2013 Latin America Perforating Symposium

SLAP-23 Perforating Options Available Today in Horizontal Shale Oil and Gas Wells

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Typical Eagle Ford Well Costs

• Total well cost approximately $10 million
• Biggest single cost is formation stimulation, i.e. fracturing
• Regarding perforating choices, the biggest cost factors are:
  – Fracture standby costs
    • In US today, ≈$2,000 per hour
  – Coiled tubing (CT) run costs
    • In US today, ≈ $40,000 per run
  – Attempts to reduce these costs are driving development of
    • New perforating technology
    • New perforating techniques
Typical Eagle Ford Wellbore

- Vertical section: 10,000 to 12,000 ft
- Horizontal lateral: 5,000 to 10,000 ft
- Typical casing: 4 1/2- or 5 1/2-in. OD
- Toe: considered the first 500 ft

- Components of fracture (after perforating)
  - Formation breaks down at ≈10,000 psi
  - Fractures propagate best at ≈100 bbl/min
  - Accomplished with no tubulars in wellbore, i.e. “bull heading”
Perforating Options

- The first operation after cementing is normally a CT clean-out run
  - Cost ≈$40,000/run (includes crane)
  - Establishes plugged back total depth (PBTD)
- Ideally, to save time and money, clean-out run should be combined with toe-prep perforating
  - Combining runs not possible with conventional explosive perforating guns
  - Combining is possible with sand jet perforation
  - First operation uses a mill and motor to drill-up any residual fill and cement in casing
  - Next operation uses high-pressure jets to direct sand against casing form perforation

Pumping unit may be required
Clean-out Run With Toe-prep Perforating

- Sand jet perforation
- Limited availability of equipment
- Cost unknown
- Risks:
  - If tool does not operate properly or if sufficient pump rate cannot be established, must perform traditional tubing conveyed perforating (TCP) toe prep
  - Limited number of holes will be created
  - May require wireline (WL) pump down perforating with related additional costs

Pumping unit may be required
Toe Preparation Using TCP

• First operation after cementing and cleanout run; no open perforations yet

• Maximum assembled length: ≈70 ft (limited by crane height/lubricator length)

• Consists of 1 to 10 guns
  – Length: 1 to 6 ft long, OD 2 3/4-, 3 1/8-, or 3 3/8-in.
  – Density/phasing: 4 or 6 SPF; 60 or 90° phase
  – Covers the first ≈500 ft of wellbore
  – TCP equipment (nonelectric) establishes the first perforations
    • Conveyed on CT
      – Cost ≈$40,000 per run + TCP guns
    • Conveyed on pipe
      – Cost of rig per day + TCP guns

Pumping unit not yet required
Pipe Conveyed Toe Preparation Using TCP

- Multiple pressure-activated firing heads fired at the same time
- May or may not have time delays attached
- Job parameters:
  - WL correlation not required, can use pipe tally
  - Packer may or may not be run
  - Gun assemblies may be spaced with tubing in between
  - Total trip time ≈8 to 12 hours

Pumping unit not yet required
CT Conveyed Toe Preparation Using TCP

- One pressure-activated firing head or ball-drop-differential firing head fires first
- Time delays between guns allow CT to move to next zone
- Number of guns and zones limited by surface lubricator and crane height
- Job parameters
  - WL correlation not required, can use CT depth recorded on clean out run
  - Total trip time ≈6 to 10 hours
  - Compared to conveying on pipe, this takes longer but is normally cheaper
Toe Preparation Using TCP Method Comparisons

- If conveyed on pipe
  - Risk: If gun doesn’t fire, additional trip on pipe is required
  - Cost of workover rig + TCP guns
  - To reduce cost, new technology has been invented which requires no rig

- If conveyed on CT
  - Risk: If gun doesn’t fire, requires additional CT run
  - Cost of CT per run + TCP guns
  - To reduce cost, new technology has been invented which removes the need for CT and explosives

Pumping unit not yet required
Toe Preparation New Toe Sleeve Technology

- Attached to casing just above shoe and cemented in place
- After placing cement, circulate a ball and plug to shift sleeve
  - Opens ports in contact with formation to allow fracturing
- Removes CT or workover rig costs and run time involved
- Limited number of holes
  - Requires following by WL pump down perforation
  - Requires pressure pumping

Pumping unit may be required
Toe Preparation New Toe Sleeve Technology Risk

- If sleeve does not operate properly or if unable to establish sufficient pump rate, operator must perform traditional TCP toe preparation

- To limit cement sheath at tool
  - May need to over displace cement
  - May need to excessively retard cement

- Risk of fluid movement behind casing

Pumping unit may be required
Toe Preparation New Toe Gun Technology

- Attached to outside of casing
  - Run just above shoe and cemented in place
  - Requires larger borehole, which carries additional drilling cost
- Guns must be run at same time as casing
  - Downhole longer, risk of leak at O-rings
  - Requires more-expensive high-temperature explosives

Pumping unit may be required
**Toe Preparation New Toe Gun Technology**

- Gun fires in two directions
  - Away from casing into the formation to create flow path
  - Into casing to complete flow path
- Removes CT or workover rig costs
- Limited number of holes
- Requires pressure pumping
- Requires subsequent WL pump down perforation
- Risk: If gun doesn’t fire or is unable to establish sufficient pump rate, must perform traditional TCP toe prep

*Pumping unit may be required*
After Toe Preparation, Fracture First Stage

- Perforations have established flow path
- Components of fracture (after perforation)
  - Formation breaks down at ≈10,000 psi
  - Fractures propagate best at ≈100 bbl/min
  - Bull-head through casing
    - Allows higher pump-in rates
After Fracturing First Stage, Perforate Next Stage

• WL pump down plug and perforation
  – Cost ≈$10,000 per stage
  – In single run
    • Sets composite fracture plug, isolating previous stage
    • Fires ≈1 to 10 guns over staged interval (determined by operator)
      – Same gun lengths and configuration as TCP
      – Electric detonators, normally select-fire (+ and – switches)
      – May have pressure on wellbore, ≈1,000 to 4,000 psi at surface
        • Pressure-control equipment required
      – Requires high volumes of fluid to position guns ≈10 to 18 bbl/min typical
      – Maximum run speed - 200 ft per min
After Fracturing First Stage, Perforate Next Stage

• WL pump down plug and perforation
  – Normal run time is ≈2 to 3 hours
  – At end of run, circulate a ball into the fracture plug, which allows fracturing this stage
  – Risks:
    • High failure rate – statistically 1 in 7 (15%) experience some type of failure
    • Simplest failure is electrical short resulting in 4 to 6 hours lost time at $2,000 per hr = $8,000 additional fracture equipment stand by cost.
    • Most complex failure is parted line with live guns lost in hole resulting in several days (≈50 hours) at $2,000 per hr additional cost
  – Rewards:
    • Limiting time and saving costs when considering fracture standby
    • Benefits outweigh the risk!
    • WL pump down plug and perforation not going away
After Fracturing First Stage, Perforate Next Stage

- WL pump down plug and perforation
  - Other risks:
    - Formation fails to break down
    - If cannot generate ≈10 to 18 bbl/min, then cannot pump down WL
    - If WL bridges out during pump down due to fill from previous fracture, remember that the wellbore has not been re-entered since
    - In these cases, WL and other options are needed
Optional TCP and CT Plug and Perforation Systems

• Set composite fracture plug and fire guns
  – With annular pressure
    • Formation must hold pressure in order to fire, which is not always possible as it has just been broken down
    • Requires CT conveyance, cost ≈$40,000 (includes crane)
    • Plug and perforation system cost ≈$15 to 20,000
  • Benefits
    – Not pumping down, so not subject to high-pressure fluid ingress
    – Not electrical, so not subject to electrical safety issues or shorts
    – One-trip system saves the cost of a CT run
  • Risks
    – Slow: ≈6 to 8 hour trip on CT incurs fracture standby costs
    – Pressuring against firing-head pins, potential for premature firing
Optional TCP and CT Plug and Perforation Systems

• Set composite fracture plug and fire guns with tubing pressure using a new proprietary system, current record
  – More than 100 successful runs in Canada
  – Re-engineered system for use in US
  – First US run successfully completed in April 2013

• Requires CT conveyance
  – Cost ≈$40,000 (includes crane)

• Plug and perforation system cost ≈$25,000 to $30,000
Optional TCP and CT Plug and Perforation Systems

• Set composite fracture plug and fire guns with tubing pressure
  – Benefits:
    • Not pressuring against formation
    • Not pressuring on firing head until after plug is set
    • Not pumping down, so water usage is less and no high-pressure fluid ingress
    • Not electrical, so not subject to electrical safety issues or shorts
    • One-trip system saves the cost of a CT run
  – Risks:
    • Slow: ≈6 to 8 hour trip on CT, incurring fracture standby costs
After all Stages Perforated and Fractured

• CT mill-up of composite plugs
• Flow-back and well-test clean-up
  – Lasts from two days to several months, depending on client’s production plans
• Well is put into production
Summary of Steps

1. First run after cementing is CT clean-out
   - May include sand-jet perforating
     - Eliminates TCP toe preparation but requires wireline pump down plug and perforation

2. Toe preparation
   - Most common is TCP run on CT
   - Optional systems, both may require WL pump down plug and perforation:
     - Toe sleeve
     - Toe gun

3. Fracture (non perforating)

4. WL pump down plug and perforation
   - If cannot get down due to fill in casing or formation did not break down
     - CT and TCP plug and perforation, annulus pressure
     - CT and TCP plug and perforation, tubing pressure

5. Fracture (non perforating)

6. After all stages perforated and fractured, CT mill-out of composite plugs

• NOTE – In all operations, time spent is one of the most critical factors in controlling costs due to the cost of fracturing equipment stand by.
Application in Latin America

- Activity is building in many basins
- Technology is easily transferrable
  - Dependent on availability of equipment
  - Dependent on availability of qualified service personnel
- Questions?