Slotted-charge perforating gun system for obtaining rectangular shaped holes in casing pipe for cement squeeze applications.

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Outline

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2. Perforation Gun Design
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1. Applications of Cement Squeezing

- **Well Abandonment:**
- **Unwanted vertical channels** in the previously cemented annulus may exist. The channels could produce vertical migration of fluids or gas along the outside of the casing in the wellbore.
- **Perforation intersects** the unwanted channels.
- **Perforate casing and pump cement** to create an impermeable barrier.
Applications of Cement Squeezing

- **Zonal Isolation:**
- **360° circumferential access to the annulus between casing and well**
- **Provide access to voids in the previous cement job and formation**
- **Repair flaws**
Applications of Cement Squeezing

- Multiple Casings:
- Perforation is restricted to inner lying casing
- Create rectangular slots in inner casing with no damage to outer casing
- Ensure zonal isolation for secondary tubing string
2. Perforation System Design

- Standard Linear Shaped Charges
- Unsuitable for this application
- Insufficient or non-perforation of slots in casing
- No control of charge design
Perforation Charge Design

- Rectangular Shaped Charge
- Geometry
- Liner composition
- Point of initiation
- Integrate to standard perforating hardware
Perforation: single shot tests

- 30g HMX-St Slotted Charge

- 86mm-13spm-20° in 5 ½” Casing

- Penetration: ~6 inches in concrete. Difficult to measure accurately due to target shattering.
Perforation Gun Design

- 3 3/8" - 4spf - 20° Slotted Charge Gun System
- Gun Phasing can be adjusted to overlap requirements
- Suitable for 4 1/2", 5", 5 1/2" Casing
3. Testing

- Reference test set-up to confirm limited entry and no perforation of outer casing
- Gun 3 3/8”-4spf-20°
- 4 1/2” (11.6 lbs/ft) Casing inside 7” (32lbs/ft) L-80 Casing
Testing

- No visible damage to inner wall of 7” casing
- 30g HMX-Steel Slotted Charge
- 3 3/8” Gun Swell -94mm
  Drift Gauge 94mm/3.7”
- 18 shots (4.5ft) required for 360° helix perforation
- Overlap from slot to slot in 4 1/2” casing ~ 18mm (50% of width)
4. Results & Analysis

- Slot overlap and size is consistent
- Burr Heights 1.3 - 1.8cm
- No visible deformation in straightness of casing pipe
Properties and condition of casing pipe after perforation: Yield Strength Testing

- Clausthal University (ITE) Institute of Petroleum Engineering
- Computer controlled test frame with displacement sensor
- Free length of 4 ½" casing in frame 1230mm / ~4'
- Maximum load of test frame is 1300KN
Yield Strength Testing

- Yield Load 951 kN
  68,087 psi Yield Strength

- Failure Load 1233 kN
  84,508 psi Tensile Strength

- API L-80 Casing (11,6 lbs/ft)

- Yield Strength: 80,000psi
- Tensile Strength: 95,000psi

- Loss in yield strength in casing ~15%
Yield Strength Testing

→ Visible widening of perforated slots from tensile test

→ Loss in tensile strength in casing ~11% due to perforation
5. Summary

- Initial Testing is positive.
- CE, transport & storage licensing pending
- Slotted Charge can be readjusted to fit systems for larger or smaller tubing/casing sizes
- Possible additional applications:
  - Tubing Punch: generate max. AOF (~0.45in²), short guns
  - Bypass stuck bridge plug in tail pipes
  - Bypass closed formation isolation valves
- Frac Applications: Horizontal Shale Gas
Thank you for your attention.