Restimulation Design Considerations and Case Studies of Haynesville Shale

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Refracturing Design for Underperforming Unconventional Horizontal Reservoirs

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Introduction/Overview

• Haynesville Shale
• Evolution of optimization in the Haynesville Shale
• Challenges of refracturing horizontal unconventional reservoirs
• Description and application of equipment and process
• Designing a refracture based upon self-removing particulate diverters
• Data and results
• Conclusions
### Physical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young’s modulus</td>
<td>1.5 to 2.5 E-06</td>
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<tr>
<td>Poisson’s ratio</td>
<td>0.25 to 0.32</td>
</tr>
<tr>
<td>Frac gradient</td>
<td>0.95 to 1.05 psi/ft</td>
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<tr>
<td>Closure gradient</td>
<td>0.90 to 0.95 psi/ft</td>
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<tr>
<td>Pore gradient</td>
<td>0.80 to 0.85 psi/ft</td>
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<tr>
<td>Temperature gradient</td>
<td>1.8°F/100 ft</td>
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<tr>
<td>Permeability</td>
<td>100 nd</td>
</tr>
<tr>
<td>Depths</td>
<td>10,000 to 13,000 ft</td>
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</table>

Haynesville Shale geographic area in east Texas and north Louisiana (Parker 2009)
Evolution of Optimization in the Haynesville Shale

- Perforation strategy
- Proppant mass
- Production strategies
Challenges of Refracturing Horizontal Unconventional Reservoirs

- Isolation control
- Leakoff
- Initial depletion
- Communication with offset wells
Description and Application of Equipment and Process

- Mechanical method
  - Rework wellbore
  - Coiled tubing

- Particulate diversion method
  - Rock salt
  - Perforation ball sealers
  - Environmentally acceptable self-removing diverting particle
Candidate Selection/Design Components of a Refracture Treatment

Candidate selection

- Narrowing the field
- Offset production comparison
- Geosteering interpretation

Design components

- Original completion
- Damage remediation
- Adding perforations
Presentation of Data and Results

- Phase I
  - Restimulate with current completion design

- Phase II
  - Leak off control
  - Larger restimulation treatments

- Phase III
  - Achieve fracture initiation pressure earlier
Phase I

• Learnings
  • Leak off into original fractures
  • Sand plug formation
Phase II

- Learnings
- Leakoff can be controlled with Crosslink fluid
- Need to achieve fracture initiation pressure earlier
## Comparison of Estimated Ultimate Recovery (EUR) Uplift

<table>
<thead>
<tr>
<th>Fluid Selection</th>
<th>Fluid Volume (bbl)</th>
<th>Proppant Mass (Ibm)</th>
<th>Cumulative Production Prior to Refrac (MMcf)</th>
<th>EUR Prior to Refrac (MMcf)</th>
<th>EUR After Refrac (MMcf)</th>
<th>EUR Uplift (MMcf)</th>
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<tr>
<td>Well A</td>
<td>FR Water</td>
<td>62,831</td>
<td>1,935,080</td>
<td>775</td>
<td>1,395</td>
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<td>540</td>
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<td>Well B</td>
<td>FR Water</td>
<td>113,382</td>
<td>2,322,400</td>
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<td>645</td>
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<td>Well C</td>
<td>Crosslink</td>
<td>104,620</td>
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<td>1,723</td>
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Conclusions

• Refracturing treatments using multisized, self-assembling, and self-removing diverting particulates increases EUR
• Proper candidate selection is vital
• Large cluster spacing requires additional clusters to be perforated.
• Mitigating leakoff along the wellbore is critical.
• Crosslinked fluid outperforms low viscosity fluids
• Additional perforations are not necessary to contact unstimulated reservoir or create incremental EUR
Candidate Selection

Selection Reasons

• Originally understimulated and underpropped
• Suitable landing zone
• Underperformed offset HVS wells
• Aggressive initial production/choke management
• Microseismic from original fracture

Objective

• Enlarge fracture geometry
• Restore fracture conductivity
• Re-energize existing fractures
Case Study 2: Original Completion

- Proppant/lateral ft: 792 lbm/ft
- Cluster spacing: 60 ft
- Lateral length: 5,400 ft

Gas Cum: 1.2 BCF
Phase III

- Wellbore Preparation
  - Pretreatment
  - Short Cycles

- Crosslink Cycles

- Hybrid Cycles
Case Study 2: Results

The graph illustrates the results of refracturing design for underperforming unconventional horizontal reservoirs. The x-axis represents stages, and the y-axis shows the number of MSM events/average rate (bbl/min) for pretreatment and crosslink schedules. The graph also shows the average rate and average treating pressure for Hybrid schedules.
Case Study 2: Results
Case Study 2: Results

The graph shows the relationship between the number of MSM events and stages across three categories: Short schedules, Crosslink schedules, and Hybrid schedules. The Y-axis represents the number of MSM events, while the X-axis shows stages from 1 to 21. The graph indicates a significant increase in % increase Diverter Concentration with Hybrid schedules compared to Short and Crosslink schedules.
Case Study 2: Results

Plug @ 14,250’

Perforations open during refrac 11,402’-14,209’

Heel Frac Perforations
Case Study 2: Results

TRACER SAMPLE DATA

Days of Flowback

Flowback Tracer Allocation

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Case Study 2: Results
Conclusions/Observations

• Microseismic monitoring indicates stimulation occurred along the entire length of the exposed lateral during the treatment for the Haynesville Shale well. The chemical diversion technique appears to aid full lateral coverage for the stimulation.

• Comparing post-treatment initial shut-in pressures from the original stimulation to the restimulation indicates a secondary treatment is able to contact virgin reservoir pressures.

• Chemical tracer data shows a restimulated interval can be immediately competitive with a newly stimulated, virgin interval’s pressure and producibility.
Acknowledgements / Thank You / Questions

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