The Complicated World of Proppant Selection…

John Kullman
October 2011
Outline

• Proppant Selection
• Modern Proppants
  - Sand
  - Resin Coated
  - Ceramic
• Niche Proppants / Future Developments
• Q&A
Getting a well to production…

We drill it…
with efficient bits, fluids, rigs, etc.

We complete it…
with long lasting tubulars & jewelry, high tech perf techniques, etc.

We frac it…
using high-tech equipment and fluids, elaborate designs, state-of-the-art monitoring, etc.
And when we are done…

All of this equipment is gone and all that is left is the well…

But how many of us really understand our fracs and proppants?

….and the frac
Proppant Selection Techniques

1) “It’s easy, just pump the least expensive proppant you can find.”

2) “It’s not too hard, just look at the depth, stress, crush, MPD, price, published conductivity, sales engineer, etc, and see which proppant is the best at my conditions.”

3) “It’s so complex, there’s all these parameters and I certainly don’t have time to run a model so I just use what everyone else is using (or what we used last time).”

4) “Pump whatever is available”

So how should one select proppant?
## Modern Proppant Choices

*List not complete.* Some names are registered trademarks, some historical.

<table>
<thead>
<tr>
<th>Other</th>
<th>Sand</th>
<th>Lightweight Ceramic</th>
<th>Intermediate Density Ceramic</th>
<th>High Density Ceramic</th>
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</thead>
<tbody>
<tr>
<td>CARBOTag</td>
<td>Ottawa</td>
<td>HYDROPROP</td>
<td>CARBOPROP</td>
<td>CARBOHSP</td>
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<tr>
<td>CARBONRT</td>
<td>Jordan</td>
<td>ECONOPROP</td>
<td>ISP, InterProp</td>
<td>Sintered Bauxite</td>
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<tr>
<td>ScaleProp</td>
<td>Hickory</td>
<td>CARBOLITE</td>
<td>SinterLite</td>
<td>SinterBall</td>
</tr>
<tr>
<td>LiteProp 105, 125, 175</td>
<td>Badger</td>
<td>ValueProp</td>
<td>VersaProp (broad sieve)</td>
<td>UltraProp</td>
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<tr>
<td></td>
<td>Colorado Silica</td>
<td>NapLite</td>
<td>BoroProp</td>
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<td></td>
<td>Arizona</td>
<td></td>
<td>ForoProp</td>
<td></td>
</tr>
<tr>
<td></td>
<td>White/Brown</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### With Resins:

- **AcFrac CR, PR, Black Tempered/Super TF**
  - OptiProp
  - Super HS (usually sand)
  - XRTGold
- **CARBOBond**
  - Ceramax E/I
  - MagnaProp
  - EconoFlex
  - DynaProp
- **CARBOBond**
  - Ceramax V
- **CARBOBond**
  - Ceramax P
  - HyperProp

*Numerous resins on any substrate (Norcote, Tempered LC, DC, HS, XRT resins)*
Does Proppant Selection Matter?

>200 field studies, written by >150 companies

Oil wells, gas wells, lean and rich condensate
Carbonate, Sandstone and Coal

Well Rates
1 to 25,000 bopd
0.25-100 MMSCFD

Well Depths
100 to 20,000 feet

SPE 119143 tabulates over 200 field studies
Production Benefit

• Excellent production gains using:
  – Higher proppant concentrations
  – More aggressive ramps, smaller pads
  – Larger diameter & stronger proppants
  – Higher quality, more uniformly sized proppant

***CONDUCTIVITY MATTERS***

• Frac conductivity appears to be much more important than we model, possibly due to:
  – Complex flow regime (low realistic conductivity)
  – Imperfectly planar fracs

Further detail in SPE 119143
Select the optimal proppant and design using a frac model.

Effective conductivities can be less than 1% of API/ISO test values.

- Jordan Sand
- Lightweight Ceramic

ISO 13503-5 Test: "Inertial Flow" with Non-Darcy Effects
- Effective Conductivity (md-ft)

Multiphase Flow
- Lower Achieved Width (1 lb/sq ft)
- Gel Damage (30# XLGW)
- Fines Migration / Cyclic Stress

Conditions: YM=5e6 psi, 50% gel damage, 250 F, 1 lb/ft², 6000 psi, 500 mcf/d, 1000 psi bhfp, 50 ft H, 2 blpd

References: PredictK & SPE 106301
Fracture Complexity

Shale Fracs tend to be very complex (either intentionally or unintentionally)

SPE 95568
Does this conclusion apply to all well configurations?
Intersection of Wellbore and Fracture

Vertical Well: Typically conductivity-limited

Horizontal Well with Longitudinal Frac: Uncemented liner
Conductivity requirements typically trivial

Horizontal Well with Longitudinal Frac: Cemented liner
Conductivity requirements may be important
What if the fracs are NOT longitudinal?

Horizontal Well with Transversely Intersecting Frac:
(Orthogonal, perpendicular, transverse, imperfectly aligned)

Oil/gas must travel hundreds/thousands of feet within fracture, and converge around a very small wellbore – high velocity within frac!

Horrible Connection; Enormous fluid velocity and near-wellbore proppant characteristics are key!

In a small fat frac (160 ft Xf, 100 ft h, .4” w), the surface area of the frac is 1 million times greater than the intersection with an 8” wellbore. Velocity can be 1,000,000 times greater in the frac than in the formation! [SPE 101821]
In some reservoirs, operators have pumped 30 stages, with 3 perf clusters per stage.

90 entry points!

**Question:** Are we convinced we “touch more rock” with more stages, or are we simply redistributing our investment, placing it nearer the wellbore with more entry points?

If you increase intersection by 90-fold, you decrease velocity by 90-fold and reduce pressure losses by $90^2$ or >8000 fold compared to a single transverse frac.

However, operators are understandably conservative on toe stages!

More Horizontal Well details in SPE 128612
“Ideal” Proppant Characteristics?

Lighter than water,

Stronger than diamonds,

Cheaper than dirt!

Readily available!!!!!
Know your proppants!!…

**Characteristics of Premium Proppants**

- Tight Sieve Distribution
- High Strength (low crush)
- High Sphericity

**Characteristics of Inferior Proppants**

- Broad Sieve Distribution
- Lower Strength (higher crush)
- Low Sphericity (angular)
Economic Conductivity is the Conductivity that maximizes the Economics of the well.
Factors that affect…

- **Width** \((W_f)\): Proppant density, proppant loading, embedment, gel filter cake
- **Permeability** \((k_f)\): Proppant size, strength, sphericity, fines, gel damage,

\[ c_f = k_f \times w_f \]
If a fracture can be filled with 100,000 lbs of Sand/RCS/Lightweight Ceramic, it will require purchase of ~120,000 lbs of Intermediate Density Ceramic.
Natural Frac Sands

• General Information
  – Sands are mined from quarries
  – In periods of high demand, supply is tight and product sieve distribution may vary (SPE 84304)

• White Sand
  – Ottawa, Jordan, Ironton, Galesville sandstones, Illinois, Minnesota, Wisconsin
  – Monocrystalline, stronger than brown sands

• Brown Sand
  – Hickory sandstone near Brady, Texas
  – Polycrystalline, composed of multiple crystals bonded together
Natural Frac Sands

- White Sand
- Brown Sand

Optical photomicrographs – courtesy of CARBO Ceramics

Note polycrystalline nature and increased angularity.
What happens to uncoated sand under stress?

As Sand crushes...

.....it shatters and fines are released.
Resin Coated Sands

• General Information
  – Quality of sand coated has large impact on quality of RCS
    • Any substrate can be coated (sand, ceramic, walnut hulls, etc)
  – Various types and grades of resins

• Curable Resins
  – Consolidate the pack and reduce proppant flowback
  – Encapsulate proppant fines

• Precured Resins
  – Encapsulate proppant fines
  – Improve distribution of stresses
Resin Coated Sands

- Standard RCS
- Premium RCS
What is the advantage of resin coating a sand?

As RC Sand is crushed...

...the resin encapsulates the fines.
Ceramic Proppants

Lightweight Ceramic
(Economy and Premium distributions available)

Intermediate Density Ceramic

High Density Ceramic

CARBOLITE
CARBOECONOPROP
CARBOHYDROPROP

CARBOPROP
Interprop
Sinterlite
Versaprop (non-API)

CARBOHSP
Sintered Bauxite
Sinterball
Ultraprop (non-API)

Increasing Aluminum Content, Strength & Cost
How proppants fail

12/20 Hickory/Brady Sand at 6000 psi (400 atm).

Resin Coated Sand at 8000 psi (544 atm).

Intermediate Strength Ceramic at 8000 psi (544 atm).
“Other” Proppants

- Underfired Ceramic Proppant
  - Yields proppant with internal/external porosity
    - Is weaker than its fully fired counterpart
  - Can be impregnated with chemical, such as scale inhibitor
    - Delivers the chemical throughout the fracture

- “Tagged” Proppant
  - Ceramic proppant “tagged” with chemical marker
  - Used to determine source of proppant flowback (e.g. screen failure in gravel or frac-pack completion)

- “Traced” Proppants (non-Radioactive)
  - Ceramic proppant “tagged” with chemical marker
  - Used to determine location of proppant (frac height and proppant placement)
Proppant Selection Summary

- Proppant selection should NOT be made solely on the basis of well depth, stress or what the last engineer did.

- Instead, fracture conductivity should be designed to accommodate expected production rates, and then the appropriate proppant chosen based on economic analysis.

Run conductivity flow tests!!!
Recommendations

• This is the first generation of engineers that must select from 100 proppant sources
• Resist generic “commoditizing” proppant identifiers
  – “20/40 white sand” or “20/40 IDC” can mean almost anything
  – Similar sounding materials easily vary 5-fold in performance
• Demand realistic flow tests (conductivity & beta)
  – Extrapolating from crush & sieve is unacceptable
• Be vigilant; secure & verify proppant quality
  – Periodically test FIELD samples

***Proppant selection does impact production. There is a big difference in proppants. The more you know about proppants, the better your selection will be.***
Questions?
Additional Slides
Game Changing Technologies

• The Challenges of Tight / Unconventional Plays
  ➢ Extremely low permeability formations
    ➢ Abnormal pressure and/or temperature (deep shales)
    ➢ Adsorbed gas (Coal-Bed Methane)

• Key technologies driving UC developments
  ➢ Drilling and Completion advancements in HZ wells
    ➢ HZ Operations - Perfs, plugs, completion designs
  ➢ Advancements in hydraulic fracturing
  ➢ Fracture Mapping

Do we understand our fractures as well as we understand our completions?
Additional Challenges for Waterfracs

• Lower density for improved transport?
• Reduced particle size
  – Reduce settling velocity
  – Entry into narrower fractures
• Unusual proppant arrangements
  – Settled bank with void above?
  – Partial monolayer?
  – Irregular proppant pillars?

All irregular distributions cause more stress on particles than we typically test.

SPE 115769, 114173, 115766, 90698
Proppant “arrangement” / purpose
Oilfield and Hydraulic Fracturing 101 “Type” Slides
Definitions & Comparisons
### Physical and Chemical Properties

#### Typical Sieve Analysis [weight % retained]

<table>
<thead>
<tr>
<th>U.S. Mesh [mesh]</th>
<th>Microns</th>
<th>12/18</th>
<th>16/20</th>
<th>20/40</th>
<th>30/50</th>
<th>40/70</th>
</tr>
</thead>
<tbody>
<tr>
<td>+12 mesh</td>
<td>+1700</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-12+16 mesh</td>
<td>-1700+1180</td>
<td>91</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-16+20 mesh</td>
<td>-1180+850</td>
<td>5</td>
<td>93</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-20+30 mesh</td>
<td>-850+600</td>
<td></td>
<td>2</td>
<td>90</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>-30+40 mesh</td>
<td>-600+425</td>
<td></td>
<td></td>
<td>3</td>
<td>90</td>
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<tr>
<td>-40+50 mesh</td>
<td>-425</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>-40+60 mesh</td>
<td>-425+250</td>
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<td></td>
<td></td>
<td></td>
<td>97</td>
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<td>-50 mesh</td>
<td>-300</td>
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<td></td>
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<tr>
<td>-60+70 mesh</td>
<td>-250+212</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

**Median Particle Diameter [microns]**

|                  | 1374 | 1001 | 730  | 522  | 334  |

#### API Crush Test

<table>
<thead>
<tr>
<th></th>
<th>@7,500 psi</th>
<th>17.9</th>
<th>14.0</th>
<th>5.2</th>
<th>2.5</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>@10,000 psi</td>
<td></td>
<td>19.3</td>
<td>8.3</td>
<td></td>
<td>4.4</td>
</tr>
</tbody>
</table>

**Sizing Requirements:** A minimum of 90% of the tested sample should fall between the designated sieve sizes. These specifications meet the recommended practices as detailed in ISO 13503-2.

#### Typical Additional Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundness</td>
<td>0.9</td>
<td>Chemistry [weight %]</td>
<td></td>
</tr>
<tr>
<td>Sphericity</td>
<td>0.9</td>
<td>Al₂O₃</td>
<td>51</td>
</tr>
<tr>
<td>Bulk Density [lb/ft³]</td>
<td>97</td>
<td>SiO₂</td>
<td>45</td>
</tr>
<tr>
<td>[g/cm³]</td>
<td>1.57</td>
<td>TiO₂</td>
<td>2</td>
</tr>
<tr>
<td>Apparent Specific Gravity</td>
<td>2.71</td>
<td>Fe₂O₃</td>
<td>1</td>
</tr>
<tr>
<td>Absolute Volume [gal/lb]</td>
<td>0.044</td>
<td>Other</td>
<td>1</td>
</tr>
<tr>
<td>Solubility in 12/3 HCl/HF Acid [% weight loss]</td>
<td>1.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Definitions**

- **Shape – Sphericity & Roundness**
  - We describe proppants in terms of roundness and sphericity
Proppant Comparisons - Shape

API RP60, From *Stratigraphy and Sedimentation*, Krumbein and Sloss
**Definitions**

- **Size (Mesh)**
  - ASTM Sieve Series
    - Based on fourth root of 2
    - Every fourth screen represents doubling of particle diameter

- **What is “in spec”?**
  - 90% of proppant falls through top screen and is caught on bottom screen
  - No more than 1% on the 2nd screen below bottom
  - i.e. 20/40, 30/50, etc

<table>
<thead>
<tr>
<th>U.S. Mesh</th>
<th>Sieve Opening</th>
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<tr>
<td></td>
<td>(in)</td>
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<tr>
<td>5</td>
<td>0.1570</td>
</tr>
<tr>
<td>6</td>
<td>0.1320</td>
</tr>
<tr>
<td>7</td>
<td>0.1110</td>
</tr>
<tr>
<td>8</td>
<td>0.0937</td>
</tr>
<tr>
<td>10</td>
<td>0.0787</td>
</tr>
<tr>
<td>12</td>
<td>0.0661</td>
</tr>
<tr>
<td>14</td>
<td>0.0555</td>
</tr>
<tr>
<td>16</td>
<td>0.0469</td>
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<tr>
<td>18</td>
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<td>20</td>
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<td>30</td>
<td>0.0232</td>
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<tr>
<td>35</td>
<td>0.0197</td>
</tr>
<tr>
<td>40</td>
<td>0.0165</td>
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<td>45</td>
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<td>50</td>
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<td>60</td>
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<td>70</td>
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<td>80</td>
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<tr>
<td>100</td>
<td>0.0059</td>
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<tr>
<td>120</td>
<td>0.0049</td>
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<tr>
<td>140</td>
<td>0.0041</td>
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<tr>
<td>170</td>
<td>0.0035</td>
</tr>
<tr>
<td>200</td>
<td>0.0029</td>
</tr>
</tbody>
</table>
**Density**

- **ASG (g/cc)**
  - Apparent Specific Gravity
    - Density of the pellet
    - Important for densitometer calibration

- **BD (g/cc or lb/ft\(^3\))**
  - Bulk Density
    - Density of loose pack (how many lbs to fill a cc or ft\(^3\))
    - Important for final frac geometry

- **Absolute Volume (gal/lb)**
  - Volume taken up by 1 lb of proppant
    - Straight conversion from ASG (using 8.33 lb/gal water)
    - Used for densitometer calibration

<table>
<thead>
<tr>
<th>Typical Additional Properties</th>
<th>0.9</th>
</tr>
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<tbody>
<tr>
<td>Roundness</td>
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## TYPICAL PROPPANT DENSITIES

<table>
<thead>
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<th>Proppant Type</th>
<th>ASG (g/cc)</th>
<th>Bulk Density (g/cc)</th>
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</thead>
<tbody>
<tr>
<td>Sand</td>
<td>2.65</td>
<td>1.60</td>
</tr>
<tr>
<td>Resin Coated Sand</td>
<td>2.72</td>
<td>1.62</td>
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<tr>
<td>Light Weight Ceramic</td>
<td>2.72</td>
<td>1.62</td>
</tr>
<tr>
<td>Intermediate Density Ceramic</td>
<td>3.27</td>
<td>1.84</td>
</tr>
<tr>
<td>High Density Ceramic</td>
<td>3.56</td>
<td>2.00</td>
</tr>
</tbody>
</table>
The Importance of Density

- The industry purchases proppant by mass; however, the value is derived from the volume/conductivity.
- Users rarely choose to purchase 20% greater mass of proppant when they use an IDC over an LWC.
- Instead, the same treatment design is pumped (total job size and concentration) regardless of proppant density.
Crush

- Crush tests procedures dictated by ISO standards.
- Originally developed for use in quickly qualifying new sand mines.
- Extreme caution must be exercised when using for proppant selection purposes.
- SPE 119242 – Crush Testing Myths

### API Crush Test

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ISO 13503-2 Crush Test Procedure

(More details in SPE 119242)

- Proppant is pre-sieved to remove particles outside of stated mesh range.
- Dry proppant placed in steel cell at ~4 lb/sq ft (sand equivalent)
- Room temperature
- Proppant evenly distributed with level surface
- Load applied at uniform rate
- Constant stress maintained for two minutes

- Proppant is sieved. The weight percent which falls below the primary screen is reported.
  - For 16/20 proppant all material < 20 mesh is reported as “fines”
  - For 30/50 proppant all material < 50 mesh is reported as “fines”
Definitions

• Proppant permeability
  – A measure of fluid friction within the proppant pack.

• Fracture width
  – Distance between formation faces. Width loss with proppant crush, compaction, and embedment into formation.

• Fracture conductivity
  – Proppant permeability multiplied by fracture width. A measure of fluid carrying capacity under low velocity flow.

• Beta factor, inertial flow coefficient $\beta$
  – A measure of the tortuosity within the pack. This describes the fluid acceleration necessary within the fracture, and is a dominant factor during realistic high velocity flow.

\[ \Delta \frac{P}{L} = \mu \frac{v}{k} \]

\[ \Delta \frac{P}{L} = \mu \frac{v}{k} + \beta \rho v^2 \]
How is Conductivity Measured?

ISO 13503-5 Conductivity Test

- Ohio Sandstone
- 2 lb/ft\(^2\) Proppant Loading
- Stress maintained for **50 hours**
- 150 or 250 \(^{\circ}\) F
- Extremely low water (2% KCl) velocity (2 ml/min)

*Typically referred to as a “Long Term” Conductivity Test*

Reference: ISO 13503-5
Remember that 5% crush on a 20/40 proppant could be a 5g of 50 mesh particles or 5g of 200 mesh particles.

Sieve distribution of fines generated at 6k psi for two proppants.
Thin section of 1.0 lb/sqft 12/20 Hickory/Brady Sand after 6000 psi and 150F. Blue areas are epoxy resin filling the porosity the top and bottom edge if shown is Ohio sandstone.

Taken from the 1993 Stim-Lab, Inc. Proppant Consortium

Photo above left
C) Fines and grain shards trapped in terminal pore throats (flow was from right to left)

Photo above right
D) Close-up showing two large grains with fractures and debris in angle of pore throat. Flow is from right to left.
Does coating with resin increase the strength of an individual proppant pellet? **NO.**

Note that application of resin does not improve grain strength, but rather improves distribution of stress between grains and encapsulates fines. When cured, it can increased the strength of the proppant pack.

Source: Stim-Lab Consortium, July 2001
The History of Proppants

1940’s
- Experimental fracture treatments without proppant
- Unpropped fractures quickly healed with little sustained benefit

1950’s
- Sand dredged from Arkansas River used in early treatments
- “White” sand from Saint Peter formation in Ottawa, Illinois
- “Brown” sand from Hickory sandstone near Brady, Texas - 1958

1960’s
- Glass beads, plastic beads, walnut hulls
- Attempted monolayer designs - failed due to settling, embedment, stress concentration
- Soluble proppant spacers

1970’s
- Curable resin coated sand - 1975
- First commercial bauxite ceramic - 1979

1980’s
- Precured resin coated sand – 1982
- Lightweight ceramic - 1985

Recent
- Porous proppant
- Improved strength / tighter sieve distributions
- *Ultra* Lightweights
- Tagged / traceable proppants
Intersection of Wellbore and Fracture

Vertical Wells: Typically benefit greatly from improved conductivity
200 field studies - SPE 119143

Images not to scale!!!

Horizontal Well with Longitudinal Frac:
Uncemented or fully perforated liner
Good connection, fluid only needs to travel ½ the pay height within the frac.
proppant conductivity requirements are trivial – almost anything will be fine
**Intersection of Wellbore and Fracture**

**Cemented Liner**

- **Horizontal Well**
- **Cemented liner with limited perforations**
  - Fluid travels shorter distances within the frac, but there is significant flow convergence around perfs.
  - **Proppant conductivity requirements are a consideration**
  - Lyco selected RCS for this completion style (SPE 90697)
Proppant Selection

- Is proppant selection important?

- Specific challenges
  - Vertical
  - Horizontal
  - Slickwater

- Proppant selection drivers in shale plays
“Other” Proppants

• “Ultra-Lightweight”
  – Developed primarily for Slickwater Fracturing
  – Goal is to exploit “partial mono-layer” theory
  – Typically 1.75 ASG to nearly buoyant
  – Various substrates
    • Stress and temperature limitations
Challenges Of New Proppants

• Cost
  – Despite commodity prices, we live in a low cost environment
  – Shale plays required larger investments in proppant (larger volumes).
  – Proppants are a large part of AFE

• Primarily talking about ‘niche’ products now
  – “Game-changers” will need to address cost
Proppant Selection Drivers in Shale Plays

- Proppant Availability
- Slickwater/light gel fluid systems
- Our understanding of the hydraulic fracture in these ultra-tight formations
- Cost vs Benefit
  - Economic Conductivity
Proppants of the Future

• Lighter Weight Proppants
  – Transport in low viscosity fluid systems

• Proppants to withstand “harsh” environments
  – Wells getting deeper
  – Steamflooding, etc.

• “Smart” Proppants
  – Microseismic/tiltmeter mapping tells us generally where the fluids go, but not the proppant
The worldwide proppant market has grown 5-10 fold in 10 years, with the current market size estimated at ~17 billion lbs/year, with more than 70% of it being sand.

Demand for all proppant types is increasing, which might surprise you.

At least 48 active frac sand mines are operational in North America, with varying quality of frac sand. At least 60 active ceramic plants worldwide, with fewer than 15 consistently producing proppant worth considering.

At least 17 resin coating facilities exist, with various chemistry and quality.

- Sand: 78%
- RC Sand: 12%
- Ceramic: 10%

Source: CARBO Internal estimates and PropTesters, Inc. 2006 Proppant Market Study.
#2 Determine what the well needs

How much conductivity does this well need?
- Reservoir deliverability

What’s the cheapest way to get it?

Am I economically optimized?
=> Economic Conductivity®
Resin Coated Ceramic Proppants

- Resin coatings can be applied to any classification of ceramic proppant
- Curable products are available for flowback control
Proppant Types - Summary

- **Sand**
  - Low cost – Brown vs White Sands
  - Potential use in shallow, extremely low rate wells, with low formation permeability

- **Resin Coated Proppants**
  - Costs more than their substrates alone
  - Precured - distribute stress and reduce fines migration
  - Curable - reduce proppant flowback

- **Ceramic**
  - More expensive than Sand/RCS
  - Should improve production in all wells
    - Mandatory in:
      - Prolific Wells & High Stress or High Temperature conditions
  - Not all ceramic proppants have the same quality