MAXIMIZING THE RESERVOIR ACCESS WITH COMPLETION OPTIMIZATION AND EFFECTIVENESS

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AGENDA:

- Completion effectiveness
- Intro Case Study
- Completion
- Production analysis
- Completion costs
- Conclusions
Completion Effectiveness

• Challenges to analyze unconventional Shale reservoirs
• Multifracture Horizontal well MFHW - Flow regimes
• Rate Transient Analysis fundamentals
• Diagnostic Plots - Linear flow Specialized plot indicator of completion effectiveness
• SPE references
Challenges to analyze unconventional shale reservoirs

- Flow regimens stay in transient flow for a long period of time
- Difficulties to estimate the ultimate recovery, XF, Permeability, Fracture conductivity and drainage area
- DCA assumptions used for conventional reservoirs not valid
  - Existence of boundary dominated flow
  - Constant flowing bottom-hole pressure

- Evaluation of unconventional Shale reservoirs requires rate, pressure and other reservoir parameters to determine the flow capacity in linear flow.
Flow regimes in a MFHW
Schematic (SPE 162647)

1. Bi-Linear Flow
2. Formation Linear Flow
3. Transition Period
4. Compound / SRV Linear Flow
5. Transition Period
6. Boundary Dominated Flow
Rate Transient Analysis fundamentals

Multifracture Horizontal well MFHW

\[ A_f = A_c = 2X_f \ast h \ast 2n \]

Horizontal wellbore

Horizontal wellbore

Lineal flow (equation solution)

\[ \frac{(P_i - P_{wf})}{q} = 16.26 \cdot \frac{B}{A_f} \cdot \left( \frac{\mu \cdot t}{k \phi C_t} \right)^{1/2} + 141.3 \cdot \frac{B \mu}{kh} \cdot S f \]

\[ \frac{P_i - P_{wf}}{q_g} = \frac{C \ast \sqrt{t}}{A_c \sqrt{k}} \]

Normalized pressure vs SQR time

Diagnostic Plot – Linear flow Specialized plot

Source: SPE 162646

Good indicator of “completion effectiveness” based on early well performance data

More contacted area than

Completion case 2

Completion case 1
Diagnostic Plot – Linear flow Specialized plot
Normalized pressure vs SQR time

- Can be used as “Completion Effectiveness” tool if limited variation in reservoir properties
- Good indicator of “Completion Effectiveness” based on early well performance data
- Plot identifies transient lineal flow and quantifies total connected fracture area and square root of SRV permeability.

- Use of linear flow tendency over predict EUR........however, Good correlation between Norm.AQRT vs Norm.EUR
References

• SPE – 162646: Importance of the Transition Period to Compound Linear Flow in Unconventional Reservoirs
• SPE – 162647: What’s Positive about Negative Intercepts
• SPE – 177293: Production Analysis using Rate Transient Analysis
• URTeC – 2688694: Timely Understanding Of Unconventional Reserves through Rate Transient Analysis
MAXIMIZING THE RESERVOIR ACCESS WITH COMPLETION OPTIMIZATION: CASE STUDY VACA MUERTA

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INTRODUCTION

- 2 wells in the same PAD
  - Well A => Pinpoint
  - Well B => Plug & Perf

Both wells targeting Vaca Muerta

Comparison of completion methodology, RTA analysis and costs
COMPLETION: Methodology

WELL A - PINPOINT
- 60 coiled tubing shifted sleeves installed - RECLOSABLE
  - 58 stimulated
- Average spacing ~24.9m between sleeves
- Isolation inside casing with resettable bridge plug on CT BHA
- Annular frac
- No frac plug drillout

WELL B - PLUG & PERF
- 18 frac stages / 54 entry points
- 3 perforation clusters per frac stage
  - Isolated by bridge plugs
- 10 perforations per cluster / 0.5 m
- Average spacing ~24.5m between clusters
- Required frac plug drillout

Pinpoint frac isolation tool (see schematic)
COMPLETION: Methodology
COMPLETION: Frac Design

Similar treatments
- Hybrid fluid design
- Increasing proppant size 100 mesh to 20/40

Some differences
- Fluid volumes and distribution of fluid type
- Injection Rate
- Proppant size distribution
- Lateral length

Average per entry point

<table>
<thead>
<tr>
<th>Well</th>
<th>WELL A</th>
<th>WELL B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry Point Spacing (m)</td>
<td>24.9</td>
<td>24.5</td>
</tr>
<tr>
<td>Slickwater (bbls)</td>
<td>1,636</td>
<td>1,172</td>
</tr>
<tr>
<td>Gel (bbls)</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Crosslink (bbls)</td>
<td>915</td>
<td>1,210</td>
</tr>
<tr>
<td>Total Fluid (bbls)</td>
<td>2,551</td>
<td>2,403</td>
</tr>
<tr>
<td>100 mesh (lbs)</td>
<td>16,144</td>
<td>12,315</td>
</tr>
<tr>
<td>40/70 sand (lbs)</td>
<td>45,121</td>
<td>47,220</td>
</tr>
<tr>
<td>40/80 Sinterlite (lbs)</td>
<td>40,937</td>
<td></td>
</tr>
<tr>
<td>30/50 sand (lbs)</td>
<td></td>
<td>35,739</td>
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<tr>
<td>30/60 Sinterlite (lbs)</td>
<td>26,418</td>
<td>35,433</td>
</tr>
<tr>
<td>20/40 Wanli (lbs)</td>
<td>29,028</td>
<td>29,980</td>
</tr>
<tr>
<td>Total (lbs)</td>
<td>157,648</td>
<td>160,687</td>
</tr>
<tr>
<td>Injection Rate (bpm)</td>
<td>23.3</td>
<td>17.3</td>
</tr>
</tbody>
</table>
COMPLETION: Instantaneous Shut-In Pressure

**WELL A**
- Individual entry point ISIPs (BH data)
- Show end of job pressure variability

**WELL B**
- Only ISIP data available (surface)
- Shows some variability even with “averaging” effect of 3 clusters
COMPLETION: Breakdown Pressure (BH gauge)

WELL A Formation Breakdown Pressure

- Individual entry point breakdown pressures
- Show early job pressure variability
- Deadstring data (BH)
- 58 of 60 zones treated (≈96.7%) on WELL A
- NO DATA ON EFFICIENCY ON WELL B

PINPOINT COMPLETION TECHNOLOGY IN THE VACA MUERTA SHALE: A CASE STUDY
COMPLETION: Bottom Hole Gauge Data Evaluation

Only available on WELL A

- Near wellbore restriction
  - Indication of fracture complexity
  - Relatively moderate and declines during the treatments

- Proppant distribution
  - Interpreted as being good
  - Minimal proppant bridging

- Real time net pressure indication
  - CT deadstring
  - Avoid screen out
Communication between stages - Only available on WELL A

- Zonal pressure isolation evaluation
  - Reasonable with most communication being slight in nature
PRODUCTION EVALUATION: *Basic Comparison*

Comparison of production rate and calculated bottomhole flowing pressure

- Similar lateral length (1500 m)
- Both wells navigate in the same section
- Both wells exhibit choke change at different times
- Pressures measured at surface (BH Calc)
- No tubing installed

**Chart:**

- Oil Rate (stb/d)
- Calculated BH Pressure (psi)
- Normalized time (months)

**Legend:**

- WELL A (Pinpoint)
- WELL B (Plug & Perf)

**Graph Notes:**

- Choke management
PRODUCTION ANALYSIS: *Basic Comparison*

Comparison of oil and gas production volumes

- Shows similar profiles with the WELL A performing slightly better
PRODUCTION EVALUATION: Rate Transient Analysis

Linear flow specialized plot analysis

- Slope is inversely proportional to connected fracture area (A√k)
- Geomechanical effects with choke changes

WELL A (pinpoint) 40% more connected area

Slope inversely proportional to contacted Area

Oil Linear Superposition time (d_{1/2})
PRODUCTION EVALUATION: Rate Transient Analysis

Flowing material balance (FMB)

- Quantifying the contacted Original Oil in Place (OOIP)
- Extrapolation of this plot yields a rough estimate of SRV
- Geomechanical effects with choke changes

WELL A (pinpoint) 60% more SRV

PINPOINT COMPLETION TECHNOLOGY IN THE VACA MUERTA SHALE: A CASE STUDY
**COMPLETION COST: Comparison**

<table>
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<tr>
<th>WELL A (Pinpoint)</th>
<th>WELL A (Plug&amp;Perf)</th>
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<tr>
<td>90.8%</td>
<td>100%</td>
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**Comparison of bundled completion costs**

- Include only those expenditures directly associated with the specific completion methodology employed.
- The cost of proppant and other variable costs not associated specifically with the style of completion were not included in the totals.

**Savings of approximately 9% for the comparable Pinpoint costs vs the Plug&Perf completion costs**
CONCLUSIONS

- Cost and production benefits were realized by the application of the pinpoint completion method.

- RTA analysis of well performance suggests a greater stimulated reservoir volume (fracture area) is produced by the pinpoint completion method, and that a larger hydrocarbon volume is contacted by the completion as a result.

- Reclosable sleeves opens up a wide range of completions design, including refracturing and shuttle frac (non sequential)
QUESTIONS