REDEFINING REFRACS
What Is, What Isn’t, & What Might Be...

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NCS Multistage
OUTLINE

• Refrac Activity & Challenges
• Refrac Diagnostics
• The IDEAL Refrac
• **Hypothesis:**
  New Tools
+ New Options
= New Results?

*Hydraulic fracturing operations in the Montney Canada. Calfrac Well Services Photo.*
REFRACS STILL HAPPEN....
WHERE DO WE REFRAC?

Number of refractured horizontal wells by play, as of August 2015. Source: Rystad Energy NASWlData and Rystad Energy analysis.
DUC’s vs. REFRACS

ESTIMATED "DUCS" BY BASIN, YE 2015

Appalachian: 452
Eagle Ford: 420
Permian: 506
Williston: 602

Data From Navport Analytics
One Days Headlines, April 2016....

- **Breaking:** Goodrich Eyes Bankruptcy After Lackluster Offering

- Chaparral Warns of Bankruptcy; $1.6B in Debt

- Midstates Saddled with $1.9 Billion in Debt; Heading for Bankruptcy

- Southcross Parent Files Chapter 11 Bankruptcy

- W&T Offshore Credit Line Cut 60%; Heading for Bankruptcy

- Bakken E&P Black Ridge Talks Restructuring Plans
LOWER FOR LOOOONGER?

Debt Wall
How much U.S. junk-rated energy companies owe over the next seven years

$50 billion

45 O&G CH11 IN 2015

Bloomberg data
$WHY\ REFRAC?$

Average daily production (boe/d) for Bakken wells refracked in 2014 and 2015.

Rystad Energy NASWellData and Rystad Energy analysis.
Refracking older wells definitely increases the recovery of the well, but given current results, it is more profitable for operators to drill a new well. Recompletion is still an immature recovery technique but once better results are replicable, refracked wells could provide a large potential for low cost production.

*Development cost per boe for Bakken wells compared to refrack wells in each year.*

*Rystad Energy NASWellData and Rystad Energy analysis.*
SUCCESSFUL REFRACS

1. Increase EUR &/or
2. Provide Rate Acceleration

Ref: RPSEA Report
M. Sharma
REFRACS CAN

1. RESTORE FRACTURE CONDUCTIVITY (Re-Touch “Old” Rock)
2. FRAC NEW ROCK
   • ADD FRAC STAGES (Reduce Stage Spacing)
   • Diversion & Reorientation
3. APPLY NEW FRAC LEARNINGS (Fluids, Proppants, Chemistry etc)
4. PROVIDE FRAC-HIT “PROTECTION”
5. PRESERVE CAPITAL
## DATA, STUDIES, SUMMARIES & COMMONALITIES

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors/Companies</th>
<th>Conference Paper Details</th>
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<tbody>
<tr>
<td>Refracs: Why Do They Work, and Why Do They Fail in 100 Published Field Studies?</td>
<td>Vincent, Mike C., Insight Consulting</td>
<td>134330-MS SPE Conference Paper - 2010</td>
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<td>Restimulation of Unconventional Reservoirs: When are Refracs Beneficial?</td>
<td>Vincent, Mike C., Insight Consulting</td>
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<td>Grieser, Bill, Halliburton</td>
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<td>A Case History of Refracs in the Oak Hill (Cotton Valley) Field</td>
<td>Hunter, J.C., Graham Resources Inc.</td>
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<td>Stress Field Change Due to Reservoir Depletion and Its Impact on Refrac Treatment Design and SRV in Unconventional Reservoirs</td>
<td>Han, Jiahang, Baker Hughes</td>
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<td>Hurt, Robert, Baker Hughes</td>
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<td>174951-MS SPE Conference Paper - 2015</td>
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<td>Surface Tiltmeter Mapping Shows Hydraulic Fracture Reorientation in the Codell Formation, Wattenberg Field, Colorado</td>
<td>Wolhart, Stephen Lee, Pinnacle Technologies</td>
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<td>McIntosh, Gregory Edward, Kerr-McGee Rocky Mountain Corp.</td>
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<td>Weijers, Leen, Pinnacle Technologies</td>
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EXTENSIVE REFRACT LITERATURE

References noted in text (additional references in Appendix)


“The efforts of many researchers have already cast much darkness on the subject, and it is likely that if they continue, we will soon know nothing about it at all.”

Mark Twain
SOME “TYPICAL” OBSERVATIONS

• “Initial completions exhibit inconsistent proppant coverage across the perforated interval.” – SPE-174979, Leonard, Moore, Woodruff, Senters

• Wells employing (refrac) diversion techniques ... are not consistently contacting new rock. - SPE 174979

• “The biggest challenge in re-stimulating old wells is how to handle the existing perforations.” - SPE 174979

• “…the variation in (refrac) outcomes is too wide for refracturing to be adopted on a large scale today.” – SPE 174951, Indras, Blankenship

• “… Can we design wells that can be easily isolated and refractured?” – SPE 136757, M. Vincent
WHAT TO CONSIDER

• WELL CONFIGURATION & HYDRAULIC ISOLATION
  • Balls/Perfs/Ports/Baffles/Plugs

• WELL INTEGRITY
  • Casing Size, Weight, Erosion, Corrosion, Cement Integrity, External Packers, Casing Deformation etc.

• Existing Fractures
  • Conductivity, Location, Dimensions, Inter-well Communication

• Remaining Resource (Recovery Factor)
  • Where Is It & How Do We Target It
PERF CLUSTER PERFORMANCE

Percentage of all perforation clusters that are not producing. Gray bars include all fracture stages. Green is for stages producing from 110% to 150% above the average rate. The red bars are for stages producing greater than 150% the average rate (Miller et al. 2011).
Realistic Conductivity Reductions

- Low Quality Sand
- Best Quality Ottawa Sand
- Premium Light Weight Ceramic

Effective conductivities can be less than 1% of API test values
HOURS, NOT MONTHS

McDaniel 1986
OPPORTUNITIES

..... 40% to 60% of stages produce little or no hydrocarbons, while 30% of the stages represent 80% of a well’s entire production. Baker Hughes estimates that ineffective stages have come at an annual cost upward of USD 40 billion.
Why Refracture

The simple reason to refracture a well is to boost production. But to do that, operators need to pinpoint the problems they seek to remedy and then design the proper refracture treatment.

- Address proppant embedment or rock creep.
- Implement new completion learnings.
- **Contact virgin rock by adding perforations, diversion, or reorientation.**
- Reorient existing fractures to new areas of the reservoir.
- Replace crushed or low-conductivity proppant.
- Bypass damage caused by salt deposition, scale, or fines plugging.
- Fix stages where proppant was overflushed or flowed back into the wellbore.
- Improve the durability of initial proppant.
- Repressurize an existing well before offset drilling and completions.
- Re-energize natural fractures or rearrange existing proppant pack.
- Deliver production chemicals such as emulsion breakers and scale inhibitors.

Reference: JPT April 2015 – Trent Jabobs’ Interview with Mike Vincent
Measuring Refrac Performance

- Restore or Improve Apparent Conductivity
- Increase Fracture Area
- Increase Stimulated Reservoir Volume

\[ k_f w \quad A \quad \text{OGIP or OOIP} \]
RTA Modelling & The Concept of Effective Permeability

Physical Description
Fractured reservoir with matrix permeability

Functional Model
Unfractured reservoir with equivalent permeability

\[ k_{\text{matrix}} = A \times \frac{A \sqrt{k_{\text{matrix}}}}{A_n} \times \left( \frac{A \sqrt{k_{\text{matrix}}}}{A_n} \right)^2 \]

A = total connected fracture area
Sum of all connected \( x_f h_f \)

\( A_n = L \times h \)
RTA Methodology

\[ A\sqrt{k} \text{ and } FCD' \]

Slope

Intercept

Flow Regime ID

Forecast

OGIP

SRV

Vertical Well with bi-wing frac

Legend:
- Normalized Pressure
- Boundary Controlled Curve
- \( t \)

Flowing Material Balance

Normalized Gas Cumulative Production (Bscf)

UR-GVPH 1

Fracture Schematic

\( X_a = 659.9 \text{ ft} \)

\( X_r = 330 \text{ ft} \)

\( X_m = 328.9 \text{ ft} \)
Barnett Well Case Studies

1) Vertical Well with 2 Refracs
2) Horizontal Well with 1 Refrac
Barnett Field Example 1 – Vertical Well
Barnett Field Example 1 – Vertical Well

2 Refracs in 2011 & 2015
Ex. 1 - Reinitializing with Sqrt Time Plot

\[ P_{\text{bar}} \text{ becomes } P_i \text{ for performance after Refrac} \]

- Initial Frac: 117 Mlbs
- 1st Refrac: 583 Mlbs
- 2nd Refrac: 588 Mlbs
Ex. 1 - Reinitializing with Sqrt Time Plot

Initial Frac
Good conductivity
Low Frac Area

1st Refrac
Low conductivity
High Frac Area

2nd Refrac
High conductivity
Massive Frac Area
Example 1 – Performance Modeling

**Initial Completion**
- \( A_{SRV} = 4 \text{ ac} \)
- \( FCD = 300 \)
- \( k_{eff} = 800 \text{ nd} \)
- \( k_m = 50 \text{ nd} \)

**1\text{st} Refrac**
- \( A_{SRV} = 6.5 \text{ ac} \)
- \( FCD = 35 \)
- \( k_{eff} = 2000 \text{ nd} \)

**2\text{nd} Refrac**
- \( A_{SRV} = 6.5 \text{ ac} \)
- \( FCD = 1000 \)
- \( k_{eff} = 10,000 \text{ nd} \)

History matching bottomhole flowing pressure
Example 1 - FMB Analysis
Example 1 - FMB Analysis
Example 1 - FMB Analysis
Example 1 - Cum vs. Time (Forecasting)
Example 1 - Cum vs. Time (Forecasting)
Example 1 - Cum vs. Time (Forecasting)

- **1st Refrac**
- **Initial Completion**
Example 1 - Cum vs. Time (Forecasting)
Ex. 2 – Linear Superposition Time Analysis

Initial Completion 960 Mlbs

Refrac 1300 Mlbs
Example 2 – Performance Modeling

\[
\begin{align*}
A_{\text{SRV}} &= 27 \text{ ac} & A_d &= 46 \text{ ac} \\
k_{\text{eff}} &= 216 \text{nd} & k_m &= 50 \text{nd}
\end{align*}
\]

Initial Completion

\[
\begin{align*}
A_{\text{SRV}} &= 27 \text{ ac} & A_d &= 46 \text{ ac} \\
k_{\text{eff}} &= 400 \text{nd} & k_m &= 50 \text{nd}
\end{align*}
\]

Same SRV following Refrac!

Post-Refrac
Example 2 - FMB Analysis

Initial Completion

Post-Refrac
MUCH NEEDED ANSWERS

• While production data analysis cannot tell us the specifics of fracture geometry, it can tell us if a refrac has accomplished the following:

  1- Increased SRV
  2- Increased fracture area (effective permeability) within SRV
  3- Changed fracture conductivity
The Goal; Frac Placement Control
Mechanical ReFrac Systems
Mechanical ReFrac Systems
Mechanical ReFrac Systems
DEFAULT TO DIVERSION
CONTROL OF FRAC PLACEMENT?

SPE-177306-MS

Refraiming Design for Underperforming Unconventional Horizontal Reservoirs

J. T. Kreenger, J. Fraser, and A. J. Gibson, Devon Energy; A. Whitsett, J. Melcher, and S. Persac, Halliburton
WHAT MIGHT AN “IDEAL” REFRACT LOOK LIKE ??

• FLUID & PROPPANT PLACEMENT CONTROL
• REDUCED RISK OF WELL BASHING
• REFRAC EXISTING STAGES
• CAPACITY TO ADD NEW STAGES
• MULTIPLE REFRACCS OVER WELL LIFE
• LOWEST OPERATIONAL RISK
• PRODUCTION MANAGEMENT
• MAXIMUM SRV
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• PRODUCTION MANAGEMENT SELECTIVE PRODUCTION
• MAXIMUM SRV FRAC DESIGN OPTIMIZATION
START WITH THE END IN MIND:
START WITH THE END IN MIND: 

RE-CLOSABLE FRAC SLEEVES
START WITH THE END IN MIND: **RE-CLOSABLE FRAC SLEEVES**

- MEETS ALL “IDEAL” CRITERION
- NEEDS FIELD TRIALS IN REFRAC APPLICATIONS
- A POTENTIAL STEP-CHANGE IMPROVEMENT
  - Proppant Distribution
  - Refrac Capabilities
TO DATE: ONE WELL ONLY...

1. SLEEVES OPENED & ACIDIZED (Individually)

2. PRODUCED FOR SEVERAL WEEKS

3. SLEEVES CLOSED

4. SLEEVES FRACTURED INDIVIDUALLY

5. WELL PLACED ON PRODUCTION
WHAT MIGHT AN “IDEAL” REFRACT LOOK LIKE ??

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• MAXIMUM SRV FRAC DESIGN OPTIMIZATION

... ? INDUCED COMPLEXITY ?
Vertical Well Frac Re-Orientation

Ebel & Mack 1993
SPE 134491, Sharma & Roussel
ZIPPERFRACCS & MODIFIED ZIPPERFRACCS

Fig. 15—Fracture placement in zipper-frac design

Fig. 16—Fracture placement in MZF design
Poroelastic & Mechanical Stress Effects

Comparison of stress reorientation resulting from (a) mechanical effects and (b) poroelastic effects (direction of maximum horizontal stress).

SPE 134491, Sharma & Roussel
FRACTURE INTERFERENCE
Initial Completion
FRACTURE INTERFERENCE
Initial Completion
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Initial Completion
FRACTURE INTERFERENCE
Refrac / Recompletion
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FRACTURE INTERFERENCES
Refrac / Recompletion
OUT OF SEQUENCE FRACS WILL HAVE DIFFERENT GEOMETRY & PROP DISTRIBUTIONS
Open / Close Simplicity
CTU Deployment Offers Downhole Information
BH GAUGE DATA – WHAT DOES IT MEAN?
INTER-STAGE DIAGNOSTICS

Pressure spikes indicate a differential pressure across the equalizing valve opens. Open hole packers are sealing.

Lack of differential pressure when the equalization valves opens indicates pressure transfer across the lower open hole packer.

Communication

No Communication
In Conclusion

- Initial Completion Designs Play A Significant Role In The Potential For Refrac Optimization & The Potential For Refrac Success
- Production Analysis (RTA) Can Help To Identify The Source (SRV, $K_{eff}$, FCD) Of Production Rate and EUR Improvements Realized Through Refrac Operations
- Discreet Fracture Placement & Frac Sequencing Is Now Operationally Viable, And May Provide Otherwise Unattainable Fracture Enhancements