Western Dakota Energy Association
Annual Meeting

Refracs: Completion Discussion for Bakken Generation 1 Wellbores

Originally presented to the Interim Energy Development and Transmission Committee by Pete Lewis (Completion Engineer), Jeff Parker (Region Manager), and Zac Weis (Government Relations) – August 1st, 2017

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MRO Completion and Stage Spacing Evolution

- **Stage Spacing, Ft**

- **2006-2009**
  - Open Hole, no liner

- **2009-2012**
  - 10-15 stages 4.5” lateral liner
  - 20 stages, sliding sleeves, frac down 4.5” Tieback
  - 30 stages, sliding sleeves
  - 30-34 stages, sliding sleeves
  - 30-40 stages, sliding sleeves and PNP

- **2013-2017 Plan**
  - 30-60 stages, averaging 45 PNP
  - 40-50 stages, sliding sleeves and PNP
  - 30-60 stages, averaging 45 PNP

- **15 stages with swell packer zonal isolation**
MRO Proppant Loading Evolution

2006-2009
~45 lbs/ft

Completion trials

Proppant Per Lateral Foot (ppf)
Well Type of Current Re-frac Program

Open-hole or ‘Barefoot’ Completions (2006-2009)

‘Barefoot’- Open Hole Wells:

- Typically completed with 6” open hole horizontal laterals
- Initial treatment: low concentration stimulations pumped at high rates
  - Used rate for diversion
  - Placed a disproportionate amount of proppant near heal
- Marathon has an active re-frac program to optimize recovery from initial ‘Barefoot’ completions
  - Project shows competitive economics
What does it take to Refrac an Open Hole Lateral?

- Refrac Candidate Selection
  - Thorough well history review to identify operational risk
    - Squeeze perforations, sidetracks, or any mechanical constraint
- Pre-investment Approvals
- Well preparation
  - Decompletion
    - Completed by a workover rig
      - Remove the existing production equipment (surface + downhole)
      - Test the casing and securing the well for large (drilling) rig mobilization
  - Downhole Equipment Installation
    - Clean-out run to TD
    - 4-1/2” lateral liner installation (cemented in-place)
    - Run 4-1/2” tieback string
- Stimulation execution
  - 5.5 MMlbs proppant
  - 110 Mbbls water
- Coiled tubing clean out (mill up frac plugs)
- Flowback
- Production
Overview of Existing Horizontal Well Types

**Generation 1 Staged Completions (2009-2011)**

**Generation 1 Staged completions:**
- Ball + Seat (sliding sleeve) systems with annular packers for isolation
- Limited stages (<20) with low proppant concentration within each stage
  - Mechanical isolation of each stage
  - Placed a proportionate amount of proppant across each stage
  - Significantly lower induced fracture complexity than current design
- Initial completion limits ID (access) and increases cost/risk of operations required for re-frac
Available Refrac Completion Options

Existing Generation #1: Ball + Seat Systems Refrac Option #1

• **Option #1: Particulate Diverters**
  – Existing Ball + Seat installations can be refrac’d using the existing 4-1/2” liner assembly
    • Requires a lateral liner cleanout before and after treatment
      – Also, a 4-1/2” tieback string installation
    • Least expensive option
    • Multiple stages of proppant and particulate diverter pills are ‘bull headed’ from surface
    • Concept is predicated on treating path of least resistance
      – Generating enough ‘net’ pressure to divert flow to another sleeve

![Diagram of particulate diverters](image)

**Challenges:**
• Least effective option. There is no reliable way to divert to different sleeves other than pumping particulates.
• Difficult to add effective perforations and additional zones
Available Refrac Completion Options

Existing Generation #1: Ball + Seat Systems Refrac Option #2

• Option #2: Inner String Installation (with sleeves)
  – Install a 3-1/2” Flush Joint (FJ) lateral liner with a slim-hole ball + seat system (using swell packers for zonal isolation)
    • Ball + Seat Sliding Sleeve system (27 Stages possible, but not practical due to ID)
    • Annular isolation accommodated by swell packers
    • A 2-7/8” system cut for 3-1/2” Flush Joint tubing to minimize friction pressure
    • If more stages are required, the lateral liner must be perforated prior to running the internal assembly

Challenges:
• The 2-7/8” ball and seat systems leave a small ID which limits any remedial workover capability. (2.1” max)
  • An operationally difficult completion to install and maintain. Small tools limit options to clean out sand/debris.
  • Not practical for longer laterals - measured depth limitation of 2.0” tools
  • Difficult to add perforations (more zones)
Available Refrac Completion Options

Existing Generation #1: Ball + Seat Systems Refrac Option #3

• **Option #3: Inner String Installation**
  - Install a Flush Joint (FJ) lateral liner (inner string) to accommodate Plug and Perforation stimulation techniques.
    - Annular isolation can be accommodated with either:
      - #1: Expandable packers (for zonal isolation)
      - #2: Can be cemented in place despite tight clearances
    - Designed for plug and perforation re-stimulation activity
    - More versatile than available ball + seat systems due to a larger ID.
      - **Accommodates increasing the stage count and the use of particulate diverter**

**Challenges:**
- Very tight tolerances to deploy especially in depleted conditions
- Cement isolation very difficult due to low circulation rates
- Expensive specialty pipe required for 3-1/2” installation
What does it take to Refrac a Generation 1: Ball + Seat Installation?

• Well preparation
  – Decompletion
    • Completed by a workover rig
      – Remove the existing production equipment (surface + downhole)
      – Mill up the existing ball seats to accommodate an inner string deployment
      – Install a 4-1/2” tieback string (likely)
  – Downhole equipment installation
    • Deploy an inner string (2-7/8” or 3-1/2”) inside the existing 4-1/2” lateral liner
      – Zonal isolation achieved by either cement or mechanical (expandable packers) 4-1/2” lateral liner installation (cemented in-place)
• Stimulation
  – Plug and perforation techniques
• Coiled tubing clean out (mill up frac plugs if Plug and Perforation Techniques are used)
• Flowback
• Production
**Initial Completion and Remaining Hydrocarbon**

*Reservoir Pressure Maps*

- Significant **un-depleted area** before refrac with original open hole completion

- **Open hole** completions has greater undrained area resulting in **larger remaining hydrocarbon** volume

- **Generation 1 completions** refrac’d by **adding stages** to the original completion
Re-frac Project Value

*Economics driven by remaining hydrocarbon*

**Refrac Project Value Plot**

- Project economics grossly depends on **remaining hydrocarbon** volume accessible with a refrac

- Largest remaining refrac inventory is **Generation 1** completions (10-20 stages)

- Variation in reservoir properties, well production and completion history generate **uncertainty** around refrac performance

* Bubble size represents remaining refrac inventory

- performance uncertainty
Staged Completion Re-frac Considerations

How do we reduce economic uncertainty to better understand potential value?

**Top View Generation 1 Completion (< 20 stages)**

- **before refrac**
  - Undrained area
  - Well

- **after refrac**
  - Refrac'd with 33 additional stages
  - Well
  - Heel
  - Toe

**Reserves / Resources**

- Incremental benefit uncertainty
- Dependent on:
  - DSU remaining hydrocarbon volume
  - Re-frac completion effectiveness
  - Geologic uncertainty

**Completion**

- Cost of technology
- Risk of execution
- Operational risk of future well work activities due to reduced ID requiring small tools in tight clearance

**Investment Decisions**

- Deferred production / risk of lost production from existing well
- Partner approval requirements
- Confidence in technology
- Economic competitiveness within opportunity portfolio