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Openhole Gravel Packing With Zonal Isolation

M.D. Barry, SPE, M.T. Hecker, SPE, D.C. Haeberle, SPE, and J. Blacklock, SPE, ExxonMobil Development Company, and C.S. Yeh, SPE, ExxonMobil Upstream Research Company

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Abstract

Many current deepwater and high rate wells are being completed in an openhole environment as openhole completions provide the greatest opportunity to maximize reservoir flow potential. Current technology, however, lacks the subsurface control necessary to effectively manage the reservoir in situations where sand control is required. ExxonMobil is pioneering technologies to model well performance more accurately and to provide subsurface control during completion and production operations. The first hardware developments within this initiative build on the success of Alternate Path® and NAFPac℠ gravel packing technologies and address water or gas breakthrough in openhole, multi-zone gravel pack completions. ExxonMobil affiliates collaborated with third party suppliers to design and qualify new hardware to facilitate zonal isolation, extend gravel pack reach, and simplify rig site operations. This process included engineering design, component testing, and full-scale prototype evaluation. First application of this technology is targeted for early 2008.

This paper discusses newly developed sand control screen hardware that is enabling technology to perform openhole gravel packs with true zonal isolation. The equipment provides the ability to seal off bottom water, selectively complete or gravel pack targeted intervals, perform a stacked openhole completion, or isolate a gas/water-bearing sand following production. Application of the technology is expected to extend well life and ultimately increase volumes and reserves capture.

Background

Continued economic success in remote or deepwater environments requires delivery of high rate, high capacity, and long-life wells. In these developments, it is often necessary to drill and complete high angle wells, penetrating multiple pay intervals and incorporate sand control technologies. Reservoir conditions, wellbore geometry, and production performance expectations can all introduce significant cost and complexity that frequently limit application of traditional cased hole sand control techniques. Openhole gravel pack completions are now commonly installed to connect multiple payzones over long intervals and improve well productivity.

Because openhole completions have no perforation tunnels, formation fluids can converge on the wellbore radially from 360 degrees, thus eliminating the additional pressure drop associated with converging flow and then linear flow through gravel filled perforation tunnels. The reduced pressure drop, associated with an openhole sand control completion, virtually guarantees that it will be more productive than an unstimulated, cased hole gravel pack in the same formation. Operationally, openhole techniques eliminate the need for costly cementing, perforating, and clean-up operations, the complexity of stacked completions, and in some areas an additional casing string or liner. The downside, however, is that openhole completions do not have the same level of installation flexibility and subsurface control to manage geologic and reservoir uncertainty versus traditional cased hole gravel pack techniques. Operators are particularly challenged in their ability to manage fluid inflow along the wellbore in openhole completions, including avoidance of watered-out or depleted zones during installation and shutting off unwanted water and gas during production.

Stand Alone Screens

Recent advances have introduced a number of effective hardware options for use in openhole stand alone screen (or screen-only) applications. Openhole zonal isolation packers and inflow control devices (i.e., downhole chokes) can be installed to regain some of the subsurface control lost in openhole completions. In the Chayvo development off the coast of Sakhalin Island, a combination of these relatively new technologies is being utilized to: (1) maintain a desired production profile, (2) mitigate the potential for sand production, and (3) maintain zonal isolation between various reservoir facies. In this development, screens are run across weak intervals to minimize the potential for sand production. Inflow control devices are added in high permeability intervals to delay the breakthrough of gas and/or water and enhance production from the lower permeability intervals. Pre-drilled liner is run across competent intervals that exhibit a low probability of sand production, and swellable packers are run

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to isolate the various zones. This completion design meets all completion objectives, resulted in significant cost savings (~50 percent), and improved operational performance versus the original cased and perforated field completion design.[1]

Openhole stand alone screen applications are best suited for high-angle completions in reservoirs with high permeability and well-sorted sands. The use of stand alone screens under other conditions, however, can result in screen plugging, poor productivity, or even sand control failure. If poorly sorted and unconsolidated formations are encountered, gravel packing is often deemed necessary.

Circulating Water Packs

Operators and service companies are beginning to report application of subsurface control technologies, similar to those used in standalone screens, in high-angle circulating water packs (alpha-beta).[2,3] Alpha-beta gravel packing is used in wellbores with inclinations greater than ~60 degrees and relies on an alpha wave, controlled by fluid velocity, to deposit a gravel bed or dune on the low side of the wellbore. Fluid returns are essential for successful placement of gravel using this technique. Once the alpha wave reaches the toe of the well, a beta wave forms, packing the remaining wellbore from the toe of the well back towards the heel as fluid leaks off into the screen. Wellbore sections are left unpacked or "jumped," if fluid leakoff is not available. It is therefore possible to intentionally form a partial void in the gravel pack, creating the space necessary to set an openhole zonal isolation packer after gravel packing.[2] Packers add subsurface control to openhole completions by providing near-term and long-term isolation capabilities. A limitation with this circulating water pack technique is the difficulty eliminating the alpha wave from forming adjacent to the packer, leaving a high permeability gravel channel susceptible to gas or water bypass behind the packer element. Similar problems exist in low angle circulating water packs where gravity settling will result in gravel filling the void space adjacent to the packer. This would render zonal isolation ineffective as undesirable water or gas fluids can easily pass through the high permeability gravel.

Alternate Path Gravel Packing

Alternate Path gravel packing is an open or cased hole method applied at all well inclinations that minimizes the risk of an incomplete pack. This technique uses shunt tubes, a secondary packing system, to completely fill voids after the initial screen out. Two types of shunt tubes comprise this system, transport and packing, and attach externally to standard screen hardware. Transport tubes form a continuous conduit along the entire length of the completion and deliver fluid to packing tubes that branch off at the top of each screen joint. Packing tubes contain nozzles spaced approximately every 6 ft to deliver gravel slurry to the annulus. Typical systems use a "two-by-two" design, with two transport tubes and two packing tubes on each joint. The rectangular-shaped tubes and an eccentric cross-sectional screen design shown in **Fig. 1** minimize the effective outside diameter of the assembly. In openhole applications, an outer shroud covers the entire assembly, providing shunt tube protection during installation.

An Alternate Path gravel pack is pumped using viscous slurry designed to transport gravel to the bottom of the well. Packing occurs from the toe of the well back towards the heel as fluid leaks off into the screen by base pipe annulus. A sand bridge may form in the annulus if fluid leakoff to formation fractures or high permeability sands becomes excessive. Packing continues until gravel covers the top of the gravel pack screens and an initial screen out occurs. With conventional techniques, gravel packing terminates upon screen out, leaving voids beneath the premature sand bridge. With Alternate Path technology, packing continues as slurry diverts into the transport shunt tubes and distributes to the unpacked or under-packed intervals through the packing tubes. After all intervals have been completely packed, pressure increases sharply again, signaling full screen out and a complete pack.[4,5,6] In practice, an entire interval can be successfully packed through the shunt tube system. A 100-percent success rate using NAFPac, a variation of the Alternate Path gravel packing technique used when drilling with nonaqueous fluid, has been reported for Angola Block 15 in the completion of long, openhole gravel packs.[7]

Although routinely deployed and extremely successful, Alternate Path screens currently available for openhole applications have a number of inherent technical and operational limitations. These limitations include:

- Packable length of ~3,200 ft dictated by the pressure capacity and frictional pressure drop associated with the shunt system
- Challenges associated with incorporating openhole zonal isolation packers into the screen assembly due to the eccentric screen design
- Complexity of connection make-up (oriented connections and cross-coupling jumper tubes are required)
- Deployment exposure (outer shroud is required in openhole applications to protect the shunt tubes)

Many environments utilizing Alternate Path openhole gravel packs can benefit from improved subsurface control. While a zonal isolation packer (non-expandable, cup type with shunt bypass) has been designed for cased hole Alternate Path gravel packing applications, effective tools for openhole applications are not available.[8,9] The eccentric design of the "two-by-two" Alternate Path system limits the ability to incorporate a concentric openhole packer that can be set prior to gravel packing, seal openhole geometries, and provide necessary pressure integrity.

New Alternate Path Screen Design

Continuous expansion and integration of Alternate Path technology with other evolving completion technologies is needed to accommodate the more challenging openhole completion environments of the future.

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Internal Shunt Alternate Path technology is a new, enhanced design that has been developed and qualified to mitigate existing limitations and broadly expand the capabilities of current Alternate Path technology.

- The mechanical and hydraulic design of both the screen and the shunt tube system facilitates openhole gravel packing in wells with openhole intervals up to 5,000 ft in length.
- The product is concentric in design which provides the opportunity to incorporate specially designed external isolation shunt packers set prior to gravel packing to provide true zonal isolation while still achieving a complete gravel pack in an openhole completion.
- Unique connections between screen joints facilitate rapid and effective field make-up eliminating the need for both oriented connections and cross-coupling jumper tubes.
- Robust mechanical design eliminates the need for an outer protective shroud.

In order to create an operable shunt system, a number of challenges were identified and resolved:

- Sufficient flow capability, pressure integrity, and erosion resistance of the internal shunt system
- Exit nozzles at appropriate spacing along the length of the screen
- Flow manifold to divert fluid between packing tubes and transport tubes
- Design that enables simple handling and rig floor make-up

Sand Control

Internal Shunt Alternate Path screen incorporates direct wrap sand screen technology where the wrap wire is applied directly on the basepipe.[10] Direct wrap techniques were modified to produce sand control screens with high (20+ mm) axial ribs on 5-1/2-in base pipe to create sufficient offset to facilitate installation of round shunt tubes under the wire wrap (i.e., "internal shunt") shown in **Fig. 2**. This technique results in a mechanically robust, concentric screen that eliminates the need for an outer protective shroud and facilitates interface with openhole packers. The 7.76-in OD of the internal shunt screen is comparable to the 7.65-in OD of the currently available Alternate Path screen.

Connection

The connection between screen joints is based on a standard premium coupling, as shown in **Fig. 3**. A concentric outer sleeve installed outside this coupling during manufacturing provides an annular conduit, or manifold, to transport shunted fluid flow between screen joints. This connection design facilitates simple rig floor make-up similar to conventional tubing handling operations. In contrast to the existing Alternate Path technology, there is no need to orient or align shunt tubes.

Shunt System

Nine round shunt tubes are integrated into the screen design, six tubes for joint-to-joint slurry transport and three tubes with exit nozzles for the gravel packing operation. Round shunt tubes provide a higher burst capacity than the rectangular tubes of the existing design, resulting in higher shunt system pressure capacity and longer packable length. Access to all transport and packing tubes is at the top of each joint in the manifold section. Smooth, machined profiles in the manifold were optimized by extensive laboratory testing and computational fluid dynamics (CFD) analyses to reduce shunt system pressure loss. Nozzle rings are spaced along the length of the joint and house three nozzles per ring (at 120 degrees apart) to allow for discharge of sand slurry from the packing tubes.

Qualification Testing

Significant testing was conducted on both components and full-scale prototypes to verify screen functionality. Tests targeted flow capacity, erosion, pressure integrity, mechanical integrity, gravel packing, and rig handling. At the conclusion of qualification testing, the Internal Shunt Alternate Path screens met or exceeded all design requirements.

Flow Capacity

Initial tests were run to determine the size and number of round shunt tubes required to fully pack a 5,000 ft openhole section at a rate of 4 - 5 bbl/min through the shunt tubes. Base gel, of known rheology suitable for Alternate Path gravel packing, was pumped through 100-ft lengths of various sized round shunt tubes to determine the friction loss through each tube. Six 20mm x 16mm (OD X ID) shunt tubes yielded frictional response comparable to the two 1.5 x 0.75-in transport tubes in the current "two-by-two" Alternate Path system. Although larger shunt tubes reduce the pressure drop and thus the pressure requirements for the Internal Shunt Alternate Path screens, the screens become too large for the desired application.

Erosion

A physical model was built to determine erosion effects of pumping ceramic proppant through the manifold located at each screen connection. The slurry was pumped at the proposed field pumping rates of 5 bbl/min. The manifold inlets and outlets were misaligned to represent the worst case field scenario when two screen joints are coupled together. One hundred fifty-two thousand (152,000) lbs of 30/50 ceramic proppant, the amount of proppant required to fully pack 5,000 ft of 9-7/8 in openhole by screen annulus with 50 percent excess, were pumped at 2-4 PPA (pounds of proppant added) and 5 bbl/min through the system. No erosion was observed in the manifold, but an unacceptable pressure drop through the manifold was measured. CFD models were calibrated using the experimental data from the physical test and used to optimize the manifold redesign. Based on results of the modeling, the length of the manifold was extended and subsequent testing revealed a 50 percent reduction in pressure drop. One hundred twenty-seven thousand (127,000) lbs of 30/50 ceramic proppant was pumped through the redesigned

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system at 4 PPA and 4-5 bbl/min to verify no erosion concerns with the new design.

While packing through the shunt tubes, gravel is deposited around the screens through the packing tubes. A test was developed to determine the erosional effects of pumping slurry through the nozzles. The physical model, consisting of a single packing tube with six nozzles, simulated pumping the entire gravel pack through the top two to three joints of shunted screen at 5 bbl/min with one of the three nozzles at each nozzle ring plugged. Thirty-eight thousand six hundred (38,600) lbs of 30/50 ceramic proppant were pumped through the apparatus. Flow rate and proppant concentration were measured through each nozzle. The tungsten carbide nozzles showed minimal erosion. Photographs of the nozzles from the erosion test are shown in **Fig. 4**.

Pressure Integrity

Throughout all the physical testing, friction pressure drops were measured through the shunt system and manifold section in order to establish a baseline friction pressure through each joint of Internal Shunt Alternate Path screen. The final friction pressure associated with pumping through each joint of screen, including the redesigned manifold, is shown in **Fig. 5**.

At 4 bbl/min, 6,000 psi would be required to pump through the entire 5,000 ft of shunt tubes, therefore, the pressure integrity of the shunt system must be rated higher than 6,000 psi. Individual shunt tubes welded to an end ring were designed and pressure tested to 10,000 psi. The manifold seals required a specially designed seal stack to withstand the 10,000 psi test. The entire system was pressure tested to 10,000 psi at ambient temperatures and 180°F. Six thousand five hundred (6,500) psi was held at 170°F for a period of eight hours simulating the pumping of an entire gravel pack job through the shunt tubes.

Mechanical Integrity

Burst and collapse testing of the sand control screen was required to evaluate the behavior of the new, higher axial rib wires (support structure for the wrap wire). A burst condition exists when an inside the screen fluid loss pill is placed in an overbalanced condition during a completion or workover operation. Burst tests were performed on samples of 9-gauge, Internal Shunt Alternate Path screen. Strain gauges were placed along the length of the assembly. The screen was installed in a test fixture and a carbonate pill was placed inside the screen. Pressure was applied to the inside of the screen until excessive strain was observed in the wire wrap. Final burst pressures exceeded 2,400 psi, and upon examination of the screens, no gaps larger than 12-gauge were found in the samples. Sand control was maintained in all cases, and the pill remained intact at the end of each test.

While a true collapse condition where the screen is completely plugged is unlikely, the screens were tested to ensure the top screen joint could withstand the elevated pressures while pumping through the shunt system and at the time of final screen out. Collapse testing was performed by placing a ¼-in thick layer of 30/50 ceramic proppant around the circumference of a 9-gauge, Internal Shunt Alternate Path screen sample. The proppant was held in place with an impermeable barrier adhered to the sample. The screen sample was placed inside a test fixture, and pressure was applied to the outside of the screen. Initial collapse test results led to an end ring modification and increase in the number of axial wires from 18 to 27. Final testing after incorporating all of the enhancements yielded a collapse pressure of 5,785 psi. Collapse resulted in a screen indentation, but sand control was maintained. Finite Element Analysis (FEA) was conducted to validate the physical testing and to specify mechanical property requirements for shunt tubes and wrap wire.

Gravel Packing

A horizontal test fixture (10-in ID) was used to test the packing functionality of the Internal Shunt Alternate Path screens. The prototype consisted of two screen joints (11.3 and 14.5 ft respectively) made up together with a manifold section. Each screen joint contained two nozzle rings with one of the three nozzles in each nozzle ring intentionally plugged. The uphole end of the test fixture was blocked, simulating either a sand bridge or an openhole packer, forcing all the slurry through the shunt tubes. The slurry consisted of base gel with 4 PPA 30/50 ceramic proppant. Rates were limited to 1 bbl/min during the test due to test fixture pressure constraints at the time of screen out.

Gravel pack tests were run using the prototype screens, both with and without 3-1/2-in washpipe inside the basepipe. As shown in **Fig. 6**, a 100-percent gravel pack was achieved. Fluid was then flowed back through the gravel pack at a rate of 15.7 gal/min through the 25.8 ft of screen, equivalent to 25,000 B/D through 1,200-ft screen. The gravel pack remained intact, leaving no exposed screen.

Rig Handling

Full length prototype joints of Internal Shunt Alternate Path screen were taken to a rig site, shown in **Fig. 7**, to evaluate the ease of handling and make-up of the screen joints with 140,000 lbs of buoyed weight below the screen joints. After a safety briefing and a short equipment orientation, the rig crew, who had previously never seen the screens, ran the screens at a rate of 12 joints per hour, compared to the typical five joints per hour rate for the current "two-by-two" Alternate Path system. One test joint of the screen was axially loaded to 408,000 lbs, simulating 5,000 ft of screen with 230,000 lbs of overpull. A post-test slot size inspection indicated less than 0.5-gauge change in slot width.

Application Opportunities

To grasp some of the potential for Internal Shunt Alternate Path technology, a few application opportunities and associated benefits will be briefly discussed.

Opportunity 1: Isolating Bottom Water

When bottom water is encountered during the drilling phase, few operationally attractive and cost effective mitigation options are available. The operator can attempt to set an openhole plug (cement or openhole packer) to isolate the zone.

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Alternatively, the operator could choose to plug and abandon the openhole interval and then, with better geologic control, drill a sidetrack with the intent to avoid penetration of the water zone. Regardless of the technique chosen, the required remedial action takes significant time and results in substantial added cost.

With Internal Shunt Alternate Path technology, the openhole can be drilled through the entire payzone until the bottom water is encountered, thus maximizing the productive reservoir interval. The Internal Shunt Alternate Path screens are run with an openhole isolation packer spaced out and located in a low permeability zone above the water contact (identified using the openhole log). After mechanically setting the isolation packer, gravel packing commences and all productive intervals are fully packed above the water zone.

As shown in **Fig. 8**, Internal Shunt Alternate Path technology allows the operator to:

- Drill the entire reservoir section
- Respond efficiently to geologic uncertainties
- Eliminate costly plug back or sidetrack operations

Opportunity 2: Isolating Mid-Zone Water / Gas

With current technology, mitigation options to isolate mid-zone water or gas are quite limited. An operator could decide to complete the well as drilled and accept the constrained hydrocarbon production rates associated with the production of the undesirable fluid (water and/or gas). Alternatively, the well could be plugged back and redrilled to just above the identified water/gas zone. Although the undesirable fluid could be avoided, this technique is only partially effective as substantial hydrocarbon reserves from deeper horizons may be permanently lost.

After drilling the well, the undesirable gas or water zone can be identified on the openhole log. Shown in **Fig. 9**, Internal Shunt Alternate Path technology sand control screens, along with isolation packers and specially designed shunted blank pipe, can be configured and run to straddle the water / gas bearing intervals with the packers set in low permeability shale zones. After mechanically setting the packers, gravel packing operations commence packing the top zone first, skipping the blank section, and then fully packing the lower zone through shunt tubes.

Note that such a completion with true zonal isolation can only be achieved with Alternate Path technology, which is able to pack across any obstruction in the wellbore, be it natural (premature sand bridge in the annulus or collapse of formation around the screen) or intentional (installation of external isolation packers).

The cost savings and reservoir recovery potential associated with this technology is substantial. The Internal Shunt Alternate Path screens and isolation packer assembly:

- Eliminates costly sidetrack or plug back operations
- Facilitates aggressive drill well planning which can maximize reservoir recovery potential from every wellbore
- Enhances long-term production performance and wellbore reliability by delivering a complete gravel pack across all payzones

Opportunity 3: Isolating Gas / Water Breakthrough

Openhole, multi-zone completions are especially susceptible to premature water or gas breakthrough. This is particularly pertinent in developments where injector - producer pairs are installed to maximize reservoir recovery. When breakthrough occurs, production performance can be impaired significantly. Often, the breakthrough occurs in discrete, high permeability stringers that if properly isolated, could enable the well to be returned to its desired production rate.

Internal Shunt Alternate Path technology screens with zonal isolation packers that are pre-installed at strategic, low permeability intervals in the wellbore make it possible to effectively isolate water or gas breakthrough zones that may evolve over the course of routine production **(Fig. 10)**. Straddle isolation tools are installed through intervention workover operations across problematic zones resulting in true isolation of the undesirable fluid (gas or water).

Opportunity 4: Stacked Pay, Openhole Gravel Packing

Completions in stacked pay applications, such as the Gulf of Mexico, have typically been managed by leveraging cased hole completion techniques, such as frac pack, high rate water pack, or slurry pack. If the number of pay intervals and / or the distance between target zones is large, the operator is often driven to complete each zone separately. Wellbore diameter, casing size, cementing, perforating effectiveness, and fluid loss during the completion phase, all have significant implications on the eventual production performance and long-term reliability of the well.

Internal Shunt Alternate Path screens with external isolation packers can be used to complete the entire well in a single operation. The internal shunt screens, along with shunted blank pipe and isolation packers, are spaced out as necessary to isolate each payzone interval and/or straddle zones containing undesirable water or gas. After mechanically setting the packer, gravel packing commences with the top payzone packing first. The slurry jumps across each blank section, while fully packing all screened sections below in a single pumping operation. The resulting completion is shown in **Fig. 11**.

In stacked pay applications the Internal Shunt Alternate Path technology screens with isolation packers:

- Eliminates the need for casing and cementing operations
- Eliminates the need for perforating, surging, and cleanout operations
- Eliminates the need for repeated pumping operations for each of the stacked intervals
- Improves productivity by decreasing the pressure drop through the completion
- Can be run in any hole deviation

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- Can save 12 to 15 days of rig time for a typical three-zone stacked pay completion

Conclusions

New screen technology has been developed and qualified to facilitate openhole gravel packing with true zonal isolation. Internal Shunt Alternate Path hardware enables new application opportunities through improved operational performance and subsurface control. Project objectives were achieved and have resulted in enhanced Alternate Path screen functionality which:

- Adds zonal isolation capability in an openhole gravel pack to seal off bottom water, isolate a zone, and/or leave an unpacked section
- Adds selective gravel packing capability of specified intervals in stacked pay applications
- Extends gravel pack reach from ~3200 to 5000 ft
- Reduces connection make-up time and complexity
- Eliminates the screen's outer protective shroud

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References

1. Helmy, M. W. *et.al.*: "*Application of New Technology in the Completion of ERD Wells, Sakhalin-1 Development*," paper SPE 103587 presented at the 2006 SPE Russian Oil and Gas Technical Conference and Exhibition, Moscow, Oct. 3-6.
2. Lorenz, M. *et.al.*: *"Advancement in Completion Technologies Proves Successful in Deepwater Frac-Pack and Horizontal Gravel-Pack Completions*," paper SPE 103103 presented at the 2006 SPE Annual Technical Conference and Exhibition, San Antonio, Sept. 24-27.
3. Augustine, J. *et.al.*: "*World's First Gravel-Packed Uniform Inflow Control Completion*," paper SPE 103195 presented at the 2006 SPE Annual Technical Conference and Exhibition, San Antonio, Sept. 24-27.
4. Jones, L. G. *et.al.*: "*Alternate Path Gravel Packing*," paper SPE 22796 presented at the 1991 SPE Annual Technical Conference and Exhibition, Dallas, October 6-9.
5. Bryant, D. W. and Jones, L.G: "*Completion and Production Results from Alternate-Path Gravel-Packed Wells*," SPE Drilling and Completion (September 1995), 146-151.
6. Jones, L. G. *et.al.*: "*Gravel Packing Horizontal Wellbores with Leak-Off Using Shunts*," paper SPE 38640 presented at the 1997 SPE Annual Technical Conference and Exhibition, San Antonio, October 5-8.
7. Hecker, M. T. *et.al.*: "*Reducing Well Cost by Gravel Packing in Nonaqueous Fluid*," paper SPE 90758 presented at the 2004 SPE Annual Technical Conference and Exhibition, Houston, Sept. 26-29.
8. Bryant, D. W.: "*Tool for Blocking Axial Flow in Gravel-Packed Well Annulus*," U.S. Patent Number: 5,588,487, Dec. 31, 1996.
9. Jones, L.G.: "*Spectacular Wells Result from Alternate Path Technology*," Petrol. Eng. Int. (May 1999) 31-33, 36-38.
10. Moen, T. *et.al.*: "*A New Screen Concept: No Longer the Weakest Link of the Completion Screen*," paper SPE 68937 presented at the 2001 SPE European Formation Damage Conference, The Hague, May 21-22.

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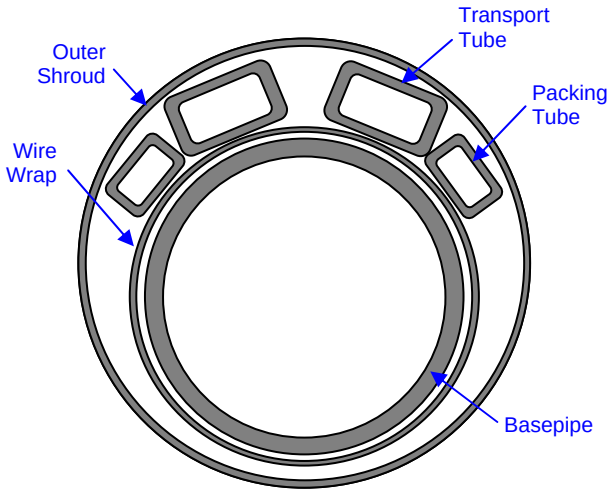

Fig. 1. Alternate Path "Two-by-Two" Screen Cross-Section

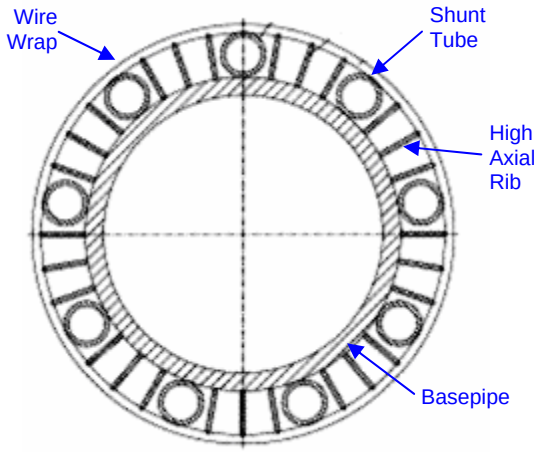

Fig. 2. Internal Shunt Alternate Path Screen Cross-Section

Fig. 3. Shunt System Manifold Box-End (without outer sleeve)

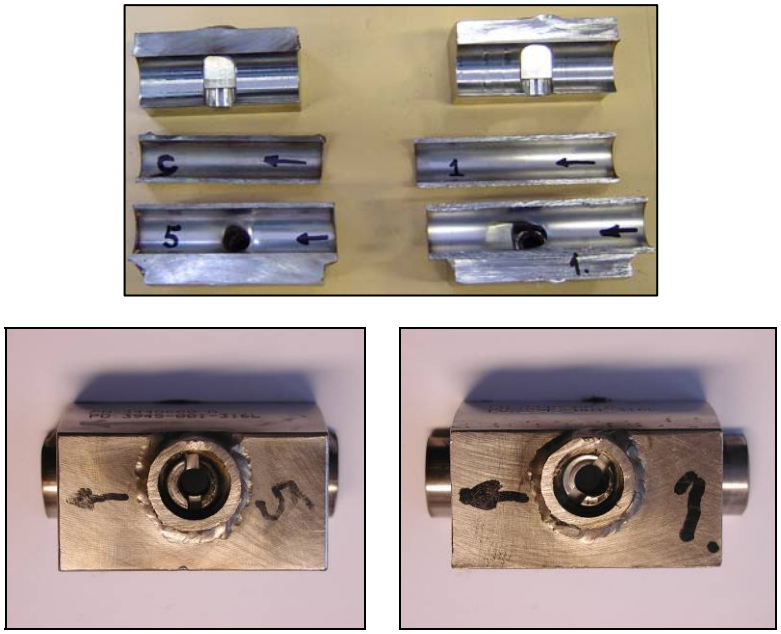

Fig. 4. Nozzle Erosion Test Results

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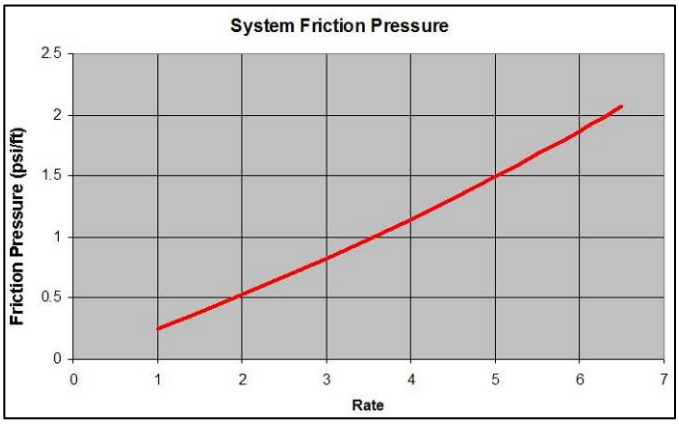

Fig. 5. Shunt System Friction Pressure

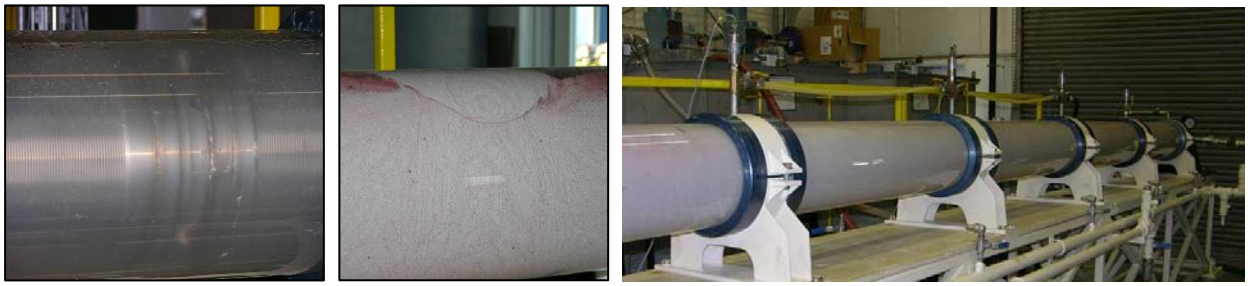

Fig. 6. Gravel Pack Qualification

Fig. 7. Rig Handling Qualification

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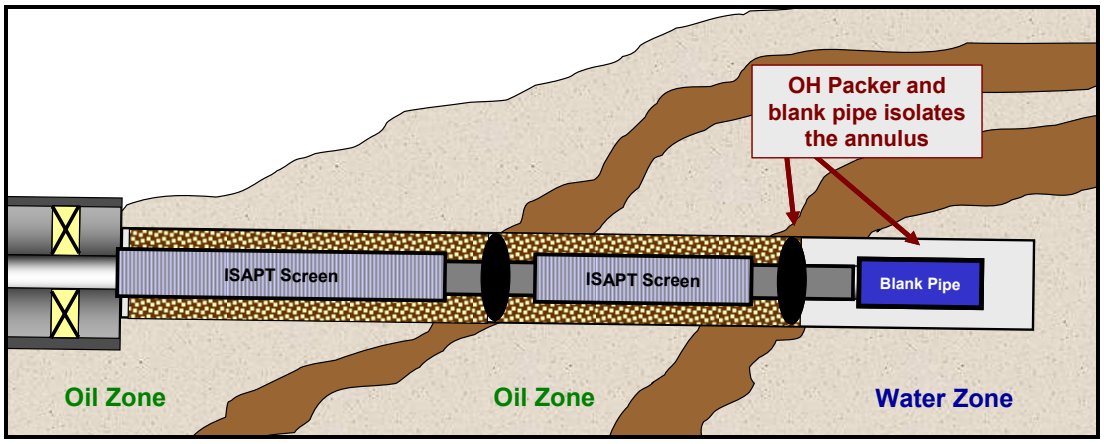

Fig. 8. Opportunity 1: Isolating Bottom Water

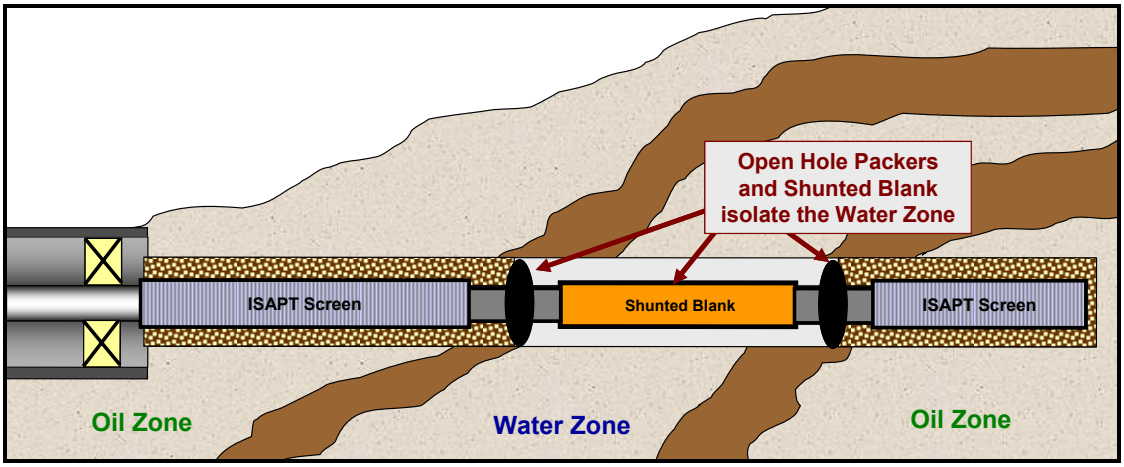

Fig. 9. Opportunity 2: Isolating Mid-Zone Water / Gas

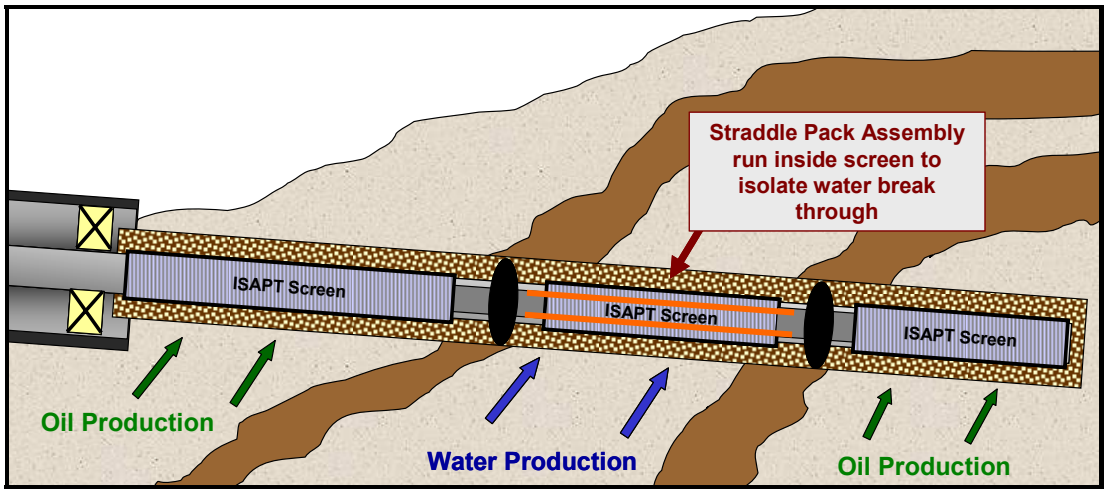

Fig. 10. Opportunity 3: Isolating Gas / Water Breakthrough

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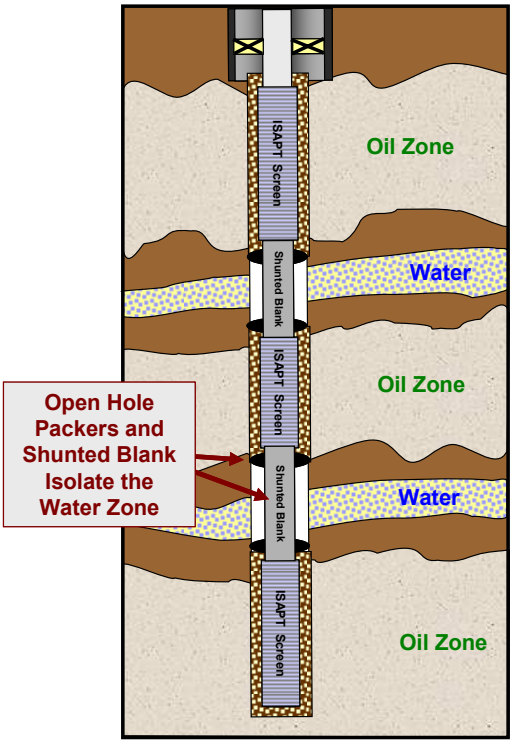

Fig. 11. Opportunity 4: Stacked Pay, Openhole Gravel Packing

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