Diversion Strategies

Liberty Engineering Solution
Diversion

• Diversion is used in a range of industry applications
• Used in ~5% of all US frac jobs (based on FracFocus data)
• Three areas of application
  o Perf/Cluster
  o Far Field
  o Refracs
• We have diversion covered at Liberty
  o Covering everything “Everything but your Kitchen Sink”
  o Focus on field evaluation
Diversion Toolbox – Everything but the Kitchen Sink

- At the perforation
  - Bioballs / perforation knots
  - Self-degrading PLA diverter with customized particle distribution (polydispersity), administered multiple times throughout a job or following proppant ramp
  - Higher proppant concentration spike with coarser proppant
  - Hesitation fracs
  - Rate changes / Dynamic pulsing
  - Acid relief

- In the far field
  - Pre-job injections to re-pressurize, pre-job gas and surfactant injections
  - Pre-job injections in other (vertical/horizontal) offset wells to help enhance hydraulic fracturing in areas that were not stimulated before
  - Particle diverters in variety of sizes

- Refracs

Pressure evaluation before and after diversion is key to ensure diversion effectiveness
Focus Material - Most Common Today:
PLA = Polylactic Acid
LOS naming = DVA-65, DVA-75, DVA-85

Key Attributes:
Low cost and can be ‘cut’ with sand
Green = biodegradable, comes from plants (corn, sugar cane)
Relatively low density = easily transported
High compressive strength = able to withstand pressure
Self degrading = once it starts, it degrades 100% = minimal water contact
Degrades completely = no damage
Equipment and fluid compatibility
Customizable geometry, degradation rates and blend ratios
Can be modified to be oil soluble
Porosity of particles can be manipulated to reduce density

Replacing or replaced many traditional diverters:
Rock Salt
Benzoic Acid Flake
Naphthalene
Ball Sealers
In focus PLA = Polylactic Acid
Most Common Frac Diverter In Use Today:

Key Attributes:
- Low cost vs competitive products
  - Can be ‘cut’ further by blending with sand
- Considered green
  - Made from corn and sugar cane
  - Fully biodegradable
- Comparable density relative to the frac fluids
  - Easy downhole transport
- High compressive strength
  - Can hold high differential pressures
- Self-degrading
  - Degrades to completion with minimal or no water contact
  - It degrades completely
  - Leaves no damage to conductivity
- Compatibility with frac equipment and fluids
- Highly customizable
  - geometry
  - specific gravity
  - temperature degradation rates
  - particle size & shape & blend ratios

Due to it’s performance flexibility, it has evolved to replace many traditional diverter materials such as:
- Rock Salt
- Benzoic Acid Flake
- Naphthalene & Ball Sealers
**Most Common Diversion Material Today**

**DVA-75 Diverting Agent**

So, why is PLA the default favorite for practically all types of diversion in Frac?

Key drivers for PLA at the moment is price.
- Lower cost relative to the not too distant past.

Properties of PLA are good but most of the beneficial properties of PLA that are being exploited can be accomplished by using other polymers on the market.

One of the more unique properties of PLA, however, is its degradation behavior. Influenced by: temperature, pH, water TDS, sample morphology & molecular weight.

- Degrades via hydrolysis
- Self-degrading and self-catalytic
- The degradation goes to completion
- Smaller particles do not hydrolyze at increased rate

![Hydrolysis of various PLA Products available at 140°F](chart.png)
DVA-75 Diverting Agent

Most Common Diversion Material Today

So, what are the available properties and ranges for this material?

**Geometry** can be altered
- Typical grind sizes utilized in frac range from
  - 200 mesh for some far field applications to
  - 6-8 mesh used to initiate bridging at the perforations
- But the material can be purchased down to 2500 mesh or 5 micron.
- Flake product
- Degrees of sphericity and roundness
- Custom grind sizes & blend ratios

**Density** can be altered
- Typical Specific Gravity for PLA is 1.25 s.g.
- Lowest density to date is about 0.90 s.g.

**Morphology** can manipulated
- Crystalline vs amorphous materials
- Temperature Customization
Most Common Diversion Material Today

DVA-75 Diverting Agent

Why is the morphology of your PLA important?

Controls the chemical and mechanical properties

Manipulated 3 ways:

1. Molecular weight
   Primary driver behind the rate of hydrolysis.

2. Degree of crystallinity
   Primary driver of mechanical properties
   How the properties change with increasing temp

3. Monomer content.
   3 lactide monomers used to make PLA: L-lactide, D-lactide, and meso-lactide.
   Varying ratio effects reactivity
   Also affects crystallinity

Need: Soft polymer to place at low rates and pressures that can survive in a high temp environment.
Possible solution: A high molecular weight amorphous polymer.

Need: Something for low temperatures that must support higher pressure differentials such as an open hole frac treatment.
Possible solution: Low molecular weight semi crystalline variant.
Diverter Testing

What are some ways that we test the performance of our diverters?

Hydrolysis (degradation) testing
   Confirm degradation vs time
      Temp
      Water type
      Static or dynamic

Slot plugging
   Optimize blend ratios and
   Insure efficient bridging across a specified gap size

Such as maximum pressure differential testing

Modified fracture conductivity cell for far field behavior
Diversion – Engineering Evaluation

• Diversion does not work in the same way everywhere – evaluation is key
• Evaluation tools
  o Before/after impact on
    ▪ Pressure
    ▪ Injectivity (psi/bpm)
  o Stepdown test
    ▪ Perforation friction
    ▪ # open perfs
  o Other diagnostics
    ▪ Tracer
    ▪ Fiber optics
  o WellWatch
    ▪ Timing / volume of offset frac hit

We let the data / evaluation determine what diversion strategy is best in an area or application