FRACTURE INITIATION: THE IMPORTANCE OF PERFORATIONS

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Most of Today’s Perforating Systems are Based Upon Historic Natural Completion Designs

1. Focused upon deep penetration, and inflow from all directions – especially the Perf Design Engineers.
2. Big holes would be good.
3. Typically, a spiral pattern so larger charges could be utilized.
4. Hole size variation in the casing has no significant effect on inflow/production.
What do we actually get?

- Nearwellbore complexity can be significant and problematic
Phasing Distribution

Which design would be better for fracture initiation and reducing tortuosity?
Perforation Types

- Sandstone
- Carbonate
- Shale

FRAIQIQ
Perforation Damage
Perforation Damage

- Conventional Shaped charge jet is designed to provide penetration.
- Normally, diameter of jet reduces at higher clearances.
  - High side of the hole has a smaller entry hole diameter.

![Diagram of perforation damage with zones labeled: Plastically Compacted Zone, Reduced Permeability Zone, Perforation Tunnel, Pulverized Compacted Zone.]

**CONVENTIONAL PERFORATING**

**CRUSHED ZONE**

**COMPACTED FILL**
Lab Testing

Bullet-guns
• Avoid plastic compaction and may generate fracturing and perm enhancement

Hydrojetting
• Abrasive sand-jetting can cut deep, efficient holes with minimal mechanical damage
Field Data MWX

- **Casing**
- **Perforation**
- **Tip of Perforation**
- **High Stress Halo**
- **Fracture Surface (Dye)**

Warpinski, 1980

- **Dyed rock**
- **Perforation tunnel**
- **Perforation in cement sheath**

Warpinski, 1980
Fractured with a 32g jet charge, injected with dye and then mined back.
Limited-Entry
Perforation Friction

- Correct number & size of perfs can be estimated
- Pressure drop should be at least 100-200 psi more than the confining stress between zones
- Depends on coefficient of discharge ($C_d$)
  - Jet perfs 0.75; Bullets: 0.82
  - higher value indicates more efficient perf (as it erodes less of an issue)

Bernoulli Eqn.

$$\Delta P_{pf} = \frac{0.2369 Q^2 D}{C_D N^2 d^4_p}$$

where:
- $\Delta P_{pf}$ = pressure drop across the orifice/perf (psi)
- $Q$ = Injection rate (bbl/min)
- $D$ = Fluid/slurry density (lb/gal)
- $C$ = Discharge coefficient
- $N$ = Number of perforations
- $d_p$ = orifice/perforation diameter (in)
Limited Entry

- Perforation entry hole is used as a choke to apply back pressure
- Choked flow through a limited perforations
- Backpressure mitigates the impact of variable inter-zonal fracture propagation pressure
- Treatment distribution among zones can be controlled (to a degree), especially at the beginning

Dave Cramer (OGJ, 1987) & IPS-10-002 Perforating for Controlled Hydraulic Fracturing Presentation 2010
Step Down Test
Perforation Friction Dominated Regime

Step Down Test
Near-Wellbore Friction Dominated Regime
Tortuosity

- Stress halo around perf
- Flow around cement micro-annulus
- Perforation interference
- Narrow fracture width
- Fracture turning and branching (multiples)
- Off-vertical fractures
- Pulverized cement debris
- Charge debris
- Leakoff into drilling and perf induced fracs
Perforation Toolbox
Options around hole size in high strength casings used for today’s stimulations.

1. **Standard Charge Technology**
2. **Clean Perforation Technology (CPT)**
3. **Consistent Entry hole Limited Penetration Technology (CLPT)**
4. **Convergent/Planar Systems (PCLPT)**
5. **Angled Diversion Technology (ACLPT)**
CPT – Clean Perforation
More than 12,000 CPT test shots have been made using a variety of rocks (sandstones, carbonate, and others) under a wide range of stress conditions.

3,500 psi Castlegate

Castlegate – Stressed

Parker County 10,000 psi +
CLPT – Consistent Hole, Limited Penetration
DPT Hole Size

• Entrance hole dia. (EHD)
  • Varies widely with clearance
  • Published data is **averaged** from API testing in lower grade and weight casing

• Penetration
  • Variation in clearance also has an impact on penetration

Average EHD = 0.36”
CLPT Overview

- **CONSISTENT ENTRY HOLE** diameter and **LIMITED PENETRATION** at all phases
- Consistent even though the clearance between the carrier and inner wall of the casing varies

![Diagram showing entry hole and clearance](image)

3-3/8 in. carrier in 5-1/2 in. 23lb/ft casing

0.40 in. – all phases/clearances
PCLPT – Planar Consistent Hole Limited Penetration
PCLPT Overview

• Cluster placement of fracs possible with short separation
• Engineered initiation for precise placement of fracs
• Every perforation is able to feed more transverse fracture development
High stress anisotropy transverse fracs

- Fracture initiation points are on the same plane near wellbore
- Fracture growth converges away from the near wellbore
- Every perforation is able to feed fracture development
- Converging system allows strategic arrangement of tip fractures
ACLPT – Angled Consistent Limited Penetration
Angled Entry Hole Perforation

- Evolution of the system combines aspects of the Radial Plane and Consistent perforating systems
- Provides an “off ramp” flow path for more efficient diversion of proppant
- Perforating tunnels tilted in direction of fluid flow
- Constant entry hole size in eccentered conditions
- Decreased tortuosity because of angled “stress cage”
Conclusions
The future:
• Industry going in direction of ‘Perforating for Performance, rather than Penetration’
• Better understanding of perforating damage
• Better understanding of the amount of tunnel ABLE TO FLOW

Fracture initiation now possible with consistent hole and limited-entry/angled penetration
1. Improve options for tailor-made design considerations
2. Minimize induced stress cage issues
3. Simulation design and selection improving