Primary funding is provided by

The SPE Foundation through member donations and a contribution from Offshore Europe

The Society is grateful to those companies that allow their professionals to serve as lecturers

Additional support provided by AIME
Fracturing for Sand Control: How Hydraulic Fracturing has Changed Sand Control

Raymond Tibbles
Schlumberger Oilfield Services

Society of Petroleum Engineers
Distinguished Lecturer Program
www.spe.org/dl
Sand Control Goal

• The big three goals of Sand Control
  – Stop/minimize production of formation solids
  – Maximize production rate/ minimizing impairment
  – Maintain performance over well life

• Has fracturing improved our ability to delivered these goals. And can it continue to do so in the future?
Main SC Completion Types

• Non Frac
  – Cased Hole Gravel Pack (CHGP)
  – Open Hole Gravel Pack (OHGP)
  – Stand Alone Screen (SAS)
  – Formation Consolidation

• Fracturing
  – Screenless Frac Pack
  – High Rate Water Pack (HRWP)
  – Frac Pack
  – Frac followed by Expandable Screen
Screenless Frac Pack Completions

Indirect Vertical Fracture

Indirect Vertical Fracture + Intelligent Perforating

Optimized Perforating and Fracturing W or WO Resin Consolidation

Piltun-Asstokhsky Sakhalin SPE 68638

Jauf Reservoir Saudi Arabia SPE 73724

Main Pass 41 SPE 107440 Yegua Formation SPE 96289
HRWP Completions

- Application
  - Wells where height growth is a concern
  - Equipment for frac pack is not available
- Multiple pad/slurry stages create short fractures.
Frac Pack Completions

• Application: Most if not all cased hole completions

• Single Stage of fracturing fluid (pad) followed by multiple slurry stages (ramped prop conc.) with tip screenout design.

• Key design requirement is a wide highly conductive fracture.
Does Exceeding Frac Pressure Make a Difference?
Fracturing Improves Reliability

Data courtesy of George King (June 2003)
Fracturing Improves Production

**Flow Efficiency**

- **Frac pack**
- **Gravel Pack**
- **HRWP**

**Cumulative Probability**

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5000 bopd
Chance to get 3000 bopd?

24.8% max 6600 bopd

50.2% max of 8400 bopd

37.3% max of 6600 bopd
Causes of Low Productivity in Gravel Packs

• Low gravel permeability in the perforation tunnels.
  – Crushed zone;
  – Gravel/sand mixing;
  – Post-perforating fluid loss pills

• Fines migration over time
Reality of Packed Perforations

Ideal Perforations

The Cold Hard Truth

Region A
Region B
Region C

Region A
Region B
Region C
Fines Migration in a Gravel Pack
(data supplied by NS Operator)

50% of the PI is lost in the first year.
(26 lb/ft gravel)
What Does Fracturing Do To Help?

• Ensures that the critical area of the perforation tunnel is full of clean gravel free of formation sand or debris ➔ High perm gravel in perfs

• Increases the reservoir contact area.
  – Decreases fluid velocity in the reservoir ➔ Reduced tendency for fines migration
Fracturing Puts More Gravel Through Perforations

• Generally accepted industry value for gravel packing perforations: 25 lb/ft of perforations.

• One NS Operator HRWP Avg: 112 lb/ft of perforations.

• Same NS Operator Frac Pack Avg: 516 lb/ft of perforations
Fracturing Increases Reservoir Contact

Gravel Pack

- 200 ft²

3 ft Half Length Frac

- 1100 ft²
- 82% Reduction In Sand Face Velocity

30 ft Half Length Frac

- 11000 ft²
- 98% Reduction In Sand Face Velocity

H = 92 feet
Rw = 8.5 inch
Perf diameter = 0.83 inch
Shot density = 21 spf
More Area Means No Fines Migration

Every formation has a different critical fines movement velocity. This is one case where it was 0.00029 ft/sec.
Impact of Gravel Volume
(oil well case in a low bhp reservoir)

For this example there appears to be a link between gravel mass and Normalized PI. This is not always the case.
Better Understanding is Improving Results
(SPE 71658 Morales et al)

- Near wellbore temperature cool down from injection of pre-frac and frac-pack fluids.
Temperature cool down inside the fracture (after Sinclair)

\[ T_D = \frac{T - T_i}{T_r - T_i} \]

X/L

Normal range of \( T_D \) for FracPacks
New Techniques – Fluid Selection

- Cool-Down Based Fluid Selection
  - Improved success rate of achieving Tip Screenout (TSO)
  - Allows optimization of polymer and breaker loading

Bottom hole temperature profile during treatment – Fluid Designed at 190°F
Facing Up To The Challenges?

• Unwanted adjacent water and gas
• Brown fields/depleted reservoirs
• High permeability formations
• Thicker zones (> 500 ft) w/ Multi-lobes
• Emerging area deep water.
• UltraDeep water
  – Deeper
  – Absence of stress barriers
  – Higher Pressure
  – Higher Temperature
Is Fracturing Out of Zone Really a Problem?

- Soft rocks and standard design limits height growth.
  - Low Young’s Modulus
  - TSO inhibits growth
  - Low efficiency frac fluids.
- Proper precautions minimize even severe risk. (SPE 73776 Guichard et al.)
- SPE 85259 deals with one of the most difficult cases.
Height Control in Unfavorable Case

Perforate the whole zone
Frac out of zone

Limit the perforation height and control the fracture height

SPE 95987
8 ft shale with water below
Small frac pad
Small slurry stage
Fracture did not break through the shale

Tracer Log

25
Fracs Deliver in Brown Fields

• Well Data
  – Casing: 5 inch
  – Deviation: 33 deg
  – KH: 5100 md-ft
  – Depth: 7550 ft
  – BHST: 200 F
  – Perforation:
    • Density: 24 spf

• Treatment Data
  – Fluid: 30 lb borate xlink
  – Gravel: 16/20 LWC
  – Placed: 1243 lbs/ft

• Results
  – Produced via ESP
  – Post FP PI/Pre FP PI: 1.04
  – Post FP Skin: -0.5
High Permeability Concerns

• SPE39475: limit frac packs
  – Oil Kf < 900 md
  – Gas Kf < 150 md.
  – OH GP for the highest rate wells

• SPE 111455: Frac Packs are the best solution for high permeability formation if the wellbore is properly aligned with the fracture.
Cased Hole Frac-Packs

Openhole Horizontal or Openhole Frac-Pack or Openhole GP Above Frac Pressure?

Oilfield Review, Summer 2001 (BP, Chevron, EniAgip, M-I, Repsol-YPF, Schlumberger, Shell, Stone Energy, Texaco)
High Rate Limitations

– Pressure Loss in Perforation tunnel (Forchheimer)

\[ \Delta P = \frac{0.888 L \mu Q}{KA} + 9.1 \times 10^{13} \beta L \rho \left( \frac{Q}{A} \right)^2 \]

Where:
- \( A \) = Perf Cross-Sectional Area (Ft2)
- \( B \) = Inertia Coefficient (Ft-1)
- \( \Delta P \) = Differential Pressure (psi)
- \( K \) = Permeability (Darcies)
- \( L \) = Length Of Perforation (ft)
- \( \mu \) = Viscosity (Centipoise)
- \( Q \) = Flow Rate (B/D)
- \( \rho \) = Density Of Fluid (lb/Ft3)
High Rate Gas Skin (SPE 68753)

- Avg Damage Skin
  (Deviation and Partial completion skins removed)
  - All Cases
    - FP = 18
    - HRWP = 55*
  - Less than 1 Darcy
    - FP = 18
    - HRWP = 31*

*Neglected 800 Skin
Frac Packs Can Deliver High Production Rate Completions

• **Gas**
  – SPE106854 BP Trinidad and Tobago:
    • FP 75-150 MM/day (100 – 600 mD)
    • OH GP: 72 – 320 MM/day (100 – 1700 mD)

• **Oil**
  – SPE 78322 Total Angola:
    • FP 15,000 – 25,000 bopd (800-2700 mD)
  – SPE 84415 ConocoPhillips USA:
    • FP two wells 22,400 bopd/well
  – FP Non documented GOM – 40,000 bopd
  – SPE 48977 BP North Sea:
    • OH Horizontal – 30,000 bopd
Other Options in Emerging Deep Water

• Rig Based Fracturing
  – Dependent on available deck space
  – Inhibits many rig operations
  – Limited rates and volumes

• Supply Boat Based Fracturing
  – Limited Rates and Volume but more flexibility
  – Minimum impact on rig operations
Modular Supply Vessel Operation

(900m² deck area)

- 650,000 lbm of proppant
- 10,000 psi MWP
- 40 BPM max rate
- 9,000 HHP

- 200,000 gals batch mixed gel stored below deck
- Connected to Rig via 4” 10,000 psi Coflexip hose c/w EQD on TR12 Reel
Lower Tertiary - Miocene and Paleogene

- Water Depth: 4 – 10,000 ft
- TVD: 15,000 ft – 33,000 ft
- BHP: 13 ppg – 15.2 ppg
- BHT: 160 OF – 310 °F
Challenges and Solutions

• Temperature: No problem we have fluids to handle 400+ degrees F.

• High Pressure:
  – 20000 psi treating equipment - does the market justify the cost?
  – High density frac fluids to help but there are limits. SPE 116007 reported surface pressure reductions from 22 to 39% with an average surface pressure reduction of 34%

• Temperature and Pressure: Still struggling to provide a high density fluid that can work at 325+ °F

\[
\frac{\Delta p}{L} = \frac{2f\rho V^2}{D}
\]
Facing Up To The Challenges?

- Unwanted adjacent water and gas
- Brown fields/depleted reservoirs
- High permeability formation
  - Gas
  - Oil
- Emerging Area Deep Water
- UltraDeep Water Plays
  - Deeper
  - Higher Pressure
  - Higher Temperature
Conclusions

• Sand Control fracturing completions have clearly shown increased productivity in many different environments.

• Many of the challenges to using fracturing have already been overcome
  – Unwanted water/gas
  – High permeability formations
  – Application in developing areas

• Some challenges still require work or may not be applicable
  – Ultra high permeability (especially in gas wells)
  – High pressure especially in combination with temperature above 325 F
Questions?
Your Feedback is Important

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http://www.spe.org/events(dl/dl_evaluation_contest.php