Cost reductions for well abandonment procedures by employing an alternative perforation method using a slotted charge design for cement squeeze applications.

DynaEnergetics
Presenter Liam McNelis

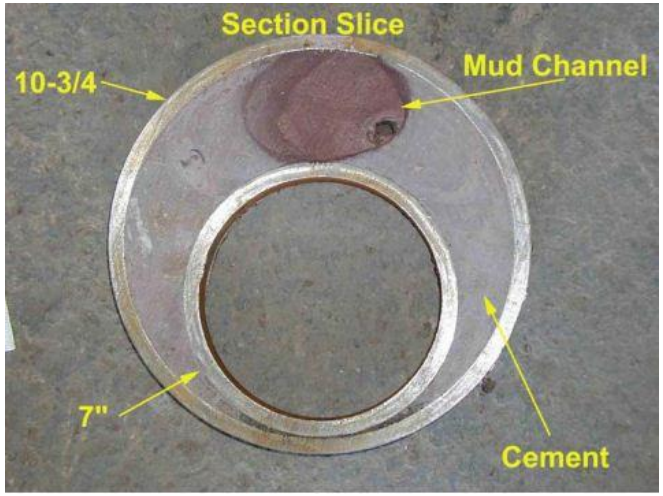
Overview

- Current Situation & Challenges for Well Abandonment
- Introduction of a new concept
- Development steps and testing of the new perforating technology
- Areas of applications
- Field Testing

Challenges in Permanent Sealing and Abandonment of Wells

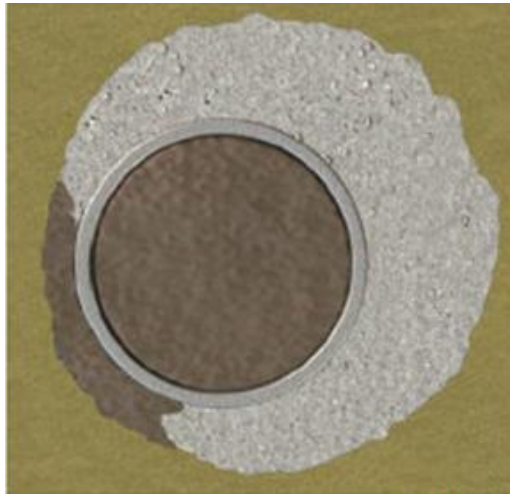
- Poorly executed cementation operations can result in partial cementation behind the casing
- Unwanted vertical channels or voids can occur
- These channels can lead to fluid or gas migration behind the casing pipe to the surface
- A vertical sealing mechansim between zones or a reliable sealing of the annulis cannot be acheived.

Examples of Bad Cementation



Channel in Drilling Fluid/Mud

Gas Channels



Partial Cementation

Challenges in Permanent Sealing and Abandonment of Wells

Status quo

- Perforate or Section-Mill the area to be sealed
- Cement Squeeze oder new cement to hopefully create an impermeable barrier
- The perforation does not allows hit the voids or vertical channels. Section milling is very time consuming and expensive.

Ideal Scenario

- Quick and efficient perforations which will hit all vertical channells or voids
- The cement squeeze successfully achieves a new impermeable barrier

➢ This results in low abandonement costs

➢ Increased reliability in vertically sealing off zones permanently





Conventional Shaped Charge Types

Deep Penetrating (DP)

Good Hole (GH)

Big Hole (BH)

Images from Section IV rock targets

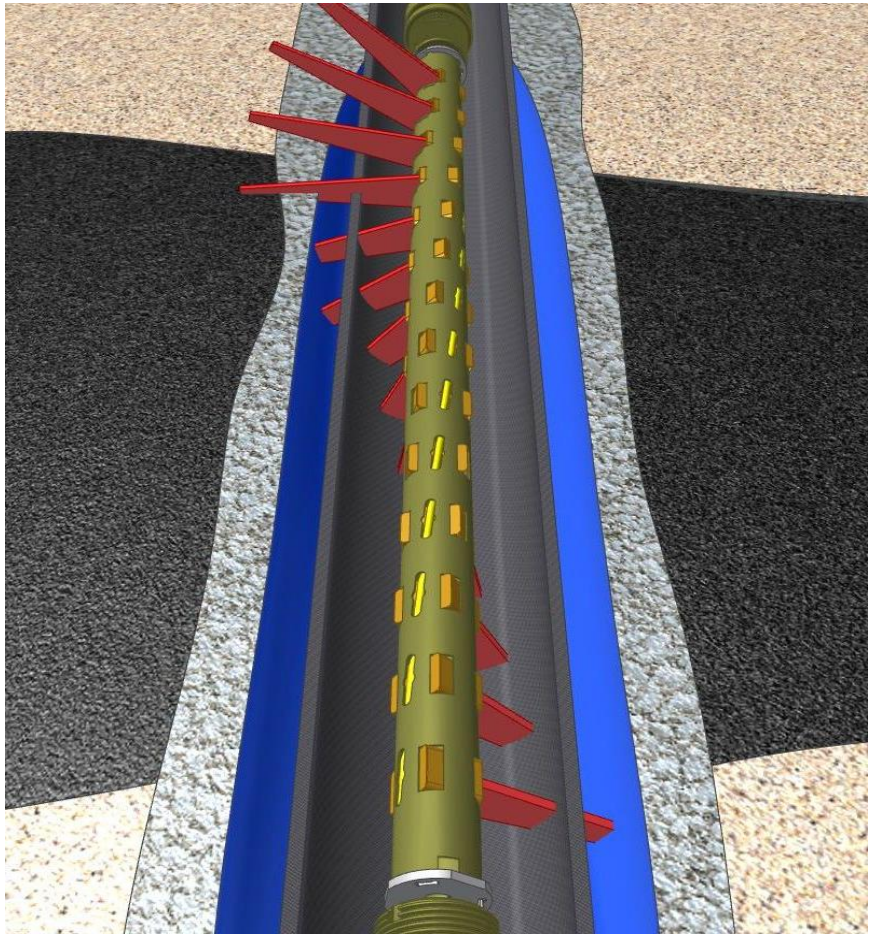
Ideal perforating scenario for a cement squeeze operation

Overlaping slots provides an uninterrupted coverage of the area to be sealed-off

A complete 360° helix allows entry to the annulus between two casings or between the pipe and formation

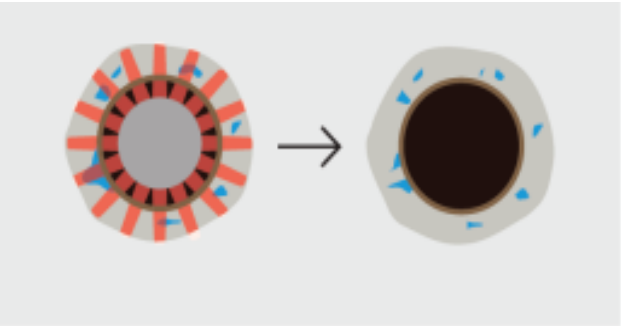
Reliable access to all voids or cavities in the previously-cemented annulas

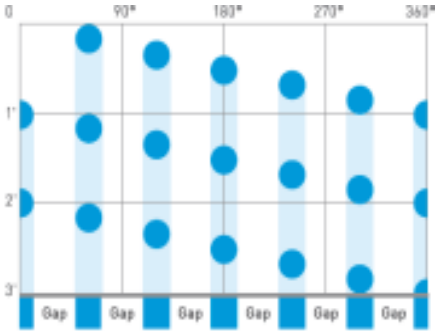
Complete pressure isolation between zones or intervals



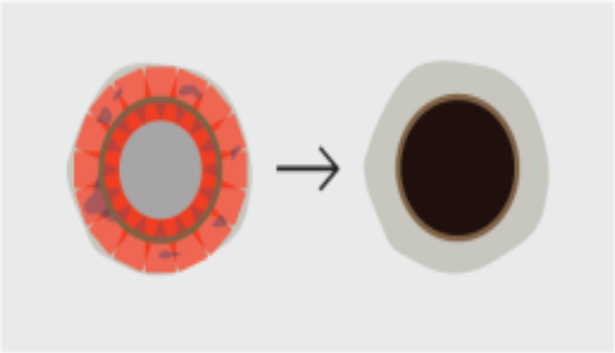
How to achieve the ideal perforating scenario for a cement squeeze operation

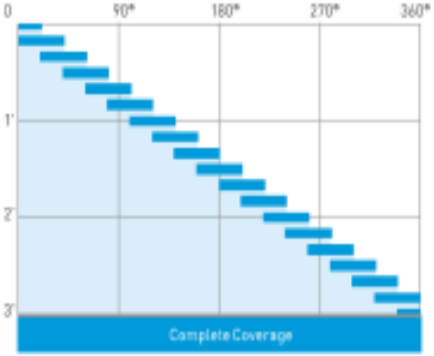
- Conventional DP, Puncher or BH Perforators cannot always hit the vertical voids – even when using a HSD gun.





- Create a new perforator type which guarantees an overlap from one hole to the next. Low phasing angle configuration acheives a full converage.

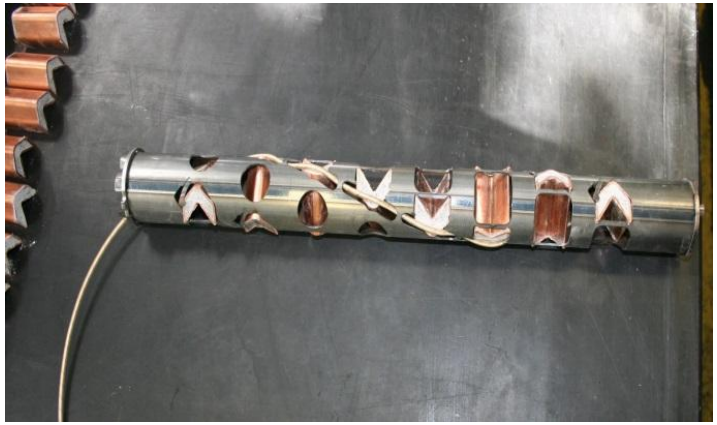


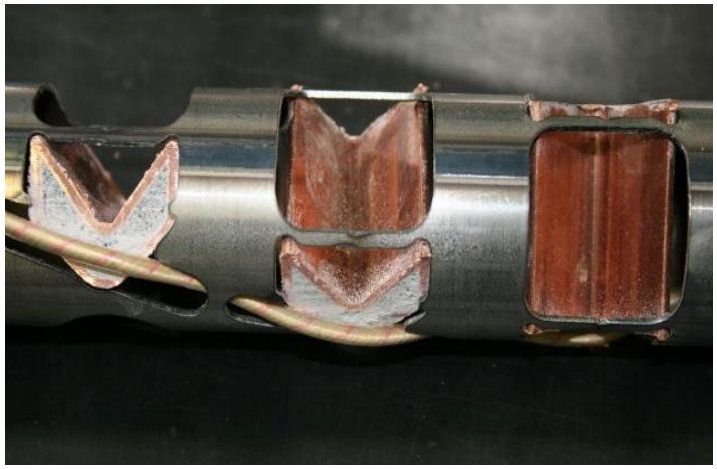


Back to the beginning: Slotted Charge development and testing

Original idea was to use conventional linear-cutters which were cut into segment which fit a gun size

Testing soon confirmed that the cutting performance was not sufficent for the casing and tubing pipes in the oilfield industry.



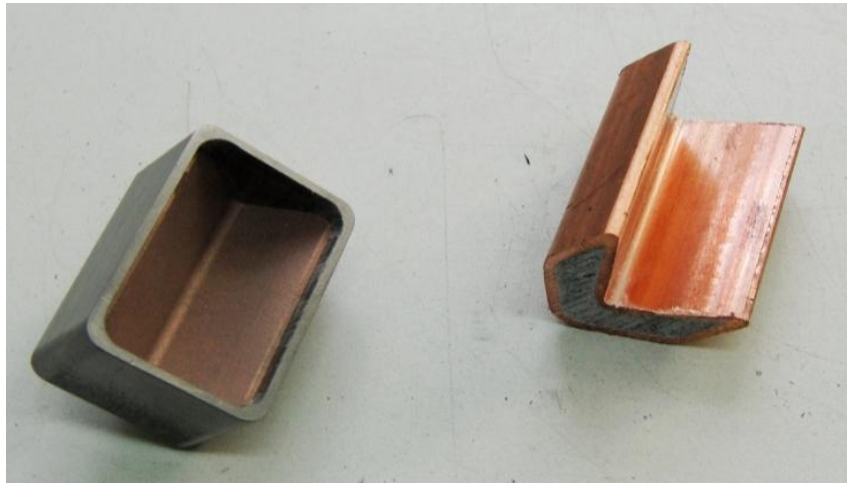


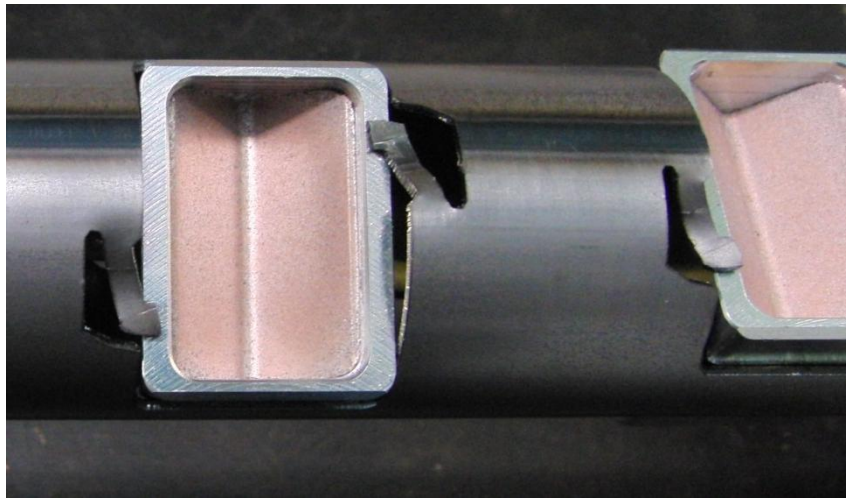
Back to the beginning: Slotted Charge development and testing

Performance improvement by design a rectangular charge case to house the explosives

Performance enhancement by employing powdered metal liners rather than drawn sheet metals.

Initiation point in the center of the charge rather than on the side



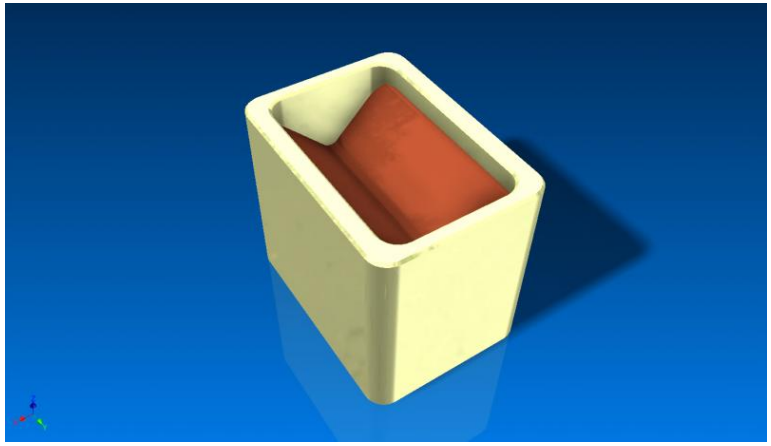


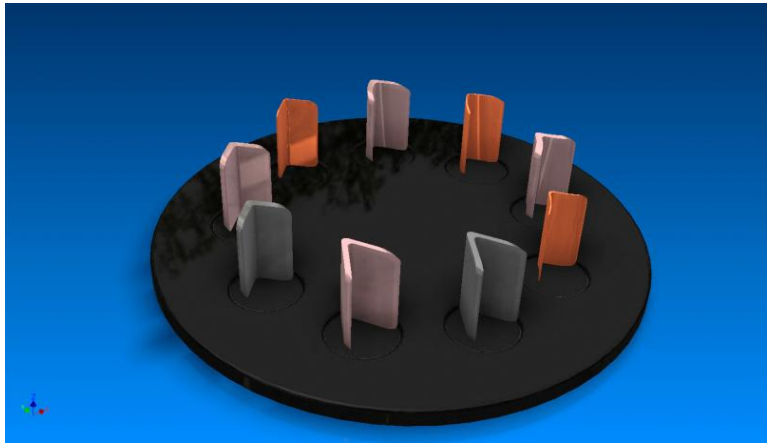
Slotted Charge- development and testing

Further performance enhancement through the Liner geometry and use of FEM

2nd generation slotted charges have improved

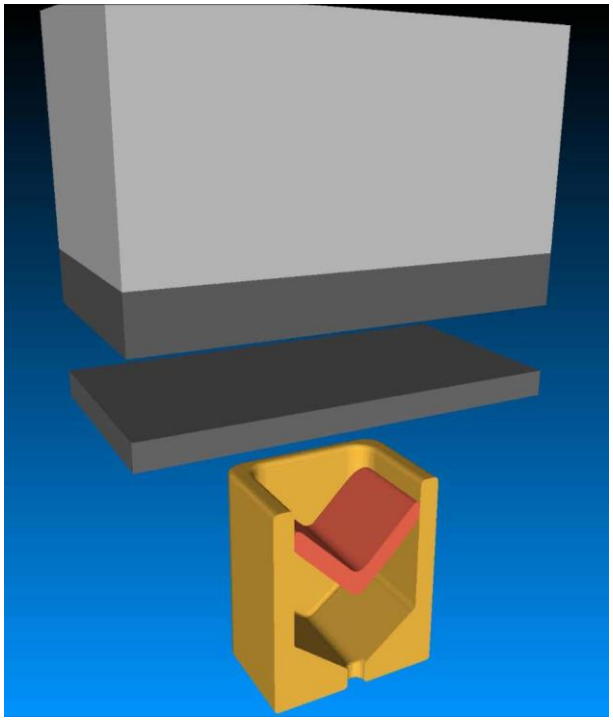
- Housing geometry
- Liner Optimization
- Liner geometry
- Liner Blends

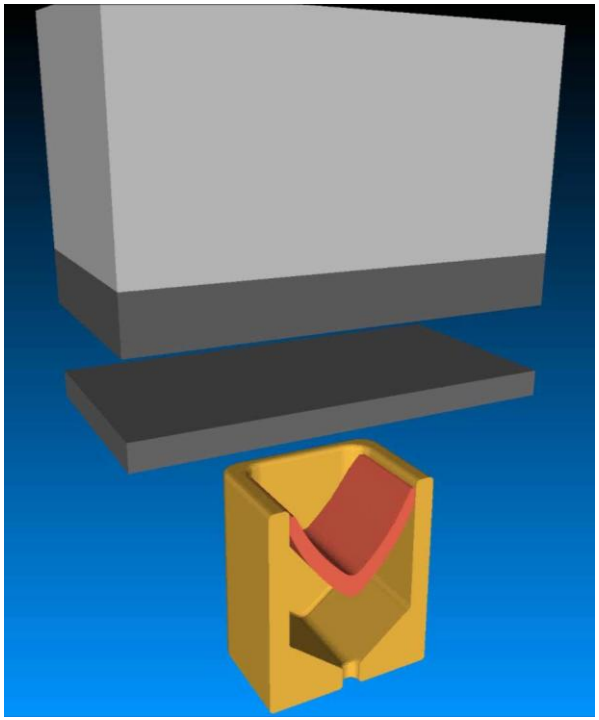




Slotted Charge- development and testing

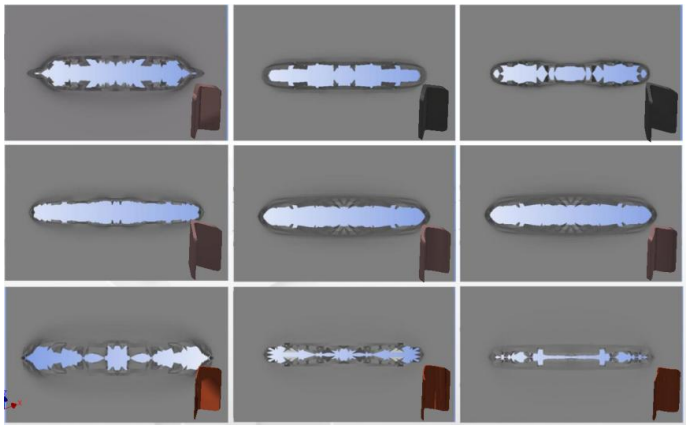
Examples of two FEM Simulation with an identical Liner mixture but different Liner shape.

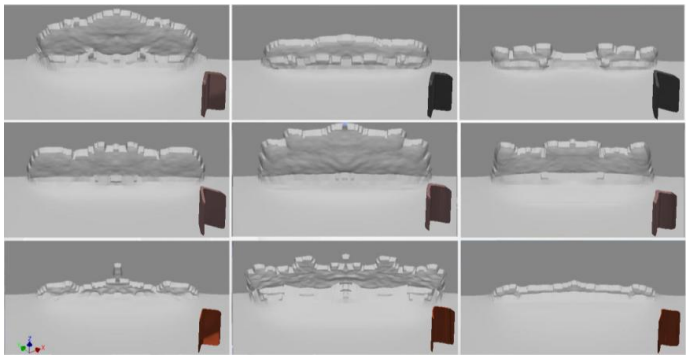


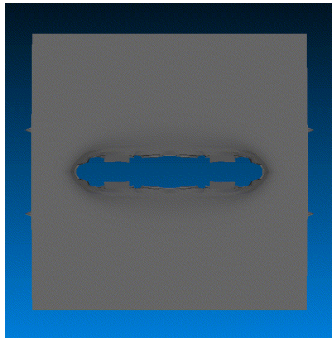


Slotted Charge development and testing

- Critical Outcome of designs from Simulation Modelling for Cement Squeeze applications
- Casing Opening – Slot size
- Hardware configuration
- Penetration into cement or formation behind



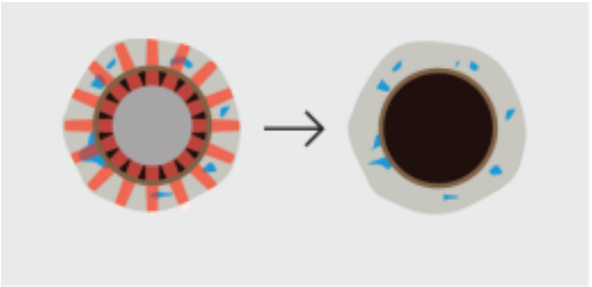


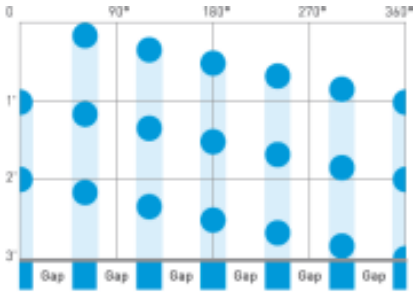


Reliable match between modelling and practical testing

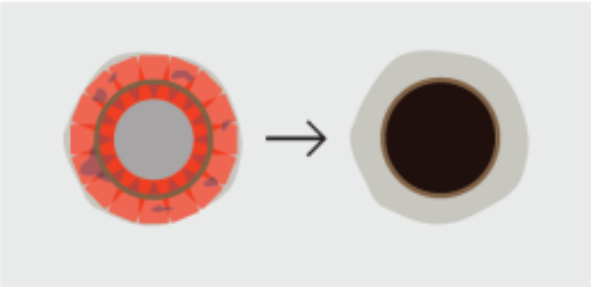
Achieving the ideal perforating scenario for cement squeeze

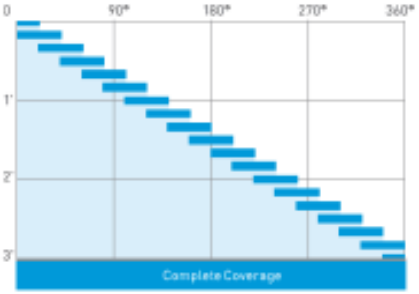
Conventional DP, Puncher or BH Perforators





Slotted Charge Perforatoren

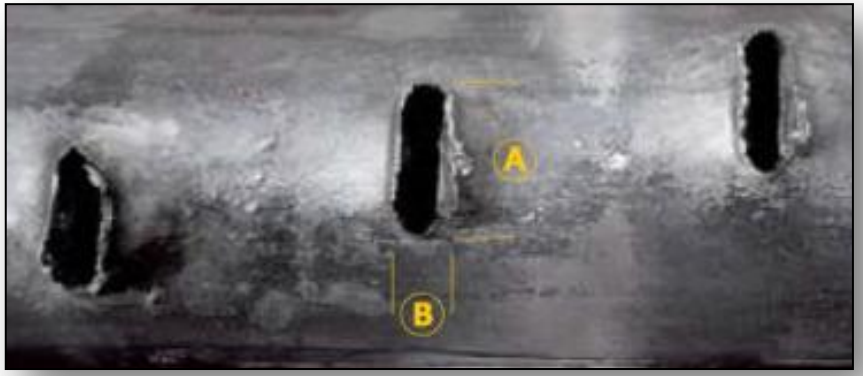




Casing perforated with DynaSlot achieves full coverage through the overlap

Examples of Slotted Charge geometries in casing and tubing

- 86mm (3 3/8”) Perforating Gun
- 13spm (4spf), 20º Phasing
- 360º coverage in casing with 50% slot overlap in a 4 ½” casing.
- System suitable for 4 ½(114mm) to 5 ½”(140mm) tubing sizes
- Slotted Charge variants depending on application
    - Puncher (limited entry)
    - DP (enhanced penetration)



A: 35-38mm (1,38”-1,50”)
B: 7-9mm (0,28”-0,35”)

Examples of 4 ½” Casing

Gun Swell (Max Gun OD after shot)
95 - 96 mm

Examples of slotted charge geometries in casing and Tubing
Downhole restrictions for heavy wall casing

Slotted Charge application – client had concerns due to downhole restriction of 96mm (heavier walled P110 casing)

Switched to 79mm (3 1/8”) Perforation assembly

- Reduced shot density - 6spm (2spf), 20º Phase or 40º Phase
- 360º coverage with ~40% overlap
- Clients successfully deployed the system and sealed a gas well

A: 30-33mm (1,18”-1,30”)
B: 6-7mm (0,24”-0,28”)
>200mm^2 of AOF per shot

In a P110 4 ½” Casing
Gun Swell 90mm (Max Gun OD after shot)

Examples of Slotted charge geometries in larger casing sizes 7” – 9 5/8”

- Slotted charge for 7”- 7 5/8” casing
- 125mm System currently in field trial phase
  - 13 spm (4spf), 22,5º Phase
  - 360º Coverage mit 50% overlap
  - 61g HMX/St Sotted Charge variants depending on application
  - Puncher (limited entry)
  - DP (enhanced penetration)

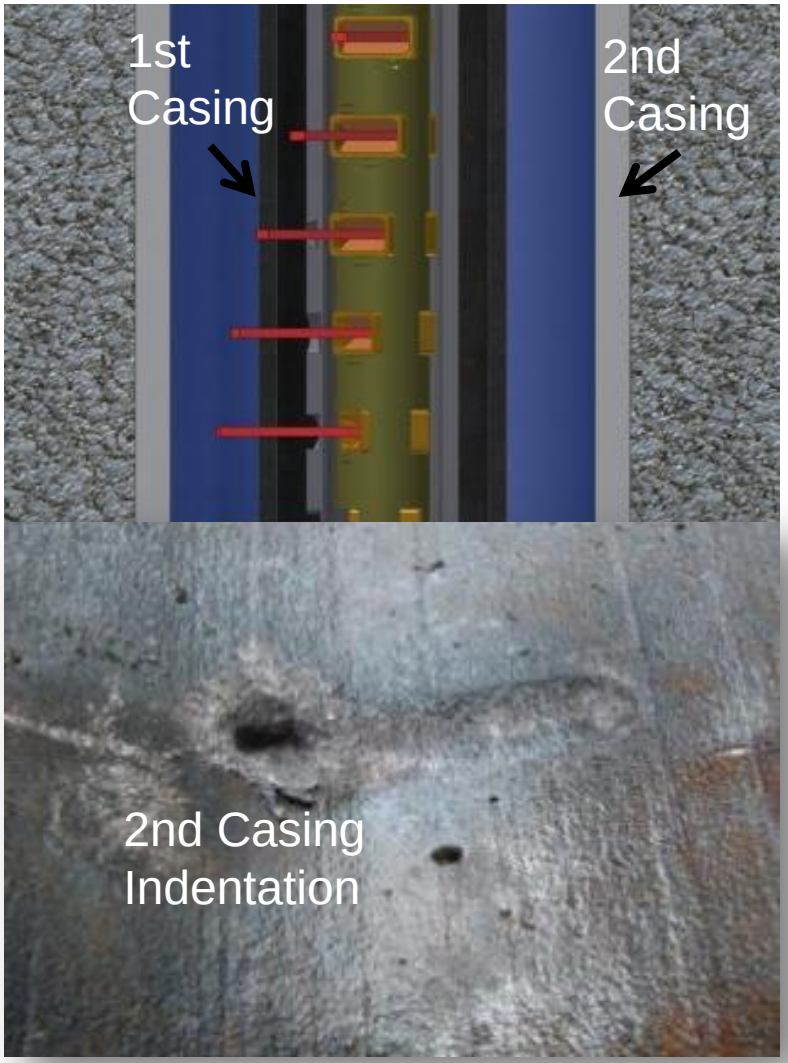
In 7” L-80 Casing (non-consolidated
Gun Swell (Max Gun OD after shot) 135 mm

Slots in confined casing do not split open

61g Slotted Charge puncher for dual casing scenarios

Dual or multiple Casing scenarios:

- Perforation must be limited to 1st Casing
- Produce a clean an open slot in the inner casing without damaging the outer casing
- Indentations can occure without sacrificing the pressure integrity



61g Slotted Charge puncher for dual casing scenarios – Client specific test.

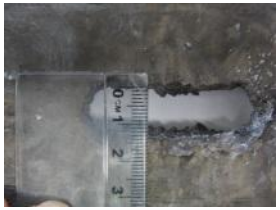
7“ P110 Casing 35 lbs/ft cemented (off-center) inside a 9 5/8“ outer casing

Perforated with 61g HMX/St slotted charge in a 125mm-4spf(13spm) 22.5^{o} Phasing gun

Inner 7“ casing is perforated with slots
Cement was cracked or shattered in places
Outer casing shows indentations on the low side (thin cement layer) but no damage

Examples of Slotted charge geometries in larger casing sizes 7” – 9 5/8”

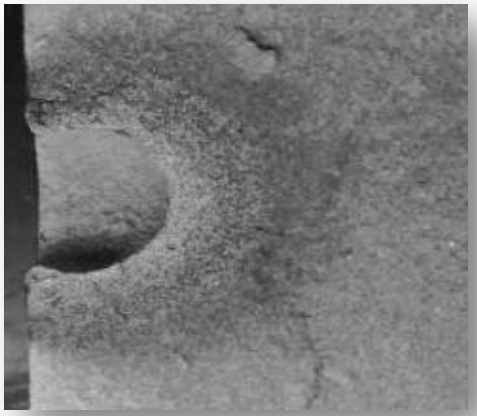
- 178mm (7”) System in Fieldtrial phase
- 26 spm (8spf), 22.5 º Phasing (Double-helix Back to Back)
- 360º coverage. Coverage depends on casing size
- Enhanced Penetration
- Puncher Version

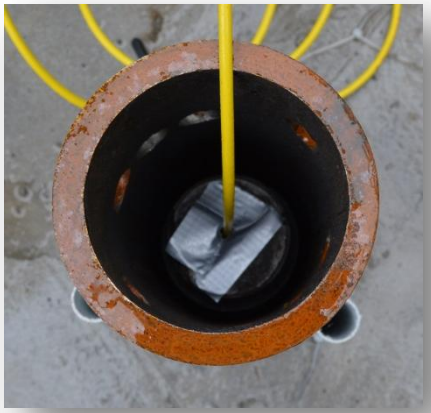


Slot Width: ca. 47-50mm (ca. 1,85”)
Height 8-10mm (ca. 0,4”) in 9 5/8” Casing
Gun Swell (Max Gun OD after shot) 185 mm

Testing of Slotted Charge for Enhanced Penetration

- Clean rectangular slot in Casing
- Large area open to flow with overlapping
- Penetration into cement and rock formation
- Vertical channel are hit (through simulation test usng red dye)





An additional type of shaped charge alongside conventional perforators

Deep Penetrating (DP)

Good Hole (GH)

Big Hole (BH)

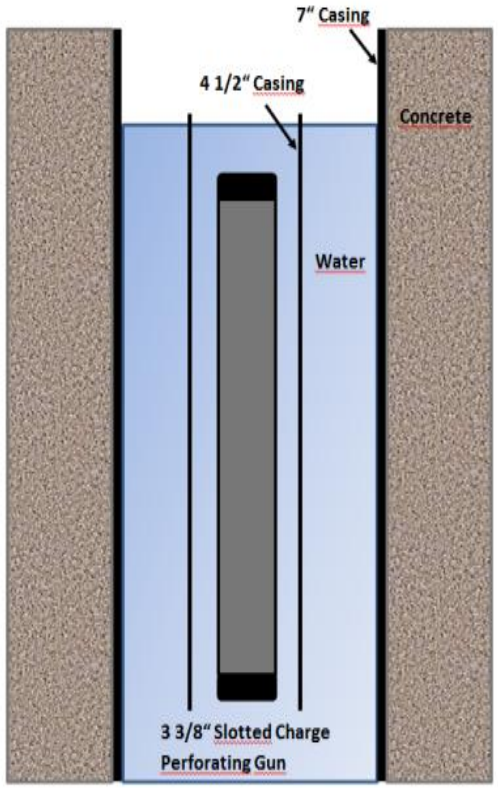
DynaSlot

Testing for limited Entry of perforation and Casing Integrity Post-Perforation

- Test Objective
  - Confirm the limited entry of the Slotted Charge puncher to secondary casing.
  - Verify the Casings‘ mechanical stability after the perforation.
- Gun System 3 3/8“-4spf(13psm)-20°
- 4 1/2“ (11.6 lbs/ft) Casing in 7“ (32lbs/ft) L-80 Casing

✓No visable damage to the inner surface of the 7“ casing

✓Sufficient slott size and overlap was verified



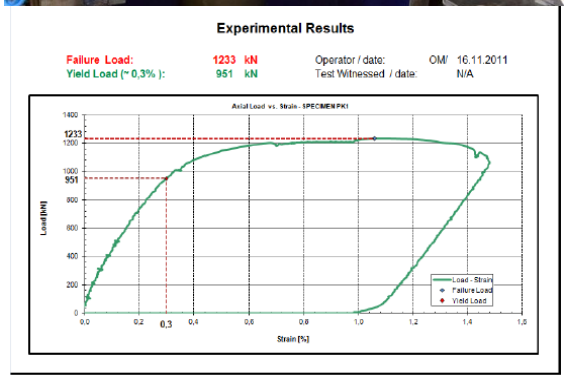
Testing of mechanical integrity of casing after slotted perforation

Yield & UTS testing of perforated Casing at the ITE, TU-Clausthal, Germany

- Nominal Casing Yield Strength: 80,000psi
- Nominal Casing Tensile Strength: 95,000psi
- Measured Yield Strength 68,087 psi
- Measured UTS (Tensile Strength) 84,508 psi

➢Reduction in Yield strength in Casing ~15%

➢ReductionTensile Strength in Casing ~11%



Field Trial NorthSea- Client specific testing with 3 3/8” Slotted Charge Puncher

3 3/8” DynaSlot in 5 ½” 13Cr Tubing in 9 5/8” Casing

Indentations were evident in outer 9 5/8”. This casing was pressure tested at clients location to confirm pressure integrity.

Experiences in the field

Over 100 Deployments with the 3 3/8“ system

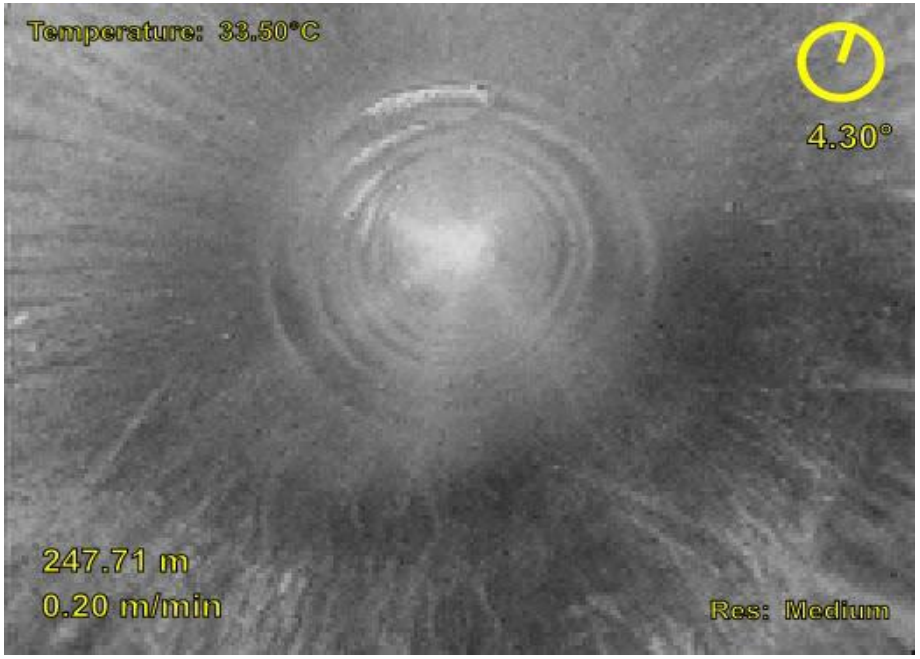
- Main applications has been in Canada for Surface Casing Vent Flow (SCVF) and gas migration since 2013.

- First deployments in USA began in 2016

- Sucessfull deployment for major operator in China in combination with a new synthethic resin in 2016.

- First deployment in 2015 in the North Sea UK region accordance to the previously shown configuration of punching slots in 5 ½“ tubing inside a 9 5/8“ casing.

Experiences in the field



Спасибо

Thank you - Vielen dank

Questions?

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