Fracturing the Smart Way
Smart about the well
Smart about the environment

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Agenda

• Hydraulic Fracturing
• Environmental Stewardship
Hydraulic Fracturing
Why Do We Hydraulically Fracture?

- Low permeability reservoir (the capability of a porous rock or sediment to permit the flow of fluids through its pore spaces)
  - Make the well a commercial producer
  - Improve and accelerate the recovery rate of the well
  - Access more of the reserves
- Moderate to high permeability reservoir - bypass the damage
Hydraulic Fracturing Process

• Fracturing fluids and proppants are pumped into the producing formation under high pressure and rates.

• When fluid pressure at the bottom of the well builds to a level greater than the stress on the rock around the well, a crack or fracture forms in the rock, allowing gas to flow into the wellbore.

• Proppant is needed to “prop” open the fractures once pumping has stopped; the frac fluid flows back to surface leaving the proppant in place.

• The propped fractures create highly conductive flow paths for the hydrocarbons to reach the wellbore.
Hydraulic Fracturing is a Proven Technology

- The first commercial fracturing treatment was performed more than 60 years ago
- Since that time, it had been used in more than two million wells in the United States
- Operators now fracture tens of thousands of wells each year with no record of harm to groundwater
Benefits of Hydraulic Fracturing

- Hydraulic fracturing is responsible for the addition of more than 7 billion barrels of oil and 600 trillion cubic feet of natural gas in the United States.
- By economically producing natural gas in the U.S., our dependence on foreign sources of oil and gas can be decreased.
- Millions of Americans are either directly employed by oil and gas producers, or businesses who support energy exploration and production activities.
Why Fracturing is Big in the U.S.

- 65-70% of global fracturing occurs in the U.S.
- 70 to 80% of wells drilled in the U.S. are either tight gas sands or unconventional gas wells (shale and CBM)
- Virtually all tight gas and unconventional gas wells have to be hydraulically fractured to be economically productive
US Natural Gas Production

Figure 2. U.S. natural gas production, 1990-2035
(trillion cubic feet per year)

- History
- 2009
- Projections

- Shale gas
- Tight gas
- Lower 48 onshore conventional
- Lower 48 offshore
- Coalbed methane
- Alaska

Conventional Gas Basins

Gas Production in Conventional Fields, Lower 48 States

Gas Production, Last Reported Year (Billions of Cubic Feet)
- 0 - 5
- 5.1 - 20
- 20.1 - 50
- 50.1 - 290

Basins and OCS Areas
Inter-Basin Areas

Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS
Updated: April 8, 2009
CBM Basins

Coalbed Methane Fields, Lower 48 States

Source: Energy Information Administration based on data from USGS and various published studies
Updated: April 8, 2009
Tight Gas Basins

Major Tight Gas Plays, Lower 48 States

Source: Energy Information Administration based on data from various published studies
Updated: June 6, 2010
Shale Fracturing Boom

• 7X increase in drilling over last six years
• More than 50% of U.S. net completion spend
## Shale Gas Basin Data Comparison

<table>
<thead>
<tr>
<th>BASIN</th>
<th>BARNETT</th>
<th>FAYETTEVILLE</th>
<th>WOODFORD</th>
<th>EAGLE FORD</th>
<th>HAYNESVILLE</th>
<th>MARCELLUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth, Ft</td>
<td>6,500 - 8,500</td>
<td>1,000 - 7,000</td>
<td>6,000 - 11,000</td>
<td>4,000 - 12,000</td>
<td>10,500 - 13,500</td>
<td>4,000 - 8,500</td>
</tr>
<tr>
<td>Thickness, Ft</td>
<td>100 - 600</td>
<td>20 - 200</td>
<td>120 - 220</td>
<td>300 - 475</td>
<td>200 - 300</td>
<td>50 - 200</td>
</tr>
<tr>
<td>IP Rate, MMCFD</td>
<td>2.5</td>
<td>2.8</td>
<td>3.6</td>
<td>7.0* &amp; Cond*</td>
<td>14</td>
<td>3.5</td>
</tr>
<tr>
<td>Avg Lateral, Ft</td>
<td>2,500 - 3,500</td>
<td>1,500 - 5,000</td>
<td>2,500 - 5,000</td>
<td>3,800 - 5,500</td>
<td>3,500 - 3,800</td>
<td>2,500</td>
</tr>
<tr>
<td>Reserves, TCF</td>
<td>44</td>
<td>42</td>
<td>11</td>
<td>21</td>
<td>251</td>
<td>262</td>
</tr>
<tr>
<td>Well Cost, $MM</td>
<td>2.8</td>
<td>3.0</td>
<td>5 – 6</td>
<td>5.0</td>
<td>7.5</td>
<td>3.7</td>
</tr>
<tr>
<td>EUR/Well, BCF</td>
<td>2.8</td>
<td>2.6</td>
<td>4.0</td>
<td>4.0</td>
<td>6.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Reserves = Technically Recoverable (TRR)

*Condensate Ratio ~ 50 Bbl/MMcf
Shales are often highly fractured / laminated

Paleozoic “fissile” shale
Tulsa area

Breccia zone – Monterey Shale
California

Interbedded
Massive/laminated

Marcellus
Northeast U.S.

Slickensides on fault surface
Basic Fracture Geometries

Vertical Well, Horizontal Plane

Horizontal Well, Vertical Plane, Perpendicular to Wellbore

Vertical Well, Vertical Plane

Horizontal Well, Vertical Plane, Parallel to Wellbore

\( \sigma_{h,\text{max}} \)

\( \sigma_{h,\text{min}} \)
Simultaneous Fracturing in the Barnett Shale
Simultaneous Fracturing Location

- 25 frac pumps (50,000 HHP)
- 9 sand kings (2MM+ proppant)
BHI U.S. Frac Statistics - 2010

- 500+ frac pumps
- 1.3MM HHP
- 60 blenders
- 15,000 + jobs

Total U.S. Market
- ~10MM HHP
- 80,000 jobs
BHI Canada Frac Statistics

- 170,000 HHP
- 15 blenders
- 2 liquid CO$_2$ blenders
- 2,000 fracs (last 12 months)
Frac Statistics - 2010

- Total Global Market
  - ~13MM HHP
  - Revenue - $15+ billion
Rhino Quintaplex Unit - 2000 HHP
Gorilla Frac Unit - 2700 HHP
Chemical Additive Unit
2700 Sand King
Blending Unit
Treatment Monitoring Van
Fluids Van
Remote Monitoring for Customers
Fracturing Can Be Done Multiple Ways

- Conduits - casing, tubing, annulus or triple entry
- Multizone techniques
  - Ballsealers
  - Limited entry
  - Just-in-Time-Perforating with ballsealers
  - Sliding sleeves, packers and balls
  - Coiled tubing with abrasive cutter with sand plugs or packer
  - Wireline perforating with bridge plugs or sand plugs
  - EXCAPE Completion Process
  - Stress diversion
- Isolation with sand plugs, balls, bridge plugs or packers
Hydraulic Fracturing

Typical Hydraulic Fracturing Solution

| 99.51% Water and Sand | 0.49% Additives |

Source: Energy InDepth

<table>
<thead>
<tr>
<th>Acids</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium bisulfite</td>
<td></td>
</tr>
<tr>
<td>Borate salts</td>
<td></td>
</tr>
<tr>
<td>Citric acid</td>
<td></td>
</tr>
<tr>
<td>Ethylene glycol</td>
<td></td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td></td>
</tr>
<tr>
<td>Guar gum</td>
<td></td>
</tr>
<tr>
<td>Isopropanol</td>
<td></td>
</tr>
<tr>
<td>Petroleum distillates</td>
<td></td>
</tr>
<tr>
<td>Polycrylamide</td>
<td></td>
</tr>
<tr>
<td>Potassium chloride</td>
<td></td>
</tr>
<tr>
<td>Proppant</td>
<td></td>
</tr>
<tr>
<td>Sodium chloride</td>
<td></td>
</tr>
<tr>
<td>Sodium or potassium carbonate</td>
<td></td>
</tr>
</tbody>
</table>
What’s In a Fracturing Fluid?

EXHIBIT 35: VOLUMETRIC COMPOSITION OF A FRACTURE FLUID

Source: ALL Consulting based on data from a fracture operation in the Fayetteville Shale, 2008
## Frac Fluid components – Common Uses

<table>
<thead>
<tr>
<th>Additive Type</th>
<th>Main Compound(s)</th>
<th>Purpose</th>
<th>Common Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diluted Acid (15%)</td>
<td>HCl or muriatic acid</td>
<td>Dissolves minerals</td>
<td>Swimming pools</td>
</tr>
<tr>
<td>Biocides</td>
<td>Glut or THPS etc</td>
<td>Eliminates bacteria in water</td>
<td>Disinfectant; sterilize medical and dental equipment</td>
</tr>
<tr>
<td>Breaker</td>
<td>Ammonium persulfate</td>
<td>Delayed break gel polymer</td>
<td>Bleaching agent in detergent manufacture household plastics</td>
</tr>
<tr>
<td>Corrosion Inhibitor</td>
<td>N,m-dimethyl formamide, etc</td>
<td>Asset protection</td>
<td>Pharmaceuticals, acrylic fiber, plastics</td>
</tr>
<tr>
<td>Friction Reducer</td>
<td>Polyacrylamide or mineral oil</td>
<td>Reduce friction</td>
<td>H2O treatment, soil conditioner make-up remover, laxatives and candy</td>
</tr>
<tr>
<td>Gel</td>
<td>Guar gum or HEC</td>
<td>Thicken water</td>
<td>Cosmetics, toothpaste, sauces, baked goods ice cream</td>
</tr>
<tr>
<td>Iron control</td>
<td>Citric acid</td>
<td>Prevent metal oxides</td>
<td>Food additive flavoring/beverages, lemon juices ~7%</td>
</tr>
<tr>
<td>KCl</td>
<td>Potassium chloride</td>
<td>Brine solution</td>
<td>Low sodium table salt substitute</td>
</tr>
<tr>
<td>Oxygen scavenger</td>
<td>Ammonium bisulfite</td>
<td>Remove O2 Asset protection</td>
<td>Cosmetics, food &amp; beverage processing water treatment</td>
</tr>
<tr>
<td>pH adjusting agent</td>
<td>Sodium or potassium carbonate</td>
<td>Maintain pH</td>
<td>Washing soda, detergents, soap, water softener, glass and ceramics</td>
</tr>
<tr>
<td>Proppant</td>
<td>Silica, quartz sand, ceramics</td>
<td>Prop fracture for production</td>
<td>Drinking water filtration, play sand, concrete aggregate, brick mortar</td>
</tr>
<tr>
<td>Scale inhibitor</td>
<td>Ethylene glycol</td>
<td>Prevents scale deposits in pipe</td>
<td>Automotive antifreeze, household cleaners and deicing agent</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Isopropanol</td>
<td>Viscosity of frac fluid</td>
<td>Glass cleaner, antiperspirant, hair color</td>
</tr>
</tbody>
</table>

*Modern Shale Gas Development in the United States: A Primer (April 2009)*
Environmental Stewardship
Environmentally Compliant Frac Fluids

- Environmental stewardship is a key component of the BHI health, safety and environmental policy.
- In 2008, BHI voluntarily switched to environmentally friendly liquid frac concentrates for all water-based frac fluids in the U.S., ensuring that the fluids meet the U.S. Clean Water Act requirements prohibiting benzene, ethylbenzene, toluene and xylene (BETX) components.
Environmental Leadership

• BHI products meet or exceed environmentally related federal, state or local compliance guideline and regulations

• BHI is taking action:
  – Guidance from environmental consultants
  – Awareness - employees & customers
  – Marketing
Voluntary Chemical Registry - fracfocus.org

- The GWPC (Ground Water Protection Council) and IOGCC (Interstate Oil and Gas Compact Commission) working through All Consulting based in OKC have released the website to the public
  - HF services provide MSDS sourced chemical information, chemical totals per well, common well information, total treatment volume per well
  - The operators reviews and posts this information as a fixed formatted pdf
- Searchable by the well API number, State and or county information
http://nwis.waterdata.usgs.gov/nwis/inventory
http://nwis.waterdata.usgs.gov/nwis/inventory
SmartCare™ Systems

Technology that delivers superior well performance and value using fit-for-purpose systems comprised of compatible, quality-ensured chemical additives and systems that are physically safe and environmentally responsible
SmartCare Product Evaluation - Objectives

- Better understand the potential hazards of products
- Numerically “rate” products best to worse
- Flag areas for improvement
- Identify best in class products
- Guide R&D efforts
- Support marketing claims
- Compare systems

- Ongoing: 140 plus products
- Requires full disclosure
  - Environmental consultants
### SmartCare Product Evaluation - Categories

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Human Health</th>
<th>Physical hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic toxicity</td>
<td>Mammalian toxicity</td>
<td>Explosive</td>
</tr>
<tr>
<td>Bioaccumulation</td>
<td>Irritation/corrosion</td>
<td>Flammability</td>
</tr>
<tr>
<td>Biodegradation</td>
<td>Carcinogenicity</td>
<td>Oxidizer</td>
</tr>
<tr>
<td>Priority pollutants ¹</td>
<td>Genetic toxicity</td>
<td>Corrosive</td>
</tr>
<tr>
<td>VOC content ¹</td>
<td>Reproductive and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>developmental toxicity</td>
<td></td>
</tr>
</tbody>
</table>

**Globally Harmonized System of Classification and Labeling of Chemicals (GHS)**

- Addresses health, physical and environmental hazards of chemicals
- Creates a hazard classification process
- Establishes standards for labels and safety data sheets
- Waiting on US OSHA final ruling – probable implementation by 2012/2013

¹ EPA List Based
## SmartCare Product Evaluation - Scores

<table>
<thead>
<tr>
<th></th>
<th>Score</th>
<th>Hazard</th>
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</thead>
<tbody>
<tr>
<td><strong>Environmental</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aquatic toxicity</td>
<td>3-2-1-0</td>
<td>High-Moderate-Possible-Not</td>
</tr>
<tr>
<td>Bioaccumulation</td>
<td>3-2-1-0</td>
<td>High-Moderate-Possible-Not</td>
</tr>
<tr>
<td>Biodegradation</td>
<td>3-2-1-0</td>
<td>Not-Slow-Moderate-Readily</td>
</tr>
<tr>
<td>Priority pollutants</td>
<td>3......0</td>
<td>Yes............................No</td>
</tr>
<tr>
<td>VOC content</td>
<td>3......0</td>
<td>Yes............................No</td>
</tr>
<tr>
<td><strong>Human Health</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mammalian toxicity</td>
<td>3-2-1-0</td>
<td>High-Moderate-Possible-Not</td>
</tr>
<tr>
<td>Carcinogenicity</td>
<td>3-2-1-0</td>
<td>Known-Presumed-Suggestive-Not</td>
</tr>
<tr>
<td>Genetic toxicity</td>
<td>3-2-1-0</td>
<td>High-Moderate-Possible-Not</td>
</tr>
<tr>
<td>Reproductive toxicity</td>
<td>3......0</td>
<td>Evidence......................Not</td>
</tr>
<tr>
<td>Irritation/corrosion</td>
<td>3......1</td>
<td>High-Moderate-Possible-Not</td>
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<tr>
<td><strong>Physical Hazards</strong></td>
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<td></td>
</tr>
<tr>
<td>Explosive</td>
<td>3-2....0</td>
<td>High-Moderate...............Not</td>
</tr>
<tr>
<td>Flammability</td>
<td>3-2-1-0</td>
<td>High-Moderate-Possible-Not</td>
</tr>
<tr>
<td>Oxidizer</td>
<td>3-2-1-0</td>
<td>High-Moderate-Possible-Not</td>
</tr>
<tr>
<td>Corrosive</td>
<td>3......0</td>
<td>Yes.........................No</td>
</tr>
</tbody>
</table>
Product Evaluation – Conclusions

- Advantages
  - Scientific “rating” process to compare products and select environmentally preferred options
  - “Clearing house” verified
    - Adds credibility
    - Allows analysis of 3rd party proprietary products
  - Understanding of potential environmental, toxicological and physical hazards
  - Solid basis to guide product development efforts
  - Support for marketing claims
Would you believe a Trifrac!

- 4, 4, 5 stages
- 55,200 HHP
- 14.7 MM gals (56,000 m³)
- 5.5 MM lbs prop (2.5 million kg)
Fracturing the Smart Way

Smart about the well
Smart about the environment