# Flow Through Perforating System

## A Practical Approach to Game Changing Technology



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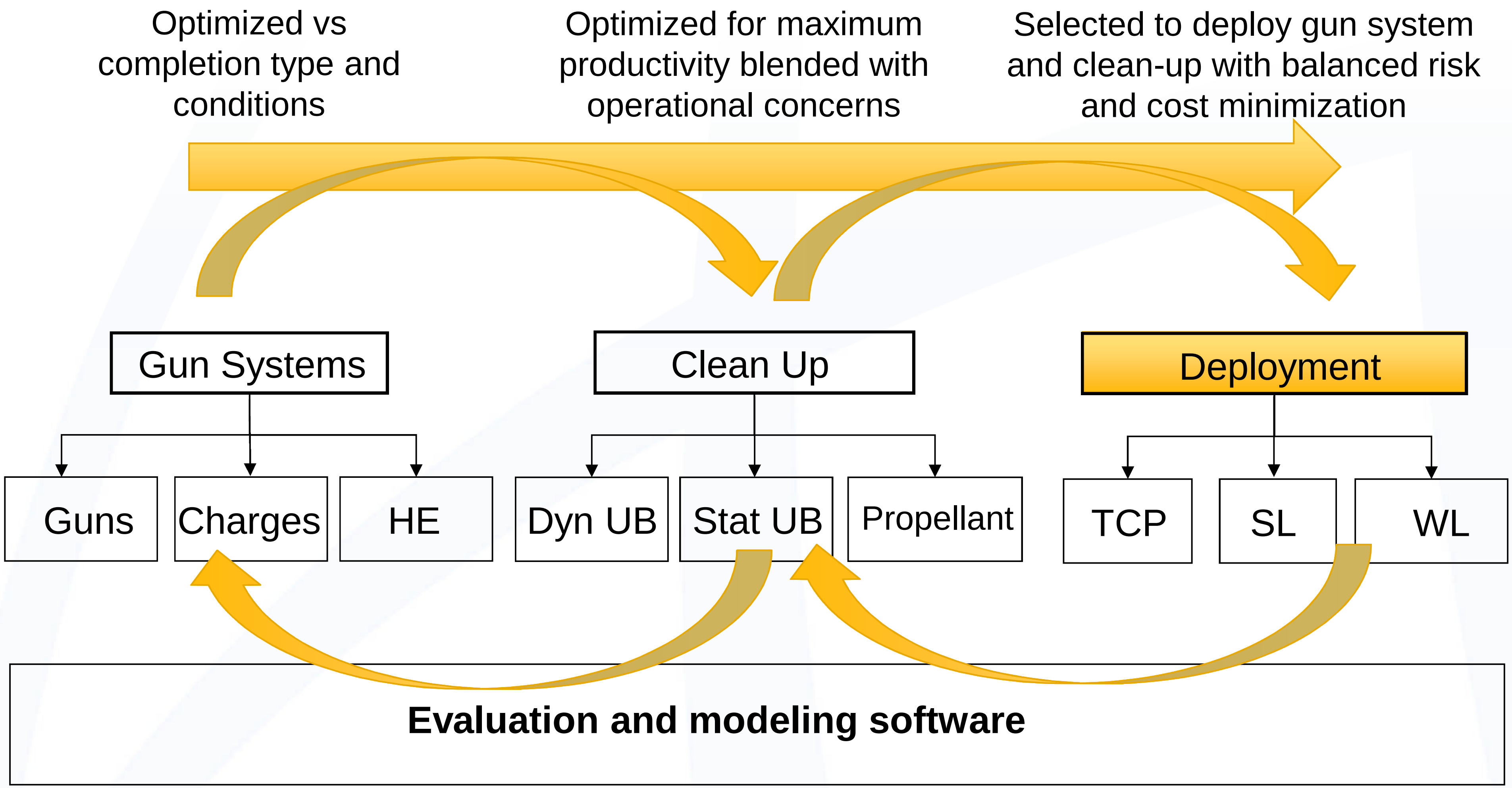
# Discussion Topics

- 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



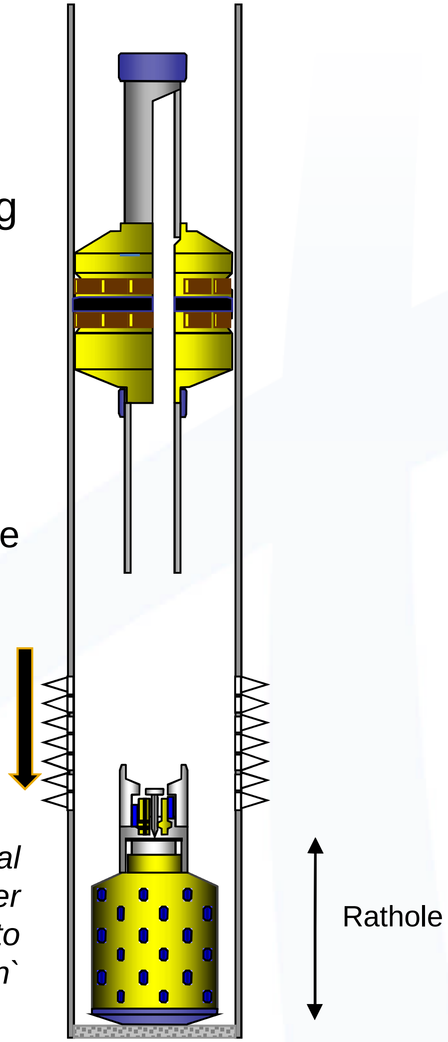
# Standard Tubing Conveyed Perforating (TCP) Methods

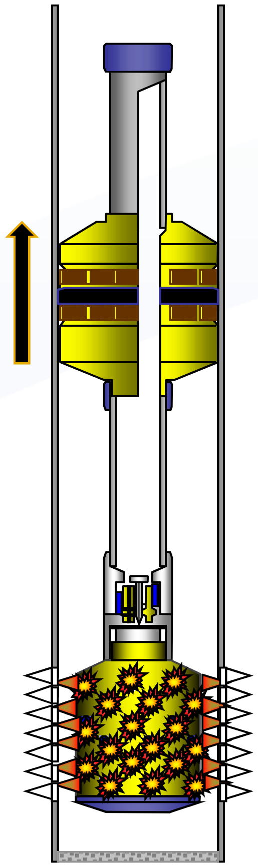
## Shoot and Drop*

- 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*

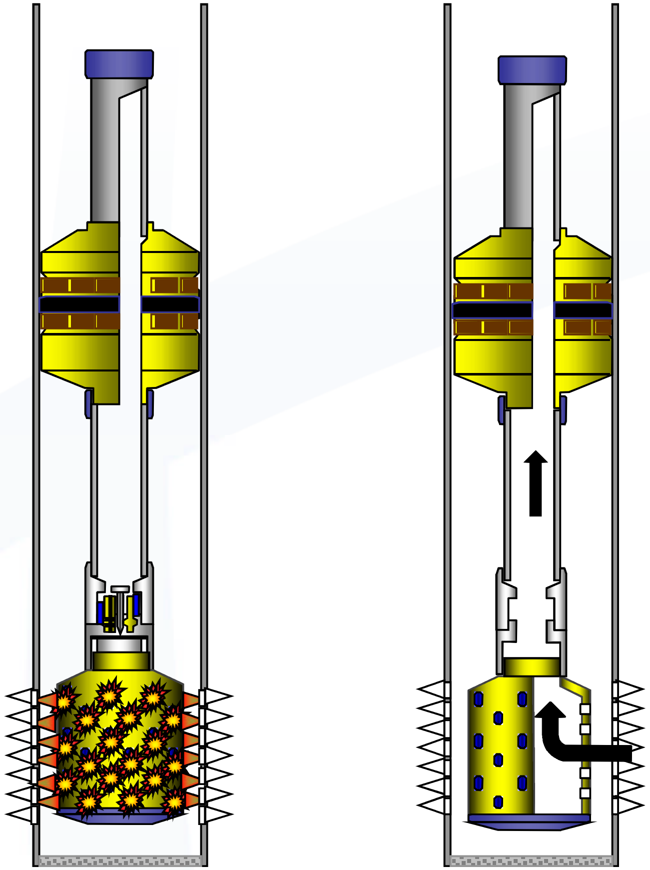
# Variations in Field Conditions versus Lab Conditions

**Kill Weight Fluids and LCM Challenges**

- Completion fluid filtration
- Wellbore clean-up
- Rig mixing capabilities
- Pill storage concerns
- Pill agitation
- High temperature challenges

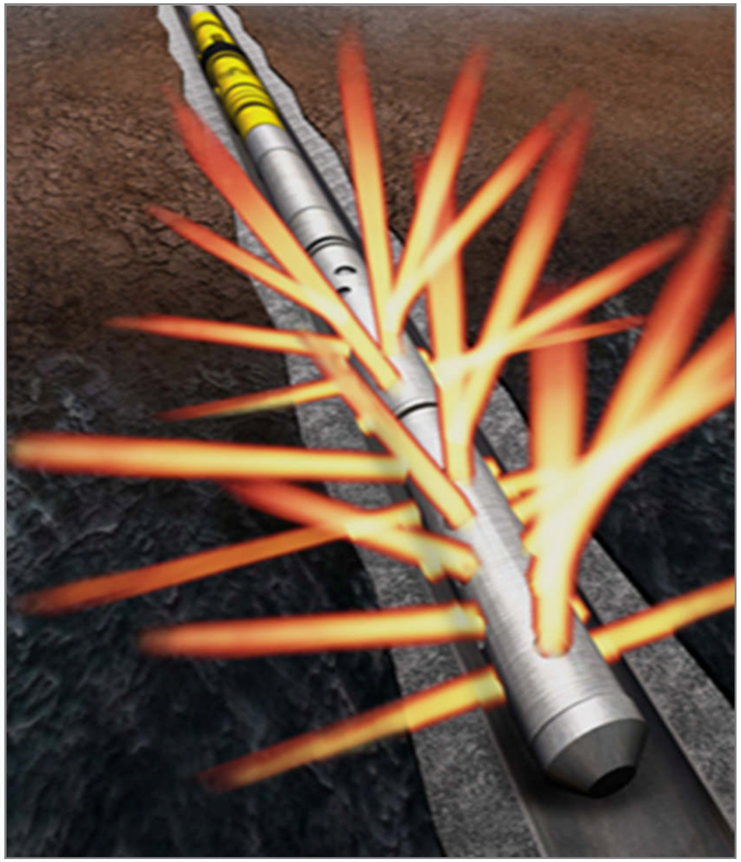
# Flow-Through System Benefits

- 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

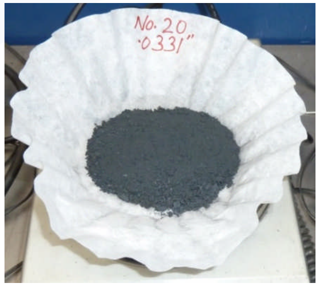
- Internal gun debris
- Full opening conduit

# Development and Testing Process

Overall Design and Testing Approach

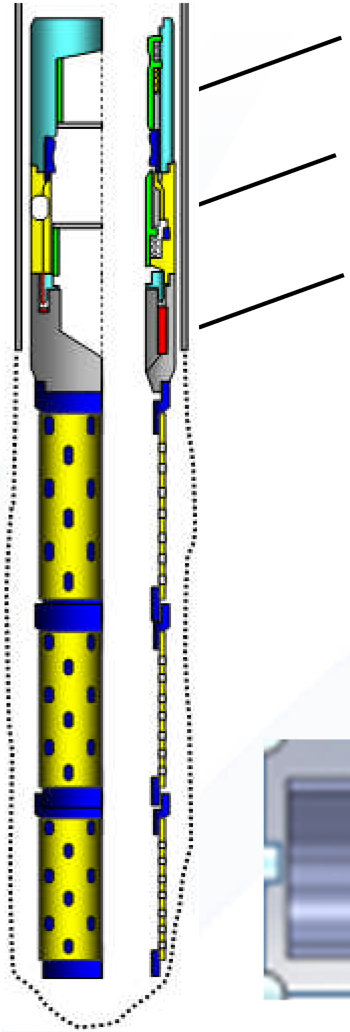
- Bench testing
- Lab / range testing
- Design/Operations Failure Mode and Effect Analysis
- Stack-up testing
- Controlled field test







# 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

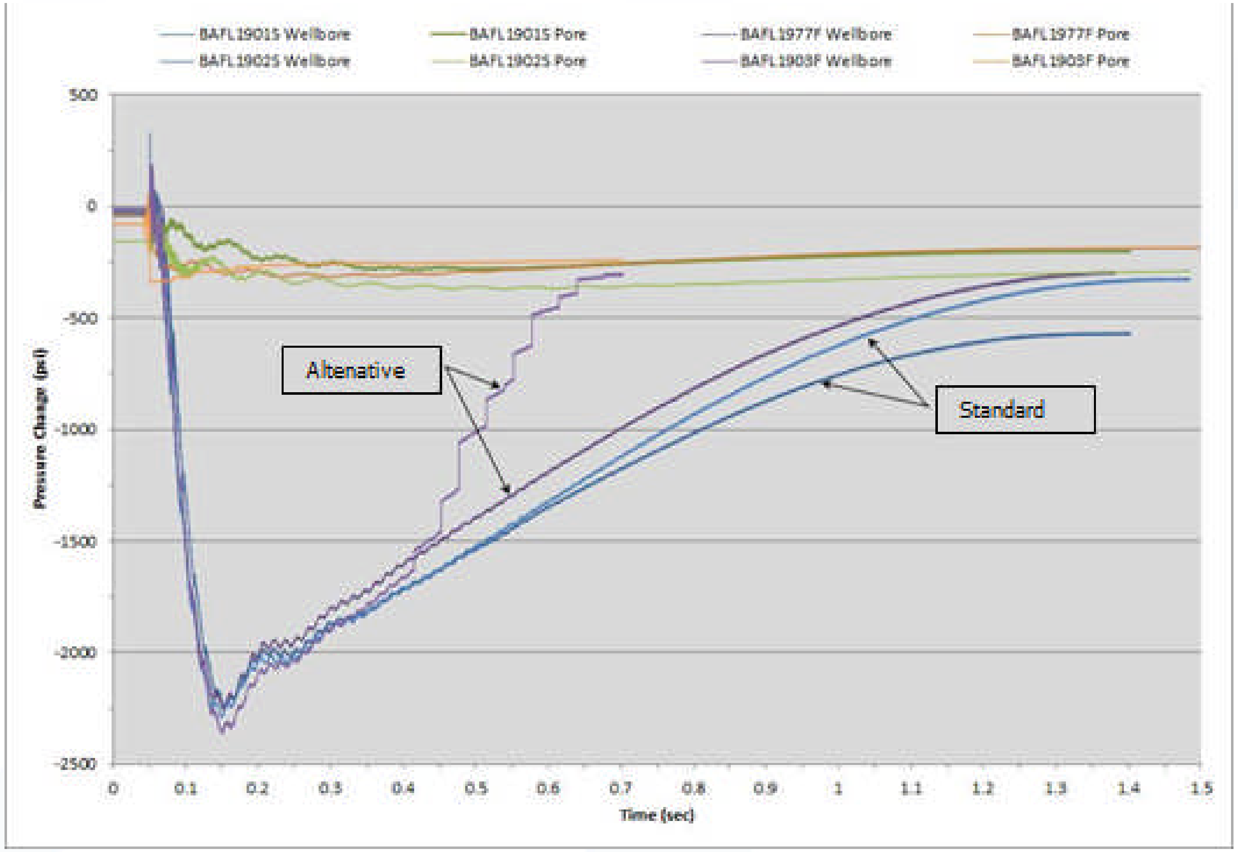
# Lab and Ballistics Range Testing

| Focus | Test |
|---|---|
| Safety | Standard loading and downloading |
| | Downloading after simulated leak |
| | Firing system drop test (API RP67) |
| | Horizontal (ambient) and vertical (ambient and 350F) drop testing, up to 4' |
| Reliability /Durability | 4-1/2" connection/body collapse testing |
| | Connection pressure test / drift / breakout after overtorqing |
| | Valve and firing head assembly and initial function testing |
| | Section III ballistic transfer test at max temperature |
| | Gun survival and swell testing |
| | Mechanical back-up firing system function test |
| | Charge tube stability testing at max temperature |

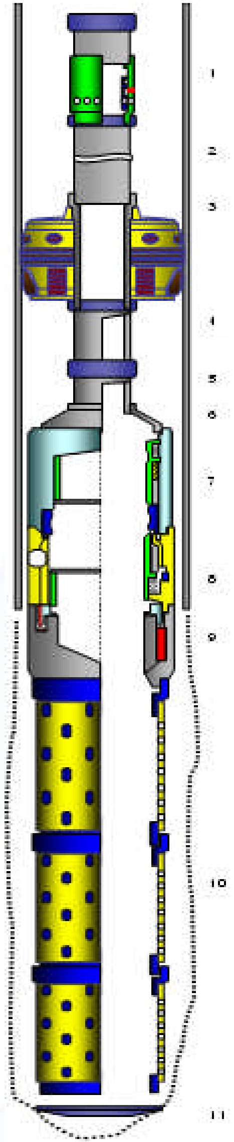
# Lab and Ballistics Range Testing

| Focus | Test |
| --- | --- |
| Productivity | High temp charge tube debris testing: return perm, sizing, composition, and solubility analysis |
| | Shaped charge time/temperature stability testing |
| | API RP19B Section I System Performance Testing |
| | API RP19B Section IV testing for performance and clean-up characterization |
| | System Debris Test (modified API RP19B Section V) |
| Overall Validation | System Stack-Up Test |
| | Field Test Installation |

# Section IV Testing



# Controlled Field Test



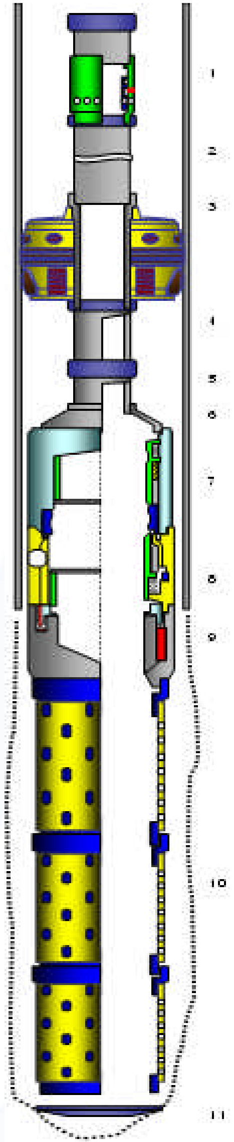
Well Environment

- 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




<u>Operational Sequence</u>

- 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

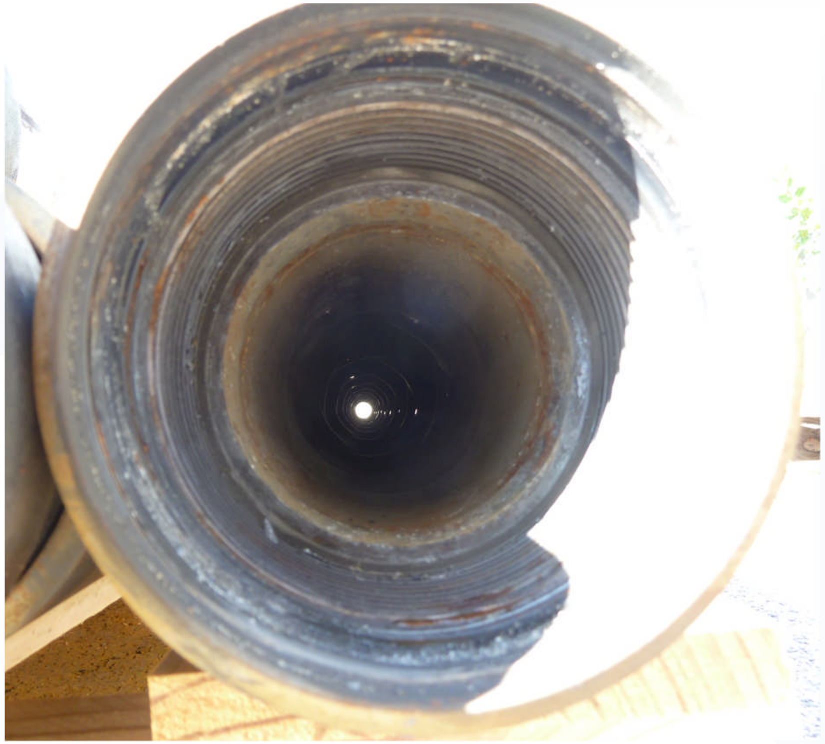

Results

- ✓ 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.