




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

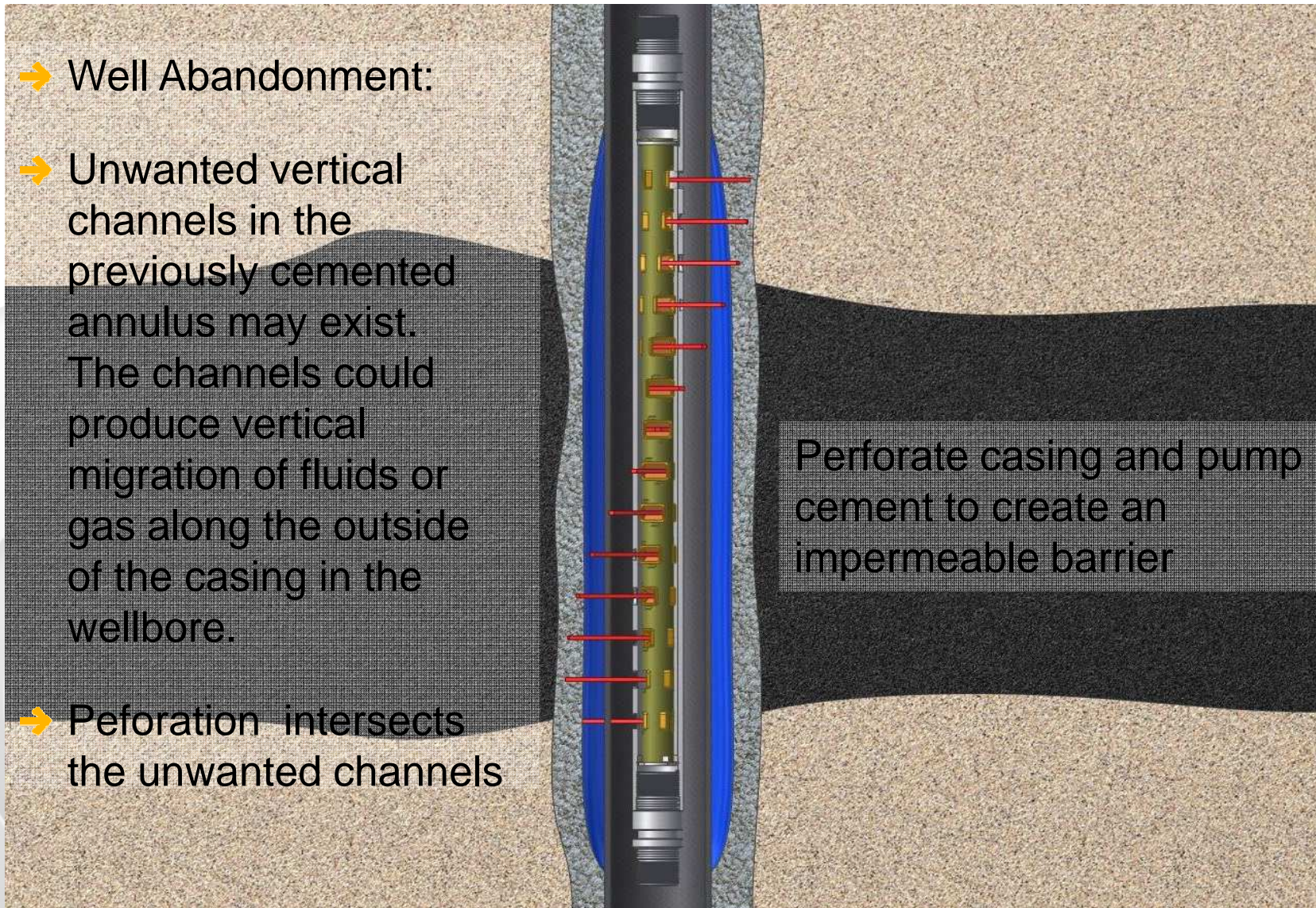
Liam McNelis.

Outline

- 1. Introduction - Cement Squeeze Applications
 - 2. Perforation Gun Design
 - 3. Testing
 - 4. Results & Analysis
 - 5. Summary
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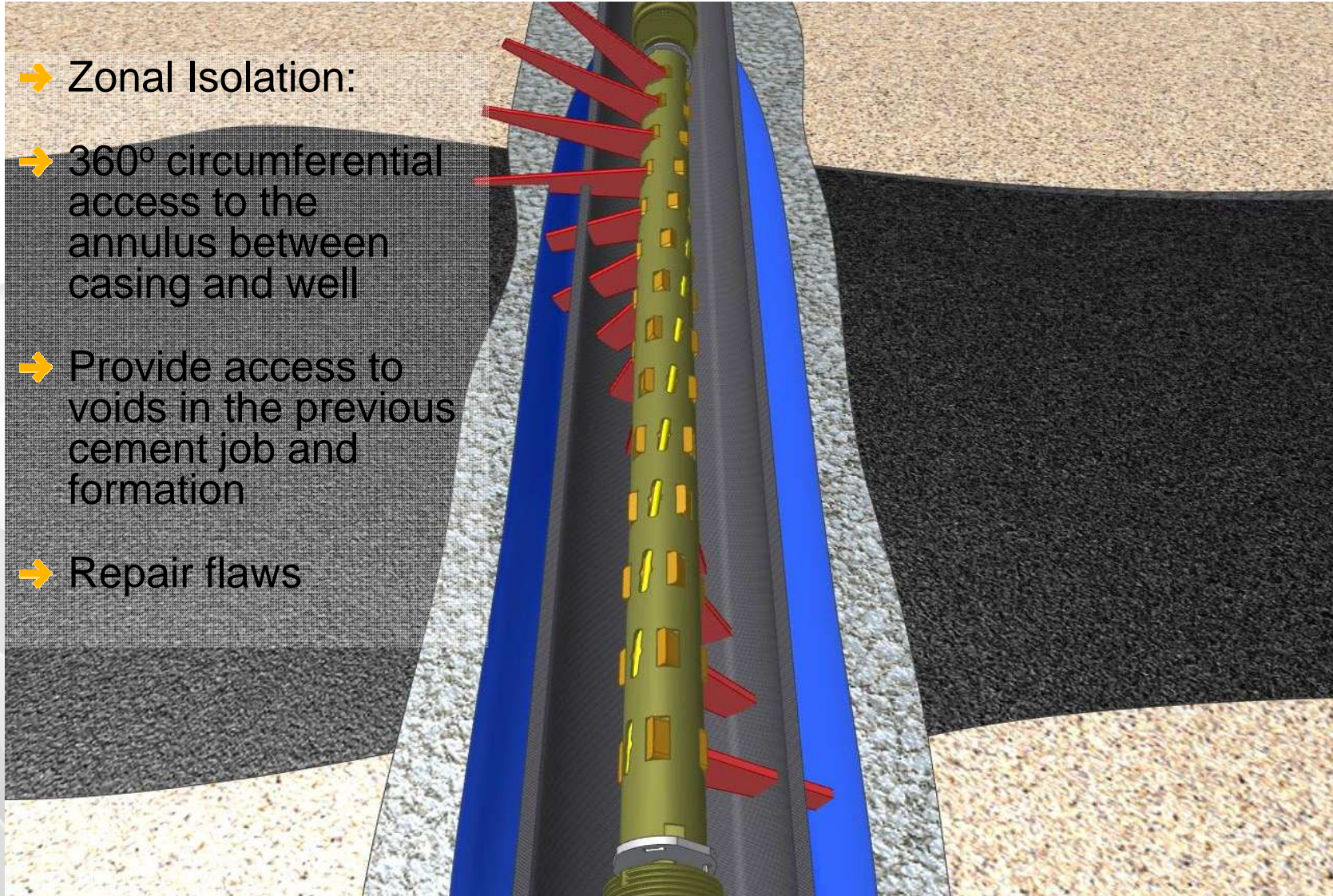
1. Applications of Cement Squeezing

- 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



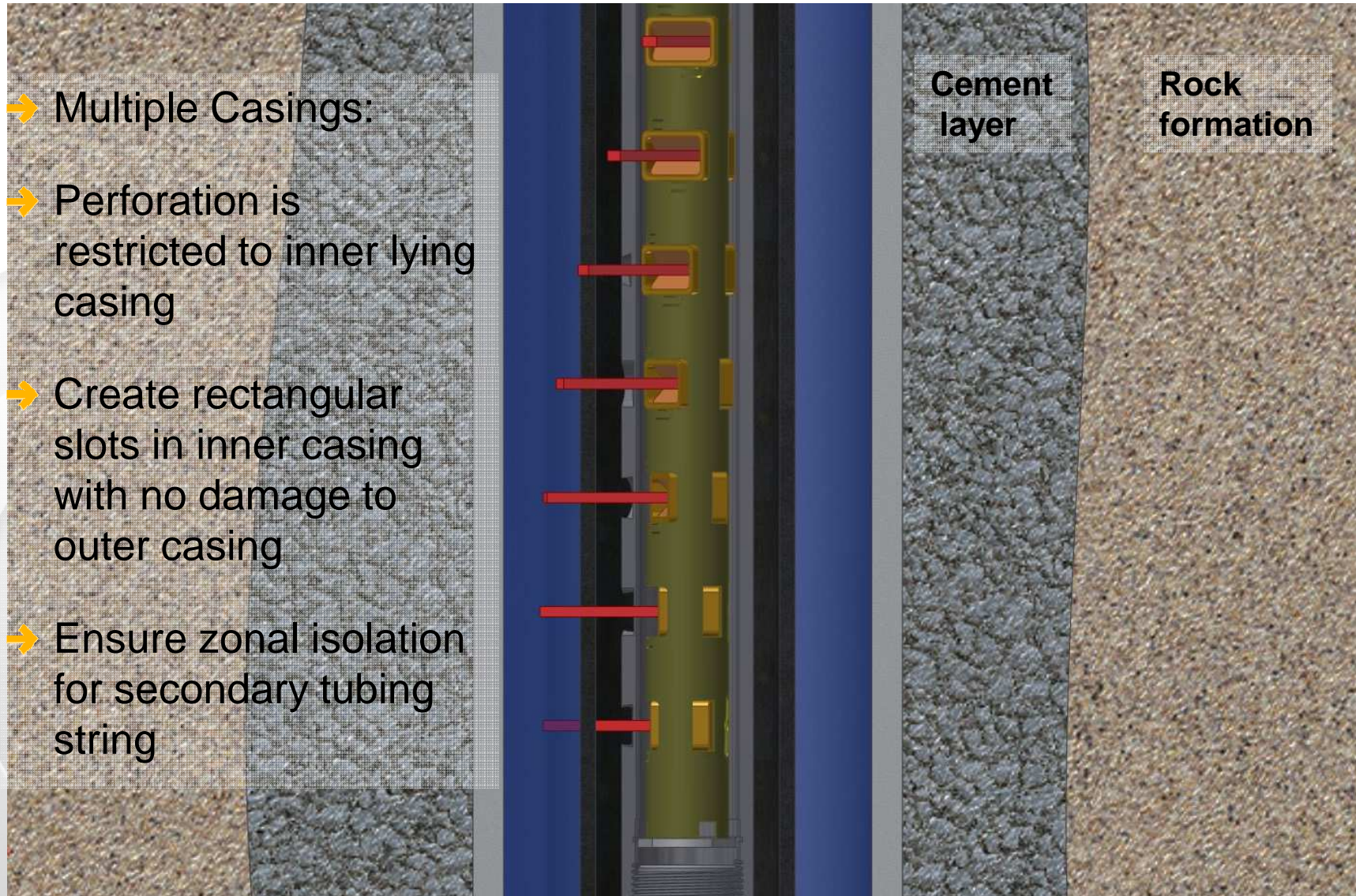
Applications of Cement Squeezing

- 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

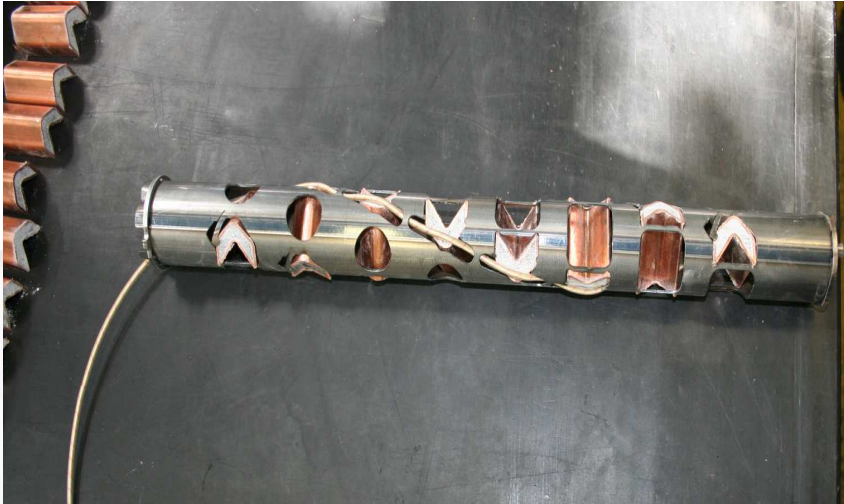


Applications of Cement Squeezing

- 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



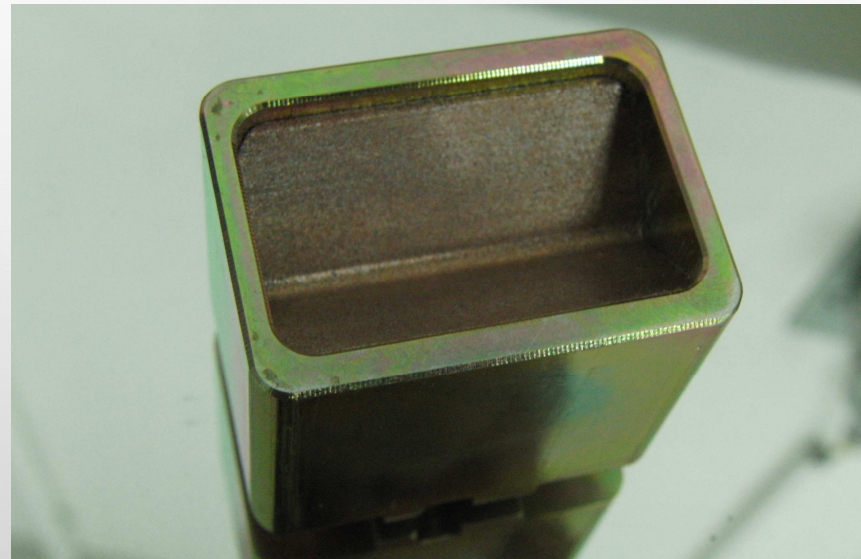
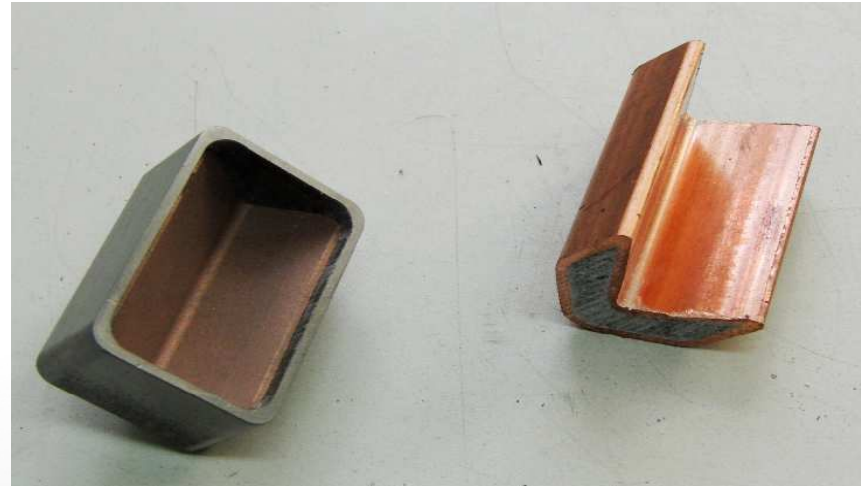
2. Perforation System Design



- 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

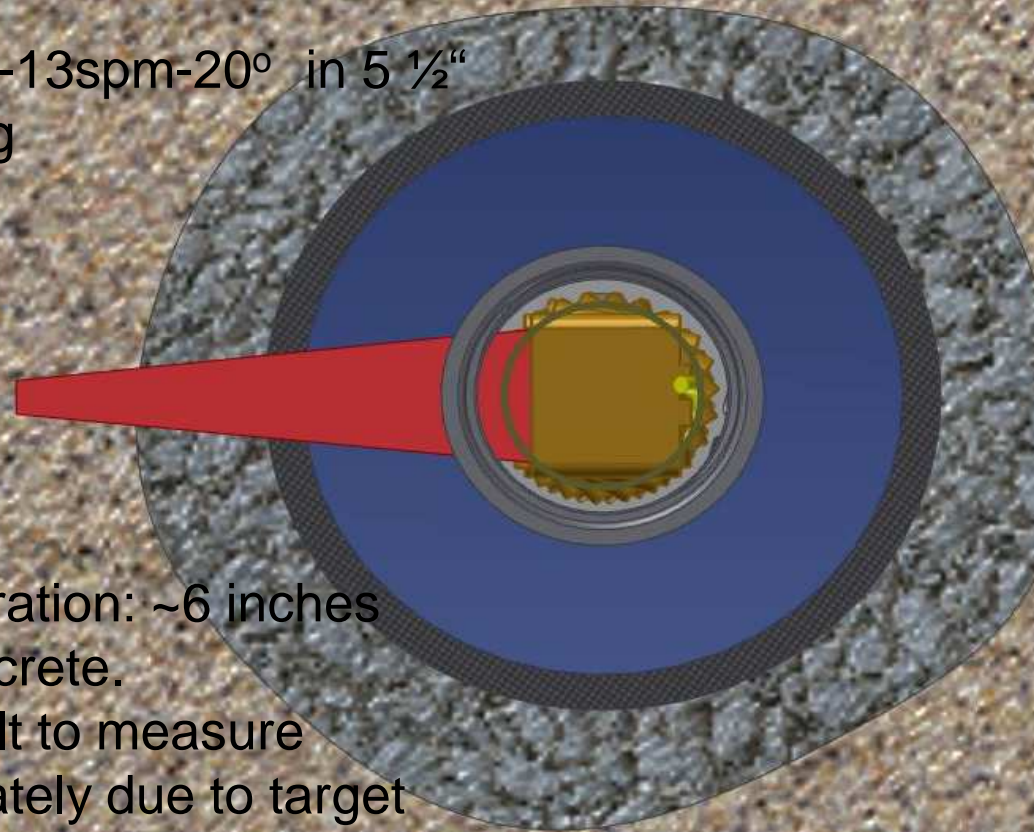


Perforation: single shot tests

→ 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



Casing Coupon

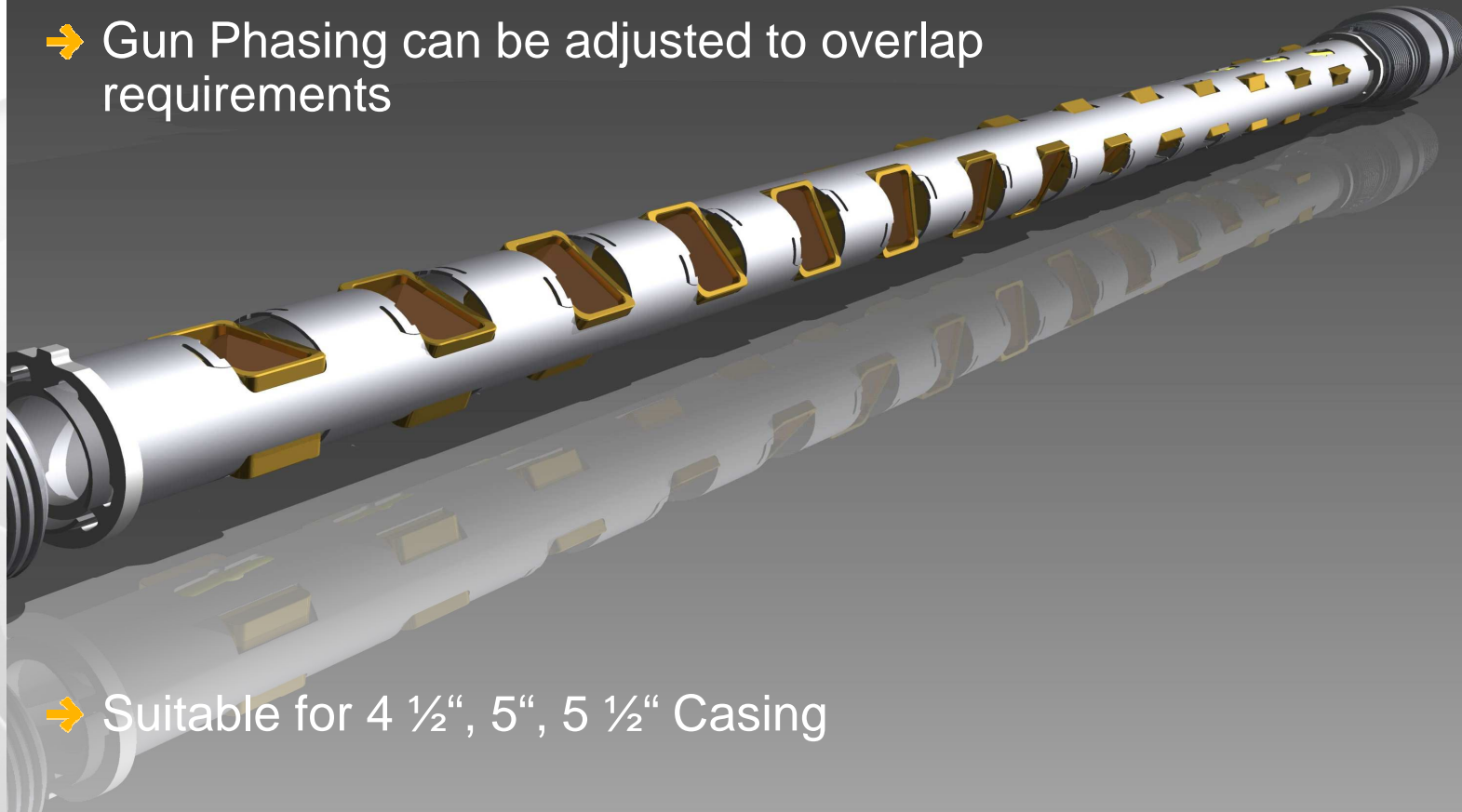


Perforation Gun Design

→ 3 3/8"- 4spf - 20° Slotted Charge Gun System

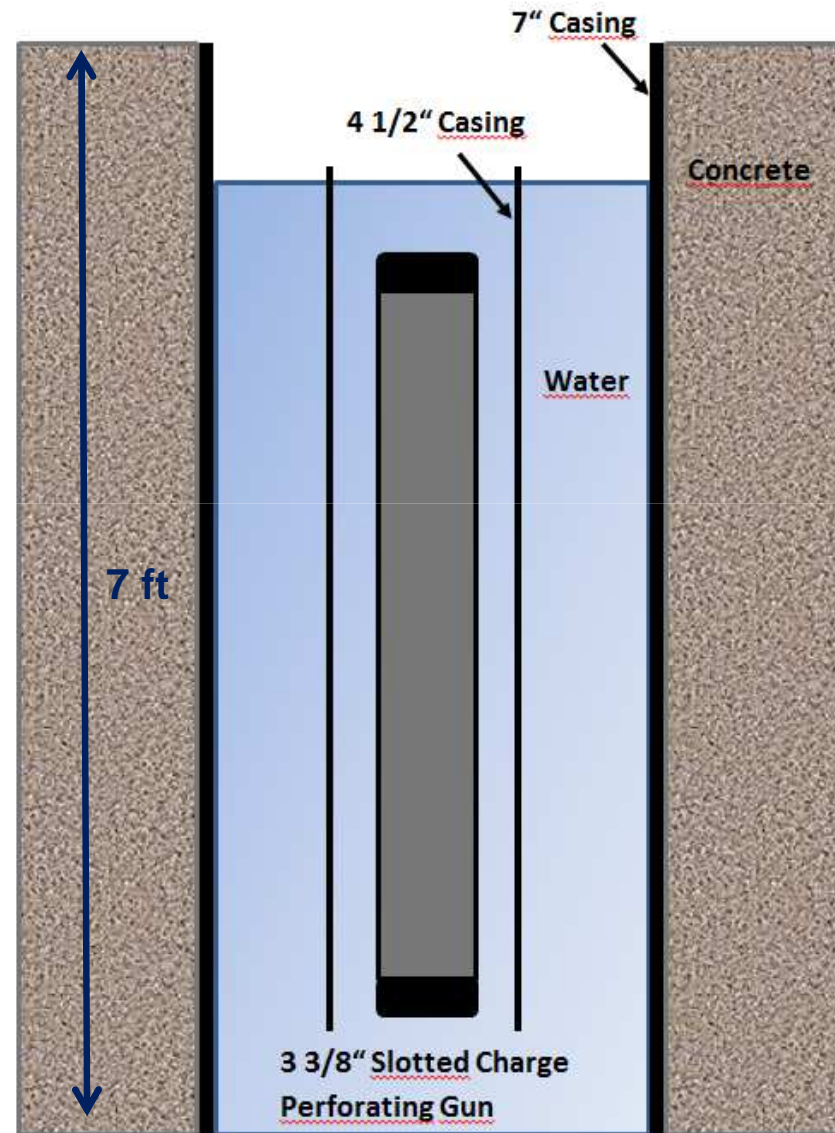
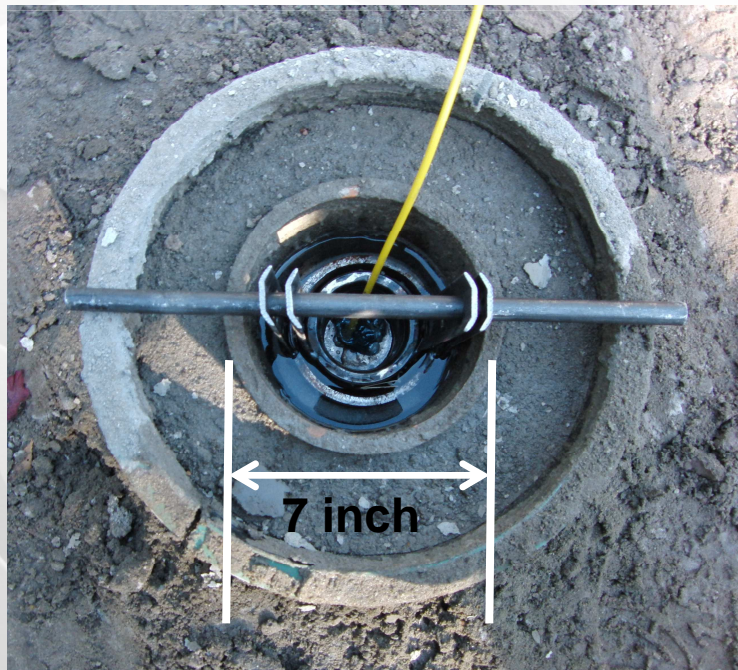
→ Gun Phasing can be adjusted to overlap requirements

→ Suitable for 4 1/2", 5", 5 1/2" Casing

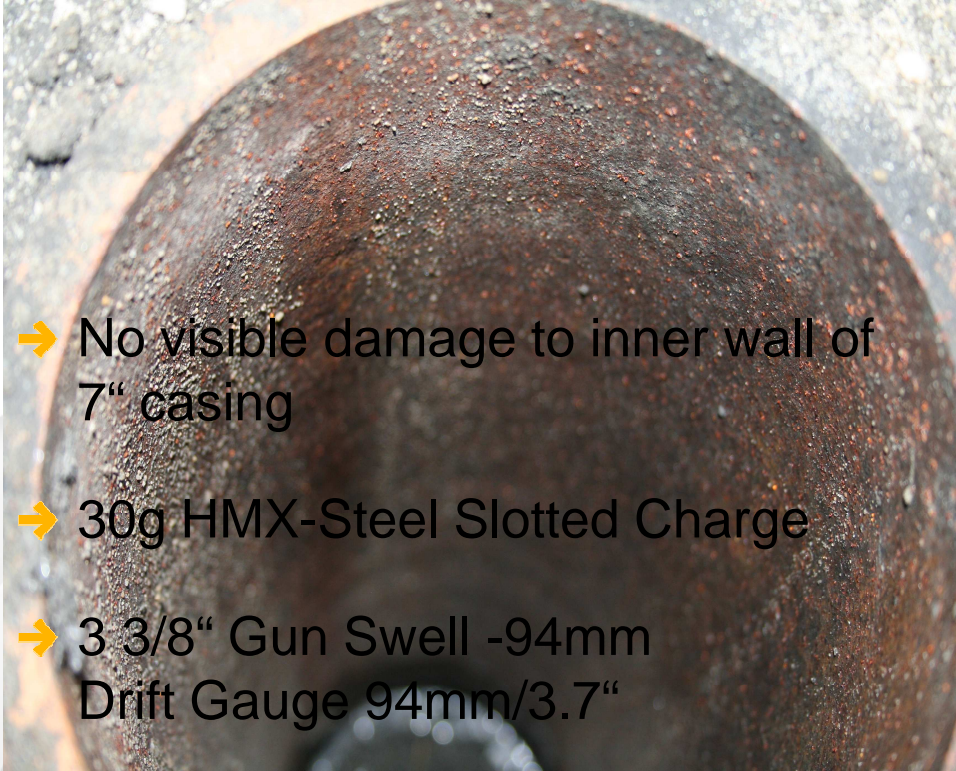


3. Testing

- 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



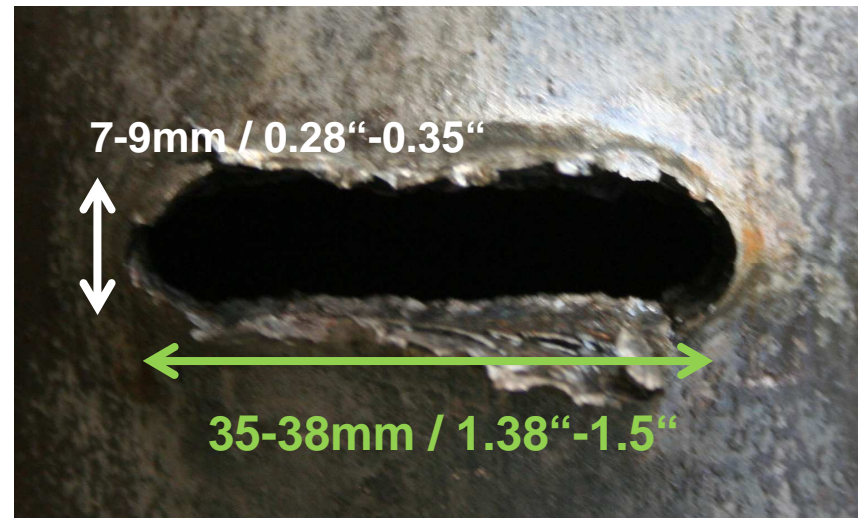
Testing

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- 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



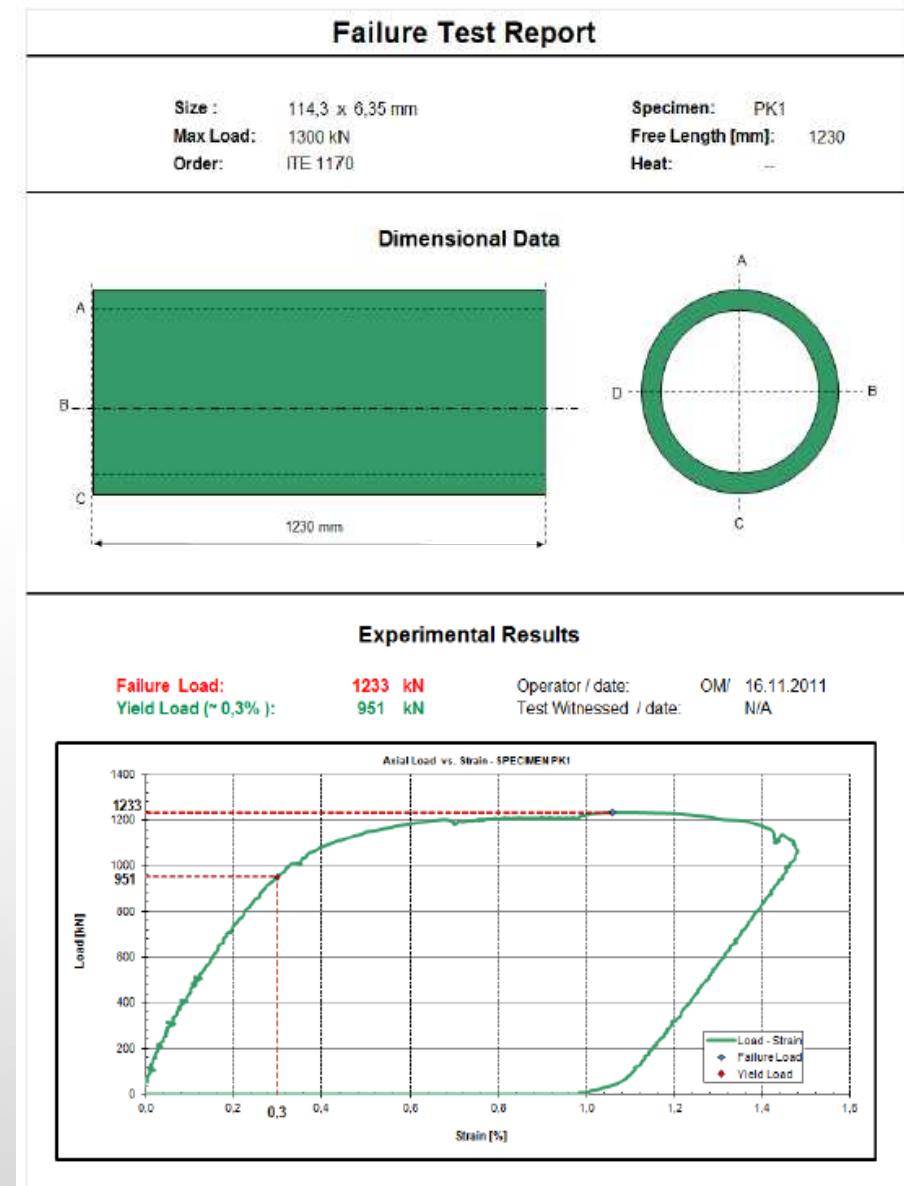
Properties and condition of casing pipe after perforation: Yield Strength Testing

- 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 ($\sim 0.45\text{in}^2$), short guns
 - Bypass stuck bridge plug in tail pipes
 - Bypass closed formation isolation valves
- Frac Applications: Horizontal Shale Gas

Thank you for your attention.

