FORMATE MATTERS

Issue no. 7 – August/September 2011 News and opinion from Cabot Specialty Fluids www.formatebrines.com

World-record expansions improve well economics

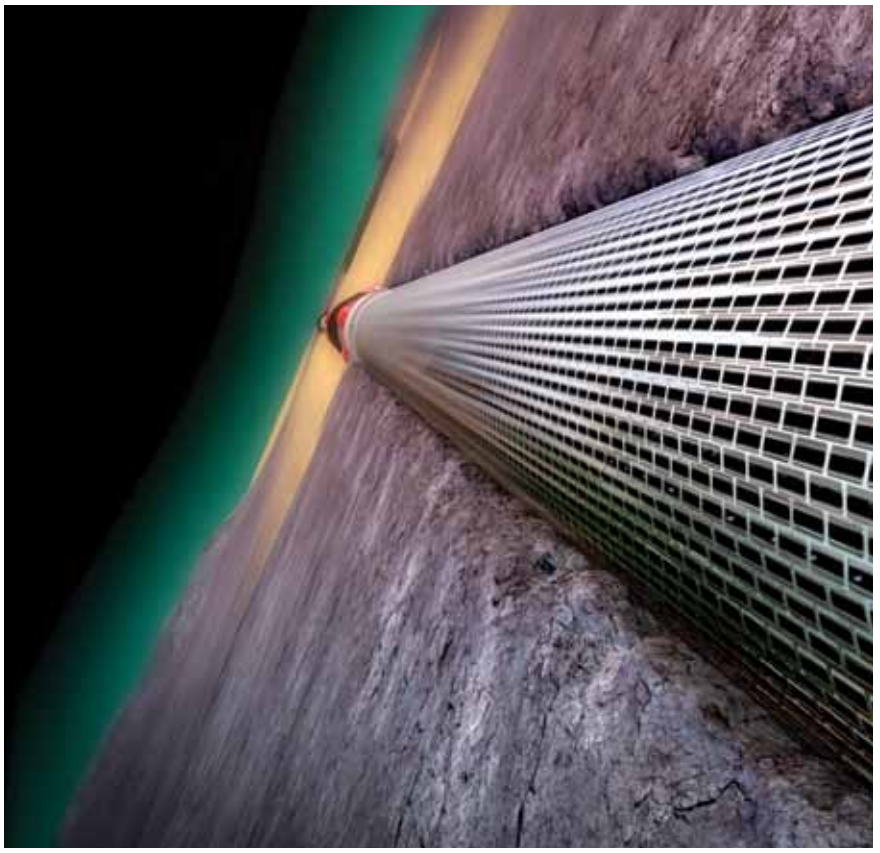

IMAGE: COURTESY OF WEATHERFORD INTERNATIONAL LTD.

Formate brines helped Saudi Aramco set the world record for the hottest and deepest ESS installation

Longest, hottest and deepest Expandable Sand Screen installations – formate brines have helped Shell and Saudi Aramco break six world records and improve well economics.

Open-hole sand-control completions offer several advantages over traditional cased-hole completions:

- They improve production – much larger flow areas afforded by open-hole completions allow wells to flow at higher rates with lower flow resistance.
- They have lower installation costs – open-hole sand-control completions are generally quicker and easier to install.

Open-hole completions with expandable sand screens (ESS) are of particular interest because expanding the screens against the sand face helps to improve sand retention, reduce plugging, eliminate annular flow and improve well productivity[1]. More than 600 wells have been completed with ESS since their commercial launch in 1999.

Low-solids reservoir drilling and completion fluids, such as formate brines, are frequently used in conjunction with sand-screen completions to avoid open-hole formation damage and minimise screen plugging. In one case, using cesium formate brine with conventional sand screens resulted in the fastest HPHT well completion ever recorded in the North Sea (12.7 days in Kvitebjørn A-6)[2].

Formate brines and ESS were both developed by the Well Technology division of Shell Research in the 1990s, and it is notable that using these two technologies together creates synergies resulting in world-record ESS installations.

Brigantine field, offshore UK North Sea[3]

Brigantine is an offshore gas field in the UK southern North Sea owned jointly by Shell and ExxonMobil. In 2000/2001, Shell set three world records deploying ESS in Brigantine wells A, B and C. Using a 1.22 g/cm^3 (8.35 lb/gal) formate brine as the reservoir drilling and completion fluid, Shell ran and expanded 4,000 ft, 7,000 ft and 2,150 ft of ESS in 6" horizontal holes. The three wells were completed 32 days ahead of plan, with an added net present value of GBP 13.5 million (around US$ 22 million at today's exchange rates). As an added economic bonus, production from the Brigantine wells was 23–40% higher than expectations.

K-field, onshore Saudi Arabia[4]

K-field is a deep gas reservoir in the Greater Ghawar area, onshore Saudi Arabia. Saudi Aramco originally drilled the K-3 well to a depth of 16,149 ft MD and completed an unsuccessful frac-pack before suspending it in October 2002. A horizontal 5-7/8" open-hole side-track was then drilled to 16,747 ft MD (15,125 ft TVD) in 2004, using a 1.43 g/cm^3 (11.93 lb/gal) formate drilling fluid. The total length of open hole was 1,556 ft and the inclination was 84.5°. At TD the well was displaced to clear 1.43 g/cm^3 formate brine and 1,410 ft of 4" ESS screens were run and then expanded against the borehole in two separate expansion runs. The screens, provided by Weatherford, were constructed of special high-nickel Incoloy 825 to resist the very corrosive (low pH, high chlorides, high CO_2), high-temperature production stream.

This project saw the first use of ESS in Saudi Arabian gas wells and set world records for the hottest and deepest installation. Aramco reported that ESS simplified completion and eliminated a number of costly frac-pack operations. This resulted in a 50% reduction (over US$ 1 million) in completion costs and allowed the well to be put on production six to nine months earlier than normal. The well flowed up to 25 MMscf/day of gas during clean-up, but had to be shut in for three years following the partial closure of a full-bore isolation valve. It was brought back onto production after a workover in 2007 and a production build-up survey confirmed a completion skin of < 1[5]. Saudi Aramco reported in 2009 that "the well continues to produce successfully at a sustained, high sand-free rate"[4].

INSIDE

References

1. *Hembling, D., et al: "A Comprehensive Study on the Effect of Compliance on Productivity", SPE 116581, September 2008.*
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3. *Weekse, A., et al: "Expandable Sand Screen: Three New World Records in the Brigantine Field," SPE 74549, February 2002.*
4. *Ginest, N., et al: "A Successful Expandable Sand Screen Case History in a Deep, Corrosive Gas Well Application", SPE 122847, May 2009.*
5. *Morgan, Q.: "Expandable Sand Screens achieve neutral skin in deep, hot and corrosive gas well after three-year shutdown", publication by Weatherford International, 2008.*

CABOT creating what matters
Specialty Fluids

Issue no. 7 – August/September 2011

TECH MANUAL UPDATE

B12 studies solubility of salts and minerals – such as galena – in formate brines

Formate Technical Manual grows again

The Formate Technical Manual is developed further with the addition of 'B12 Solubility of Minerals and Salts in Formate Brines'. This latest section studies the solubility of alkaline earth metal salts, clays, silicates, galena, hematite, ilmenite and calcium carbonate in formate brines.

Furthermore, a significant update to A5 Crystallization Temperature is also available free of charge on **formatebrines.com/manual**.

PEOPLE

David Farr

New regional manager

David Farr, 33, replaces newly-retired Malcolm Cook as regional manager for Europe and the Caspian. David has a BSc in Exploration Geology from Cardiff University and an MBA from Warwick Business School, UK. Most significantly, he has worked globally for M-I SWACO for almost ten years finishing as UK Fluids Operations Manager.

He says: "Cabot offers me the opportunity to work on high-profile HPHT projects in a smaller, dynamic company with significant growth potential."

David is married with one child and enjoys cycling, golf and football in his spare time.

The Norwegian decade

This year sees the tenth anniversary of the first use of cesium formate brine in Norway. It was Statoil that started the ball rolling by using cesium formate brine as a drilling fluid in its HPHT Huldra field.

PHOTO: STURE NEPSTAD

Gunnar Olsvik, Cabot Specialty Fluids's new Global Business Manager, at CSF's base in Norway

Ten years, and almost 200 jobs later, cesium formate remains Statoil's preferred high-density brine for enhancing value and reducing risk in challenging offshore field developments. Recently TOTAL, DONG and BP have joined Statoil in successfully deploying cesium formate brine offshore Norway.

So why do operators and service companies, such as M-I SWACO and Halliburton, use cesium formate brines time and again? *Formate Matters* put this question to Gunnar Olsvik, the new Global Business Manager at Cabot Specialty Fluids (CSF). Gunnar was previously Regional Manager Scandinavia for CSF and has been involved with cesium formate development in Norway from the early days right through to the latest applications in Statoil's Snorre, Morvin and Vega fields. "Naturally, a benign solids-free fluid with a density range of 1.57 to 2.3 g/cm^3 provides unique benefits – for instance it facilitates faster drilling and completion, protects the formation, improves well control, enables better reservoir imaging and is environmentally superior. It all adds up to improving field development economics and reducing operator risk. For example, Statoil experienced zero well control incidents in all 15 HPHT drilling operations and 20 HPHT completion operations in the Kvitebjørn, Kristin and Huldra fields over five years[1]. Another example is Visund, where oil production indices increased by up to a factor of 15 following a revised well design and perforation using cesium formate brine."

Records have been set over the past ten years. In 2003, Statoil used cesium formate to drill and test the longest HPHT well offshore Norway in Valemon. All wells in Kvitebjørn have been drilled and completed using cesium formate, including the fastest HPHT completion in the North Sea at 12.7 days[1]. In addition, Kvitebjørn saw cesium formate used in innovative managed pressure drilling and as the base for designer fluids, where the fluids are designed to contain optimum particle blends and size distributions to plug fractures and formation pores. "What's also noteworthy is the increasing application diversity," says Gunnar. "Beyond the typical HPHT drilling and completion applications we're seeing cesium formate used in low-solids OBMs, slugs and various pills. Overall, the future's looking very interesting indeed."

1. SPE 105733.

DID YOU KNOW?

Pluto's secret

The oil industry can thank Pluto for the coiled tubing used today. We're not talking about the loveable Disney character, but rather the WWII project with the acronym P.L.U.T.O.

Pipe-Lines Under The Ocean was one of the war's most secret initiatives and part of Lord Mountbatten's plans to invade France and liberate Europe. As fuel was desperately needed for the invasion force, the decision was taken to build a pipeline under the English Channel connecting storage tanks in southern England with the continent. These would relieve pressure on the overstretched tanker fleet and be relatively safe from weather and enemy action.

Two main pipeline types were employed. HAIS, short for Hartley–Anglo-Iranian (Oil)–Siemens, was a flexible three-inch lead pipeline similar to an underwater power cable without a core. The second, named HAMEL, after H.A. Hammick, chief engineer of Iraq Petroleum Company and B.J. Ellis, chief oilfield engineer of Burmah Oil Company, was a rigid steel three-inch pipe laid from huge floating steel drums known as Conundrums – similar in shape to cotton spools.

PHOTO: COURTESY OF THE NATIONAL ARCHIVES, UK

A Conundrum weighed as much as a destroyer and carried 70 miles of pipe

Pipelines were initially laid from the Isle of Wight to the Cherbourg Peninsula and later – and much more effectively – from Dungeness to Pas de Calais. In all, 21 pipelines were laid carrying an estimated 173,000,000 gallons of fuel under the Channel to further the war effort.

PHOTO: MONTY RAKUSEN/SCIENCE PHOTO LIBRARY

Laboratory testing led to the evolution of a novel fracture-sealing perforating pill

Bridging the gap

Baroid deploys a novel formate-based perforating pill to solve a major fluid-loss problem.

Baroid's completion fluid engineers were faced with a tricky fluid-loss control problem during completion operations in a complex North Sea reservoir. Two successive wells suffered major fluid losses after perforating the 7" liner with a conventional brine-based perforation pill at high overbalance.

An evaluation of local rock mechanics indicated that the most probable cause for losses was self-induced fractures following perforating, as a result of the hydraulic pressure of the completion fluid exceeding the minimum horizontal stress gradient. A customised perforation pill was required to bridge these fractures and cure the high completion-fluid losses. It was essential that the size and amount of fracture-bridging solids allowed in the pill were restricted to allow free passage of the Downhole Instrumentation and Control System (DIACS) completion package within the 7" liner.

Baroid set about designing a special perforating pill that would meet the following specifications:

- Low losses into reservoir matrix and fractures at operating overbalance and downhole temperature
- Compatibility with reservoir matrix, fluids and gases
- Low circulating pressure losses, to avoid exceeding the minimum horizontal stress gradient
- Particle concentrations less than or equal to 270kg/m^3
- Fluid stability for over 28 days under bottom-hole conditions
- Particle sizes to be small enough to allow the free passage and setting of DIACS packers

The different pill formulations were tested for matrix and fracture losses, as well as their stability. Matrix losses were optimised on porous plates resembling relevant pore throat sizes. Fracture sealing ability was checked on slotted discs with 350 to 700 µm slot openings and stability verified for time periods of up to four weeks. This revealed that the conventional perforation pill, containing 120kg/m^3 of calcium carbonate, was unable to bridge simulated fractures on the slotted discs.

The testing led to the evolution of a special high-solids 'designer fluid' perforation pill based on potassium formate or potassium/cesium formate brines. The matrix and fracture-sealing components included specifically-sized calcium carbonate and resilient graphitic particles at the maximum allowable concentrations.

The customised perforation pill was successfully deployed in two wells. No fluid losses were observed after perforation in either of the completion operations, confirming that if any fractures had opened, the pill immediately sealed them. As a further validation of fluid design, the lower completion assembly was run through the perforation pill without any problem.

In conclusion, the development and deployment of this novel formate-based perforating pill enabled the operator to complete two challenging wells and start production.

MEET US AT THESE EVENTS

28–29 September	World Oil HPHT Drilling & Completions Conference, Houston, USA
24–26 October	SPE/IADC Middle East Drilling Technology Conference and Exhibition, Muscat, Oman
15–17 November	2011 International Petroleum Technology Conference, Bangkok, Thailand

Salmuerasdeformiato.com

Formatebrines.com is now fully translated into Spanish

A Spanish-language version of Formatebrines.com is accessible at **salmuerasdeformiato.com**. It contains all the information of the English-language site, including a significant number of translated Formate Technical Manual section downloads, in Spanish.

TECHNICAL FORUM

Getting heavier with cesium brines

A cesium formate/cesium acetate blend increases brine density to 2.42 g/cm^3 (20.2 lb/gal)

New research by Cabot Specialty Fluids (CSF) shows that the density ceiling of cesium formate brine can be raised significantly when blended with cesium acetate brine.

Cesium formate and acetate brines are both monovalent cesium salts of organic carboxylic acids. Cesium acetate is slightly more soluble in water than cesium formate and can easily reach densities over 2.30g/cm^3 (19.2lb/gal) without compromising TCT (true crystallisation temperature). The trade-off for this higher density ceiling is higher viscosity – cesium acetate has a viscosity many times that of cesium formate.

The real benefit of acetate brine becomes evident when it is blended with cesium formate. A blend of these two fluids yields cesium brine with a density of 2.30g/cm^3 and TCT as low as -35°C/-31°F. This cannot be achieved using either of the two brines alone. By changing the blending ratio and removing water, a whole range of brines with various densities, viscosities and TCTs can be created. For example, CSF has created blended cesium formate/acetate brine with a density of 2.42g/cm^3 (20.2lb/gal) and TCT of -1°C/30°F. More work is underway to push the density ceiling of this high-performance cesium brine system even further.

But it doesn't stop there. Cesium phosphate brine (blend of cesium dihydrogen phosphate and dicesium hydrogen phosphate) with a density of about 2.7g/cm^3 (22.5lb/gal) has been investigated as an internal phase in oil-based muds. Cesium phosphate brines are not best suited for use as water-based drilling or completion fluids because they are corrosive and distinctly incompatible with reservoir components. However, they could be used as a heavy internal brine phase emulsified in low-solids oil- or synthetic-based fluids. Cesium formate has been used in these types of heavy low-solids oil-based fluids since 2001 with great success. The additional density obtained by replacing heavy formate brine with the even heavier cesium phosphate brine could significantly raise the density ceiling of these novel fluid systems.

Can you sea?

Offshore drilling is an integral part of today's oil and gas industry. Many of the world's seas have been explored, but do you know which ones? Hidden in the grid to the right are ten of them. They can be printed forwards, backwards, up, down, or diagonally. If you're able to identify the ten seas (the first is given) then you'll have a chance to donate US$ 250 to your favourite charity. The first three entrants drawn at random with correct answers can instruct Cabot Specialty Fluids to donate the money to the registered charity of their choice. Furthermore, for every correct answer received, Cabot will donate US$ 10 up to a total of US$ 3,000 to Care International to help fulfill its mission to create lasting change in poor communities. (Rules apply.)

R	G	I	O	W	U	D	E	R
X	C	R	S	R	O	H	O	S
A	E	I	D	O	R	D	P	T
F	L	S	T	D	O	Y	**V**	N
L	T	H	U	A	M	F	**O**	E
O	I	B	B	R	I	R	**Z**	R
R	C	A	L	B	T	R	**A**	A
E	L	D	E	A	T	P	D	B
S	U	L	U	L	N	E	C	A

Please send your entry, together with the registered charity and its location, to formatematters@cabot-corp.com or fax (44) 1224 870089 by 14 October 2011. Your full name and organisation must be included. In relation to the previous issue's Wordsmith competition, we never knew how many words could be made from 'cs formate'. The highest number of correct words – 176 – was found by Vasily Golubev of Schlumberger Moscow Research Center. Well done Vasily! For the previous word list, or for the complete rules for this puzzle, please email formatematters@cabot-corp.com.

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AND FINALLY...

"Opportunity is missed by most people because it is dressed in overalls and looks like work."

Thomas Alva Edison 1847–1931 *(American inventor who, singularly or jointly, held a world record 1,093 patents and created the world's first industrial research laboratory.)*

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