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Appropriate Hydraulic Fracturing Technologies for Mature Oil and Gas Formations

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BJ Services

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Today’s Talk

• Understand the Reservoir First
• Get Value for Money
• Techniques for Mature Assets

+ Case Histories
Understand the Reservoir
Understand the Reservoir

• Reservoir Engineering is a Necessary Part of any Mature Field Redevelopment
• Field Studies
  – Recoverable reserves
  – Economic justification
  – Fracture azimuth
  – Extent of water, steam or gas flooding
  – Potential for infill drilling
Understand the Reservoir

- Importance of Understanding Fracture Azimuth:

  - Producing Well
  - Injection Well
  - Producing Well
  - Injection Well

  Poor Candidate

  Good Candidate
Understand the Reservoir

- Production Well Studies
  - Reserves behind pipe, pressure
  - Potential for water production
  - Permeability!
- Establish Candidate Selection Criteria
  - Review and adjust regularly
- Injection Wells can be Fractured to Improve Sweep Efficiency
  - Economic justification usually harder
Case Study #1

• Tanjung Field, S. Kalimantan, Indonesia (from SPE 88604)
  – Mature oil field, first production 1961
  – Low pressure, medium permeability, shallow, multi-zone, ESP’s
  – Fracturing used to redevelop field
  – Extensive reservoir engineering
  – Systematic approach to candidate selection
  – Simple, low-tech frac treatments

(ESP = Electric Submersible Pump)
Case Study #1

Oil Production, bopd

Start of Fracturing

Start of Waterflood

(after SPE 88604)
Get Value for Money
Get Value for Money

- Plan on a Field-Wide Basis, rather than Well by Well
  - High Volume = Low Unit Cost = High Value
  - Reduced per frac costs
  - Reduced day rate
Get Value for Money

• Get Appropriate Technology and Equipment
  – Use the right technology, not necessarily the latest technology.
  – State-of-the-art frac equipment = state-of-the-art pricing!
  – Keep it simple
Get Value for Money

• Pump the Right Sized Treatment
  – Don’t pump large volumes of proppant just because you can
  – We need the right combination of length and width - too much propped width means wasted proppant
Get Value for Money

• Avoid False Economies
  – Use artificial proppant rather than frac sand
  – Be prepared to re-perforate
  – Get downhole pressure data
  – Be prepared to minifrac
  – Use clean fluid systems - Filtration!
Get Value for Money

• Give the Service Company a Reliable Scope of Work
  – The easier it is for the Service Company to plan ahead, the lower the cost of fracturing
  – Uncertainties increase Service Company risk and hence add to costs
Get Value for Money

• Low Cost Workovers
  – To get maximum effect from hydraulic fracturing, it is usually necessary to perform some sort of workover prior to fracturing
    • Zonal isolation
    • Removal of ESP’s etc
    • Completion unsuitable for fracturing operation
    • Fishing
Get Value for Money

• Most Successful Mature Field Projects have had Access to Low Cost Workovers
  – Cost effective, readily available and reliable workovers can dramatically alter the project economics.
  – Doing a workover can also dramatically increase the effectiveness of the treatment (e.g. zonal isolation)
Techniques for Mature Assets
Skin Bypass Fracturing

• Small Scale Frac Treatments Designed to Produce a Conductive Path Through the Skin Damage
• Cost Effective, Easy to Perform
• More Suitable for Medium and High Permeability Formations
  – Higher $k$ formations tend to have greater skin factors and so get more benefit from bypassing skin damage
Skin Bypass Fracturing

• Production Increase Based on Reducing Skin Factor to Zero or Slightly Lower
  – Will not produce as much stimulation as “full scale” treatment.
  – Better stimulation than matrix acid treatment

• Treatments can be Performed by Cement Units
Case Study #2

• SPE 56473 - South Texas
  – Gas well
  – Permeability 0.1 md

• Skin Bypass Frac Treatment
  – 14,000 lbs 20/40 Low Density Ceramic
  – 9.6 bpm maximum rate
  – VES fluid system

(VES = Viscoelastic Surfactant)
Case Study #2

- Gas Production
  - From 100 mscfd
  - To 800 mscfd

- Flowing Wellhead Pressure
  - From 70 psi
  - To 300 psi
Batch Fracturing

- Eliminates the Need for Complex Blending Equipment
- Proppant is Pre-Slurried in Batch Tanks
  - All QC performed before going downhole
- Gel Type and Quality Critical

(QC = Quality Control)
Batch Fracturing

Pad Fluid

Proppant Slurried at 4 ppg

Proppant Slurried at 8 ppg

Proppant Slurried at 12 ppg

Flush

To High Pressure Pumps
Proppant Partial Monolayer
Darin and Huit (SPE 1291)

- Very Low Concentration of Proppant Produces Same Effects as Higher Concentrations
  - 0.09 lbs/ft$^2$ gives the same frac conductivity as +/- 4 lbs/ft$^2$.
  - Applicable for lower permeability formations
  - Low closure stress formations only
Proppant Partial Monolayer

Full Monolayer

A complete coverage of the fracture face, one proppant grain thick

(from SPE 90698)
Proppant Partial Monolayer

Partial Monolayer

Increased permeability due to spaces between proppant grains. Mono-Layer keeps the same fracture width.

(from SPE 90698)
Neutral Density Proppant

• Neutral Density Proppant does not Require Viscosity to keep it Suspended in the Fracturing Fluid
  – Fluid Costs Dramatically Reduced

• Proppant Can be Batch Mixed into Fluid Prior to Treatment
  – Sophisticated Blending and Metering Equipment not Required
Neutral Density Proppant

• Therefore, Neutral Density Proppant can Dramatically Reduce the Costs, Logistics and Complexity of Fracturing Operations
  – Current limited by depth and closure pressure
  – Some temperature limitations
# Neutral Density Proppant

<table>
<thead>
<tr>
<th>Proppant Type</th>
<th>Specific Gravity</th>
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</thead>
<tbody>
<tr>
<td>Neutral Density</td>
<td>1.08 – 1.25</td>
</tr>
<tr>
<td>Resin-Coated Sand</td>
<td>2.45 – 2.55</td>
</tr>
<tr>
<td>Frac Sand</td>
<td>2.65</td>
</tr>
<tr>
<td>Low Density Ceramic</td>
<td>2.71</td>
</tr>
<tr>
<td>High Density Ceramic</td>
<td>3.27</td>
</tr>
<tr>
<td>Sintered Bauxite</td>
<td>3.55</td>
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</tbody>
</table>
Water Conformance Fracturing

• Hydraulic Fracture Treatments Performed with Relative Permeability Modifier (RPM) as part of the Treatment Fluid
  – RPM works by affecting the wettability of the formation grains
  – RPM makes it harder for water and easier for oil to flow
  – Effective in gas formations as well
  – Medium to high permeability only
Case Study #3

- SPE 101019
  - 5 Water Conformance Fractures
  - 3 Offset Conventional Fractures
  - Mature Oil Field in South Sumatra, Indonesia
Case Study #3
Refracturing

• Don’t Ignore a Field because the Wells Have Already Been Fractured
  – Refracturing is a highly successful and established technique

• By Definition, it is Always Used on Mature Assets
  – Reservoir depletion is necessary to re-orient fracture

• Updated Technology
Case Study #4

- SPE 101026 - Wyoming, USA
  - Refracturing Tight Gas
  - Frontier Formation
Case Study #4

- Post-Initial Frac
- Pre-Refrac
- Post-Refrac

Time Between Fracs:
- 12 Months
- 14 Months
- 72 Months
- 222 Months

Gas Rate, mscfpd:

Well A: Post-Initial Frac
Well B: Pre-Refrac
Well C: Post-Refrac
Well D: Post-Refrac
Summary of Techniques

- Skin Bypass Fracturing
- Batch Fracturing
- Proppant Partial Monolayer
- Neutral Density Proppant
- Water Conformance Fracturing
- Refracturing

Techniques Can Be Combined!
Mature Field Redevelopment with Hydraulic Fracturing

- Understand the Reservoir First
  - Permeability, reservoir pressure, reserves, fracture azimuth

- Get Value for Money
  - Appropriate technology
  - Economies of scale
  - Avoid false economies
Thank You

Any Questions?