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Ceramic screens prevent proppant flowback

Offshore Europe show preview

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SPECIAL FOCUS: SAND CONTROL

Ceramic screens control proppant flowback in fracture-stimulated offshore wells

Deployed in the Danish North Sea, the screens employ a ceramic construction and loose-fitting design that enable them to withstand erosion more effectively than wire screens.

HANS-HENRIK KOGSBØLL and SABINE WAGNER, Maersk Oil

Several wells in Maersk Oil-operated Tyra field, in the Danish North Sea, had to be shut in due to sand production several times, until the installation of a modified ceramic sand screen facilitated sand-free production.

Maersk Oil operates a large portion of Danish oil and gas fields, producing some 300,000 boepd. The reservoirs are mainly tight Cretaceous carbonates with low permeability, which means many wells must be stimulated with propped hydraulic fracture treatments to produce economically. To address wells that required additional stimulation, the operator implemented controlled acid jetting liner and perforate-stimulate-isolate (PSI) completions. The latter completion method is generally used along with frac treatment, and benefits reservoirs with permeabilities ranging 0.5–2.5 mD.

One major challenge in these wells has been proppant flowback, which leads to numerous downhole and production problems. Over the years, the operator has tried a number of conventional sand control methods, which have either failed or been too costly to use regularly. To this day, some wells are shut in while waiting for expensive and risky workovers or conformance treatments. Faced with these challenges, the company investigated other options for proppant control.

Joining forces with German ceramics manufacturer ESK, Maersk Oil developed and patented a new sand control device, called PetroCeram. The device looks like a wire-wrapped screen, but uses ceramic rings instead of wire, fitted to the tubing so as to keep sand and proppants out and let oil in. The uniqueness comes from the use of ceramic and from its loose fitting, which enables it to withstand erosional forces more effectively.

The ceramic sand screens were originally implemented to prevent proppant flowback in new completions. Since 2010, Maersk Oil has implemented the screens in the completion of two multistage-fractured horizontal oil wells in the Danish North Sea, and has adapted the design for use as a remedial installation in a deviated gas producing well suffering from excessive proppant production.

BACKGROUND

Maersk Oil began performing massive propped hydraulic fractures (200–2,000 klb of proppant) in the late 1970s during the initial development of Dan field using deviated wells. Stimulation was required due to the formation's low permeability and formation damage incurred while drilling. During the subsequent development in the late 1980s, horizontal wells were drilled and stimulated with multistage acid fracture treatments. However, performance was poorer than expected. Ultimately, some horizontal wells were completed with multistage acid fracture treatments and others with multistage propped frac treatments. Subsequently, the propped hydraulic fracture treatments have been implemented at Gorm, Valdemar and Tyra fields, Fig. 1. To date, more than 670 massive propped hydraulic fracture treatments have been pumped in wells in the Danish North Sea.

Several completion systems were investigated for the fracture stimulation of these horizontal wells. Ultimately, the operator selected the PSI system, which proved to function well for massive propped hydraulic fracture, acid fracture and acid matrix stimulation, while providing the possibility of zonal isolation during the lifetime of the well. The propped frac treatments were designed to achieve tip screen-out to maximize fracture conductivity over the lifetime of the well, since re-fracturing using proppant would not be cost-effective with the PSI completion system.

Typically, a packed fracture results in a fracture width at the wellbore of more than 1 in., making proppant flowback likely to occur. Initially, several different types of resin-coated proppant (RCP) were used to prevent proppant flowback, but none were completely successful.

In Fig. 2, the PSI completion system is shown for three zones, each equipped with a sliding side door and an isolation packer. This system is repeatable; to date, up to 22 packers and sliding sleeves have been installed in one well. The total length of this completion is defined by the reach of coiled tubing, which is needed to operate the sliding sleeves.

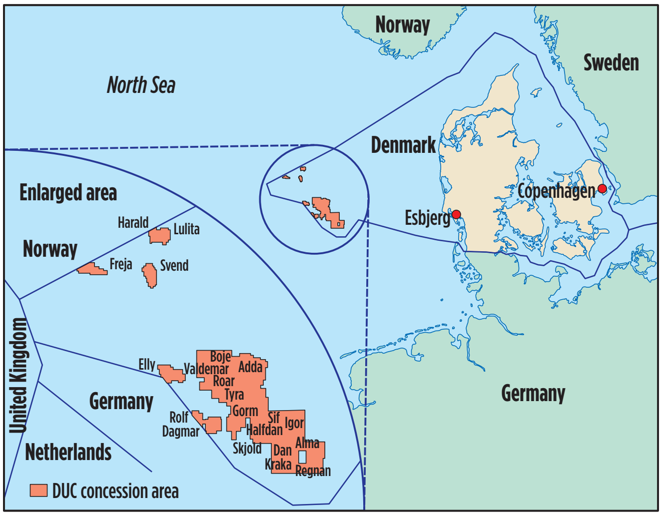
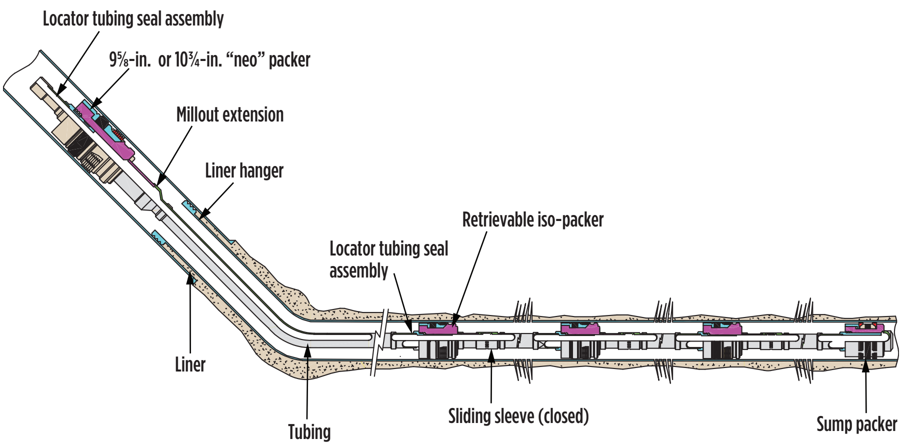


Fig. 1. Concession areas in the Danish North Sea licensed to the Dansk Undergrunds Consortium, a joint venture of Maersk Oil (operator, 39%), Shell (46%) and Chevron (15%).

Fig. 2. Schematic of the perforate-stimulate-isolate (PSI) completion system.



While pumping the propped hydraulic fracture treatment through a service string, the completion for this section is protected from internal sand erosion by means of a short flow tube, to be retrieved with the packer running tool after the job. Excess proppant after the fracture treatment is reverse-circulated out of the liner, but some proppant is left behind in the completion-liner annulus. After a well has been successfully completed, a coiled-tubing cleanup is undertaken and proppant left in the annulus may be produced, depending on the well flowrate. This can be costly, since new wells have to produce nearly proppant free before they can be put on permanent production.

Sand was chosen as the fracturing material in these treatments. The strength of this material has proven sufficient to withstand the closure stress of the formation, and, due to the high amount of proppant needed, it is the most cost-effective choice. High proppant loading designs (5–10 lb/sq ft) are used to combat embedment, plugging by fines migration and damage from frac fluid. Since the late 1980s, all propped frac treatments have been designed to receive an RCP tail-in. This procedure was adopted to prevent proppant flowback. This proved successful compared with some early treatments where no RCP was used and proppant production issues occurred.

Tailing in with RCP has since become a standard procedure. Although, to date, most of the zones treated with resin-coated tail-in are still effective, the lifetime of the resin-sand bond is limited and, eventually, sand will be produced. Another issue is that some propped fracture treatments end prematurely due to the response of the formation and, therefore, are left without RCP in the formation.

The use of ceramic sand screens avoids flowback of the remaining proppant, which is kept in the annulus between the perforations and the completion. This design eventually removes the need for RCP tail-in and thereby reduces cost, while also cutting the time used to clean up a well. With the ceramic sand screen installed, proppant flowback from prematurely terminated frac treatments will not be a concern, since the proppant is kept downhole.

CERAMIC SAND SCREEN DESIGN

The design of the ceramic sand screen consists of three construction elements: a stack of ceramic rings, two clamping ele-

Fig. 3. Ceramic sand screen mounted on a 3½-in. sliding side door during assembly.

ments and a fixing device to mount the assembly to a tubular support. For the ceramic rings, sintered silicon carbide (SSiC) was chosen because of its hardness—50 times that of steel. The SSiC ring geometry (ID, OD and gap width/shape) can be adapted to nearly any prevailing wellbore geometry or well conditions. The bottom faces of the rings are spherically dished, providing keystone gaps that are narrower on the outside surface of the ring. This design allows high laminar flowrates and prevents plugging of the gap by fines, since any particle passing through the gap at the outer diameter will continue to flow through rather than lodging within the gap. The upper face of the rings has a series of equally spread bumps that are used to adjust the gap width of the ceramic stack. The gap width can be chosen according to the frac sand or any other grain size distribution. Ideally, the ceramic rings are manufactured with three bumps shaped as spherical segments, ensuring only point contacts between the stacked rings. The spherically dished ring shape is well suited to ceramics, providing flexibility to the stack and stability against torsion and flexure.

The stack of ceramic rings is placed between the upper and lower clamping elements and mounted on the tubular support (e.g., a sliding sleeve or a perforated base pipe). Clamping features on both sides of the stack mechanically constrain the ceramic rings. The load is transferred to the stack via a number of coil spring elements and the clamping elements. The flexibility of the spring elements enables the dissipation of any mechanical stress that could be imposed by torsion, bending or shock as well as temperature-induced stresses between metal and ceramics. This type of clamping mechanism prevents any accidental damage of the basic sleeve and provides excellent damage tolerance to the ceramic assembly. In addition, the outer part of the assembly can be surrounded by a metallic shroud to protect the ceramic screens during installation.

The ceramic screen can be mounted on any type of tubular flow-through device with flexible lengths. For longer ceramic sand screens, a modular setup is preferred where hardmetal-coated metal intersections align the individual ceramic screen section.

IMPLEMENTATION IN TWO HORIZONTAL OIL WELLS

Valdemar field consists primarily of a northern reservoir called North Jens, put onstream in 1993, and a southern reservoir called Bo, onstream since 2007. Both are anticlinal chalk structures associated with tectonic uplift. In addition, the field includes several separate accumulations. Oil and gas have been discovered in Danian chalk, and large volumes of oil have been identified in Lower Cretaceous chalk. The extremely low-permeability layers in the Lower Cretaceous chalk possess challenging production properties in most parts of the field.

The ceramic sand screens were originally designed for the PSI completion system, and were installed to avoid proppant production through the commercially available 3½-in. sliding sleeve. With a length of 3 ft, a maximum OD of 5.63 in. and a slot opening of 250 μm, the screens were mounted around the sleeve, **Fig. 3.** Before deploying the ceramic screens, it was decided to have standard, unprotected sliding sleeves as a backup in every zone in case the ceramic-screened sleeves became plugged by formation fines. The ceramic-screened sleeves were placed opposite the perforations to reduce the pressure drop along the annular gravel-pack, and backup sleeves were installed as well, **Fig. 4.** A minimum distance of 30 ft was needed so that the sleeves could later be distinguished from each other, so that they could be operated using coiled tubing. A maximum spacing of 40 ft was necessary to allow an internal flow tube to protect the ceramic-screened sleeves from sand erosion during stimulation.

The chosen oil producing well, Well A, is located in the Lower Cretaceous chalk in Valdemar field, which has poor reservoir qualities due to the presence of high argillaceous content. The matrix permeability varies from 0.01 mD to 0.4 mD, with porosities ranging 20%–35%. The shale and clay content varies over the different reservoir units from 4% to 70% and is present in extensive layers (the thickest one being about 2–3 ft on average) that act as barriers and limit the contact of the well to the different reservoir units.

Well A was planned to be stimulated with nine sand fractures. Zones 1 and 2 were designed for 500 klb of sand, Zones 3–6 for 750 klb of sand and Zones 7–9 for 1,000 klb of sand. The ceramic sand screens were installed as a contingency. Due to problems with the internal flow tube, it was not possible to protect the ceramic sand screen and the full-flow sliding sleeve at the same time. The ceramic sand screens were only deployed in Zone 1 and Zone 3.

During the completion of Zone 1, the isolation packer could not be set properly. The completion assembly had to be retrieved, which offered a unique opportunity to inspect the ceramic-screened sleeve. It had been exposed to running-in/running-out of about 36,000 ft of hole. There was no damage to the ceramic rings or the clamping features—only expected wear and tear on the protective shroud.

In Zone 3, a proppant screen-out occurred during stimulation before RCP could be placed in the fracture. A subsequent frac-pack was unsuccessful, and the zone was left with only non-coated proppant in the fracture. It was decided to install the ceramic screen in this zone to avoid later proppant flowback.

Initial production was as expected with respect to production rate and watercut. Despite the absence of RCP in Zone 3, which would usually have led to a large amount of sand flowing back, very little sand flowback was reported during cleanup. After 13 months, there was no deterioration of production performance, with only a negligible amount of sand observed at the surface.

Unfortunately, the individual zones could not be tested separately, and no production logging was performed. However, from the small quantity of sand ob-

Fig. 4. Valdemar field application: a) setting of sleeves; b) completion design of Well A, with nine fracture stages.

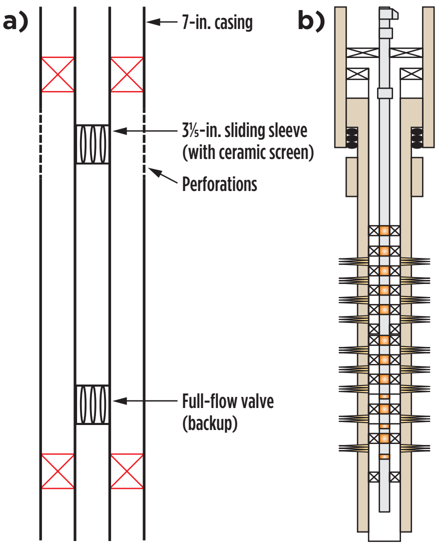
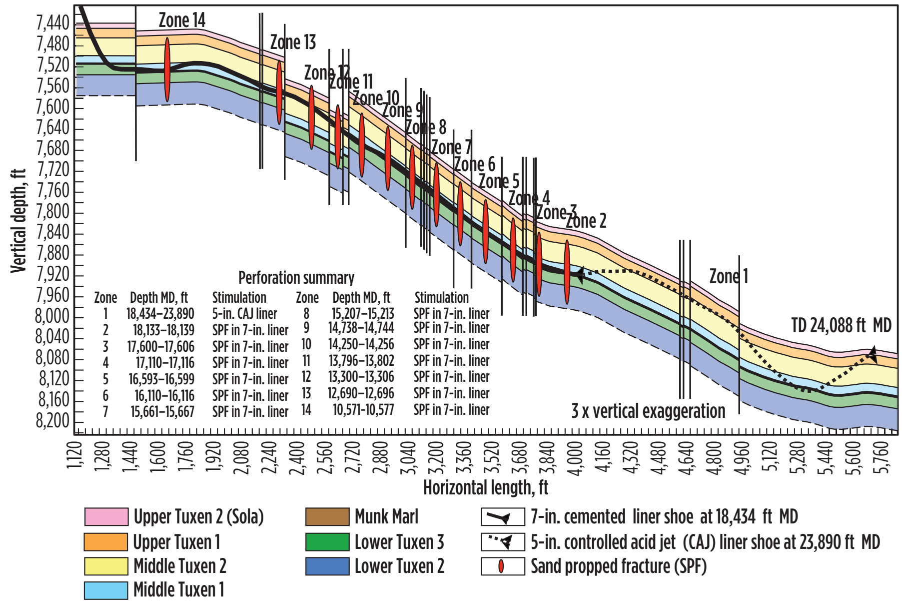


Fig. 5. Well trajectory for Well B, including position of propped frac treatments.



served at the surface, it may be concluded that the ceramic screen concept worked as expected.

At the time of this writing, Well B is being completed. In this producing well, 13 zones were run, all of which could be completed with sliding sleeves protected by ceramic screens and additional backup full-flow sleeves, Fig. 5. Based on the lessons learned from Well A, slight modifications were made to the isolation packers. Together with improved procedures for tripping in and setting the packer, these modifications allowed for the deployment of the ceramic screens in all propped fractured zones.

As Well B is an appraisal well, a dedicated testing program including production logging and well flow testing is planned. This will evaluate the performance of the ceramic-screened sleeves.

REMEDIAL COMPLETION WITH ADAPTED CERAMIC SCREEN

Tyra field is an anticlinal structure created by tectonic uplift. The accumulation consists of free gas containing condensate overlying a thin oil zone. The reservoir is only slightly fractured. The field was placed on production with 36 deviated wells in October 1984, and subsequent development phases have added 34, mostly horizontal, wells from the Tyra Main complex. The Tyra Southeast satellite platform was added in 2001.

The Tyra structure is a broad, low-relief domal anticline, and the Tyra Southeast area is a low-relief ridge extending some 11 km from the eastern flank of the field. The reservoir rocks are high-porosity Ekofisk and Tor chalks. The Ekofisk reservoir contains a gas accumulation that is continuous over the entire Tyra area to the Tyra Southeast fault zone. The gas extends into the Tor reservoir in two separate areas: A large volume is within the Tyra Main complex, while a smaller accumulation is present in Tyra Southeast. The Tor gas is underlain by an oil rim, which extends over the whole Tyra area.

Well C is a deviated gas production well in Tyra field. The well was drilled and completed in 1983, perforated over a 16-ft interval, and acid fracture stimulated with proppant, which involved some 600 bbl of acid followed by about 10 klb of 10/20-mesh sand at a maximum sand concentration of 3 lb/gal.

In 1991, a re-stimulation was performed but, when the well was returned to production, it produced sand. In 1993, an attempt to stop proppant production had little success, and the well was converted to gas injection in 1997. In 2007, the well was converted back to production, but several subsequent attempts to return the well to production failed. In 2009, the well was permanently shut in.

That year, a group of engineers from different departments was gathered to line out options to return the well to production. Three options were considered: chemical consolidation, frac-pack and installation of a downhole screen.

A chemical consolidation treatment using a resin system under development was initially preferred, but due to the operational complexity it was deemed too risky. A frac-pack was rejected due to the requirement for coiled tubing to clean out the tubing to the top of the perforations and to either spot a chemical consolidation treatment or perform a frac-pack. The intervention program was considered too risky relative to the potential gain.

Running a commercially available wire-wrapped screen was initially rejected due to the risk of plugging and erosion. The risk of the tool becoming stuck due to solids packing around it, thereby preventing any further attempts to regain production, was also deemed high.

It was then decided to adapt the original design of the ceramic sand screen—as a protective accessory mounted on a sliding sleeve—for placement in the tail pipe of the existing 4½-in. tubing. The ceramic screen was designed to accommodate 3–6 MMcfd of production. It was assembled in a modular design with a total length of 16 ft and a maximum OD of 2⅞ in., including the protective shroud. The slot opening, based on the grain size distribution evaluated prior to the design work, was set at 320 µm. The ceramic sand screen was set on wireline in the existing landing nipple below the production packer and locked in place, Fig. 6.

After being put on production, the well produced sand free with a lowered flowing tubing-head pressure (FTHP) of

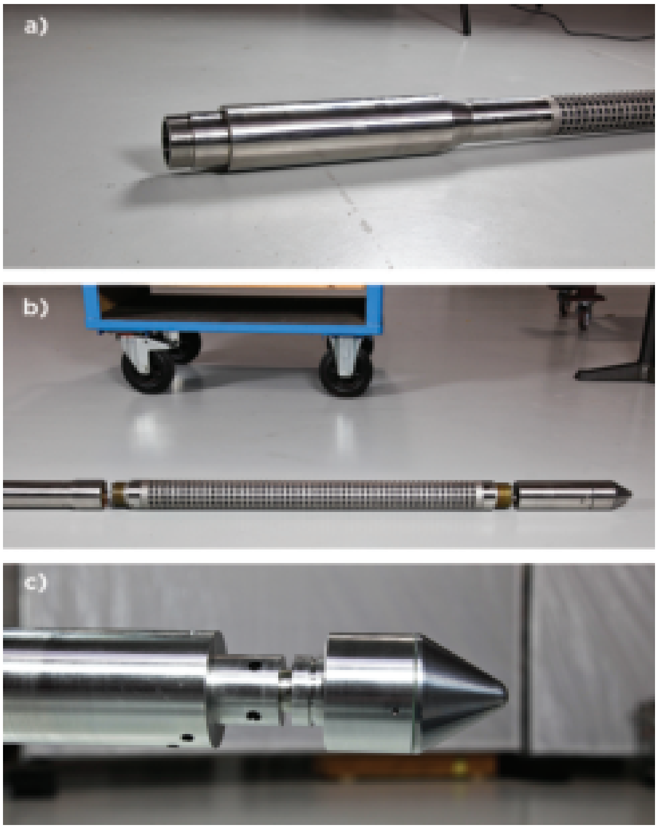


Fig. 6. Ceramic sand screen details: a) crossover to landing nipple, b) modular setup and c) pressure-equalizing plug.

850 psi. Before the permanent shut-in, the well was producing at an FTHP of 1,250 psi in order to limit sand production. Since installation of the screen, the FTHP has been further lowered to 650 psi.

The cost for this operation, including a caliper survey prior to the job and flow tests through solids-handling equipment during startup, was well below conventional sand control conformance treatments, making it an economically attractive alternative. Currently, Maersk Oil is considering equipping three more wells in Tyra field with ceramic sand screens similar to that used in Well C. WO

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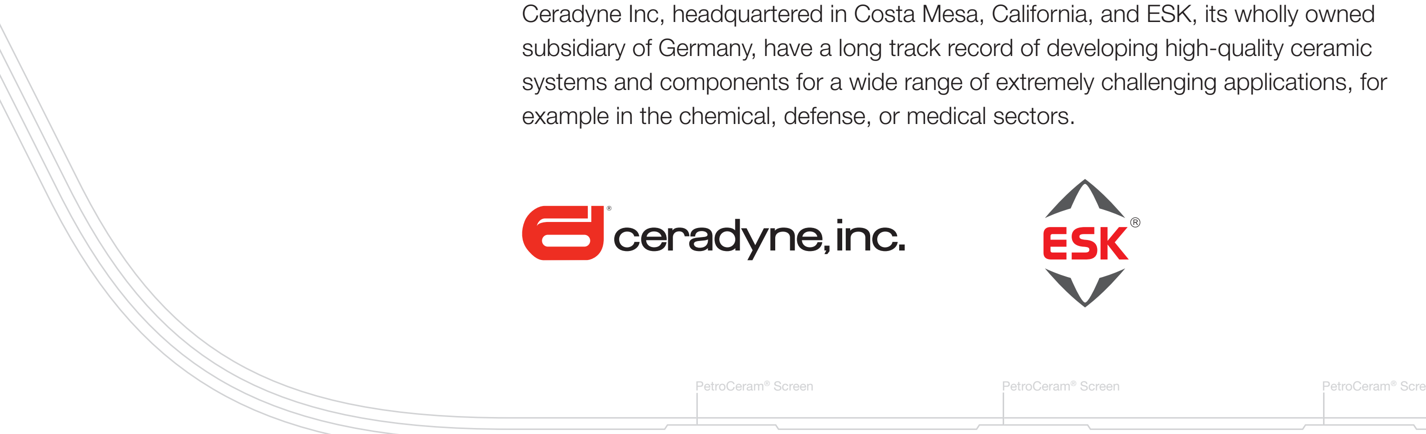
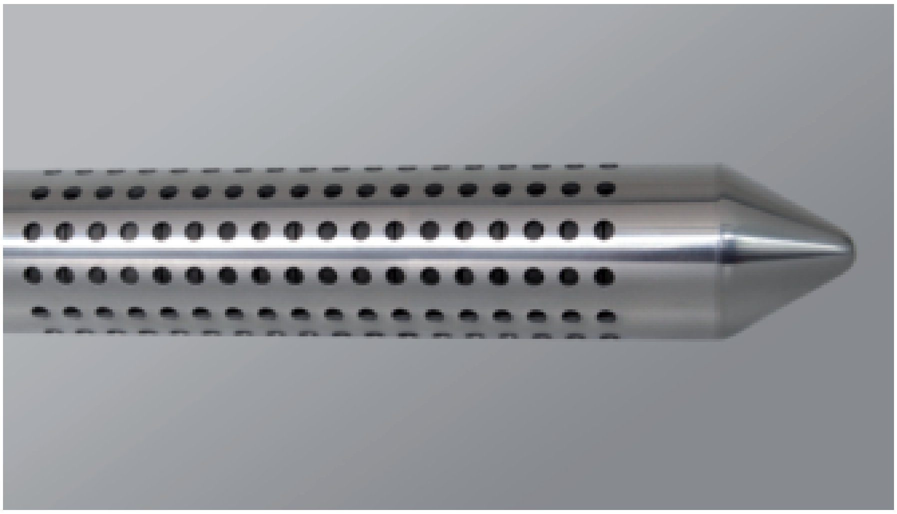


PetroCeram® CERAMIC SAND SCREENS

Working beyond the limits of state-of-the-art metallic sand screens. Designed for unconsolidated reservoirs with the risk of significant sand production.



The new PetroCeram® Sand Screen offers a breakthrough sand control technology especially under demanding conditions where abrasion is a major challenge.

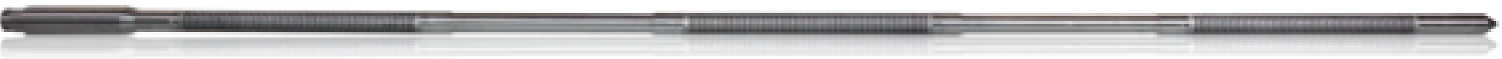
State-of-the-art sand screen systems generally consist of metals that are not abrasion resistant. Since the degree of abrasion is determined by material properties, PetroCeram® Sand Screens use ceramic materials, which are one order of magnitude harder than metallic materials and show no indications of abrasion under reservoir conditions.

The screens can be deployed for regular sand-control in new wells or retrofitted to existing wells that suffer from sand problems as a result of reduced reservoir pressure. They can be set in most standard well completions and offer the opportunity to produce reserves that would otherwise have been lost.

Solution

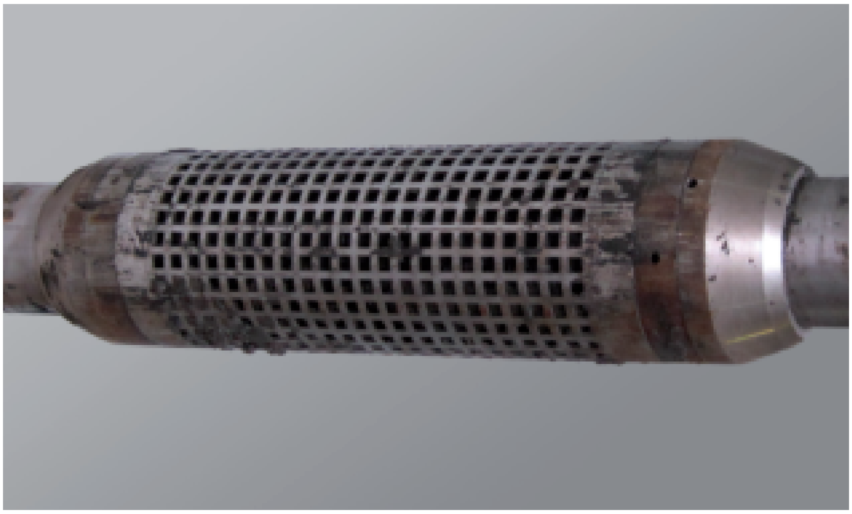
PetroCeram® technology improves the known wire wrap screen principle by taking advantage of the unique properties of technical ceramics.

- Flexible stack of ceramic rings
- Specially designed with v-shape or keystone gaps
- Gap width, length and diameter tailored to the specific application / well bore
- Alternatively as self-supported systems or provided with an internal perforated tube
- Protection of valves and sliding sleeves is also an option



One of the few issues with ceramics is its limited toughness. However, with more than 85 years of experience in ceramic materials, this drawback has been overcome. The company's design and engineering competence facilitates the tailoring of ceramic systems for challenging applications.

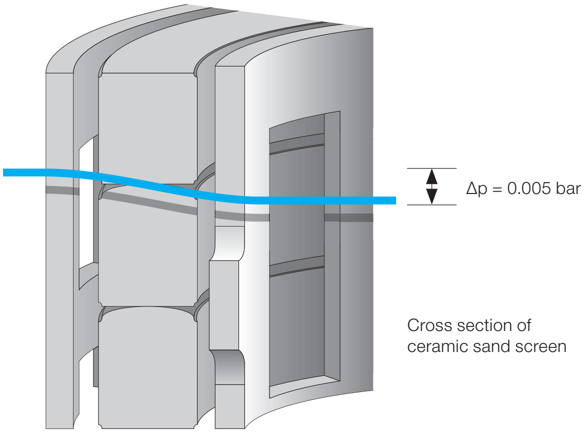
The PetroCeram® Sand Screen design is well suited to ceramics and gives flexibility to the stack of ceramic rings while providing stability against torsion and flexure. As a consequence, the PetroCeram® Sand Screen savely passes dog legs and can even be retrieved without harming the ceramic rings.



Benefit

- No abrasion
  (20 times higher hardness than metal)
- Higher collapse resistance
  (twice the stiffness than metal)
- For horizontal, slanted and vertical wells
- Retrofitting with the system on existing commercial landing nipples

Minimizing pressure losses is a major issue during oil and gas production. To meet this important goal, extensive modeling on ring and gap design as well as a set of flow tests has been performed. The comparison of theory and practice is fully congruent:
The pressure loss over the PetroCeram® Sand Screen stays very low for a broad range of flow rates up to 2,500 stb/d.



Cross section of ceramic sand screen

DOWNLOADS

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