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Natural Diamonds - PDC cutters - TSD cutters

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Over 10 Designs Available

1.875" MD26, Natural Diamond Mill

s/n E-004

Set with exposed 4-6 spc and 6-8 spc processed round natural dian] monds in the face along with 4mm TSD cubes near the center.

Gage pads are flush-set with 1/4" TSD discs

PDC Updrill cutters

1" API Reg Pin (also called AMMT)

TFA = .33

2.3" MD26, Carbide Updrill

Connection: 1-1/2" Reg.
4-1/2" Shank length
Standard port size

3.800" MD26, Natural Diamond Mill

3.800" MD26, Natural Diamond Mill

Set with exposed 4-6 spc and 6-8 spc processed round natural diamonds in the face along with 4mm TSD cubes near the center.

Gage pads are flush-set with 1/4" TSD discs

PDC Updrill cutters

2 3/8 API Reg Pin

TFA = .55

3.7" MS26, Carbide Updrill

Connection: 2 7/8" Reg.
3.75 Pass through waterways
6" shank length

SPE 68432

Improvements in Coiled-Tubing Window-Milling Operations Cut Costs and Increase Reliability, Prudhoe Bay, Alaska

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Abstract

The original through-tubing window milling procedure was designed to run through 4-1/2" tubing, milling a window in the 7" casing below the tubing tail. The window was milled off a pre-set mechanical whipstock that was set on electric line before the coiled tubing unit was moved over the well. It generally took 2 to 3 mill runs before an effective exit window was obtained in the 7" casing.

The goal of the project was to obtain an effective one-trip window exit. The milling assembly had to reduce the torque and work effectively with minimal weight on bit to allow deployment on 1-3/4", 2" and 2-3/8" coiled tubing. By milling the window in one trip versus 2 trips, approximately 12 hrs of rig time could be saved.

Introduction

Coiled tubing (CT) sidetracks (see Fig. 1) currently account for 50-60% of the total sidetracks constructed on the North Slope of Alaska. Approximately 75% of the CT sidetrack operations are conducted utilizing a mechanical whipstock through 4-1/2" tubing (3.82" ID), exiting through the 7" or 5-1/2" liner. The window milling operation accounts for 10-20% of the time spent on CT drilling operations.

Conventional carbide mills used initially were very aggressive, causing numerous drilling motor stalls as the milling process was initiated. Equipment failures (motor rotors, stators and drive shafts) were directly related to the aggressive carbide mills and the effects of sinusoidal buckling.

Two-Assembly Window Milling Operations

Previous to this project, the 3.80" exit windows were cut in using a process that employed two bottom-hole assemblies (BHA's).

Based on the proposed directional drilling plan, the whipstock depth was selected to avoid casing collars, corroded casing and troublesome shale intervals. The mechanical whipstock was set at the predetermined depth using an electric line (0.625" OD, 7-conductor line) logging unit. In high angle wells, coiled tubing was used to deploy the whipstock. After the whipstock was set, the CT unit was moved over the well and the milling operation commenced. Bottom hole assembly #1 was made up to mill the 3.8" OD exit window:

- 3.80" OD Baker Carbide Dimple Mill (See Fig. 2)
- 2-7/8" positive displacement motor (pdm)
- 3-1/8" drill collars or 2-3/8" tubing (60 ft)
- Circulation sub (ball drop)
- Disconnect sub (ball drop)
- Coiled tubing connector or crossover to drill pipe.

Seawater with polymer sweeps was used in milling the landing profile and the exit window.

BHA #1 was run in the well and milled the profile nipple inner diameter from 3.725" ID to 3.80" ID. (Landing nipples are positioned 30-60 ft below the production packer.) Minimal weight on the mill reduced the risk of backing off tailpipe. (See Fig. 1.)

After milling through the landing nipple, the assembly was run in the well to the preset whipstock. The window milling operation started off the mechanical whipstock. Due to the aggressive nature of the carbide mill, starting the window was the most critical part of the milling operation. After numerous motor stalls, milling/drilling proceeded to approximately 6 feet below the casing exit point. The average rate of penetration (ROP) while milling the casing was 1-2 feet/hr. After no further milling progress could be made or after 6 ft of new formation had been drilled, BHA #1 was pulled from the well.

BHA #2 was picked up to enlarge the window to 3.80":

- 3.625" OD Formation Mill (See Fig. 3)
- 3.80" OD carbide string reamer (See Fig. 4)

- 2-7/8" positive displacement motor (pdm)
- 3-1/8" drill collars or 2-3/8" tubing (60 ft)
- Circulation sub (ball drop)
- Disconnect sub (ball drop)
- Coiled tubing connector or crossover to drill pipe.

The slightly undergauge (3.625" OD) formation mill and a 3.80" OD string reamer were used to enlarge the window such that a 3.75" OD polycrystalline diamond compact (PDC) bit and 3" OD directional drilling assembly could pass through the window. Motor stalling was also a problem with assembly #2 due to the aggressive nature of the string reamer and formation mill. The formation mill cutting structure was also carbide, which tended to heat check (in sandstone formations) or ball up (in shale formations). Some milling operations required multiple trips before a satisfactory 3.80" OD window was obtained. With marginal success, PDC cutters were added to a formation mill to improve formation drillability.

Multiple stalls were encountered getting the window started. Many wells required extra trips to change out damaged motor parts (rotors, stators, output shafts, etc.) caused by the multiple motor stalls and fatigue due to sinusoidal buckling, Also, extra trips were required to drill formation below the exit point to allow the string reamer to wipe the lower portion of the window. To alleviate these problems, a goal was set to mill a 3.80" ID exit window in 7" casing through 4-1/2" tubing using one milling assembly.

Evolution of the One Trip Window Milling System

Based on the low torque generated, a diamond mill was the most promising mill design.

The first attempt at a 3.80" exit window used a diamond mill run off a mechanical whipstock inside a 4-1/2" 12.6 #/ft L80 liner. Three carbide mills had been run without success. To finish the window, a cement ramp diamond mill (See Fig. 5) replaced the carbide mills. Minimal motor stalling and smooth milling allowed the window to be cut in approximately 7 hrs. The exit window was enlarged with a string reamer on the subsequent trip. Total milling time including the string reamer trip was approximately 25 hours. The 3-3/4" OD directional drilling assembly passed through the exit window without problems.

Based on the cement ramp milling success, the next 3.80"exit window through 4-1/2" tubing set in 5-1/2" casing whipstock used the cement ramp diamond mill. After milling for 8 hrs with minimal progress, the diamond mill was pulled. The concave mill face appeared to have cut into the top of the whipstock tray instead of riding down the tray and cutting the casing wall. Based on the tray distance from the casing wall, the cement ramp diamond mill was modified with a slight bevel on the edge to allow the mill to ride up over the top of the tray to the pinch point of the whipstock/casing. Fig. 6 shows the difference between the two diamond mills.

The next 3.80" window was cut in two trips using the redesigned one-trip diamond mill (See fig 7). The first trip cut the 6' window and 10' formation. On the second trip the window was cleaned and elongated using a string reamer that was added to the BHA. This mill has a smooth OD (See Fig. 8) with carbide on the leading and following edges to lengthen and ream the window.

The 3.80" window was milled in 4.5 hours with one motor stall and reamed and elongated for in 3 hours. Both operations went very well. Total window milling time, including trip time was 18.5 hours.

Since the initial 2-trip milling test, most of the 3.80" OD exit windows have been milled in one trip using the following assembly (bottom to top):

- Hughes Christensen DP 0261 diamond mill
- Baker 3.80" smooth OD string mill 2-7/8"
- High speed positive displacement motor (7/8 lobe) RPM range: 150-250
- 2 joints, 2-3/8" 4.7 ppf PH-6 tubing (for stiffness)
- Ball drop circulation sub
- Ball drop disconnect
- Coil connector (dimple type)

This milling system has proven to be very reliable. The diamond mill and smooth OD string mill have substantially reduced torque requirements and major motor failures (broken parts).

Conclusions

By combining the diamond mill with the smooth OD string reamer into one assembly, at least one trip has been eliminated from the Through Tubing window-milling operation. The milling time starts when the first assembly is picked up and continues through milling and reaming of the window and until the last window assembly is laid down. Fig. 9 shows the average milling time for one trip milling system is 13 hours, which is a 12 hours savings as compared to the two-trip carbide system.

Combining the two milling tools (diamond mills and carbide string reamers) into one BHA produced a successful one-trip milling system.

Similar milling operations have been conducted successfully in conventional jointed pipe applications. One trip milling operations would obtain greater time saving in the jointed pipe operations due to the longer trip times involved.

Acknowledgments

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Opinions and conclusions of this paper are those of the authors and are not necessarily shared by BP, other Prudhoe Bay Working Interest Owners, Hughes Christensen or Baker Oil Tools.

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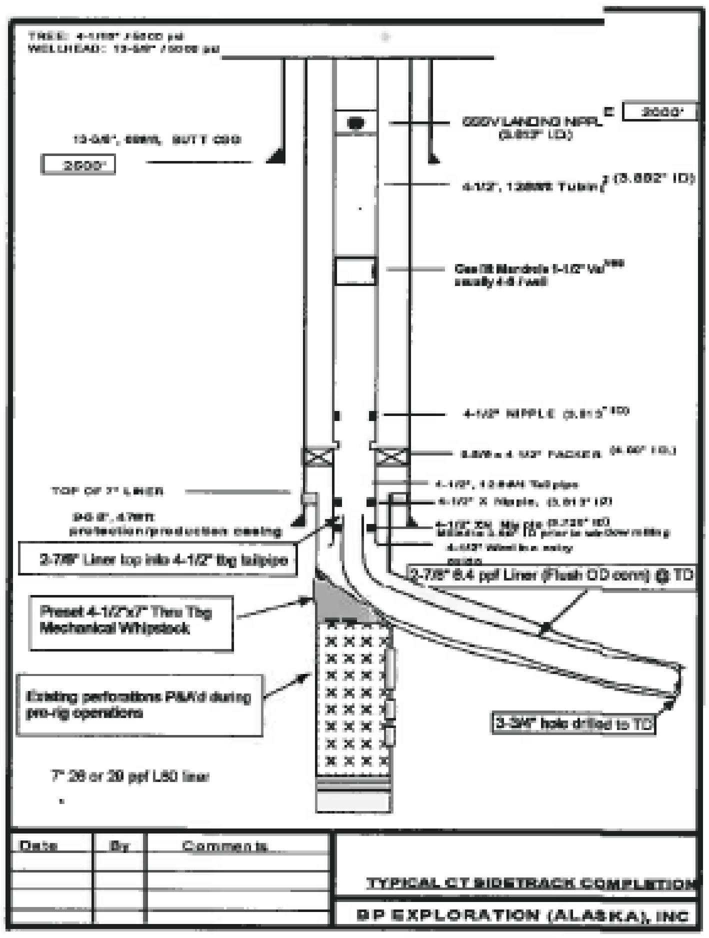

Fig. 1 Typical North Slope CT Sidetrack

Fig 2 Carbide Dimple Mill

Fig. 3 Carbide Formation mill (3.625" OD)

Fig. 4 Carbide String reamer (3.80" OD)

Fig. 5 Cement ramp Window mill

Fig. 6 Cement Ramp Mill & One trip Window mill

Fig. 7 One Trip Window Mill

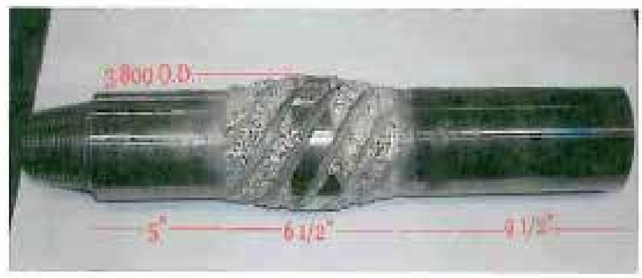

Fig. 8 Smooth OD String Reamer

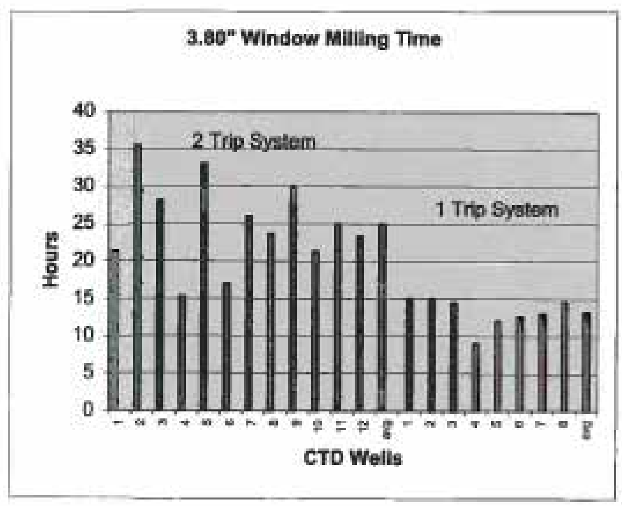

Fig. 9 Comparison of Window Milling Times

SI Metric Conversion Factors

Ft x 3.048	E - 01=m
In x 2.540	E + 01=mm
ppf x 4.448	E – 01= N

Bit size/type	Price	Notes
1.750″ MD-26	$10,632.00	
1.875″ MD-26	$10,632.00	
2.300″ MD-26	$13,032.00	
2.740″ MS-26	$13,032.00	
3.700″ MS-26	$15,432.00	
3.800″ MD-26	$15,432.00	
3.700" MPT-66	$17,940.00	*(dragon back updril)*
3.700" MD-16	$16,531.20	*(larger synthetic rounds)*

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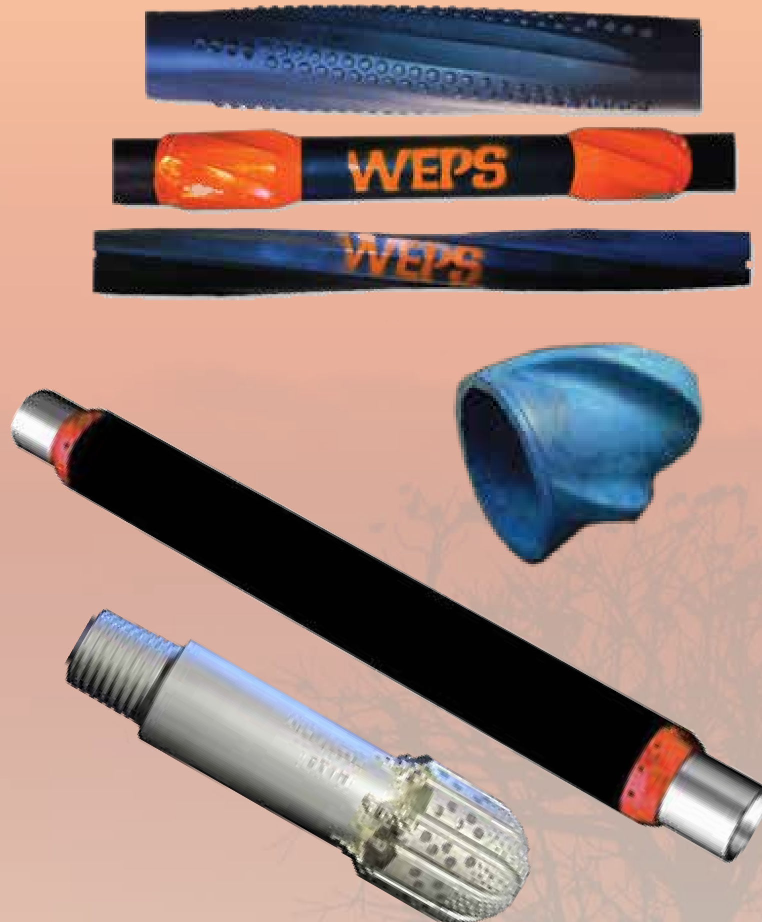

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