

PARTICLE DRILLING TECHNOLOGIES OVERVIEW





What is Particle Drilling

Simple Technology, already commercial

- MV² Mass Times Velocity Squared
- Removes rock by blasting it away with hardened steel particles
- Particles accelerate to 500 fps through bit and impact rock 12 Million times per min
- Particle volume 2-3% of total fluid volume
- Drill bit challenges solved by ReedHycalog
- Theoretical max ROP in Granite greater than 120ft/hr











Particle Injection Unit

Self-contained "Plug and Play" design allows for rig up in a matter of hours

Redundancy on primary components for added reliability

Three shot vessels

one injecting shot one loading shot one standing by to inject





Three Valve Manifold



Particle Injection Unit can be easily isolated from drilling rig in a matter of minutes.





Challenges Pre NOV

- Drill bits
 - Damage from ricochets
 - Damage from torsional and lateral vibration due to lack of stabilization
 - Material of the bit body
 - Tortuous internal flow path causing erosion
- BHA Design
 - Stable heavy BHA needed
 - System needs stabilization
 - Actual Weight on Bit creates bit damage











Collaboration PD and NOV

- Joint Workshop/Partnership
- External design
- Particle Pilot, Reamer
- Cut the correct outside diameter
- Reduce lateral and torsional vibration
- Mitigate the pilot touching the bottom of the hole
- Torque, WOB, Diff P signal









NOV Lab Tests

- First 2 tests, no reamer, establish bottom hole pattern
- Third test, 60 RPM, WOB 2-3000 lbs, ROP 50 ft/hr average, 150 ft/hr instantaneous
- Fourth test, 4-6-8000 lbs, ROP 100 ft/hr
- Fifth test 4-5000 ft/lbs, 75ft/hr steady state







Collaboration PDTI & NOV

- Demo of Particle Drilling Jan 2021, East Texas
- Identified challenges in Bit and BHA Design
- Joint workshop held
- Rapid design and manufacturing of Version 1, hybrid reamer and particle bit
- Mobilized rig to granite quarry in Coldsprings Aug 2021
- Drilled 990 ft at 30-45ft/Hr. Excellent performance even with lots of rig challenges
- Drilled last 122ft with Forge PDC, heavily WOrn







Internal Design

- Internal design
- 77% of rock removed by particles
- Minimize internal erosion
- Correct bottom hole pattern







Field Testing

- Granite quarry, Marble Falls, Texas
- 45Kpsi "Pink Granite"
- 2 Particle Drilling Hybrids
- 298M in 23 Hrs, Average 13 M/hr
- 980ft in 23 Hrs, Average 43 Ft/
- Reamer Damage, Ricochet damage
- Low WOB, Shallow Depth











Version 2 of Particle Drilling/PDC Hybrid

- Bit body changed from TMS Matrix to Cast Carbide
- One-piece nozzles and accelerator sleeves
- 39 Cutters to 50 Cutters
- Shoulder radius changed from 55mm to 100mm
- Internals improved to minimize erosion
- Particle section profile made more ballistic to reduce erosion
- Target of V2 is a 1000ft at 60ft/hr













12 ¹/₄" Design (E1444-A1), ready for customers





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