Flow Through Perforating System

A Practical Approach to Game Changing Technology

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

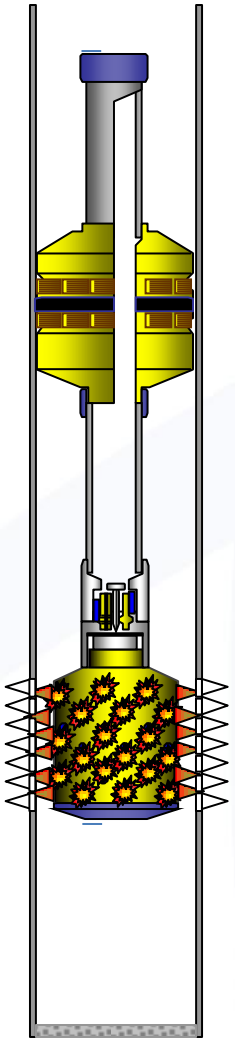
Conventional Perforating Systems

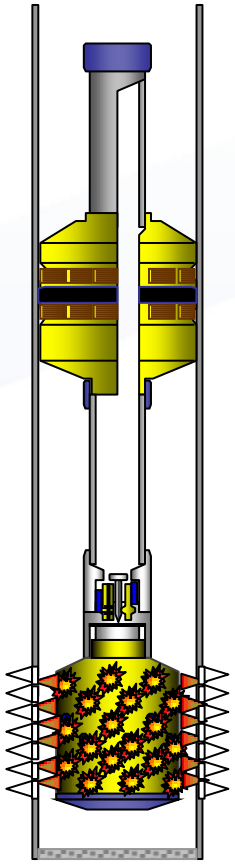
Permanent

- Requires drilling extra rathole (time and cost)
- Not viable in
  - horizontal wells
  - long intervals
  - zones just above pressure transitions
  - uphole recompletes with tight spacing

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

Best option for productivity if when viable.





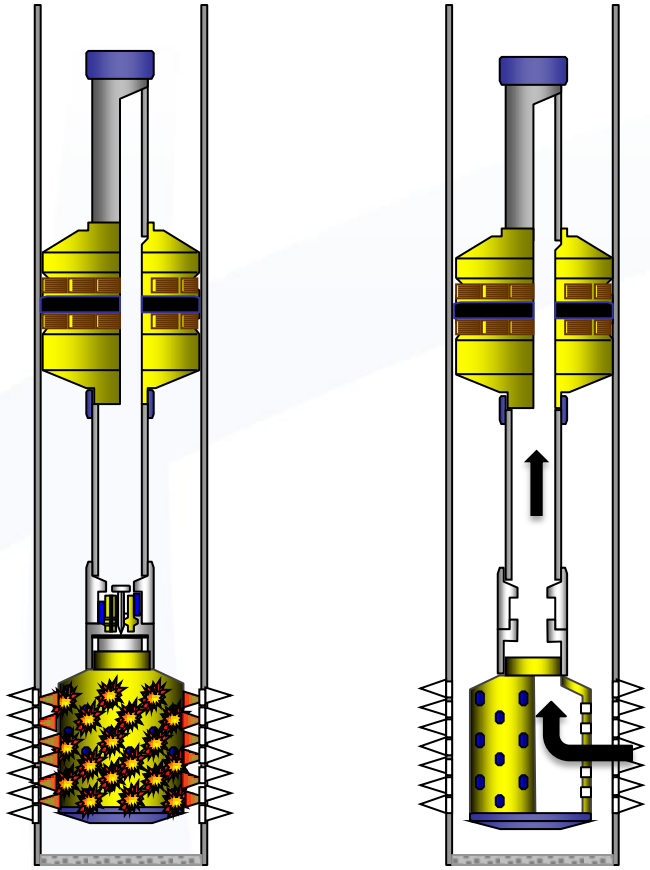
Shoot and Pull

- 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

FTGS 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

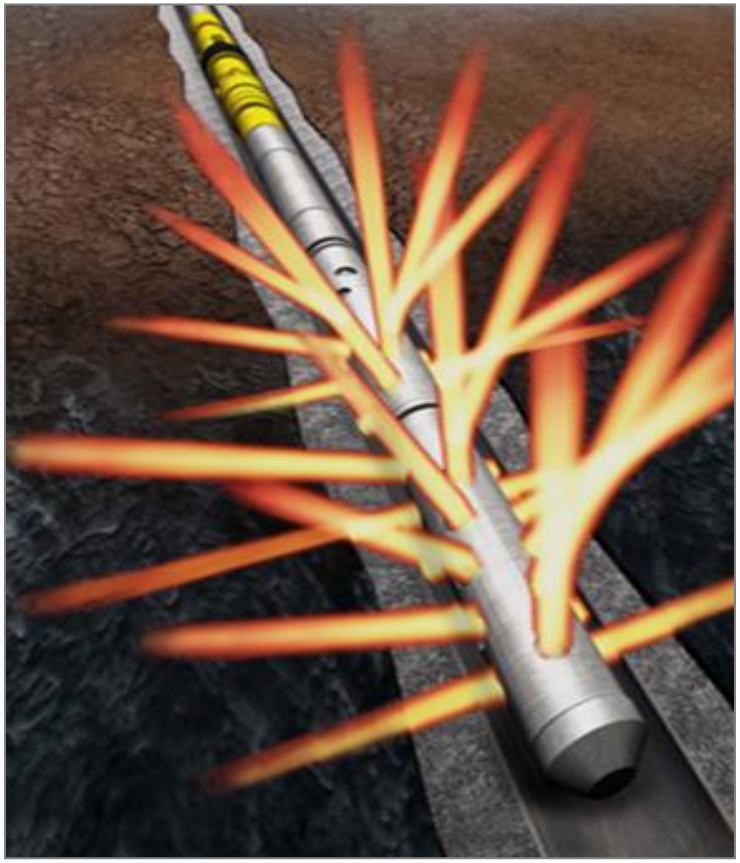
- Charge performance
- Gun survival
- Safety
- Expelled debris
- Field “friendliness”
- Clean-up options

Permanent Completion Drivers

- Initiation reliability
- Complete Detonation

Flow-Through System Drivers

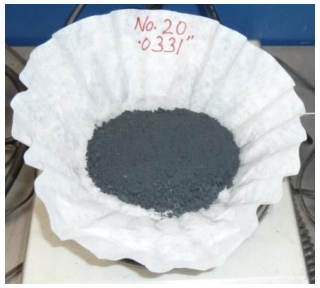
- Internal gun debris
- Full opening conduit



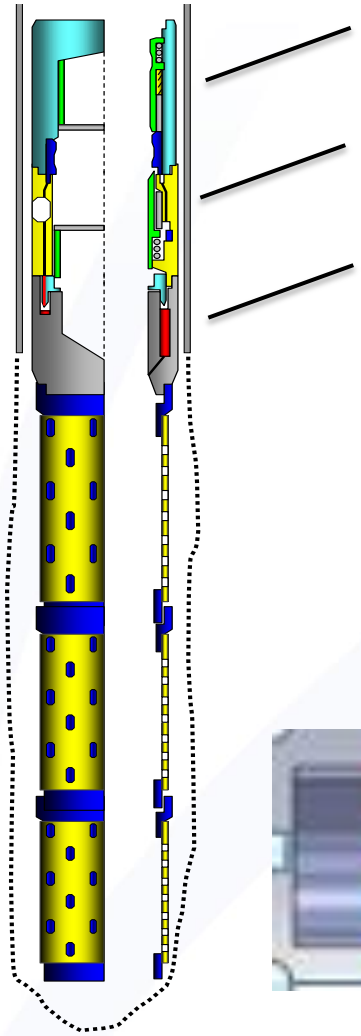
Development and Testing Process

Overall Design and Testing Approach

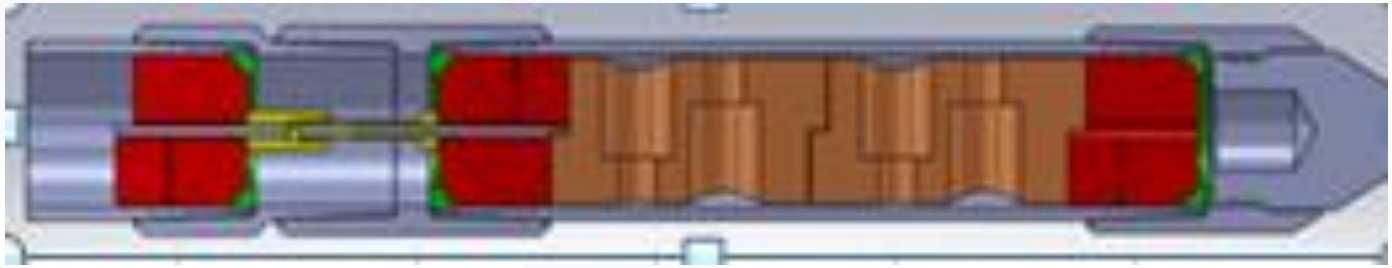
- Bench testing
- Lab / range testing
- Design/Operations Failure Mode and Effect Analysis
- Stack-up testing
- Controlled field test



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



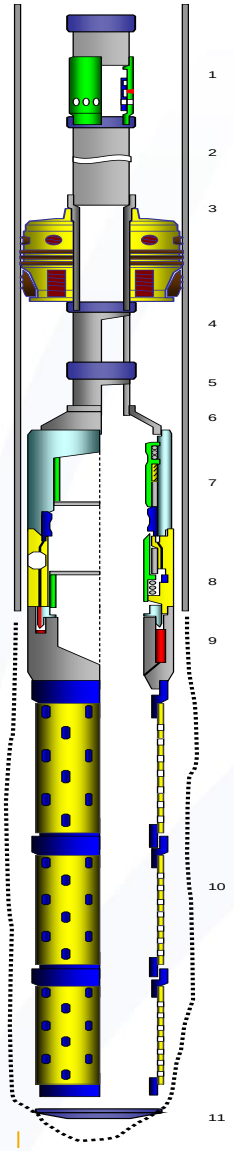
Lab and Ballistics Range Testing

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

Controlled Field Test



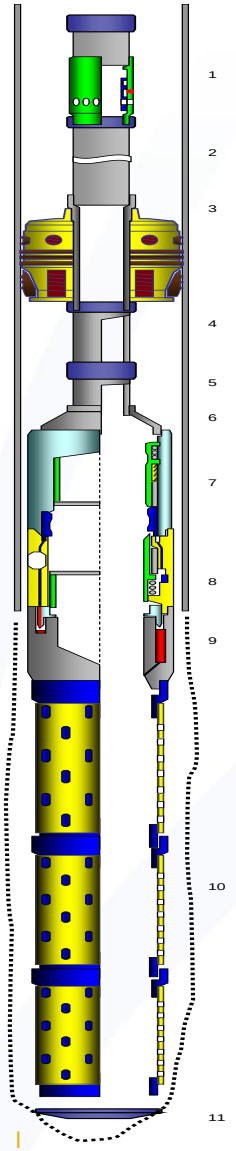
Well Environment

- 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

FTGS: Initial Candidate Selection

- **Well conditions**
  - 220F (325F pending)
  - 8,000 psi max hydrostatic
  - 7” or larger casing
  - Minimum tubing size 3-1/2” for secondary firing system
  - Brine environment (not mud)
- **Requires value vs. existing methods**
  - Rig time savings (vs. shoot and pull or live well deployment)
  - Completion fluid savings (vs. shoot and pull with high density brine)
  - Productivity increase (vs. skin effects of kill pill; vs. smaller guns of live well deployment or flow-around system—if smaller required)
  - Productivity increase (vs. slotted liner in open hole with only static underbalance for clean-up)

Questions and Discussion

Thank you.