4 - 4.0	
pH (as such)		3.4 - 4.0
Assay	33.0 - 35.0 wt%	18.4 -19.5 wt%
Liquid density (kg/m ³) at 68°F	Approx. 1260	Approx. 1130
Viscosity (mPa.s) at 68°F	13	3
Freezing point (°F)	10	23
Pour point (°F)	10	23
Solubility in water	Miscible in all ratios	Miscible in all ratios
Solubility in acids	Miscible in all ratios	Miscible in all ratios

⁺ as supplied

*recommended concentration for carbonate stimulation

2. Chemical and physical properties

- Dissolvine® StimWell
- Dissolvine® StimWell HTF

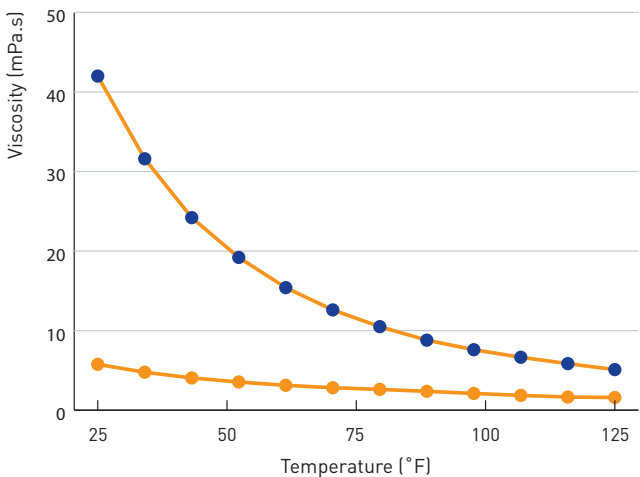


Figure 14: The viscosity as a function of temperature of Dissolvine® StimWell HTF as supplied and as 50v/v% aqueous solution.

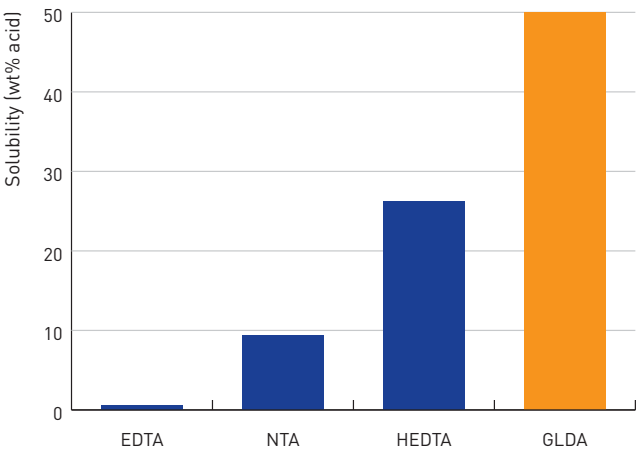


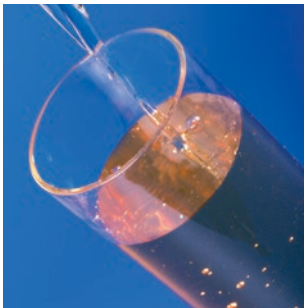
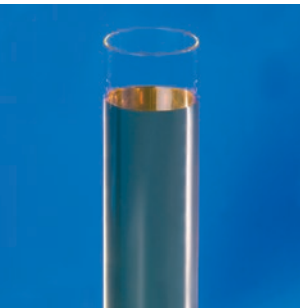
Figure 15: The solubility of various chelates at pH=3.4 and 70°F

Viscosity

Viscosity is an important parameter for pumping and propagation of fluids into the well or reservoir and depends on concentration and temperature. Figure 14 shows the viscosity of Dissolvine® StimWell HTF and a 50v/v% dilution as a function of temperature.

Solubility

Calcium carbonate is most effectively dissolved under acidic conditions, in other words at low pH. These conditions are also favorable for the control of iron and, thus, the prevention of sludge. A highly concentrated acidic solution of a chelating agent combines all these functionalities and would therefore be a perfect stimulation fluid. Figure 15 compares the solubility of several chelating agents at pH=3.4 and shows the excellent dissolution properties of GLDA under these challenging low pH conditions. The unique properties of GLDA form the basis for the unequaled versatility of Dissolvine® StimWell in stimulation.



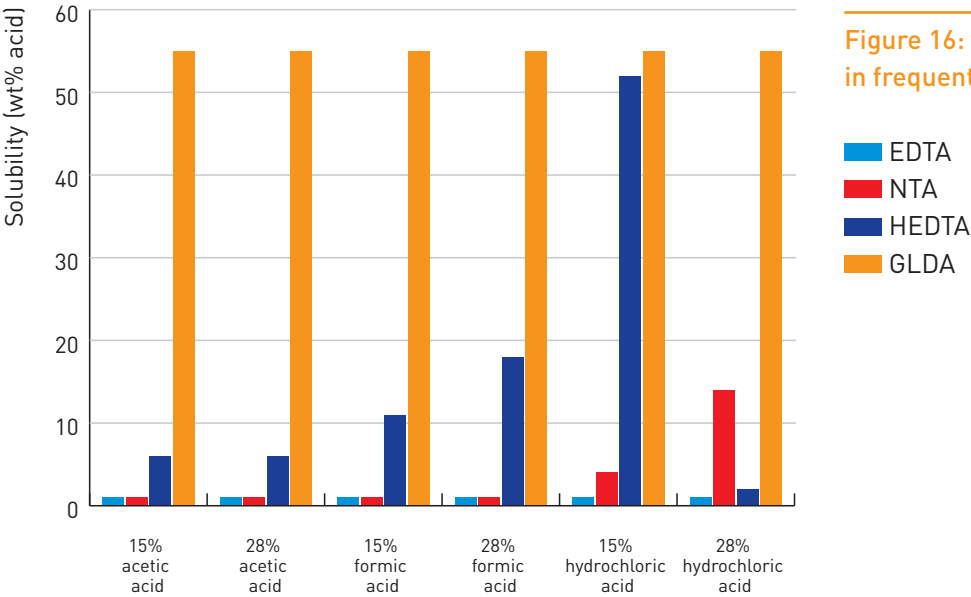


Figure 16: Solubility of various chelates in frequently used acids at 70°F.

Solubility in acids

In addition to being highly water soluble, GLDA can also be dissolved in a variety of acids. This makes Dissolvine® StimWell exceptionally well suited as an iron controlling agent in cases where, for example, HCl is preferred as the main component of the stimulation fluid. Figure 16 shows the solubility of GLDA and several other chelating agents in frequently used acids.

Calcium carbonate dissolution capacity

The success of an acidizing job depends on the amount of calcium carbonate that is dissolved, but more importantly it depends on the location where the carbonate is dissolved. In other words, the aim is to form wormholes that increase the permeability of the reservoir and to avoid face dissolution that only consumes large amounts of acid without improving the production of the well. Wash outs can also hinder further coiled tubing operations. Chapter 3 (in pages 7-9) has already explained the effectiveness of Dissolvine® StimWell in creating wormholes compared with other stimulation fluids.

Figure 17 compares the calcite dissolution capacity with various chelating agents and a strong acid. A strong acid such as HCl has a higher capacity, but much of that capacity is lost due to face dissolution, especially at low injection rate and high temperatures. For weak acids like acetic acid and formic acid, the capacity will be relatively low since the dissolution reaction will reach an equilibrium at which only part of the acid has been used.

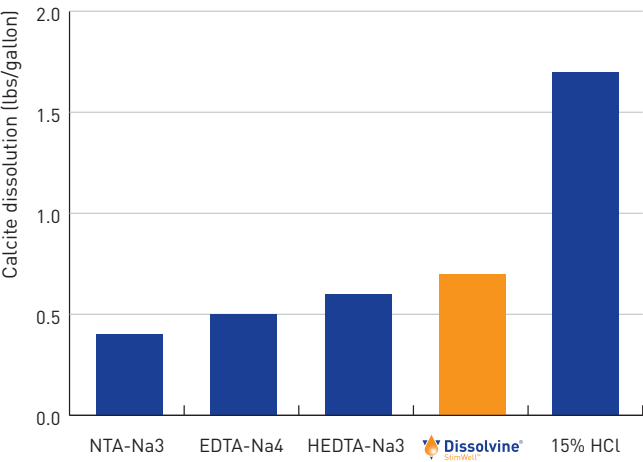


Figure 17: The calcite (CaCO₃) dissolution capacity of 20wt% NTA, EDTA and HEDTA, Dissolvine® StimWell and 15% HCl

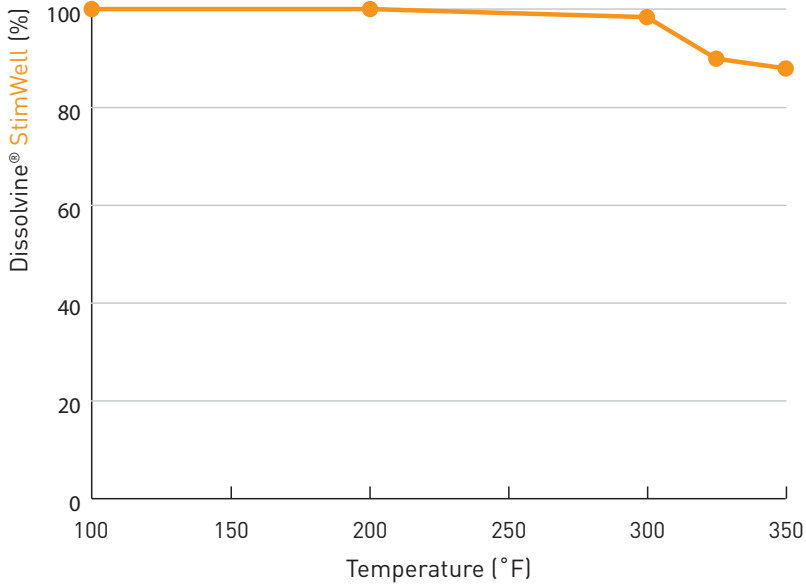


Figure 18: The thermal stability of Dissolvine® StimWell after 6 hours of heating

Thermal stability

The thermal stability of a stimulation fluid is of utmost importance due to the increasingly high reservoir temperatures. Figure 18 shows that Dissolvine® StimWell is very stable up to at least 350°F.

3. Environmental and toxicological data

A major advantage of Dissolvine® StimWell is its excellent properties with regards to aquatic toxicity and environmental acceptability. Dissolvine® StimWell is completely safe for the environment and is permitted for offshore use around the world, including the North-East Atlantic (OSPAR recommendation 2010/3) as can be seen in Tables 4 to 6.

Partitioning and bioaccumulation potential

The N-octanol/water partition coefficient (Log Pow) has been determined by experiment (OECD 117) under the principles of Good Laboratory Practice (GLP). The result is listed in Table 4.

Biodegradability

The main component of Dissolvine® StimWell is GLDA, which is based on the natural amino acid salt, mono sodium glutamate (MSG). MSG is produced by biochemical conversion of vegetable material, such as sugar beet waste.

This natural origin makes Dissolvine® StimWell a good basis for micro-organisms to feed upon, which is confirmed by several biodegradability studies under both fresh and seawater conditions.

In the OECD 306 Closed Bottle Test with sea water, carried out in compliance with GLP, GLDA was biodegraded 26 percent at day 28. In the prolonged Closed Bottle Test, this substance was biodegraded 83 percent at day 60. The biodegradation reached on the last day of the test demonstrates that GLDA should be

Table 4: The N-octanol/water partition coefficient (Log P_{ow}) of Dissolvine® StimWell HTF

Substance	Method	Log P _{ow}
GLDA-Na4	OECD 117	<0

Table 5: Biodegradability test data for Dissolvine® StimWell HTF

Conditions	Method	Result
Sea water	OECD 306	26% at day 28
		83% at day 60
Fresh water	OECD 301D	83% at day 28
	OECD 301D	75% at day 28

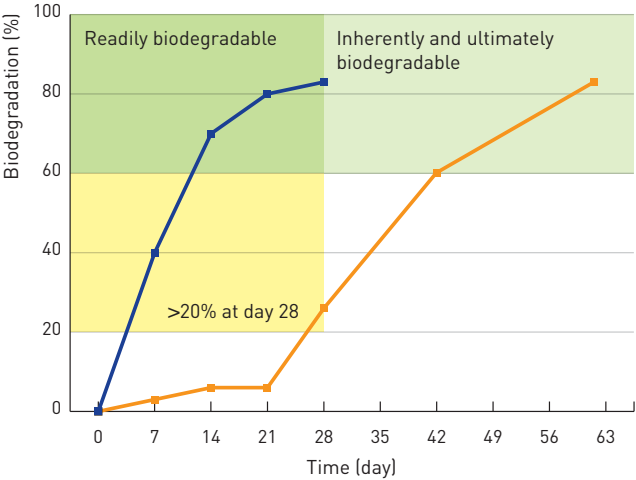


Figure 19: The biodegradation of Dissolvine® StimWell determined by OECD 301D (fresh water) and OECD 306 (sea water) tests.

classified as inherently and ultimately biodegradable in the marine environment, as shown in Figure 19. These biodegradation percentages were calculated on the assumption that the test substance was converted to water, carbon dioxide and nitrate. According to the OECD 301D test procedure carried out by various independent laboratories, GLDA is readily biodegradable in fresh water. In contrast, chelating agents such as EDTA and HEDTA degrade too slowly to permit classification as readily fresh water biodegradable (OECD 301D).

Aquatic toxicity

The toxicity of aminopolycarboxylic acids based products such as Dissolvine® StimWell is primarily tested with fresh water species. A specific sensitivity of marine species to these substances is ruled out.

Dissolvine® StimWell itself is therefore not toxic to any aquatic species as shown by all fresh water data available.

Table 6: The aquatic toxicity of Dissolvine® StimWell HTF

Aquatic toxicity	Species	Method	Result
Algae	Desmodemus subspicatus	OECD 201	EC50 (72h): >100 mg/l NOEC (72h): ≥100 mg/l
Crustacean	Daphnia magna	OECD 202	EC50 (48h): >100 mg/l NOEC (48h): >100 mg/l
Fish	Oncorhynchus mykiss	OECD 203	LC50 (96h): >100 mg/l NOEC (96h): >100 mg/l

Registrations

Our product is registered for use with the appropriate regulatory bodies around the world.

Table 7: Main registrations completed for Dissolvine® StimWell

Organization	Registered
US TSCA	Yes
EC	Yes
REACH	Yes
OSPAR	Yes*










*For all North Sea sectors of UK, the Netherlands, Denmark and Norway
*UK and the Netherlands: Gold without substitution warning
*Norway: Yellow-1



4. Safety

As well as being environmentally friendly, Dissolvine® StimWell™ has excellent safety characteristics. Handling and transport can be done with relative ease and does not require extreme safety precautions. In contrast to other frequently used stimulation chemicals, Dissolvine® StimWell™ does not carry any hazard classifications.

Table 8: Labeling requirements for Dissolvine® StimWell versus conventional stimulation fluids under GHS*

Product	Pictogram	Hazard phrases
Dissolvine® StimWell HTF	NO LABELS	NO HAZARD PHRASES
15%HCl	 	H314: Causes severe skin burns and eye damage
HF	 	H300: Fatal if swallowed H310: Fatal in contact with skin H314: Causes severe skin burns and eye damage H330: Fatal if inhaled
EDTA	 	H302: Harmful if swallowed H318: Causes serious eye damage H332: Harmful if inhaled
HEDTA		H319: Causes serious eye irritation
NTA	 	H302: Harmful if swallowed H319: Causes serious eye irritation H351: Suspected of causing cancer

* Global Harmonized System of Classification and Labeling of Chemicals

Journal Publications

- **SPE 121709**, J.N. LePage, C.A. de Wolf, J.H. Bemelaar, H.A. Nasr-El-Din, An Environmentally Friendly Stimulation Fluid for High Temperature Applications, 2010 [SPE International Symposium on Oilfield Chemistry, Woodlands, TX, US, 20-22 April 2009]
SPE Journal: vol 16, nr 1, 2011, pp 104-100
- **SPE 127923**, M.A. Mahmoud, H.A. Nasr-El-Din, C.A. de Wolf, J.N. LePage, J.H. Bemelaar, Evaluation of a New Environmentally Friendly Chelating Agent for High Temperature Applications, 2010 [Formation Damage, Lafayette, LA, US, 10-12 February 2010]
SPE Journal: vol 16, nr 3, 2011, pp 559-574
- **SPE 133497**, M.A. Mahmoud, H.A. Nasr-El-Din, C.A. de Wolf, J.N. LePage, Optimum Injection Rate of a New Chelate That Can Be Used To Stimulate Carbonate Reservoirs [SPE Annual Technical Conference and Exhibition, Florence, Italy, 20-22 September 2010],
SPE Journal: vol 16, nr 4, 2011, pp 968-980
- **SPE 163332**, H.A. Nasr-El-Din, C.A. de Wolf, T. Stanitzek, A. Alex, S. Gerdes, N.R. Lummer, Field Treatment to Stimulate a Deep, Sour, Tight Gas Well Using a New Low Corrosive and Environmentally friendly Fluid [SPE Kuwait International petroleum Conference and Exhibition, Kuwait City, Kuwait, 10-12 December 2012] SPE Production & Operations: vol 28, nr 3, 2013, pp 277-285 **Field case**

Conference Publications

- **SPE 131626**, M.A. Mahmoud, H.A. Nasr-El-Din, C.A. de Wolf, J.N. LePage, An Effective Stimulation Fluid For Deep Carbonate Reservoirs: A Core Flood Study [CPS/SPE International Oil & Gas conference and exhibition, Beijing, China, 8-10 June 2010]
- **SPE 132286**, M.A. Mahmoud, H.A. Nasr-El-Din, C.A. de Wolf, J.N. LePage, Stimulation of Carbonate Reservoirs Using GLDA [Chelating Agent] Solutions [Trinidad and Tobago Energy Resources Conference, Port of Spain, Trinidad, 27-30 June 2010]
- **SPE 139815**, M.A. Mahmoud, H.A. Nasr-El-Din, C.A. de Wolf, A.K. Alex, Sandstone Acidizing Using a New Class of Chelating Agents [SPE International Symposium on Oilfield Chemistry, Woodlands, TX, US, 11-13 April 2011]
- **SPE 139816**, A.I. Rabie, M.A. Mahmoud, H.A. Nasr-El-Din, Reaction of GLDA with Calcite: Reaction Kinetics and Transport Study [SPE International Symposium on Oilfield Chemistry, Woodlands, TX, US, 11-13 April 2011]
- **SPE 140149**, M.A. Mahmoud, H.A. Nasr-El-Din, C.A. de Wolf, A.K. Alex, Effect of Lithology on the Flow of Chelating Agents in Porous Media During Matrix Acidizing Treatments [SPE Production and Operations Symposium, Oklahoma City, OK, US, 27-29 March 2011]
- **SPE 143086**, M.A. Mahmoud, H.A. Nasr-El-Din, C.A. de Wolf, A.K. Alex, Effect of Reservoir Fluid Type on the Stimulation of Carbonate Cores Using Chelating Agents [Brazil offshore, Macae, Brazil, 14-17 June 2011]
- **SPE 143301**, M.A. Mahmoud, H.A. Nasr-El-Din, C.A. de Wolf, A.K. Alex, Novel Environmentally Friendly Fluids to Remove Carbonate Minerals from Deep Sandstone Formations [SPE Formation Damage Europe, Noordwijk, the Netherlands, 7-10 June 2011]
- **SPE 147395**, M.A. Mahmoud, H.A. Nasr-El-Din, C.A. de Wolf, Removing Formation Damage and Stimulation of Deep Illitic-Sandstone Reservoirs Using Green Fluids [SPE Annual Technical Conference and Exhibition, Denver, CO, US, 30 October-2 November 2011].
- **SPE 149127**, M.A. Mahmoud, I.M. Mohamed, H.A. Nasr-El-Din, C.A. de Wolf, When Should We Use Chelating Agents in Carbonate Stimulation? [SPE/DGS Saudi Arabia Section technical Symposium and Exhibition, Al-Khobar, Saudi Arabia, 15-18 May 2011]
- Stimulation of Sandstone and Carbonate Reservoirs Using Environmentally Friendly Chelating Agent, M.A. Mahmoud, H.A. Nasr-El-Din, C.A. de Wolf [Chemistry in the oil industry XII, Manchester, UK, 7-9 November 2011]
- **IPTC 14932**, M.A. Mahmoud, H.A. Nasr-El-Din, Challenges During Shallow and Deep Carbonate Reservoirs Stimulation [International Petroleum Technology Conference, Bangkok, Thailand, 7-9 February 2012]
- **SPE 160849**, A.K. Alex, C.A. de Wolf, A. Bouwman, H. Nasr-El-Din. A New, Low Corrosive Fluid to Stimulate Wells with Carbon Steel Tubular and Internals [SPE-Saudi Arabia Section (SAS) Annual Technical Symposium & Exhibition, al-Khobar, Saudi Arabia, 8-11 April 2012]
- **SPE 152716**, C.A. de Wolf, H.A. Nasr-El-Din, A. Bouwman, E. Bang, E. Naylor, A New, Low-Corrosive Fluid To Stimulate Deep Wells Completed With Cr-Based Alloys [SPE international Conference and Exhibition on Oilfield Corrosion, Aberdeen, UK, 28-29 May 2012]
- **SPE 155426**, S.M. Elkatatny, H.A. Nasr-El-Din, Efficiency of Removing Filter Cake of Water-Based Drill-in Fluid Using Chelating Agents Utilizing a CT Method [SPE Deepwater Drilling and Completions Conference, Galveston, TX, US, 20-21 June 2012]
- **SPE 157426**, K. Sokhanvarian, H.A. Nasr-El-Din, C.A. de Wolf, Thermal Stability of Various Chelates That Are Used In The Oilfield And Potential Damage Due To Their Decomposition Products [International Production and Operations Conference and Exhibition, Doha, Qatar, 14-16 May, 2012]
- **SPE 157467**, W. Braun, C.A. de Wolf, H.A. Nasr-El-Din, Improved Health, Safety and Environmental Profile of a New Field Proven Stimulation Fluid [SPE Russian Oil and Gas Exploration and Production Technical Conference and Exhibition, Moscow, Russia, 16-18 October 2012]
- **SPE 164480**, O.O. Adenuga, M.A. Sayed, H.A. Nasr-El-Din, Reactions of Simple Organic Acids and Chelating Agents with Dolomite, [SPE Production and Operations Symposium, Oklahoma City, OK, US, 23-26 March 2013]
- **SPE 166335**, H.B. Bakar, I.C. Xianlung, M.Z.B. M Nadzri, M.A.B. M Zaini, J.B. Jaafar, M. Hirman, H.A. Nasr-El-Din, C.A. de Wolf, Offshore Field Application of a Low Corrosive Fluid Designed for De-scaling of Well with ESP Completion [SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, 30 September-2 October 2013] **Field case**
- **SPE 168145**, C.A. de Wolf, E.R. Bang, A.J. Bouwman, W. Braun, E. De Oliveira, H.A. Nasr-El-Din, Evaluation of Environmentally Friendly Chelating Agents for Applications in the Oil and Gas Industry [SPE Formation Damage, LaFayette, LA, US, 26-28 February 2014]
- **SPE 168163**, H.A. Nasr-El-Din, H. Dana, V. Tomos, T. Stanitzek, C.A. de Wolf, A.K. Alex, Field treatment to Stimulate an oil Well in an Offshore Sandstone Reservoir Using a Novel, low Corrosive, Environmentally Friendly Fluid [SPE Formation Damage, LaFayette, LA, US, 26-28 February 2014] **Field case**

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