Flow Through Perforating System

A Practical Approach to Game Changing Technology
Discussion Topics

- Perforating system optimization philosophy
- Typical perforating methods and challenges
- Flow through gun system solution
- System requirements, drivers and challenges
- System testing
- Beta Test Results
- Path Forward
Perforating Systems Design and Selection

- Optimized vs completion type and conditions
- Optimized for maximum productivity blended with operational concerns
- Selected to deploy gun system and clean-up with balanced risk and cost minimization

Gun Systems
- Guns
- Charges
- HE

Clean Up
- Dyn UB
- Stat UB
- Propellant

Deployment
- TCP
- SL
- WL

Evaluation and modeling software
Standard Tubing Conveyed Perforating (TCP) Methods

Shoot and Drop*
- Optimum method for productivity
- However, requires drilling extra rathole (time and cost)
- Not viable in
  - horizontal wells
  - long intervals
  - zones just above pressure transitions
  - uphole recompletes with tight spacing

*Permanent

Guns are run below the final completion assembly, and after detonation fall into the rathole to allow production

Shoot and Pull
- Extra rig time to pull assembly
- Formation damage from fluid loss and LCM’s (reduced productivity)
- Increased well control risk
- Higher completion fluid costs

If rathole isn’t available to accept spent guns, assembly must be pulled prior to running final completion assembly
Variations in Field Conditions versus Lab Conditions

**Kill Weight Fluids and LCM Challenges**
- Completion fluid filtration
- Wellbore clean-up
- Rig mixing capabilities
- Pill storage concerns
- Pill agitation
- High temperature challenges
Flow-Through System Benefits

- Allows installation of entire completion prior to perforating interval(s)
- Eliminates cost and time associated with drilling rathole
- Eliminates production impairment from fluid loss and LCM damage
- Eliminates cost and risk of live well deployment (and undeployment)
- Can reduce completion fluid costs by eliminating high density brines in high pressure wells
- Radically changes completion procedures (and cost) on many long intervals in subsea environments

Guns and firing system internals “disappear” to allow unrestricted flow of production without pulling guns
Perforating System Requirements and Drivers

Standard Requirements
• Charge performance
• Gun survival
• Safety
• Expelled debris
• Field “friendliness”
• Clean-up options

Permanent Completion Drivers
• Initiation reliability
• Complete Detonation

Flow-Through System Drivers
• Internal gun debris
• Full opening conduit
Development and Testing Process

Overall Design and Testing Approach

- Bench testing
- Lab / range testing
- Design/Operations Failure Mode and Effect Analysis
- Stack-up testing
- Controlled field test
Basic System Layout and Features

- **Multi-cycle valve** for packer setting and firing initiation (included mechanical contingency opening)
- **Gun valve** isolates guns from wellbore fluid (includes mechanical contingency firing initiation)
- Redundant, hydraulic **firing head** with pyrotechnic time delays
- Gun system
  - Conventional booster to booster transfer
  - Full opening tandems
  - Charge tube
  - Retention hardware
## Lab and Ballistics Range Testing

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<td>Firing system drop test (API RP67)</td>
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<td>Horizontal (ambient) and vertical (ambient and 350F) drop testing, up to 4’</td>
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<td><strong>Productivity</strong></td>
<td>High temp charge tube debris testing: return perm, sizing, composition, and solubility analysis</td>
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Section IV Testing
Controlled Field Test

Well Environment
- Openhole water injector (carbonate)
- 7" casing, 6" openhole
- ~2,500 psi BHP / ~140F BHT
- ~5200' TVD (vertical)
- 8.5 PPG freshwater completion fluid

Perforating System
- Shoot and pull application
- Retrievable hook-wall packer
- Spacer tubing
- Multi-cycle initiation valve
- Gun valve (fluid barrier)
- Redundant hydraulic firing head
- Gun system (4-1/2")
  - 28' blank safety spacer (2 guns)
  - 42' loaded guns (5 SPF, 39grm deep penetrator)
  - Blow-out bull plug
Controlled Field Test

Operational Sequence

• Ran bit past proposed bottom of assembly depth
• Picked up gun assembly
• Ran in hole
• Set packer at depth
• Closed workstring fill-up valve
• Performed pressure sequence:
  • 11 cycles pressuring tubing to 3000 psi (held 1 min and bled off)
  • Pressured tubing to 2400 psi and observed pressure drop (valve actuation)
• Waited 8 minutes (pyrotechnic time delay) and observed surface indication of detonation
• Unset packer, pull up hole, monitor (low fluid level well)
Controlled Field Test

Results

- Loading (and downloading of back-ups) at field location
- Successful transport, handling, and make-up of system
- Proper pressure initiation of valve/firing head assembly
- Ballistic transfer across 5/5 connections
- All shots fired
- Blow-out plug released
Path Forward

Actions

- Procedure updates from field installation
- Field trial installations to fully verify dynamic characteristics seen in section IV lab testing
- Further field trial installations (and potential adjustments)
- Assess and add future sizes and enhanced features
Questions and Discussion

Thank you.