Restimulating Horizontal Oil Wells – Success and Failure*

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Abstract

More than 200 refrac jobs have been attempted in horizontal oil wells including the Eagle Ford, Woodford, Bakken, Niobrara, Wolfcamp, Spraberry and other resource plays. Although many operators remain relatively silent regarding the size of their restimulation programs, encouraging results have inspired many companies to experiment with restimulation despite the current low oil price environment.

This presentation will include updated production results from an earlier review of 100 Bakken refracs (previously published as SPE 136757). There are specific categories of refrac candidates that can be restimulated with an 80-90% success rate. Particularly good candidates in the Bakken include wells that used low strength proppant (sand or resin-coated sand), and wells that were stimulated with a low number of stages. This presentation will also show a number of previously unpublished refrac examples in other fields including the Eagle Ford.

One common problem the author observes in his consulting and training is that groups “lock in” on a refrac design before they actually identify the problem they are trying to solve. If the initial fractures collapsed because they used an inferior strength proppant, they require a different refrac solution than if the fractures have scaled up, or if the prop-pant has embedded into a relatively soft formation. Many groups mistakenly hone in on maximizing diversion or trying to blindly pump at higher rates without actually contemplating the best way to diagnose and address the actual problem. Yes, we can design “brute force” refracs that simultaneously solve a number of problems. They are often economic. However, unless we significantly change
our approach, the evidence suggests even those refracs will be of temporary durability. There are a number of fields in which the same perforations have been restimulated more than five times, and the author is aware of wells with up to eight economic refracs performed. Clearly, we have not optimized our jobs!

References Cited


Restimulating Horizontal Oil Wells

Success and Failure

AAPG GTW Mar 9-11, 2015 San Antonio

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Successful refracs have been performed in the Eagle Ford, Bakken, Three Forks, Niobrara, Spraberry, Wolfcamp, Viking, Montney, Cardium...

In addition to >30 other gas plays and >20 oil fields developed with vertical wells...

Why are refracs successful? When do refracs fail? What is the mechanism and how do we optimize the outcome?
Outline

• Refrac mechanisms
• Some examples I am allowed to share in this conference
  – Eagle Ford
  – Bakken
  – Provide references for more detail
• Comments on candidate selection
Identify your Current Notions

Why might refracs work? What would you guess to be the most important mechanism?

1. Poor implementation of original treatment
2. Achieve reorientation
3. Diversion to new perfs
4. Enlarge frac (surface area)
5. Increase conductivity
6. Replenish connection between wellbore and frac
7. Address some other mechanism

In my frac schools, I commonly find “groupthink”, especially in Eagle Ford operators.

Some companies anticipate refrac success is all about achieving diversion.

Other companies anticipate refrac success is solely tied to fixing poorly stimulated wells.

Very few companies have a big-picture view and consider all the potential reasons a refrac might work.
Where Have Refracs Worked?

Well Types
- Oil Wells (under primary depletion, waterflood, or EOR)
- Condensate Wells
- Gas Wells
- Gas Storage Wells
- Water Production Wells
- Water Injection Wells
- Steam Injection Wells
- Huff-n-Puff, cyclic injection/withdrawal Wells
- Disposal Wells

Formation Types
- Carbonates, limestones, dolomites, chalks, evaporites
- Sandstones, cherts, siliceous diatomites
- Coal (CBM), immature ductile shales, brittle shales
- Conglomerates, unconsolidated formations, siltstones

16-page Appendix is attached to SPE 134330 describing 143 field examples
Where Have Refracs Worked?

**Gas Well Refracs – Navigation**
- Canyon Sand, Texas SPE 4118, 7925, SPE 125260
- Escondido Sandstone, TX SPE 7912
- Undisclosed 7500 ft depth “low pressured field”, Texas SPE 14376
- Cooperstown, PA SPE 95511
- Morrow, Red Fork, Atoka, OK SPE 18861
- Smackover, Missississippi SPE 19768
- Mesaverde Group, CO & NM SPE 24307
- McAllen Field, Vicksburg, TX SPE 24872, 18257
- Eastern Gas Shales-Antrim, MI + Appalachian Shales SPE 26894
- Mendota, Granite Wash, TX SPE 27933
- Antrim, Shale, MI SPE 29172
- Gray Sand, Cotton Valley, LA SPE 29554
- Almond/Wamsutter, WY SPE 30480
- Hugoton, KS SPE 30651, SPE 30794
- Green River Frontier, WY + Piceance Basin, CO SPE 55627, GGRB 101026
- Barnett Shale, TX SPE 63030, FWBOG Nov 08, SLB 08-01-05
- DLeland, CRI:O, OTC 20268, 141263, 131783
- Oak Hill, Cotton Valley ETX + LA SPE 14655, Cotton Valley TX 70013
- Lower Cotton Valley, Bossier, North LA SPE 115467
- China SPE 77680
- Medicine Hat, Milk River, Alberta SPE 81730
- S. Texas undisclosed field E&P 2006
- Marcellus 131783

**Oil Wells**
- LA Basin, CA (1382)
- Clinton Sand, Ohio
- Olmos Formation, Texas
- Undisclosed, 3500 ft S. Texas
- Norge Marchand Unit, OK
- Devonian, Crane City, TX
- Westbrook Field, W. TX
- Pembina Cardium, Alberta
- Rangely Field, Colorado
- Kuparuk River Field, Alaska
- Foothills Cardium, Alberta
- China
- Hassi Messaoud, Algeria
- Chester, Kansas
- Vyngayakhinskoe Field, Siberia
- Kalimantan, Indonesia
- Bakken & Three Forks MT + ND + SK
- Volga/Urals – W. Siberia
- Arkansas undisclosed XTO field
- England – Sandstone (13858)
- Waddell Ranch-Mature Carbonate in Permian [166249]
- Eagle Ford
- Niobrara
- Viking
- Montney
- Spraberry
- Wolfcamp
- Cardium

Other slidepacks to review specific fields

Gas Well refracs  Oil Well refracs
When have Refracs been Performed?

- Immediately post-frac
  - Unsuccessful implementation
  - To achieve new entry points, diversion, reorientation
- Somewhat later
  - Most common published examples are 1-10 years later
- Much Later
  - >20 years, Clinton Sand, high perm oil, Ohio
  - >30 years, Mesaverde tight gas sand, Colorado
  - >30 years, Rangely Field, high perm oil, water + CO2 flood, Colorado
  - >40 years, Pembina mature waterflood, Alberta
  - >30 years, Medicine Hat, Milk River shallow gas
- Ideas available on the theoretically “optimal” time to refrac, but we need to discuss mechanisms first!
Why Do Refracs Work? (mechanisms)

Refrac success (143 worldwide papers in SPE 134330) attributed to:

- Enlarged frac (more reservoir contact)
  - Improved pay coverage (add pay in vertical wells)
  - Better lateral coverage (horizontal wells)
- Increased frac conductivity
  - Restore conductivity lost – frac degradation
  - Address unpropped/poorly propped portions
- Improve wellbore-to-frac connection/conductivity
- Reorientation
- Use of more suitable frac fluids
- Re-energizing natural fissures
- Other mechanisms
  - Fracturing past condensate block, inducing complexity, rearranging existing proppant pack, better containment of refrac, etc
Mechanisms – Why Refrac the Bakken based on review of 100 refracs (SPE 136757)?

Frac Collapse
- Overwhelming evidence most Bakken frac jobs heal or close over time

Poor initial completion practices
- Insufficient stage count (opportunity to add perfs)
- Single stage initial fracs
- Use of low strength sand or RCS or some of the crappy ceramics
- Insufficient near-wellbore connection (prop concentration, overflush, etc)
- Poor initial placement (cleanout 150,000 to 300,000 lbs sand before refracing!)

Salt precipitation
Failure to inhibit scale

Reorientation
Opportunity for greater containment, focus investment within target

Potential to refrac instead of infill?
- Can vertical downspacing, adjacent laterals be avoided?

Inoculate wells from frac hits from adjacent wells (more in EF&Woodford)

Up to 90% economic success rate with some Bakken candidates!
Eagle Ford

- I am aware of a number of refracs (~25 as of Dec 2014) performed in EF. Not many details have been publicly disclosed to my knowledge.

  - Pioneer June 12, 2014 ATW followed by SPE 173333 (PXD first 3 refracs)
  - Schlumberger released results from 4th PXD refrac
  - Baker Hughes used algorithm to identify 21 EF refracs based on production trend analyses, SPE 173340

- Also in Eagle Ford, hesitation fracs appear to induce diversion (microseismic mapping)
Eagle Ford – Pioneer Refracs

- Discussed 1\textsuperscript{st} three refracs; 4\textsuperscript{th} disclosed by SLB. Detailed discussion of well completion specifics and strategies, showed RAT and microseismic (did not release slides). Also discussed production!

SPE-173333-MS

Refracturing on Horizontal Wells in the Eagle Ford Shale in South Texas - One Operator’s Perspective

Mamadou Diakhate and Ayman Gazawi, Pioneer Natural Resources; Bob Barree, Barree & Associates; Manuel Cossio, Beau Tinnin, Beth McDonald, and Gervasio Barzola, Pioneer Natural Resources

- Did not show production, but showed modeling, RAT, treating pressures, pump schedules
Eagle Ford – Pioneer Refracs

- Some public statements:
  - Goals:
    • Bypass NWB damage & stim new area
    • Increase pressure prior to adjacent drill/frac
  - Results:
    • All 3 refracs increased EUR
    • No communication from new infill, no RAT in offsets
  - Initial Candidates:
    • Original slickwater jobs, high drawdown, (poor choke mgmt)
    • 1700-3400 bopd IP, EUR 1.9 to 3.6 mmcfe, declined to 130-400 mcfd at 300 to 1200 FTP
  - Paper Conclusions:
    • Original slickwater jobs provided poor conductivity and less continuity
    • Refrac with hybrid or gel and higher proppant concentrations
    • Diversion was effective with bio balls and sand slugs (but now also using degradable diverters)
    • Evidence of frac containment in lower EF in this part of field
Eagle Ford – Pioneer Refracs

- From SLB Case Study:
  - Well D:
    - Candidate was originally one of the field’s best oil producers
    - 2 years of production
    - 13 refrac stages, completed using the identical amount of proppant as initial job
    - Used pillar strategy plus composite diverter pills
    - Shut in applied after placing each composite pill to monitor change in frac gradient
    - All 13 refrac stages pumped sequentially in 36 hour period
    - No mechanical aids (no plugs or inflatable packers)

- Results:
  - PI increased by more than 600%
  - Oil 89 to 195 bopd plus still recovering 100 bwpd of load fluid
  - Gas 227 to 428 Mcf/d
  - FTP 922 to 4034 psi
Eagle Ford – Pioneer Refracs

- From SLB Case Study:
  - Well D:

Well B (bioballs, benzoic acid and sand slugs) with hybrid fluid had ISIP build of 1127 psi and was stated to have similar production improvement to this well.

ISIP measurements showing progressive increase toward values that are characteristic of newly stimulated rock.
**Eagle Ford – Pioneer Refracs**

- From SLB Case Study:
  - Well D:

- PI increased by more than 600%
  - Oil 89 to 195 bopd plus still recovering 100 bwpd of load fluid
  - Gas 227 to 428 mcf/d
  - GOR flat 2550 to 2200
  - FTP 922 to 4034 psi

*Well performance during the first 45 days before and after refracturing.*
Eagle Ford – Operator X Refracs

- From employee:
  - Two EF wells refractured
    - Modest production uplift. Likely would have been economic, but caused damage to offset wells
    - Crosslinked gel in refracs, with degradable diverters
    - Adjacent wells had both water and frac sand produced to surface
    - Due to productivity damage of adjacent wells, refrac program was deemed uneconomic
    - I believe 330’ spacing
Eagle Ford Refracs – Public Data

- Screening of public production data, algorithm to identify suspected refracs
  - Located 16 refracs in oil window
  - Located 5 refracs in condensate window
- Identification technique tends to identify successful refracs (missing wells in which production was not appreciably higher due to failure or choked production)
- Technique does not consider impact to surrounding wells
- Concluded EUR increase of 53% in Eagle Ford and 69% in Bakken
- No discernable correlation based on well age
- Similar b factors post refrac, although decline curves were typically shallower (superior) after refracturing
Eagle Ford Refracs

- 16 oil well refracs identified via production data trends (public data)

### Table 1—Performance metrics of re-fractured oil wells in Eagle Ford

<table>
<thead>
<tr>
<th>Well Number</th>
<th>Time until refrac (months)</th>
<th>( q_1 ) (IP) - STB/D</th>
<th>( q_2 ) (STB/D)</th>
<th>( q_3 ) (STB/D)</th>
<th>IP Ratio</th>
<th>Jump Ratio</th>
<th>( b_1 )</th>
<th>( b_2 )</th>
<th>EUR</th>
<th>EUR</th>
<th>EUR Ratio</th>
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<td>1.00</td>
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<td>86</td>
<td>501</td>
<td>0.53</td>
<td>5.8</td>
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<td>92.5</td>
<td>82.0</td>
<td>0.89</td>
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<td>479</td>
<td>60</td>
<td>293</td>
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<td>4.9</td>
<td>0.8</td>
<td>0.8</td>
<td>89.5</td>
<td>76.2</td>
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<td>711</td>
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<td>490</td>
<td>0.69</td>
<td>5.9</td>
<td>0.7</td>
<td>0.7</td>
<td>89.3</td>
<td>84.0</td>
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<td>641</td>
<td>97</td>
<td>429</td>
<td>0.67</td>
<td>4.4</td>
<td>1.3</td>
<td>1.5</td>
<td>85.7</td>
<td>81.6</td>
<td>0.95</td>
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<td>Well 6</td>
<td>13</td>
<td>43</td>
<td>13</td>
<td>33</td>
<td>0.76</td>
<td>2.6</td>
<td>1.4</td>
<td>1.5</td>
<td>73.4</td>
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<td>342</td>
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<td>154</td>
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<td>1.2</td>
<td>1.2</td>
<td>87.9</td>
<td>77.3</td>
<td>0.88</td>
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<td>15</td>
<td>822</td>
<td>111</td>
<td>575</td>
<td>0.70</td>
<td>5.2</td>
<td>1.0</td>
<td>1.0</td>
<td>83.6</td>
<td>62.1</td>
<td>0.74</td>
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<td>30</td>
<td>500</td>
<td>95</td>
<td>537</td>
<td>0.97</td>
<td>6.1</td>
<td>0.9</td>
<td>1.2</td>
<td>79.1</td>
<td>96.3</td>
<td>1.11</td>
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<td>793</td>
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<td>20.9</td>
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<td>0.7</td>
<td>91.5</td>
<td>95.0</td>
<td>1.04</td>
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<td>Well 12</td>
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<td>92</td>
<td>434</td>
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<td>4.7</td>
<td>1.2</td>
<td>1.2</td>
<td>85.4</td>
<td>55.8</td>
<td>0.65</td>
</tr>
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<td>30</td>
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<td>42</td>
<td>290</td>
<td>1.05</td>
<td>6.9</td>
<td>0.8</td>
<td>0.8</td>
<td>67.6</td>
<td>81.3</td>
<td>1.20</td>
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<td>331</td>
<td>15</td>
<td>287</td>
<td>0.90</td>
<td>20.5</td>
<td>0.5</td>
<td>0.5</td>
<td>82.2</td>
<td>84.1</td>
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<td>290</td>
<td>17</td>
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<td>9.3</td>
<td>1.0</td>
<td>1.0</td>
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<td>63.1</td>
<td>0.77</td>
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<td>14</td>
<td>201</td>
<td>93</td>
<td>221</td>
<td>1.10</td>
<td>2.4</td>
<td>1.2</td>
<td>1.2</td>
<td>49.6</td>
<td>39.9</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Public data rarely includes flowing pressures. Without knowledge of choke-management strategies, decline estimates are challenging and should be viewed skeptically.
Eagle Ford Refracs

- Screening of public data, algorithm to identify refrac. Rarely identifies unsuccessful refracs. Encouraging technical success shown below.

Figure 8—Plot showing EUR ratios as a function of time until re-frac for existing oil and gas condensate re-frac’d wells in the Eagle Ford.
Eagle Ford Refracs

- Cash flows assuming $2.8MM refrac cost.

Figure 9—Net Crude Oil Production with economic limit for Well 9 in Eagle Ford

Figure 10—Discounted pre-tax cashflows waterfall for Well 9

Discounted Pretax Cashflows Waterfall

<table>
<thead>
<tr>
<th>Component</th>
<th>$MM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrac Costs</td>
<td>2.8</td>
</tr>
<tr>
<td>Incremental Refrac Revenues</td>
<td>14.0</td>
</tr>
<tr>
<td>Incremental Refrac Profit w/o Refrac</td>
<td>5.3</td>
</tr>
<tr>
<td>Incremental Refrac Profit with Refrac</td>
<td>9.3</td>
</tr>
<tr>
<td>Forecast Profit w/o Refrac</td>
<td>5.3</td>
</tr>
<tr>
<td>Royalties, Tax, and OPEX Incremental</td>
<td>1.9</td>
</tr>
</tbody>
</table>

SPE 173340 – BHI
Eagle Ford Refracs

- Shows 10 of 21 uneconomic given assumptions including $2.8MM capex

Table 3—Eagle Ford Re-fractured Wells Economics

<table>
<thead>
<tr>
<th>Well Number</th>
<th>Base NPV10</th>
<th>Incremental NPV10</th>
<th>Aggregate NPV10</th>
<th>Payback months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well 1</td>
<td>2.4</td>
<td>0.2</td>
<td>2.6</td>
<td>18.0</td>
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<td>Well 2</td>
<td>2.4</td>
<td>1.9</td>
<td>4.3</td>
<td>11.0</td>
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<tr>
<td>Well 3</td>
<td>1.4</td>
<td>0.4</td>
<td>1.7</td>
<td>38.0</td>
</tr>
<tr>
<td>Well 4</td>
<td>2.3</td>
<td>1.0</td>
<td>3.4</td>
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<tr>
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<td>4.8</td>
<td>(0.6)</td>
<td>4.2</td>
<td>293.0</td>
</tr>
<tr>
<td>Well 6</td>
<td>0.2</td>
<td>(2.6)</td>
<td>(2.4)</td>
<td>n.a.</td>
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<td>Well 7</td>
<td>1.3</td>
<td>5.7</td>
<td>7.0</td>
<td>12.0</td>
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<tr>
<td>Well 8</td>
<td>1.3</td>
<td>(1.7)</td>
<td>(0.4)</td>
<td>n.a.</td>
</tr>
<tr>
<td>Well 9</td>
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<td>(0.3)</td>
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<td>(0.2)</td>
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<td>7.5</td>
<td>13.6</td>
<td>8.0</td>
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<tr>
<td>Well 13</td>
<td>2.1</td>
<td>(1.2)</td>
<td>0.9</td>
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<td>Well 14</td>
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<td>(0.1)</td>
<td>0.1</td>
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<td>Well 17</td>
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<td>(2.0)</td>
<td>(0.4)</td>
<td>n.a.</td>
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<td>Well 18</td>
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<td>3.8</td>
<td>4.6</td>
<td>7.0</td>
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<td>Well 19</td>
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<td>(2.4)</td>
<td>3.5</td>
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<td>(1.5)</td>
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<td>Well 21</td>
<td>0.6</td>
<td>0.9</td>
<td>1.4</td>
<td>9.0</td>
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</tbody>
</table>
Comments on Eagle Ford Refracs

- Success Rate in EF
  - Technical success very high (80-90%)
  - Economic success currently modest to poor (~50%)
- But in the Bakken, certain categories of refrac candidates have >85% economic success rate. What is different?
  - Many early Bakken wells were single stage or non-isolated with very small initial fracs
  - Most EF refracs have used low quality proppant
  - Most EF operators have tunnel vision, focusing on diversion as primary mechanism in refracs
  - Many mechanisms can be addressed for much less than $2.8MM
  - Poor record keeping: exact proppant quality/testing, source water
  - Bakken may have more scale & salt deposition?
  - Several EF operators have selected very poor candidates to refrac
  - Frac hits often damaging in EF, while often beneficial in Bakken
  - Industry still learning. Infancy of designing refracs in EF.
Some Refrac Strategies

- Detectable proppants
  - Both radioactive (RAT) and non-radioactive (NRT) versions available
- Use GOR as in-situ diagnostic for contacting new reserves
Detectable Proppant

- Improved Coverage of Horizontal Laterals
  - Where radioactive tracers or detectable proppants indicated missed opportunities, refracs are frequently successful

- Montana Bakken, cemented laterals **believed drilled for longitudinal growth**
- Initial fracs ~300,000 lb 20/40 RCS
- RA tracer showed incomplete coverage
- Add perfs, refrac 600,000 lb 20/40 sand, 10 ppg slugs, ball sealers

Adapted from Lantz, 2007
GOR diagnostic

- Lower breakdown pressures, but 50% greater net pressure
  - We should revisit this issue!
- Oil rates up, GORs down
- Refracs diverted into undrained areas of the reservoir
- EUR increased 1,300,000 bbls in 16 refractured wellbores
- 1 mechanical problem, but 16 of 17 successful (94%)

![Graph showing Refrac reduced GOR, increased oil rate and reserves](image)
Some Refrac Strategies

- Detectable proppants
  - Both radioactive (RAT) and non-radioactive (NRT) versions available
- Use GOR as in-situ diagnostic for contacting new reserves
- Note that diversion and reorientation can occur even without additives

Microseismic data on several Eagle Ford refracs have shown outstanding diversion to previously unstimulated portions of the lateral before the first proppant or diverting stage was pumped!
Bakken Refracs *(Dunek, 2009: 115826)*

- Uncemented liner. N-S oriented lateral. Surface tiltmeter mapping
- Unintentional termination of frac job (wellhead isolation tool failure)
  - 3892 bbl crosslinked fluid and 296,000 lb proppant at 48 bpm
- 2\textsuperscript{nd} stimulation treatment 6 weeks later
  - 6533 bbl slickwater and 193,000 lb proppant at 61 bpm

Observations:
- Diversion/Initiation at new locations
- Both Transverse and Longitudinal Growth
Refrac Candidate Selection

Select a Good Well!
- In almost all fields, the most economic refrac candidates are GOOD wells
- Proves our initial fracs failed to harvest all accessible reserves
- Only start with the “dog” well, if you know the initial frac job was poor

Poor Initial Completion Practices
- Insufficient stage count
- Insufficient proppant durability
- If gelled frac, insufficient concentration
- Lack of scale inhibition

Consider cleaning out your danged well before refracturing
- Bakken cleanout recovering 150,000 to 300,000 lbs sand in multilats
- Rarely were cleanouts needed in Bakken wells treated with ceramic

Overflushed with crosslinked fluid
- A different refrac design to address this

Potential to refrac instead of infill?
- Can vertical downspacing, adjacent laterals be avoided?

Drilling nearby?
Less Desirable Candidates

Mechanical problems
- I don’t wish to pay for a workover
- I want some working pressure to aggressively divert and possibly screenout

Bad wells in a bad part of the field
- You will make more money refracturing good wells!
- Initially avoid wells with unexplained low IPs and low EURs. [prove success with a good candidate and then expand refrac program]

Wells initially fractured with known quality ceramic
- Let’s take the easier candidates that received crappy proppant first. There are plenty of them!

Wells full of sand
- Cleanouts are expensive. But necessary in many Bakken well populations. Unclear in the EF. These wells have good upside, but must be cleaned out before restimulating

One of a kind wells
- Nice to have a large population to duplicate our successes!
Refrac Summary

Hundreds of success stories
But plenty of economic failures
Please design your refrac program to address specific mechanism(s)
  • The design to fix near-wellbore connectivity is much different than the design to increase fracture penetration distance
Where refracs work, they are among the most economic of all opportunities in our industry

Refrac candidate evaluation, planning and implementation is not routine
  • Assign it to someone on your team and relieve them of competing responsibilities for a few weeks. It takes some head-scratching and brainstorming to make progress in this area.
Conventional versus Unconventional Reservoirs Multidisciplinary Teams!

- Myths and Misunderstandings that hinder Frac Optimization
- Detailed Rock Mechanics, Fluid Rheology, and Propagation Theory
- Physics of Fluid Flow
- Frac Sand mining and QC
- Proppant Types, Characteristics - differences between sand, resin and ceramic
- Conductivity Testing
- Non-Darcy Flow
- Multiphase Flow
- Understanding Proppant Crush Testing - Are hot/wet crush tests superior?
- Other Issues - Embedment, Stress Cyclic, Elevated Temperature
- Determining Realistic Proppant Conductivity
- Field Results – 200 summarized on SPE 119143; ~30 in PowerPoint
- PTA / Well Testing considerations / Effective Frac Lengths
- Fines Migration & Plugging
- Significance of Proppant Density, Frac width, sieve distribution upon proppant value
- Gel Cleanup
  - Lab studies and field examples documenting load recovery
- Proppant Flowback and Erosive Potential of sand, ceramic, and resin-coated proppants
- Frac Pack concepts and field studies
- Zero Stress applications – Flow in wellbore annuli or packed perforations
- Frac Optimization
  - CBM frac optimization
  - Fracturing versus Acidizing - Carbonates
  - Where do unpropped fractures work?
- Horizontal Wells – Comparisons with Vertical Fractured Completions
- HZ wells – Consequences of trajectory, azimuth, toe-up, toe-down, sumps, undulations
- Specific Field Results (Bakken, Pinedale, Kuparuk, Cardium, Wamsutter, Birch Creek, Siberia, Cotton Valley, Vicksburg, Haynesville Lime, UP + Ranger, others)
- Bakken Horizontal Wells – Importance of Frac Intersection with Wellbore, Refracs, Design
- Performance under Severe Conditions (Steam, Acid) + Diagenesis
- Waterfracs/Slickwater Fracturing
- Frac Geometry – What do Fracs Really look like? What errors are we making?
- 100 mesh sand – pros & cons
- Refracturing

Some Recent Seminars

- Bakken Horizontal Wells - Importance of Frac Intersection with Wellbore, Refracs, Design
- Performance under Severe Conditions (Steam, Acid) + Diagenesis
- Waterfracs/Slickwater Fracturing
- Frac Geometry – What do Fracs Really look like? What errors are we making?
- 100 mesh sand – pros & cons
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