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Design and Execution of a 3000-ft Horizontal Gravel-Packed Completion (A Kazakhstan Case History)

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Abstract

This paper discusses the planning, design and successful execution of the first horizontal gravel pack in Texaco's remote North Buzachi field. Well NB4Z, located on land in Kazakhstan, presented extreme challenges that greatly affected the planning of the completion process.

Example of the challenges include the following:

- The combination of a 3000-ft-long openhole lateral section in a shallow reservoir meant that the screen would be over 1000 ft into the openhole before the gravel-pack packer was connected on the rig floor.
- The location had a limited supply of water for completion operations. Disposal of water was also a problem.
- The shallow reservoir made the screen placement problematic and made the torque and drag calculation much more critical.
- Because of the limited number of evaluation wells, everything had to work correctly the first time; i.e., there were no learning curve opportunities.

All aspects of the gravel-pack design are discussed (drilling fluid selection, torque and drag calculations, screen selection, selection of gravel-pack method, and pumping design). The successful executions of various completion phases are compared with the initial designs, and postcompletion well production is discussed.

This horizontal completion set several records. Among them are records for the longest slurry pack, the longest horizontal

well to be gravel packed without washpipe and the longest gravel pack using shunt screen technology. The design took an existing technology, enhanced it and stretched its application to a new limit, in the process obtaining a successful result.

Introduction

Horizontal gravel-packed completions are rapidly becoming a standard technique for high-rate oil and gas wells. Although various sand-control techniques have been applied in areas having significant completion infrastructure (personnel, operations base and local experience), this project shows how the technology can be successfully applied in a remote location with severe logistical and operational constraints.

Texaco is the operator of the North Buzachi field with a 65% interest in the field; Nimir holds 35% interest. The field contains approximately 2 billion barrels of undeveloped discovered reserve oil. The reservoir consists of shallow unconsolidated sandstone, producing relatively viscous 19°API crude oil. Well NB4Z is one of two horizontal wells drilled in the reservoir to date.

Working Environment

The field's remote location presents a major logistical challenge for well planning. Located 300 km north of the nearest city, Aktau, in the western part of Kazakhstan, (Figure 1), there is very little to no support for conventional oilfield services. Most equipment and material are imported, with delivery times ranging from three to four months.

A yearly temperature variation of –30° to 130°F adds to the difficult operating environment. The gravel-pack operation was performed in an outdoor temperature of 130°F, which complicated fluid handling and chemical mixing. The operation was executed with several different crew nationalities. This required extensive well site planning and communications required the assistance of translators.



Figure 1: Map of the area

Completion Design

Well NB4Z is essentially an exploration well designed for production. With a limited amount of formation, production and drilling data, decisions were made on the completion design before the 1999 drilling program began so that equipment could be selected, manufactured and shipped. The associated risks and unknowns were identified and then managed with the selection of equipment, services and field operations. The completion design started with the planning of the drilling program in the reservoir and finished with the well being available for production and reservoir data-gathering in the next year.

Reservoir Drill-In Fluid Design and Selection

The objectives of the fluid design were to provide a water-based drill-in fluid that would

- provide wellbore stability to successfully drill the 3000-ft horizontal section with no hole problems
- provide an “engineered” filter cake to reduce subsurface losses, especially while running the shunt screens
- minimize formation damage
- prevent or minimize damage to the screen
- ensure compatibility with all completion fluids
- facilitate optimum reservoir production
- exceed environmental standards for the region.

A water-based calcium carbonate-polymer-starch drill-in fluid was selected as providing the best drilling characteristics and minimizing potential damage to both formation and screen.

The key to the drill-in fluid system is the engineered filter cake, which provides a thin external barrier that protects the reservoir during drilling and running of screens. Pin-holes

through the filter cake will be generated with reservoir pressure drawdown, thus providing optimum production.

The system is composed of three major components:

- modified starch providing fluid loss control and low-end rheology
- biopolymer for viscosity and secondary fluid loss control
- a log linear designed carbonate for fluid loss control through optimum bridging.

The fluid was tailored to the actual reservoir requirements by adding glycol, a lubricant, and calcium carbonate. Glycols inhibit clays, and calcium carbonate addresses the formation permeability. The lubricant reduces torque and drag during drilling and running of the screen.

Horizontal Gravel-Pack Design

The first step in designing a horizontal gravel pack is selecting the method of placing the gravel. Water packing and shunt tube packing were considered. The shunt tube packing was selected based on ease of operation, logistics and water requirements (Table 1). Water packing consists of placing the gravel in an alpha-beta wave sequence using a low-viscosity carrier fluid (typically brine) at a low concentration of gravel (typically 0.5 to 1 ppa). Figure 2 depicts the typical packing sequence for a horizontal water pack. The numbers represent the progression of the settled or packed gravel front.

Shunt tube packing consists of placing the gravel in viscosified slurry at concentrations ranging from 6 to 8 ppa. Figure 3 depicts the theoretical packing sequence for the shunt treatment. Generally, shunt tube packing progresses from the heel of the well to the toe, as indicated by the numbers in Figure 3.

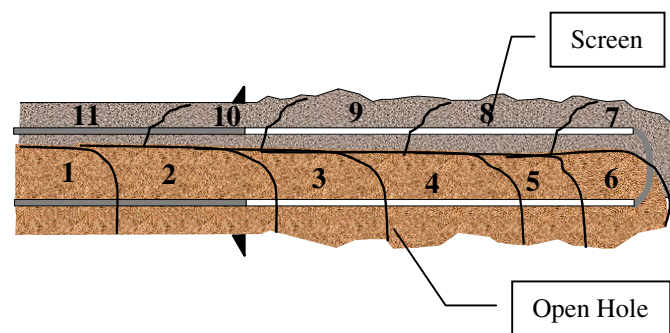


Figure 2: Water Packing Sequence

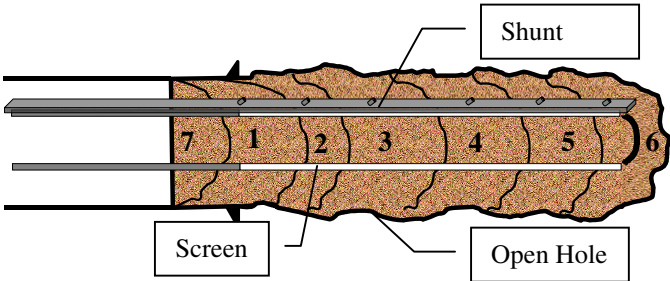


Figure 3: Shunt Tube Packing Sequence

For this 3000-ft gravel pack in an 8½-in. openhole, the theoretical gravel requirement was about 85000 lbm. Table 1 compares some of the salient features of the two gravel-packing methods.

The time required to run both types of gravel pack was analyzed and assessed. If washpipe is not used with the shunt tube packing (an option not available for water packing), then the total completion time is less when using the shunt completion.

When fluid volume is an issue, the shunt tube packing requires between 10 to 20% of the fluid required in a water pack treatment.

	Unit	Water packing	Shunt packing
Gravel volume (20% excess)	lbm	102000	102000
Screen running time	hr	6.5	15
Washpipe running and pulling time	hr	8	0
Gravel pumping time	hr	14	3
Total completion time	hr	28.5	18
Gravel concentration	ppa	0.5	6
Fluid volume for gravel	bbl	4857	405

Table 1: Comparison of Water Pack to Shunt Tube Pack

After selecting the technique, the completion hardware (principally the screen) and the pumping design were optimized. Since the 3000-ft lateral section of this well was much longer than the previous 1100 ft shunt screen record, a new screen design was introduced to

- improve the efficiency of the packing system
- reduce the makeup time for the screens.
- allow the treatment to be pumped at a higher rate

The new screen design consisted of two large transport tubes that branched off on each joint of screen to feed the packing tubes (Figure 4). This design reduced the number of shunt connections required between screen joints by 50%. In

addition, it significantly reduced the potential for fluid loss (slurry dehydration).

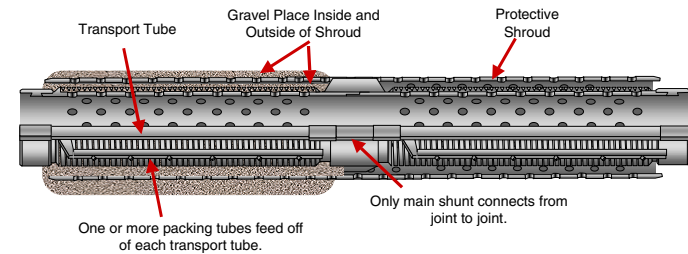


Figure 4: Transport Tube Screen Design

Torque and Drag Simulation

A major consideration in the planning of a highly deviated or horizontal well is the effective transmission of energy to the bottomhole assembly. A primary hindrance to this transmission is simple friction. The axial element of friction, drag, is the component that obstructs the transmission of work string weight to the assembly. The rotational component of the rotating friction, torque, is of paramount importance in the gravel-pack and screen completion design and must be within the limits of the threads and packer. Proprietary torque and drag software was used throughout the planning stage. The torque and drag analysis

- computes the expected friction losses along the work string and screen assembly while tripping in the hole
- selects the best path through analysis of the effects of profile changes on friction losses
- optimizes the work string design to produce the best combination of drill collars and HWDP to enable the screen to be pushed to bottom
- investigates the possibility of buckling the screen or blank pipe while pushing the screen assembly, indicating the maximum assembly that can run in a particular well
- produces charts for rig supervisors of tensile, surface loads and torque, demonstrating loads transmitted to the packer, screen and blank pipe.

The shallow TVD (491 m) and 880-m-long horizontal openhole lateral raised a concern of insufficient weight to push the screens into the openhole if the openhole friction factor was higher than expected. An openhole friction factor could not be attributed to the system because there was no database on running screen with this mud system for this particular field. As there were no data on which to model the field friction factor, assumptions were made based on North Sea experiences; i.e., 0.22 as the casing friction factor and 0.4 as the openhole friction factor for water-based mud.

Based on the simulation (Fig. 5), 5-in. heavyweight drillpipe was selected as the sole landing string. Two 5 ½-in. 17-lbm conventional blank pipes were inserted between the packer assembly and shunted blank pipe to increase the buckling resistance of the screen bottomhole assembly.

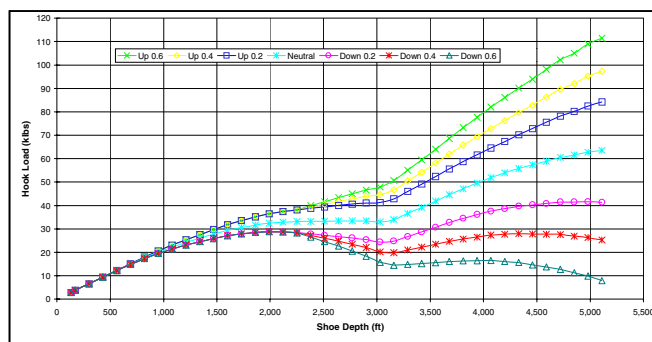


Figure 5: Torque and Drag Analysis

Drilling of the 8-½-in. Reservoir Section

The drill-in fluid system was built on the following formulation:

Calcium chloride brine to 10.8 ppg	
0.8 ppb	Polymer
5.0 ppb	Starch
30.0 ppb	Log linear carbonate
12.5 ppb	Coarse carbonate
0.4 ppb	Antifoam agent
3% vol/vol	Glycol
2% vol/vol	Lubricant

With the 9 5/8-in. shoe set at 683 m, drill-in fluid was displaced into the well. The section was drilled in three days to a total depth of 1562 m with no hole problems.

The mud density range was 11.0–11.3 ppg with the density derived primarily from calcium chloride brine. Good hole cleaning was achieved with a yield point of about 20 lbm/100 ft². The 6 and 3 rpm readings were 8 and 7, respectively. The spurt loss of the fluid was negligible, <0.5 mL with the fluid loss never exceeding 3 mL. The filter cake remained thin, pliable and elastic. The filter-cake composition and carbonate bridging contributed to zero subsurface drilling losses. At 818 m, a formation oil content of 2% was noted within the liquid mud fraction. At total depth, this oil content increased to 6%. The combination of formation oil, glycol and lubricant provided excellent lubricity with no torque or drag problems. The drill-in fluid remained in the horizontal openhole for six days, providing hole stability during the period required to drill the wellbore and run the shunt screen completion. Three wiper trips were made to establish wellbore conditions. No fill was ever encountered and hole conditions were good.

During the final wiper trip, brine was built using Volga water (total hardness = 160–340 mg/L and chlorides at 2000–3000 mg/L) and calcium chloride to a density of 1.32 sg (150 ppb calcium chloride to 0.88 bbl of water for one finished barrel). Sand-control batch mixer and tanks were used for brine mixing. A twin-pod cartridge unit and DE filter press were hooked within the system for brine filtration.

The openhole section was displaced to a solids-free drill-in fluid. Viscosity was achieved with 1-ppb polymer additions. Lubricant, at 2% by volume, was also added to provide lubricity and reduce friction coefficient while running the shunt screen. Rheological properties of the fluid were as follows:

$$600 - 33 \quad 300 - 22 \quad 100 - 12 \quad PV - 11 \quad YP - 11$$

The cased hole section was displaced to a filtered (<20 NTUs) calcium chloride brine.

Shunt Screen Installation

The special features of the shunt screen required several additional steps in making up the shunt screen connection in comparison to standard screen. These additional steps are alignment of the shunt tubes, installation of the jumper tubes and installation of the protective cover at the connection. The equipment used to run the screen is depicted in Figure 6. To improve the efficiency of the screen makeup, a “timed” thread was developed specifically for this application. This new SLHT-S thread was a shouldering thread that ensured proper alignment of the shunt tubes. During this operation 97 out of 100 screen joints lined up perfectly. The screen make-up and running speed averaged 6 joint per hour.

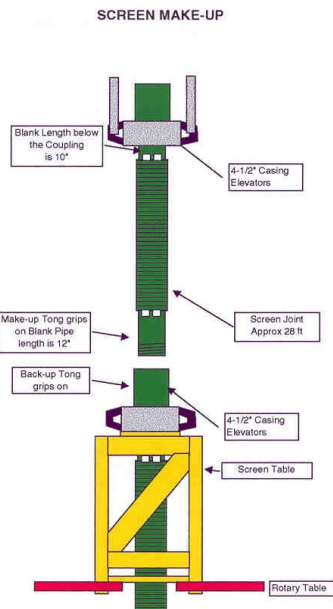


Figure 6: Screen Makeup Schematic

Gravel Pack

The gravel-packing operation was performed as planned with a complete annular pack achieved.

Figure 7 summarized the placement of the equipment used for the pumping operation. Equipment for the gravel-pack operation included

- one 850-hhp pumper skid for fracturing
- one pump truck
- one continuous mix blender
- one 2 x50 bbl batch mixer
- three fracturing tanks
- one rig tank.

Figure 8 contains the pumping chart from the gravel pack. The significant events highlighted on the chart are;

- Gravel arrives at the bottom of the well
- The annulus packs off and slurry flows through the shunt tubes
- Wet sand causes mixing problems, and the pump rate is reduced to allow the blender to keep up.
- Final screenout occurs at the end of the treatment.

The pressure increase from Point B until the final screenout at Point D was due mainly to the friction pressure of the slurry in the shunt tubes. Although the surface pressure was high enough to imply that the formation fracturing pressure was exceeded, fracturing did not occur as there was no loss of circulation throughout the operation. Figure 9 shows a

diagram of where gravel is placed and where pressure can build. Because the gravel pack was performed in circulation, and there was no washpipe, an annular bridge formed at the “top” of the screen and the gravel pack progressed from heel to toe. After the bridge formed, all pressure at Point P₀ was trapped in the area above the bridge (blank and casing annulus). For fracturing to occur, both pressure (above fracture pressure to initiate the fracture) and rate are needed to propagate the fracture.

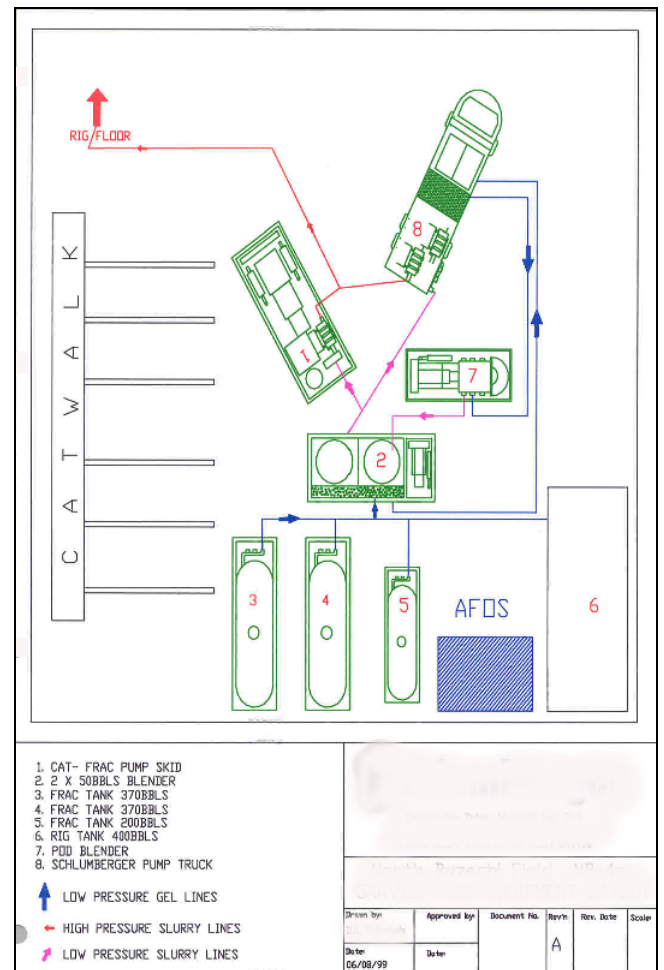


Figure 7: Surface Equipment Layout

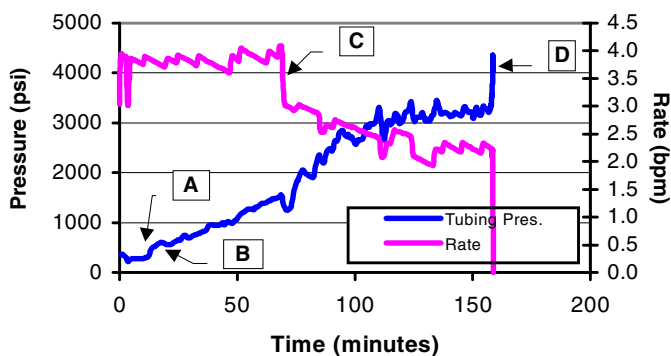


Figure 8: Gravel Pack Pumping Chart

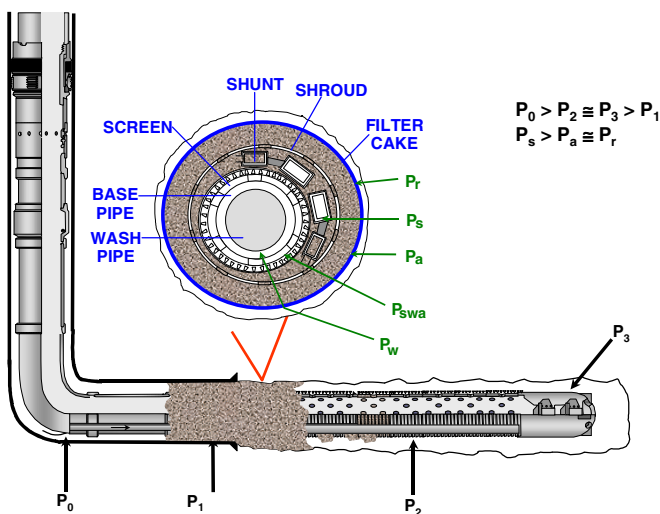


Figure 9: Pressures During Gravel Packing

Figure 10 was constructed using Darcy's linear flow equation to calculate the rates and pressures for various pack heights in the 4½-in. blank/9 5/8-in. annulus. The viscosity used in the calculation was 50 cp, which was 50% of the measured viscosity on location. Figure 10 illustrates that as little as a 2-ft pack will limit both rate and pressure seen by the openhole section.

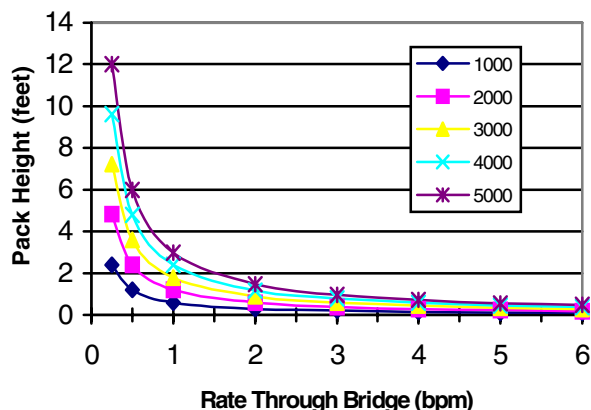


Figure 10: Linear Flow of Gel Through Packed Gravel

The theory of Pressure During Gravel Packing was tested in a surface experiment. In this test, 2000 ft of a single-transport packing shunt tube arrangement was placed in a 2000-ft slotted plastic pipe. This simulated the worst leakoff condition in the openhole section. Similar gravel and fluids were used in the test and the field. The burst pressure of the plastic pipe was less than 100 psi. Figure 11 is the pressure chart from the test. Note that at the end of the gravel-packing operation, a shunt entry pressure of over 1400 psi was observed. The field results proved the theory and experiment correct; pressure is not transmitted through the packed gravel in the blank-casing annulus.

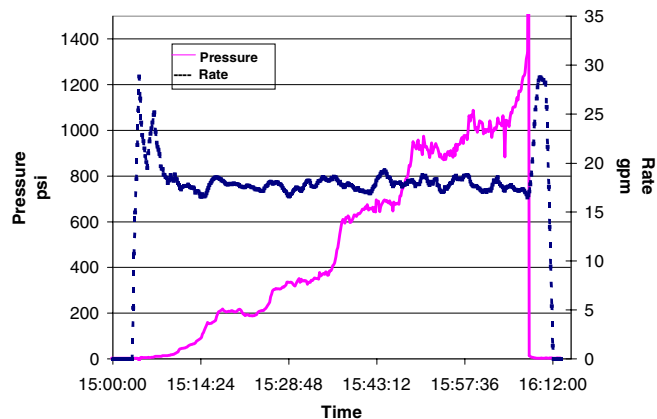


Figure 11: 2000-ft Surface Test of Shunt Packing

Results

Table 2 summarizes the production rates from the wells completed by Texaco. The initial oil production rate for the gravel packed horizontal well was a little over twice the rate of comparable vertical completions.

Well Number	Completion Type	1st Month Production	
		Oil Rate (bopd)	Water Rate (bwpd)
1	Vertical	521	2
2	Vertical	580	0
3	Horizontal Perforated Liner	321	0
4	Horizontal GP	1257	34

Table 2: Production Performance

Conclusions

The purpose of this well design and completion was to determine if economic production could be obtained from a horizontal completion given the reservoir conditions. It was also necessary to evaluate the potential of applying new technology in a remote location. The results were:

1. The gravel-packed horizontal well initially produced at twice the rate as the vertical wells.
2. The drill-in fluid performed as expected and the torque and drag predictions were close to actual recorded data.
3. Shunt technology allowed successful execution of a long horizontal gravel pack in this remote area having a limited water supply.
4. Using the shunts, an extended gravel pack could be performed without washpipe, which saved a significant amount of rig time.
5. The new timed thread allowed the shunts to be perfectly aligned each time, which reduced the total makeup time seen on earlier jobs.
6. A complete gravel pack was achieved on this well with 33% excess gravel over the theoretical volume being placed.

The shunt screen completion demonstrated that an existing technology could be enhanced and successfully implemented in a logistical difficult location. The success factors were: commitment of skilled people, detailed pre-job planning, excellent field execution, and communications at all levels.

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References

- ¹ Penberthy, W. L. Jr., Bickham, K. L., Nguyen, H. T., and Pauley, T. A., "Gravel Placement in Horizontal

Wells", SPE 31147, Proceedings SPE Formation Damage Symposium, Lafayette, La., Feb 14-15, 1996, pp 741-751.

² Jones, L. G., Yeh, C. S., Yates, T. J., Bryant, D. W., Doolittle, M. W., and Healy, J. C., "Alternate Path Gravel Packing", SPE 22796, SPE Annual Conference, Oct. 6-9, 1991, Dallas, Tex.

³ Bryant, D. W., and Jones, L. G., "Completion and Production Results from Alternate Path Gravel Packed Wells", SPE 27359, Presented at SPE Formation Damage Symposium, Lafayette La, 1994

⁴ L. G. Jones, R. J. Tibbles, L. Myers, D. Bryant J. Hardin, & G. Hurst, "Gravel Packing Horizontal Wellbores with Leak-Off Using Shunts", SPE 38640, Presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, U.S.A., 5-8 October 1997

⁵ "SandCADE version 4.2 user documentation", Torque and Drag Module, 1999.