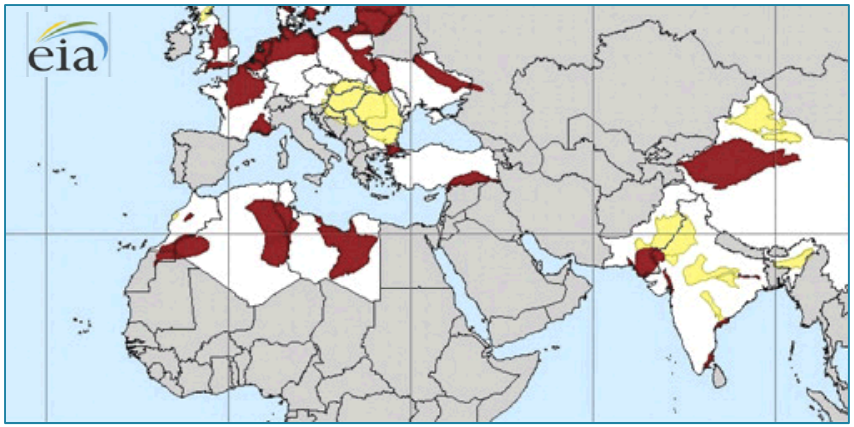


MENAPS 2013

Perforating Options Currently Available in Horizontal Shale Oil and Gas Wells

Kerry Daly, Global BD Manager- DST TCP

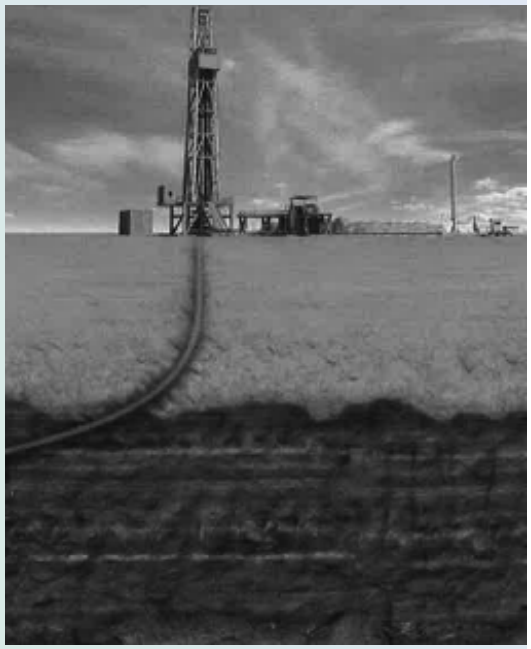
EXPRO

WELL FLOW MANAGEMENT™

Scope/ Contents:

Study Based on US Market:

- Specifically the Eagle Ford in south Texas
- Most active because it is liquid-rich play
- Technology Developed Here



Beyond Scope:

- Open Hole Sliding Sleeve Systems

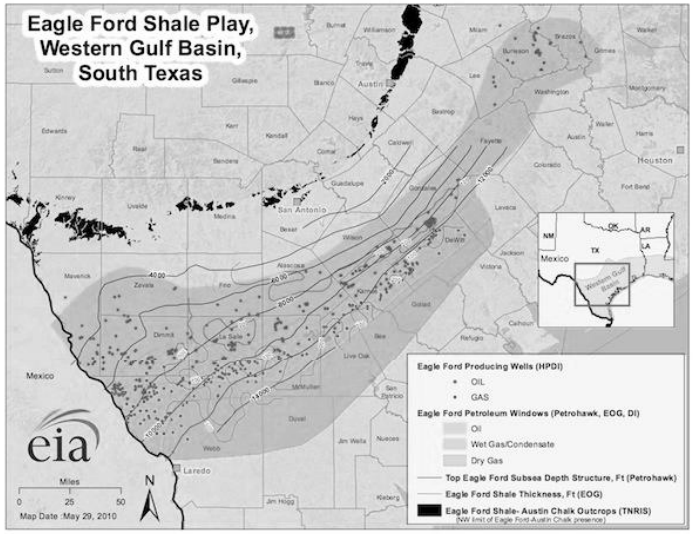
Contents:

- Discuss each step in the horizontal completion process
  - Technology being used as well as optional systems
  - Relative cost
  - Reasoning used to determine methodology.
- How it relates to MENA operations

Eagle Ford Shale:

Typical Well Parameters:

- Vertical Section: 10,000- 12,000 ft.
- Horizontal Lateral: 5,000- 10,000 ft.
- Typical Casing: 4-1/2 in. or 5-1/2 in. OD
- Toe: Considered first 500 ft.
- Components of fracture (after perforating):
  - Formation breaks down ~10,000 psi
  - Accomplished with no tubulars in well
    - i.e. “Bullheading”



Typical Total Well Cost ~$6-8 Million:

- Biggest single cost is formation stimulation, i.e fracturing
- Regarding perforating choices, biggest cost factors are:
  - Frac standby costs- ~$2,000 per hour
  - Coiled Tubing (CT) run costs- ~$40,000 per day
- Attempts to reduce these costs are driving development of
  - New perforating technology
  - Alternate technology (non-explosive)

1 First Run In> Clean out Run

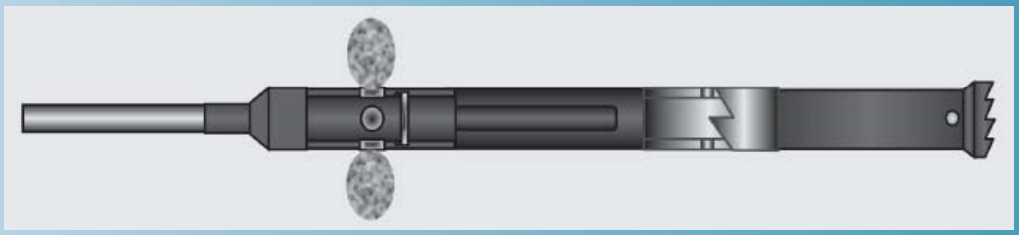
Run is becoming optional to reduce time and cost

- If Conveyed by Workover Rig:

- Run a traditional Bit & Scraper

- If Conveyed by Coiled Tubing (CT):

- Accomplished with Mill and Motor or Jetting Tool
  - ➢ Ideally, to save Time and Money, combine Clean out with Toe Prep
    - Combining guns with clean out not currently done.
    - Non-explosive systems are available that do this- Abrasive Jetting
      - o However these are expensive and not that effective
        - Recent job created 46% of holes attempted.
        - As a result, systems are not being used that much



2 Next Run> TCP Toe Prep

Parameters:

- First operation after clean-out, no open perforations yet.
- Covers the first 500 ft. of wellbore
- Stages consist of 1 - 10 guns
  - Gun lengths: 1 - 6 ft. long
  - Gun OD: 2-3/4”, 2-7/8”, 3-1/8”, 3-3/8” depending on casing size
  - Gun Type: 6 SPF, 60 degree with DP or Super DP charges
  - Guns typically not oriented, let pressure determine fracture path

2 Next Run> TCP Toe Prep

If Conveyed by Workover Rig:

- Job Parameters:
  - One or many pressure-activated firing heads fired at same time
  - May or may not have time delays attached
  - WL correlation not required, pipe tally used
  - Packer normally not run
  - Gun assemblies spaced out with tubing between, no length limitation
  - Total trip time ~8 - 12 hours
- Cost:
  - Rig ~$10,000 per day
  - TCP ~ $15,000
  - Estimated total ~$25,000
- Risk: If gun doesn't fire, lost time + additional trip on pipe required

Drivers

If Conveyed by Coiled Tubing (CT):

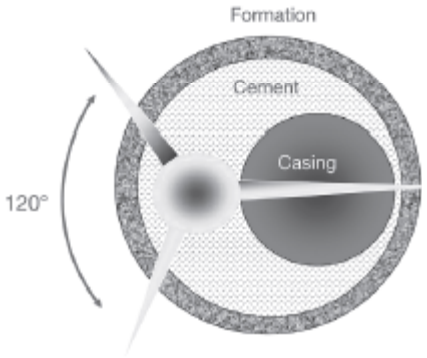
- Job Parameters:
  - One pressure-activated or ball-drop differential firing fires first gun
  - Time delays between guns allow CT to move to next zone
  - Number of guns and zones limited by surface lubricator length and crane height (~70 ft.)
  - WL correlation not required, pipe tally used
  - Total trip time ~6 - 10 hours
- Cost:
  - CT unit ~$40,000 per day
  - TCP~ $15,000
  - Estimated total ~$55,000
- Risk: If gun doesn't fire, lost time + additional trip on CT

To reduce cost, new technology has been developed which requires no rig or CT .

Alternatives

- To eliminate the cost of CT Toe Prep

Casing Toe Gun



- Attached to outside of casing and run as part of casing string
  - Run just above float collar/ shoe and cemented in place
  - Requires larger borehole, which drives drilling cost
  - Requires high-temperature explosives, more expensive
  - Guns are downhole longer, risk leak at o-rings
- After the cement cures, pressure up to rupture disk or shear pins to fire gun
- Removes Workover Rig/ CT costs and run time
- Creates limited perforations, usually maximum 10-ft. so entire toe is not prepped.
  - Requires pressure pumping
  - Requires subsequent WL pump down perforating
- Cost:
  - TCP ~ $15,000
  - WL Perforating~$10,000
  - Estimated total ~$25,000 (larger borehole costs not included)
- Risk: If gun doesn't fire or unable to establish pump rate, must perform traditional TCP toe prep.

Alternatives

- Becoming the System of Choice, Saves Two Coiled Tubing Runs.

Casing Toe Sleeve

- Run just above float collar/ shoe and cemented in place
- After the cement cures, pressure up to rupture disk or shear pins
  - Pressure shifts a sleeve, which opens ports to expose formation to frac pressure
  - Optional fluid metering allows casing test prior to opening
- Safer option as no explosives used
- Removes Workover Rig/ CT costs and run time
- Doesn't create perforations, just access to formation
  - Requires pressure pumping
  - Requires subsequent WL pump down perforating
- Cost:
  - TCP ~ $15,000
  - WL Perforating~$10,000
  - Estimated total ~$25,000
- Risk: If sleeve doesn't open or unable to establish pump rate, must perform traditional TCP toe prep.
- To limit cement sheath at tool, must over-displace cement, may need to retard cement
  - Risks fluid movement behind pipe

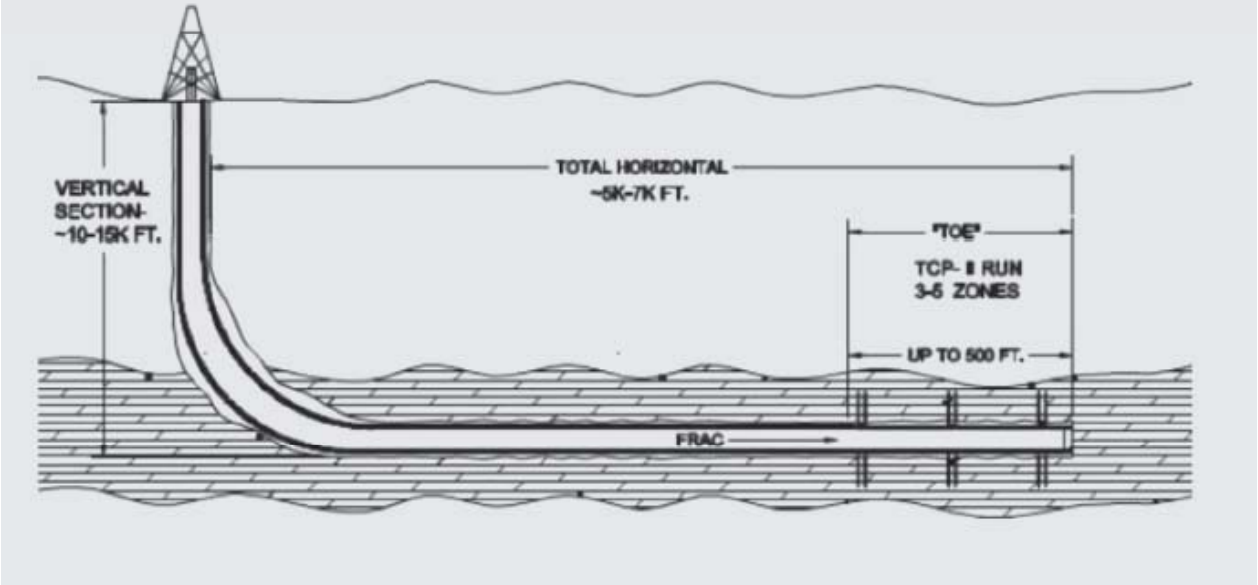
System Comparison	Casing OD	Tool OD	Min. Borehole
Toe Gun	4-1/2 in.	7.50 in.	8-1/4 in.
Toe Sleeve	4-1/2 in.	5.75 in.	6-1/4 in.

3 Next Step> Fracture the toe (first stage)

- Regardless of how toe is perforated

Parameters:

- 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 the casing
    - ▪ Allows higher pump-in rates



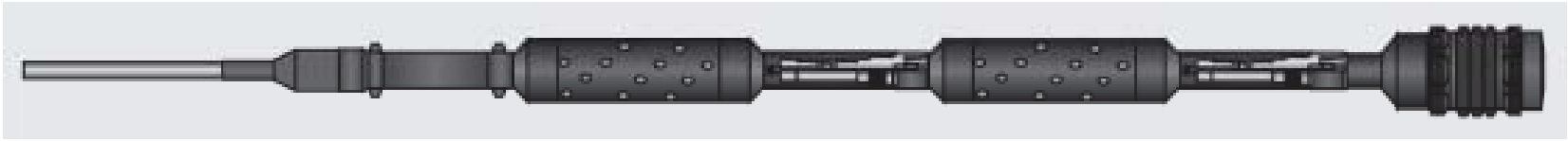
4 Next Run> Wireline (e-Line) Pump Down

MENAPS 13-17

- **Combination Plug & Perforation System**

Parameters:

- Run time is only 2 -3 hours
- First set a Composite Frac Plug
- Then move uphole to fire guns, 1-10 typically as Select-Fire with reverse polarity switches
- At end of run, circulate a ball into the Composite Frac Plug
  - This seals the zone below and allows fracturing through newly created perforations
- Risks: High failure rate- statistically 1 in 7 (15%) experience some time of failure
  - Simplest failure: electrical short resulting in 4-6 hours lost time at ~$2,000/ hour standby.
  - Most complex failure: parted line with live guns lost in hole resulting in 50 hours lost time.
- Rewards: Short operating time, limiting frac standby costs
  - Unlimited stages can be performed
  - Benefits far outweigh the risks!
  - WL Pump-down Plug and Perf is the preferred method- not going away!



Wireline (e-Line) Pump Down

- Other Risks:
  - Formation fails to break down
    - If can't generate minimum 10 bbl/min, then cannot pump down WL guns
  - If WL bridges out during pump down operations due to residual fill in casing
    - Wellbore has not been reentered since frac event
  - Necessary to run a TCP system to complete the stage
- Cost:
  - WL Perforating~$10,000 per stage (additional cost of water not included)
  - Estimated total ~$10,000
- Operation:
  - Set composite fracture plug, isolates previous stage
  - Typically have residual pressure on wellbore: 1,000- 4,000 psi
    - Pressure control equipment required
  - Requires high volume pumping to position guns, 10 – 18 bbl/min
  - Maximum running speed ~200 ft/min

Alternatives

- **CT Vibration Systems using TCP Guns (emerging technology)**
- **CT TCP Plug & Perf Systems**

Annular Pressure Firing System

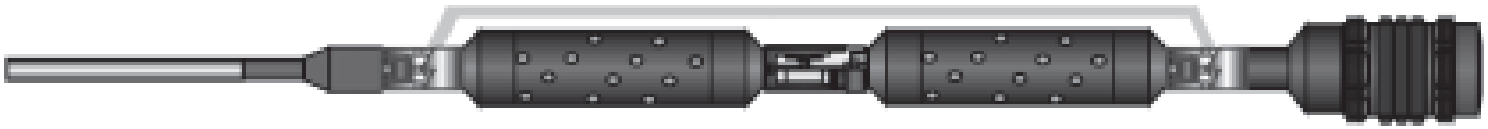
- Set a Composite Frac Plug (lower applied pressure), then fire guns (higher applied pressure)
  - Formation must hold pressure in order to fire
    - Not always possible as formation has just been broken down
- Cost:
  - CT unit ~$40,000 per day
  - TCP assembly~$20,000 (includes plug)
  - Estimated total ~$60,000
- Risks:
  - CT slow, ~6- 8 hour trip time
    - Incurring frac standby costs
  - Live well with surface pressure, so must choose firing head carefully (differential type preferred)
  - Live well with surface pressure, so may need to bleed down to meet firing head safety criteria
- Rewards:
  - Not pumping down, so not subject to high pressure fluid ingress or high fluid costs
  - Not electrical, so not subject to electrical safety issues or failure points
  - One-trip plug and perf system saves cost of CT run

Alternatives

- **CT TCP Plug & Perf Systems**

Tubing Pressure Firing System

- Set a Composite Frac Plug (lower applied pressure), then fire guns (higher applied pressure)
- Closed system when firing, so formation not pressured against
- Cost:
  - CT unit ~$40,000 per day
  - TCP assembly~$20,000 (includes plug)
  - Estimated total ~$60,000
- Risks:
  - CT slow, ~6- 8 hour trip time
    - Incurring frac standby costs
  - Live well, so surface pressure may need to be bled to meet firing head pin safety criteria
- Rewards:
  - Not pumping down, so not subject to high pressure fluid ingress or high fluid costs
  - Not electrical, so not subject to electrical safety issues or failure points
  - One-trip plug and perf system saves cost of CT run



5 Next Step> Milling of Composite Plugs

- Brings Well onto Production

Parameters:

- Mill up Composite Frac Plugs
  - By Workover or Coiled Tubing
- Flow-back and well-test clean up
  - May lasts from two days to several months, depending on client's plans
- Well is put on Production

Summary

Steps:

1. Clean-out Run> first run after running casing and cementing (becoming optional)
   - Alternate: Combination CT Clean-out with Abrasive Jet Perforating (non-explosive)
2. TCP Toe Prep> required as no perforations yet (can't pump into formation)
   - Two primary methods- 1) Tubing conveyed on Workover Rig or 2) Coiled Tubing conveyed
     - Alternate: Casing Toe Gun, run on casing but requires larger bore hole and high-temp explosives
     - Alternate: Casing Toe Sleeve, run on casing but requires over-displacement of cement (becoming method of choice for toe prep)
3. Bullhead Frac down casing
4. Wireline Pump-down Plug and Perf> unlimited stages but risky (method of choice after flow into formation established)
   - Alternate: TCP Plug and Perf (annular pressure)
   - Alternate: TCP Plug and Perf (tubing pressure)
     - Each stage followed by Bullhead Frac down casing
5. Mill up Composite Plugs
   - Frac flow back, Ccean up, and put well on Production

Application to MENA

- Historically drilling horizontal wells
- Activity is building in many areas
- Technology is easily transferrable
  - Dependent on availability of equipment
  - Dependent of availability of qualified service personnel.

Questions?

Thank You!