PDC Reamers with unique features improve Drilling Performance

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PDC Reamers with unique features improve Drilling Performance

Many Hole-Opener / Reamers Options for HDD









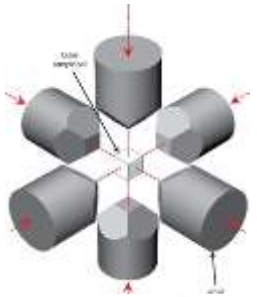



PDC Reamers with unique features improve Drilling Performance Introduction

- PDC Bits have improved drilling performance in Oil & Gas applications for over 30 years.
- PDC Reamers in HDD market has been limited in the past due to performance / high cost.
- Tool Life has been limited in hard, abrasive and fractured formations (i.e. Cobble, Granite etc).
- Unique Design features have significantly improved PDC Reamer Performance.
  - Increased Rate of Penetration, improved Tool Life, and lower costs will be discussed.
  - Skipping / Elimination of small diameter Reamer Runs have significantly improved cost effectiveness.
  - In addition, Less Rig repairs have documented that further enhance cost savings.

PDC Reamers improve Drilling Performance
Background / History of PDC Development


- HPHT Synthetic Diamond Technology / PDC Cutter History
  - First Synthetic Diamond made in 1954 (GE) - diamond grit used for grinding wheels.
  - First PDC Drill Bits were made in 1970's (Christensen; Hughes; Smith Bits; others).
  - First truly commercial PDC Bits were developed in 1980's for offshore soft formation (Stratabit).
  - First PDC Hole-Openers / Reamers began being used in the early 1990's for oilfield applications.



- PDC Cutters and Bit Designs –
  - Brazing process for PDC (Polycrystalline Diamond Compact) was a significant problem in early years.
  - Cylinder PDC Cutters were developed / eliminated the Compact to Carbide stud brazing issue (1990's)
  - Hydraulic Horsepower drives the growth of PDC Bit usage in the 1990's (High Flow Rates; High Pressure)
  - Highly Stable Bit Designs improve PDC Cutter life and Rate of Penetration (Anti-Whirl; Force-Balanced designs)
  - PDC Cutter durability (impact resistance) improved significantly in 2000's.

- Future PDC Design / Development -
  - Higher Friction / Higher Temperature Cutters will allow for more WOB and RPM, yield higher ROP.
  - 3-D Cutters (in development) are improving durability in harder formations (> 30,000 psi UCS)

PDC Reamers improve Drilling Performance

Unique Design Features

- **PDC Reamer Cutting Structure** - **Parabolic Profile**
  - Significantly increases the number of PDC cutters (per blade).
  - Limited Depth of Cut Inserts to restrict excessive Torque / Impact Loading
  - Significantly improved Cutter coverage in the Gage Profile Area (high work-load)
- **Stabilizer Ring** – **smooth rotation (RPMs) improves EVERYTHING !**
  - Maximized concentric rotation → lowers rig / operating vibrations
  - Allows for higher RPMs → delivers / increases Rate of Penetration
  - Allows for the option to ream larger areas / reduce the # of Reamer Passes
    - Open 6 ½" Pilot Hole to 18" with one run. (EX - 2200 feet run with Vermeer 100 x 140)
    - Open 6 ½" Pilot Hole to 24" or even 30" with one Run (Vermeer 100 x 140)
      - Utilizes a Dual PDC Reamer Assembly - (EX - 8 ¼" NBS/Reamer + 30" PDC Reamer)
- **Modular Blade** PDC Reamer Design – lower manufacturing / repair costs.
  - Replaceable Blades for Easy repairs / quick turn-around.
  - Cutter-only replacement for most repairs have been even quicker / easier.

PDC Reamers with unique features improve Drilling Performance

Concept - Stabilized PDC Reamer will Drill faster and Last Longer

- **Field Test Project** - Hard Rock Directional to Evaluate new PDC Reamer Performance
  - **Test Locations - near Big Lake, TX** which is considered tough "Hard Rock Application".
  - Monitor both 18" and 24" PDC Reamers Drilling Performance
    - Parameters – Formation type; Pull Back (WOB); RPM; Torque; Drill Times; ROP
- **WOB – Weight-on-Bit used for PDC was less than ½ of RC Hole-Opener WOB**
  - Roller Cone Hole-Openers typically use WOB 30,000 – 50,000+ lbs
  - PDC Reamers typically use WOB 5,000 – 15,000 lbs depending on OD size and Formations.
  - Torque - PDC Reamers showed similar 4000 – 8,000 psi to RC Hole-Openers but with lower WOB.
- **Increasing RPM → increased ROP that was directly proportional to RPM increase.**
  - Roller Cone Hole Openers typically utilize lower RPMs - 60 RPMs
  - Previous PDC Reamers runs were limited to RPMs that were similar RPMs - 50 - 70 RPMs
    - Test results **- New PDC Reamer with 60 rpms delivered 50%+ increase in ROP over RC Hole-Openers**
  - New PDC Reamers allowed higher RPMs → ROP Gains at 2 – 3 times (based on RPMs)
    - **New PDC Reamer with 120 - 140 RPMs delivers 2 – 3 times ROP as compared to RC Hole-Openers**
    - Example – **Big Lake Texas limestone applications**
      - **18" new PDC Reamer with Ring drilled at 2.5+ feet per minute (120 feet per hour)**
      - **24" new PDC Reamer with Ring drilled at 1.0 feet per minute (60 feet per hour)**

PDC Reamers with unique features improve Drilling Performance

Changes in RPM's delivers Big R.O.P Gains

Hard Rock Test 1 - with Vermeer 100 x 140 Rig - CR 205 (Job # 185226-16)

6 ¾" Pilot Hole reamed to 18" with Evolution "Cross-Guard Stabilizer Ring" PDC Reamer

Length = 120 feet; Hard Rock Application (LMST; $CaCO_3$ Caliche Rock)

Drilling Data:

Feet	Pull-Back (WOB)	RPM	Torque (psi)	Inst. ROP	Rod Time	Avg ROP
5 feet	10k	60 – 70 rpm	3500 - 5000	0.5 ft/min	15 min	20 ft/hr
20 feet	10k	85-90 rpm	3500 - 5000	1.0 ft/min	30 min	40 ft/hr
20 feet	10k	100 rpm	4000 – 5000	1 – 1.5 ft/min	35 min	34 ft/hr
20 feet	10k	120 rpm (Med)	4000 smoother	1.5 – 2.0 ft/min	22 min	54 ft/hr
20 feet	8k	140 rpm (Low)	5000 – 6000	1.5 – 2.0 ft/min	23 min	28 ft/hr
20 feet	9k	140 rpm (Med)	4500 – 5000	2.0 – 2.5 ft/min	18 min	67 ft/hr
15 feet	**8 – 10k**	**140 rpm (Med)**	**5000 smoother**	**2.0 – 2.5 ft/min**	**10 min**	**120 ft/hr**

Comments: **1) Increasing RPM increases ROP; also increasing RPM prevents stalling (Drill Pipe momentum).**

2) Overall ROP was considered 50 - 75%+ faster than Roller Cone Hole-Openers.

3) Used PDC Reamer Condition is Excellent (Like New)

PDC Reamers with unique features improve Drilling Performance

Changes in RPM's delivers Big R.O.P Gains

Hard Rock Test 2 - with Vermeer 100 x 140 Rig - CR 205 (Job # 185226-16)

18" Hole reamed to 24" with Evolution "Cross-Guard Stabilizer Ring" PDC Reamer

Length = 120 feet; Hard Rock Application (LMST; $CaCO_3$ Caliche Rock)

Drilling Data:

Feet	Pull-Back (WOB)	RPM	Torque (psi)	Inst. ROP	Rod Time	Avg ROP
5 feet	6k	80 rpm	3000	1.0 - 1.5 ft/min	10 min	30 ft/hr
20 feet	6-8k	90 – 110 rpm	5000	1.5 – 2.5 ft/min	30 min	40 ft/hr
20 feet	6-8k	120-135 rpm	5000 – 6000	2.0 – 3.0 ft/min	20 min	60 ft/hr
20 feet	6-8k	130 rpm	5000 -- 6000	2.0 – 2.5 ft/min	18 min	67 ft/hr
20 feet	6-8k	135 rpm	5000 – 6000	2.0 – 2.5 ft/min	20 min	60 ft/hr
20 feet	6-8k	135 rpm	5000 – 6000	2.0 – 2.5 ft/min	20 min	60 ft/hr
15 feet	**6-8k**	**135 rpm**	**5000 -- 6000**	**2.0 – 2.5 ft/min**	**11 min**	**82 ft/hr**

Comments:

1) Increasing RPM increases ROP; also increasing RPM prevents stalling (Drill Pipe momentum).

2) Overall ROP was considered 75%+ faster than Roller Cone Hole-Openers; very smooth Operations

3) Used PDC Reamer Condition is Excellent (Like New)

PDC Reamers with unique features improve Drilling Performance

Increase in RPM's delivers Big R.O.P Gains

Hard Rock Test 3 – with Vermeer 100 x 140 - west side of Hwy 137 (Job # 18- 5226-12)

Reamed 6 ¾" Pilot Hole to 18" section with Evolution "Cross-Guard Ring" PDC Reamer

Length = 314 feet; Hard Rock application (LMST)

Drilling Data:

Feet	Pull-Back/WOB	RPM	Rotary Torque (psi)	Inst. ROP (ft/min)	Rod Time	Avg ROP
10 feet	7 - 10k	100 - 130	5000 – 6000	1.5 – 2.0	7 min	86 ft/hr
20 feet	8 – 10k	120 – 130	5000 stalls above	2.0 – 3.5	16 min	75 ft/hr
20 feet	8 – 10k	120 – 140	5000 – 6000	2.0	20 min	60 ft/hr
20 feet	8 - 10k	120 - 140	5000 -- 6000	2.5	13 min	92 ft/hr
20 feet	8 - 10k	120 - 140	5000 – 6000	2.0 – 2.5	16 min	75 ft/hr
20 feet	8 - 10k	120 - 140	5000 – 6000	2.0	20 min	60 ft/hr
20 feet	8 - 10k	120 - 140	5000 -- 6000	2.5	13 min	92 ft/hr
20 feet	8 – 10k	120 – 130	5000 – 6000	2.5	10 min	120 ft/hr
20 feet	8 – 10k	120 – 140	5000 – 6000	3.0	8 min	150 ft/hr
20 feet	8 – 10k	120 – 130	5000 – 6000	2.5	11 min	109 ft/hr
20 feet	**8 – 10k**	**120 – 130**	**5000 – 6000**	**2.5**	**9 min**	**133 ft/hr**
20 feet	8 – 10k	120 – 140	5000 – 6000	3.0	7 min	171 ft/hr
20 feet	8 – 10k	120 – 140	5000 – 6000	3.5	6 min	200 ft/hr
20 feet	8 – 10k	120 – 130	5000 – 6000	4.0	6 min	200 ft/hr

Comments - 1) Increasing RPM increases ROP and the Drill Pipe momentum prevents stalling.
2) Overall ROP was considered 100%+ faster than Roller Cone Hole-Openers.
3) Used Reamer Condition is Excellent (Like New)

PDC Reamers with unique features improve Drilling Performance

Changes in RPM's delivers Big R.O.P Gains

Hard Rock Test 5 - Vermeer 100 x 140 - Hwy 137 - 7 miles south of Big Lake (Job # 52 26-13)

Reamed from 6 1/2" Pilot Hole directly to 24" in one trip (SKIP 18" Reamer Run)

BHA – 8 ¼" Near Bit Reamer/Stabilizer; X-Over; 24" "Cross-Guard Ring" PDC Reamer

Length = 115 feet; Hard Rock Application (mostly LMST)

Drilling Data:

Feet	Pull-Back (WOB)	RPM	Rotary Torque(psi)	Inst. ROP (ft/min)	Rod Time	Avg ROP
5 feet	12k	110 – 120	5000 – 6000	0.5 – 1.0	12 min	25 ft/hr
20 feet	12k	110 – 120	5000 – 6000	0.5 – 1.0	30 min	40 ft/hr
20 feet	12 – 14k	110 – 120	5000 – 6500	0.5 – 1.0	29 min	41 ft/hr
20 feet	12 – 14k	110 – 120	5000 -- 6500	0.5 – 1.0	27 min	44 ft/hr
20 feet	12 – 14k	110 – 120	5000 – 6500	1.0	25 min	48 ft/hr
20 feet	**12 – 14k**	**110 – 120**	**5000 – 6500**	**1.0**	**20min**	**60 ft /hr**
10 feet	12 – 14k	110 – 125	6000	0.5 – 1.0	13 min	46 ft/hr

Comments:

1) Area of Rock is Double (197.4 sq inches vs 413.9 sq inches) the typical 18" → 24" Reamer Section
2) Higher Pull-Down/WOB required due Larger Number of PDC Cutters on Rock Area;
3) Similar Torque as used for standard 24" section (Open 18" to 24"); very smooth Operations !
4) **Overall ROP 45 ft/hr was considered very Good; considering we were cutting 110% more Rock**
6) Used PDC Reamer Condition is Very Good

PDC Reamers with unique features improve Drilling Performance Long Crossing with Vermeer 100

Test 8 - Vermeer 100 x 140 - 15 miles west of Orla, TX
Reamed from 6 ½" Pilot Hole to 18" in one trip
with 18" Cross-Guard Ring PDC Reamer
Length = 2200 feet; Very Hard Rock Application
Formations - LMST; SDST; some Cobble

Drilling Data:

Feet	Pull-Back (WOB)	RPM	Torque (psi)	Inst. ROP	Rod Times	Avg ROP
2200 feet	8 - 10k	100 – 120 rpm	2000 – 3000	1.5 – 2.5 ft/min	10 - 15 min	80 – 120 ft/hr

Comments:
1) Increased RPM to the point where stalling was minimum.
2) Overall ROP was considered Very Good.
3) Used PDC Reamer Condition is Very Good !
only minor Ring wear…….. so will add Hard Facing to Ring.
4) Higher Torque with Vermeer 220 would allow even higher WOB → increase ROP.

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Hard Rock Directional Drillers and Superintendents Comments

A J Goble - "Rate of Penetration is at least 2 times that of Roller Cone Hole Openers.
We are now skipping the 18" Reamer Run and open 6 ¾" Pilot hole to 24" on the first pass.
Next step is to skip the 24" Reamer and drill directly from 6 ¾" Pilot to 30" Reamer !
Great Reamer ! I Love it !"

Heath Robertson - "Whatever is getting us the most successful penetration rate is what we need.
Thus far **the Evolution PDC Reamers have excelled over the rest of the competitors (PDC and Roller Cones)**.
Moving forward, we should do whatever it takes to get the Pipe-Pulled business and in this solid formation, these PDC Reamers have prevailed and I stand behind them 100%."

Mason Russell - "Using the Near Bit Reamer / Stabilizer and going straight to the 24" (skipping the 18" reamer section), we had very good success. Cutting out a Reamer Pass and less torque and stress on our rig. I'm very happy with these Cutters."

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Cost Savings Calculation

Cost Savings = Rig Cost / hour x (saved Drill Time + other Time reductions)

Rig Cost Estimate = Rig + Other extras + Crew + OH = $ 5000 per day
= $400 per hour (assumes 12+ hour days)

Example Job: **16" Pipeline requires 24" Hole (Reamer)**
10 jobs @ 350 foot / crossings = 3500 feet

24" PDC Reamer costs = $ 34,000
depreciated over 24 months = $ 1500 per month
minor/moderate repair after 3500 ft = $ 4000
$ 5500

Assume: RC Holeopener is similar to PDC Dep. Cost $ 1500 per month

Assume: PDC Drills 2 times faster than RC Hole-Opener

Example: 70 feet per hour PDC vs 35 feet per hour with RC
so PDC Reamer saves 5 hours per job x 10 jobs = 50 hours

Cost savings: 50 hours saved x $ 400 per hour = $20,000
minus cost for repairs for PDC Reamer - $ 4,000
Cost Savings $ 16,000

Additional Cost Savings -
Skipping Reamer Section (18" → 24") saves 10 hours per job
Skipping Reamer Run saves 10 hours x 10 jobs = 100 hours

100 hours saved x $ 400 per hour = $ 40,000 Savings

Total PDC Reamer Savings = $ 16,000 + $ 40,000 = $ 56,000 (10 jobs)

ROI = $34,000 / $5,600 per job = 6 Jobs (< 2 months)

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Summary of Performance Improvements

- **New PDC Reamer increases ROP - 2 times faster than Roller Cone Hole-Openers.**
- **New PDC Reamer life between repairs has been 5000+ feet or more.**
- **Skipping one Reamer Section 18" → 24" (or even 30") is now common (Vermeer 100)**
- **PDC Reamer expected to have a useful Tool Life of 2+ years. (Zero DBR after 1 year)**
- **Cost Savings show a ROI of 6 jobs / < 2 months.**
- **It has been noticed and documented that the Rig Repair costs are also being reduced.**
  - **Lower Carriage Bearing Assembly lasts 2 times longer = Cost Savings $ 5000 / year**