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The Evolution of Completion Designs Using Alternate Path (Shunt-Tubes) Technology

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Abstract

Alternate Path^{*} (shunt-tubes) technology has been available to the petroleum industry for well more than a decade. Its applications have expanded over time around the world ranging from single-zone cased-hole gravel packs to multizone gravel packs or frac packs and openhole gravel packs. The recent advances have expanded applicability from specialty gravel packing to a general, all-purpose technology with huge benefits. Its flexibility permits use in extremely challenging environments, allowing completions previously considered difficult or impossible.

Development of multizone packers (cup type or swellable) has helped to push the envelope for Alternate Path technology both for cased-hole and openhole applications. This technology has enabled operators to not only perform multizone gravel-pack and frac-pack completions, but also provide solutions for gravel packing in exceptional conditions such as gravel packing a new zone in presence of open perforations in the zone above, isolating unwanted zones while completing new intervals, or gravel packing in exceptional well geometry.

This paper provides a review of the recent unique completions using a shunt-tube system to overcome complicated well completion challenges and expand the limits of using this technology further.

Introduction

The shunt-tube technology was developed to bypass any annular blocking that can occur during the completion process for various reasons. This technique uses screens with steel rectangular tubes (also called shunt tubes) welded onto them. These tubes have nozzles that allow the slurry to exit out of the tubes and into the annulus once the blocked annular section is bypassed (Bryant and Jones 1994). The shunt tube comes in two dimensions depending on the required pumping rate to perform the operation: small tube (0.5- × 1.0-in. OD; 0.31- × 0.81-in. ID) or large tube (0.75- × 1.5-in. OD; 0.56- × 1.31-in. ID). The eccentric design of the tubes to the body of the screen and blank pipe allows for minimizing the external diameter (Hurst et al. 2004) (**Fig. 1**).

One of the main accessories of this system is the multizone (MZ) packer that is used to allow for completing multiple zones in a single trip. With a single pumping stage, the MZ packer saves significant rig time and eliminates the use of fluid-loss-control pills that are typically required in dual-trip or multitrip completion operations (**Fig. 2**).

^{*} Mark of ExxonMobil; technology licensed exclusively to Schlumberger

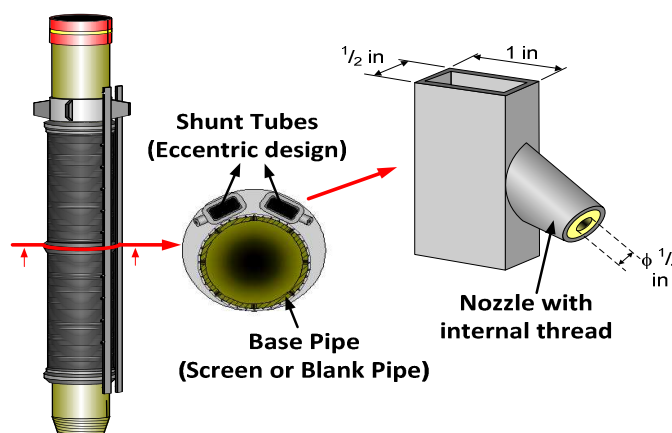


Fig. 1—Shunt-tube configurations and dimensions.

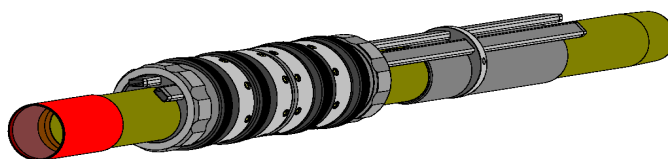


Fig. 2—MZ (cup type) packer allows flexibility in gravel packing separate zones simultaneously.

The MZ packer is a cup-type packer with shunts in the cup/base pipe annulus. The upper zone is packed conventionally, while the lower zone is packed by diverting the slurry through the shunts and bypassing the cup packer. Because the cup packer is only 6-ft long, it can isolate multiple sand bodies separated by relatively thin shale sections, whereas conventional stacked completions require a minimum of 15- to 20-ft spacing (Hurst et al. 2004). The MZ packer provides isolation of the casing/screen annulus (in a blank section); thus, an internal isolation would also be needed to selectively produce or isolate each zone. In this case, this internal isolation is achieved by placing a tail pipe with a sliding sleeve and isolation seal assembly inside the screen across each zone. This arrangement allows flexibility in terms of shutting off zones that are producing undesired fluids (water or gas). The same configuration can also be used to selectively produce each zone one at a time.

We will review a number of the recent unique completions that have used shunt-tube system to overcome complicated well completion challenges.

Gravel Packing the Lower Zone in the Presence of Existing Perforations in the Upper Zone

The conventional alternative consists of squeezing and sealing off the existing perforations, perforating the lower zone, gravel packing the lower zone, temporarily plugging the completed zone, perforating the upper zone, cleaning up the wellbore and retrieving the temporary plug, running the gravel pack assembly, and gravel packing the upper zone. This requires significantly more time and more mechanical elements to perform, thereby creating higher risk and possibility of failures (Fig. 3).

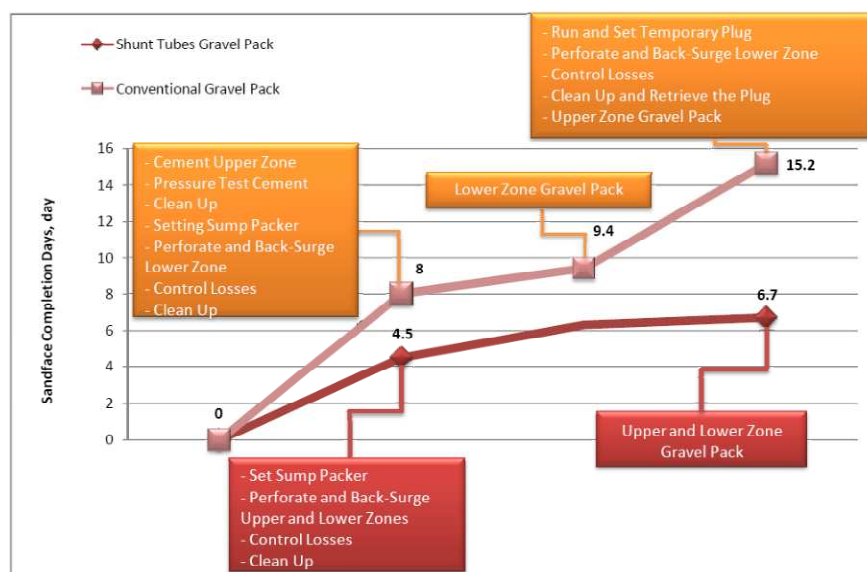


Fig. 3—Completion time for shunt tube could be less than half that for conventional methods.

To address the challenging requirements of the project, a combination of two completion techniques were implemented. Shunt-tube technology provides alternate slurry pathways that bypass the bridges to ensure 100% packing efficiency. A concentric completion system provides a circulation flow path during gravel placement, fluid-loss control after gravel placement, and selectivity during production. Fig. 4 shows the completion schematic of the candidate well.

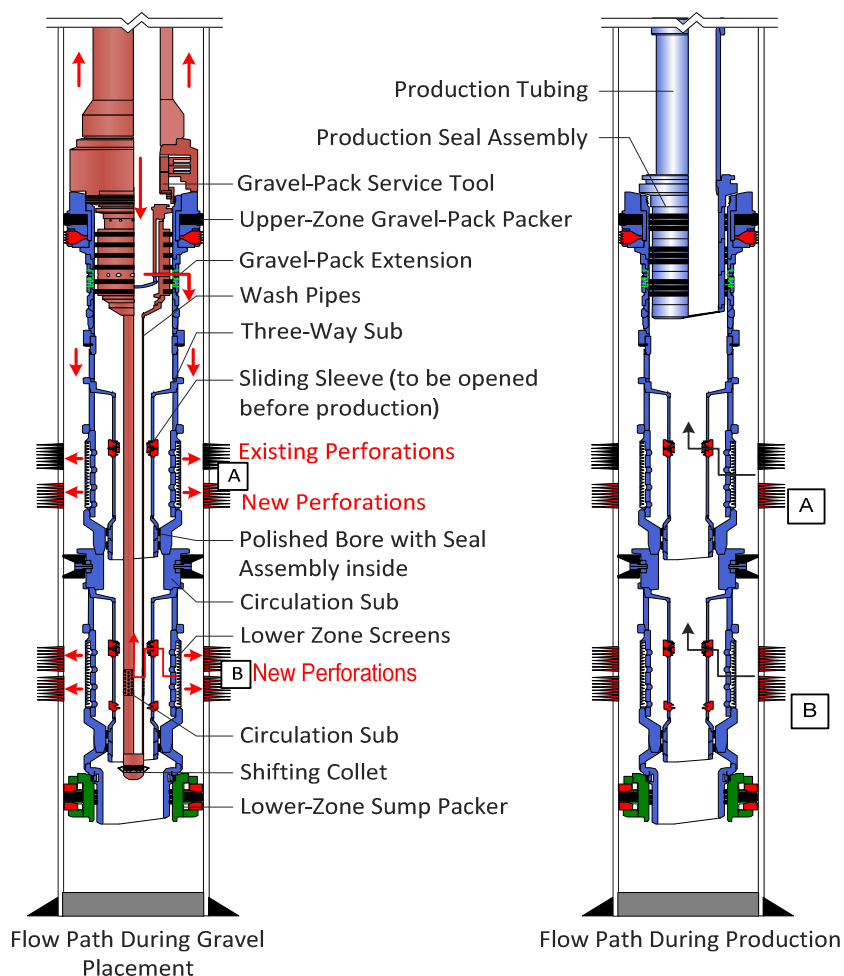


Fig. 4—Sandface completion design incorporating both shunt-tube technology and a concentric completion system ensured optimal completion of two zones, A and B.

Two zones (A and B) were completed in the target well. The target zones were gravel packed in one run using the shunt-tube technique combined with a three-way sub concentric completion system equipped with a 2 7/8-in. inner string and sliding sleeve door (SSD) for each zone. Also, polished bore receptacles were placed above the MZ packer to accommodate the isolation seal assembly and to provide internal isolation between the inner string and screens.

Gravel Packing 950 ft of Gross Perforated Interval with 600-ft Shale Section Between the Zones in a Single Pumping Operation

Three zones (A, B, and C) were completed in the target well (**Fig. 5**). Zones B and C were gravel packed in one run using the shunt-tube technique combined with a three-way sub concentric completion system equipped with a 2 7/8-in. inner string and SSDs for each zone.

Zone A was completed and gravel packed in a separate run using the shunt-tubes system as well because the gross interval of the zone reached 775 ft, and conventional gravel-pack methods would probably not be effective. Because the B and C zones were mechanically isolated by SSDs, no additional isolation plug was required during gravel packing treatment of zone A.

The upper completion with a seal assembly was then run and landed in the lower zone multiseal assembly (LZMSA) below Zone A. This configuration allowed production from zone A through the annular space between the screens and the long string into the short production string.

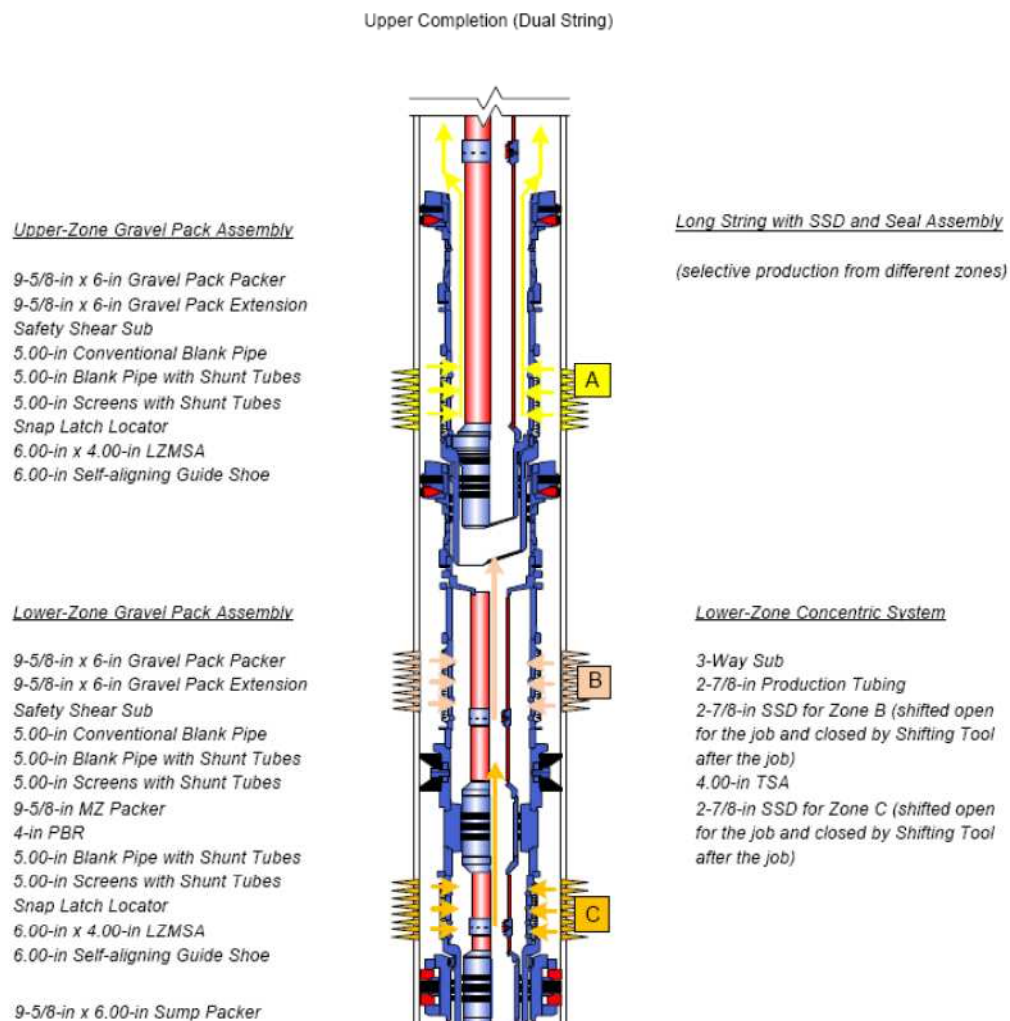


Fig. 5—Completion schematic.

Considering the long distance between the B and C zones (602 ft) and the length of each interval, 136 ft and 212 ft, respectively, the most suitable shunt-tubes configuration had to be selected to achieve the operational objectives. The proposed options are shown in (Fig. 6).

Option A. The shunt tubes are connected all the way to the bottom of assembly and all of the nozzles are open on the screens. This is a standard configuration for this type of application. The disadvantage of such a design is coping with the high-friction pressure through the long length of shunt tubes of the blank pipes below the MZ packer and also the possibility of early dehydration of the slurry in the shunts.

Option B. The shunt tubes are open ended below the MZ packer and all of the nozzles are open. The main advantage of this configuration is less friction pressure through the shunts. After packing the upper zone (conventionally or through the shunts), the shunt tubes below the MZ packer are activated, and the slurry begins to flow below the MZ packer. Because the shunts are open ended, the slurry will flow through the blank-casing annulus, which requires significantly less friction pressure for flow. The lower zone will be packed conventionally, and then by activation of the shunts on the lower zone screens (if required). The disadvantage of this approach is the possibility of crossflow between the zones through the shunt tubes during production.

Option C. The shunt tubes are connected all the way to the bottom and the nozzles of one of the upper zone shunts are plugged. In this configuration, one tube is dedicated to zone C (lower zone) and the second shunt is open to bypass the bridges on both the upper and lower zones. In such a design, the crossflow through the tubes during production is negligible but we still need to cope with possible high-friction pressure during the pumping operation. Using this configuration will also eliminate the possibility of early dehydration of the slurry in the shunt tube that is dedicated to zone C.

Considering all the advantages and disadvantages of the different configurations, option C was selected as the most suitable alternative for the application.

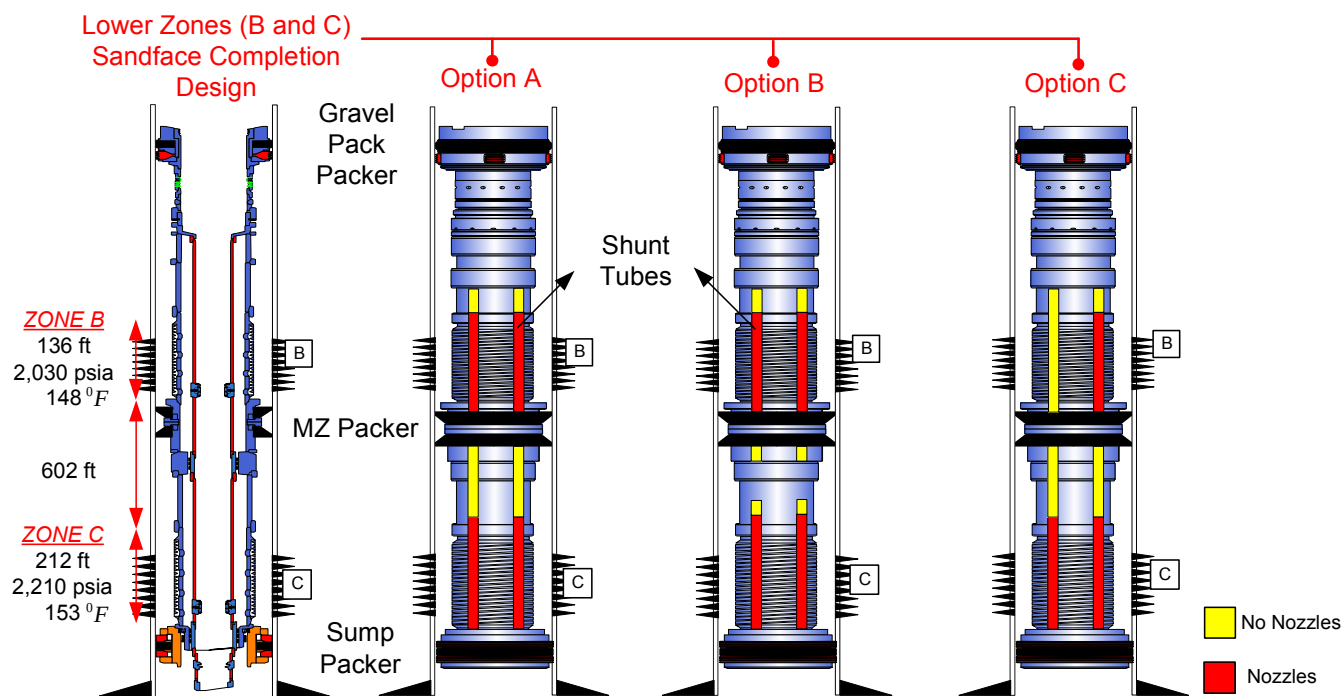


Fig. 6—Proposed completion configurations.

The customized sand-control system was successfully installed and achieved the operational objectives. Thus far, seven wells have been gravel packed using the shunt-tube system and concentric completion technique in this project.

Gravel Packing the Lower Zone and Abandoning the Upper Zone using Sandface Completion

The objective of the workover plan for the candidate well was to abandon the lower gravel-packed zone, isolate the upper gravel-packed zone, and perform a gravel pack in the middle zone. To access the reservoir section for the middle zone, both 7-in. and 9 5/8-in. casings had to be perforated. Due to the uncertainty of filling up the annular space between the two casings with gravel, the decision was made to perforate the 7-in. casing above and below the zone of interest, set a cement retainer

just above the lower perforations, and circulate cement slurry through the annular space between the two casings to fill up the void space between the two casings. The operation was continued by perforating the zone of interest through both casings and cement sheaths and performing gravel pack (Figs. 7 and 8).

The other requirement was to isolate the upper zone prior to gravel packing the middle zone. Instead of spending rig time to squeeze off and isolate the upper gravel-packed zone, the sandface completion design was modified to accommodate for this requirement. The upper zone was isolated by setting two MZ packers above and below the zone. The middle zone was gravel packed through shunt tubes that were extended all the way from above the top MZ packer to below the lower MZ packer. Since no nozzles are installed on the shunt tubes of the blank pipes between the two MZ packers, there is no leakoff to the upper zone while gravel packing the middle zone.

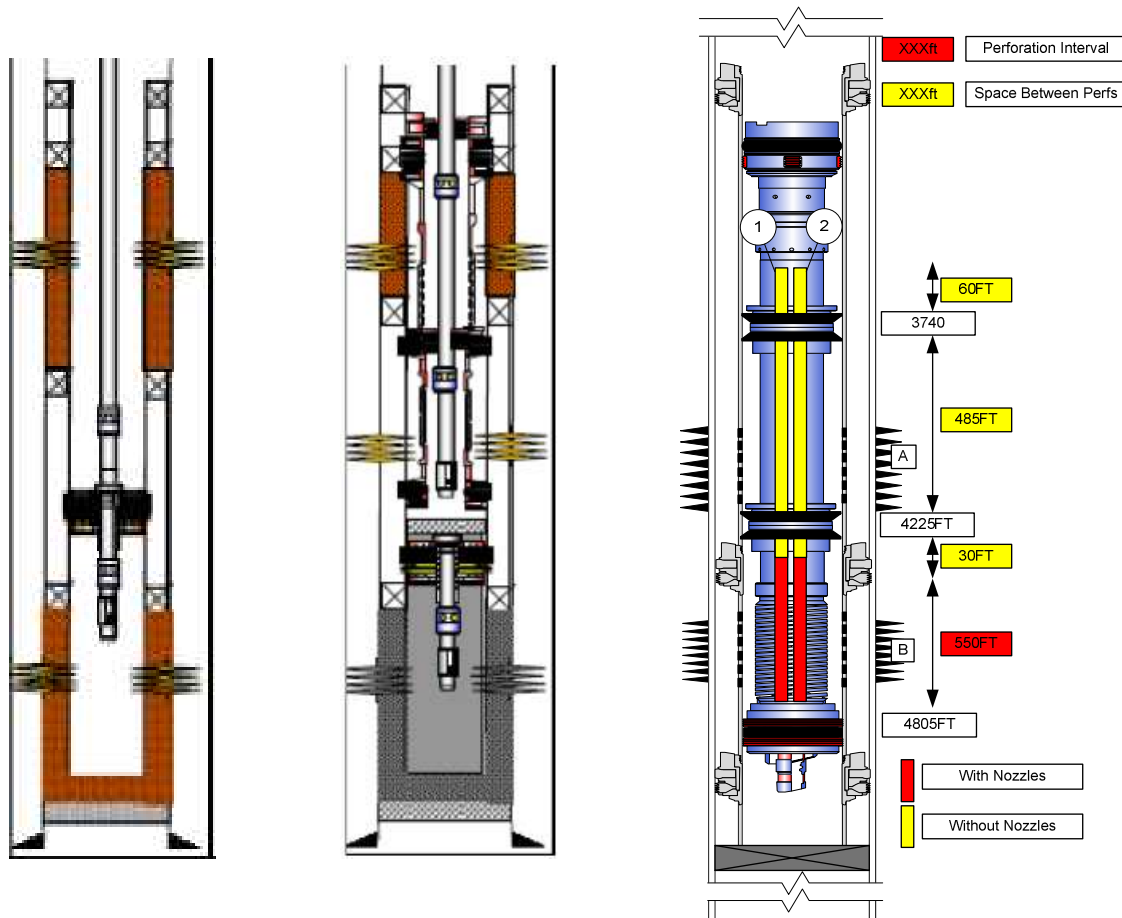


Fig. 7—Existing and proposed completion configurations.

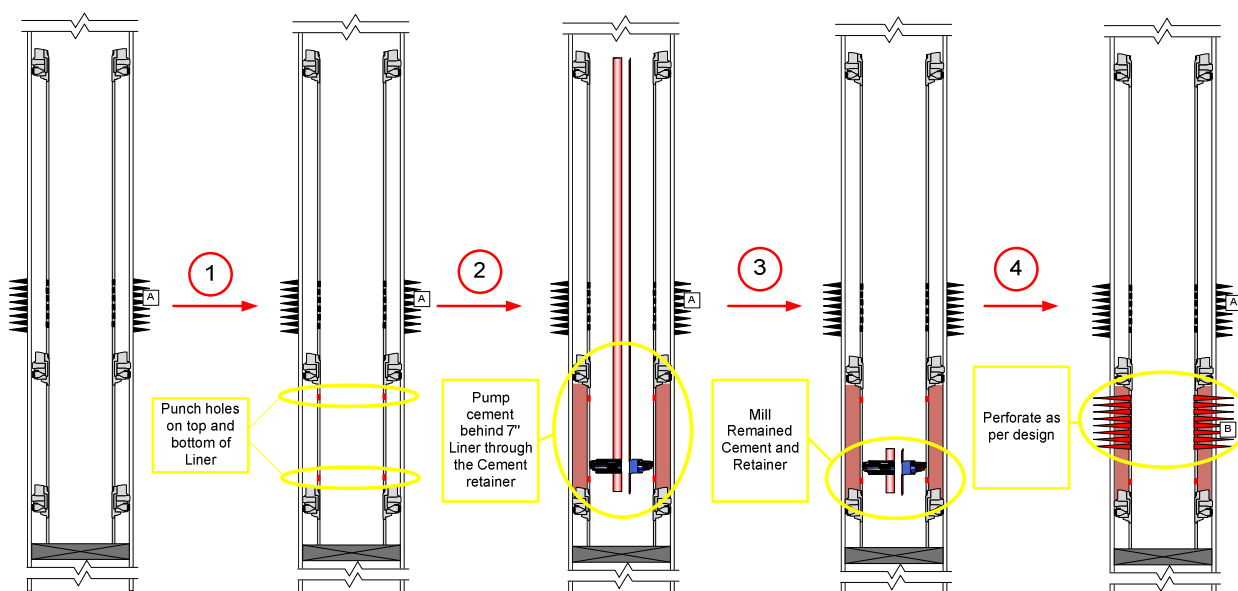


Fig. 8—Well preparation steps prior to completion.

Openhole Gravel Packing in Exceptional Well Geometry—Uphill Heel-to-Toe Packing

This technique has been used to gravel pack two fishhook wells with deviations of 126 and 131°, respectively, up to date. The fishhook wells concept has been initiated to develop near-offshore reservoirs from land locations (Sulaiman et al. 2011). The objectives of the completions were:

- Achieve a complete annular pack
- Provide the capability for zonal isolation
- Maintain bottomhole pressures below the fracturing pressure
- Deliver a low skin completion

For this application, screens with four shunt tubes (2 Transport Tubes $\times$ 2 Packing Tubes) were used.

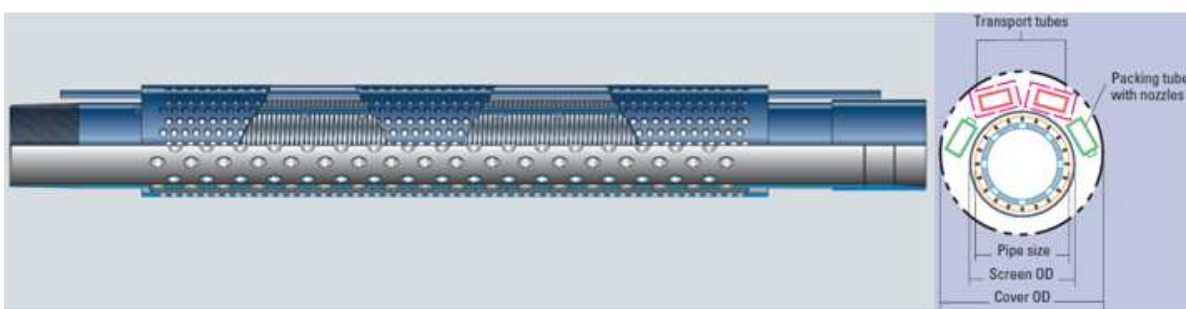


Fig. 9—2 Transport tubes $\times$ 2 Packing tubes screen.

A front end engineering design was initiated as a starting point for an in-depth discussion of the precompletion using the screen with shunt tubes. Several challenges were identified, with solutions proposed using both existing proven technologies and new technologies and innovative ideas that were to be applied for the first time (Sulaiman et al. 2011).

TABLE 1—CHALLENGES AND SOLUTIONS		
	Technical Challenge	Proposed Solution
1	Ensure 100% annular pack at 120 to 130° deviations	Screen with shunt tubes
2	Setting of packer with ball in “upside down” position	Lighter density ball for setting packer
3	Packer setting ball falling back into belly section	Ball retainer at ball seat
4	Initiate heel to toe uphill packing	Use APS packer between screen and X-over ports as well as diverter valves at various locations on the washpipe.
5	Prevent pack sliding downhill during uphill gravel packing	Use APS packer between screen and X-over ports and encourage heel-to-toe packing.
6	Achieve zonal segmentation of precompletion	APS packer (oil swellable packer with shunt tubes)
7	Ensure zonal segmentation with oil swellable packers	Preswelling of APS packer prior to gravel packing
8	Minimize preswelling time of APS oil swellable packer	Design and use of fast-swell elastomer
9	Minimize preswelling time of APS oil swellable packer	Use clean solids-free elastomer swelling fluid\
10	Ensure 100% annular pack at blank sections	Design and use quasi APS blanks
11	Avoid exceeding fracture pressure at shoe during GP	Diverter valves in the washpipe string
12	Avoid exceeding fracture pressure at shoe during GP	Low-friction carrier fluid—VES
13	Ensure low skin at sandface	Solids-free carrier fluid—VES
14	Ensure low skin at sandface	Effective filtercake-removing agent
15	Design a gravel-pack simulator for uphill heel-to-toe packing	Purpose-built simulator

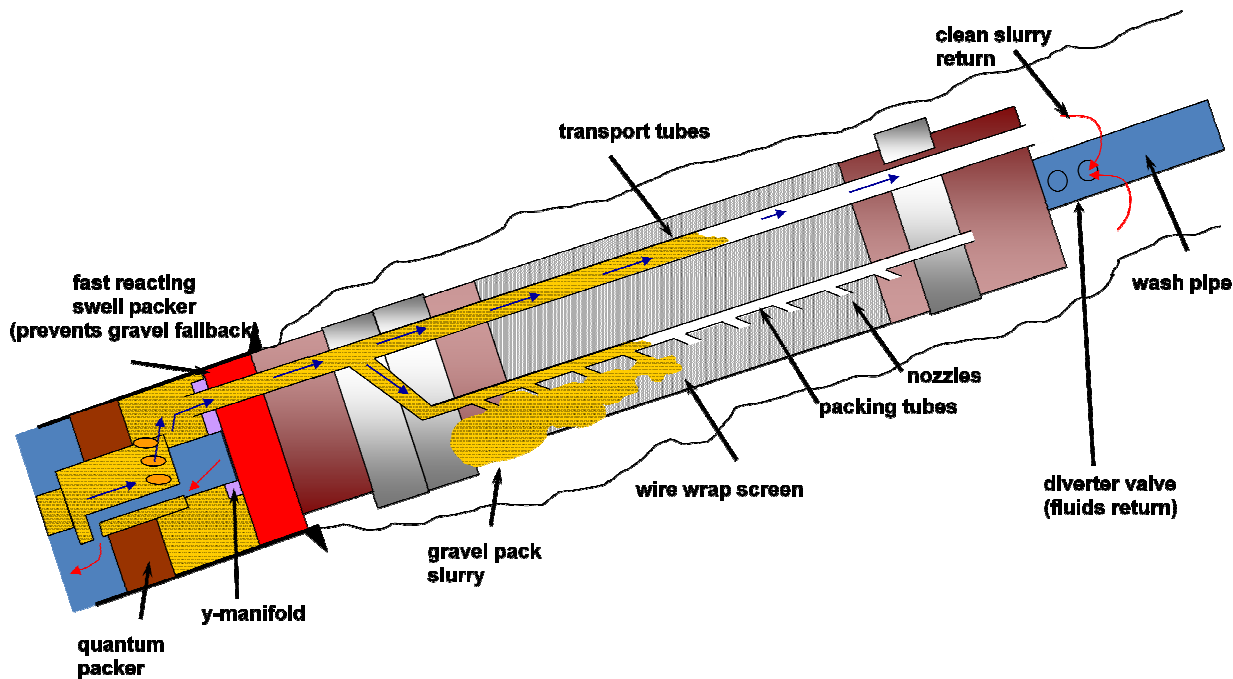


Fig. 10—Uphill gravel-packing process.

Conclusions

A series of exceptional well completions have been performed recently using Alternate Path (shunt-tubes) screens and accessories. The innovative approach taken to address the challenges imposed by each well completion design provided great value to the operation and could also be used as lessons learned for future similar applications.

Acknowledgments

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SI Metric Conversion Factors

bbl	×	1.589 E-01	=	m ³
ft	×	3.048 E-01	=	m
cp	×	1.0 E-03	=	Pa.s
gal	×	3.785 E-03	=	m ³
in.	×	2.54 E+00	=	cm
lbm	×	4.535 E-01	=	kg
psi	×	6.894 E+00	=	kPa

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