History of Hydraulic Fracturing

Mark Parker
Halliburton
Mid-Continent Area
Technology Manager
Safety Moment – Driving Safety
Distracted Driving

- The only thing you should do when Driving is Driving
- Focus on the task at hand – Driving Safely
  - No interfacing with GPS/Navigation systems
  - No calls
  - No texts
  - No eating
The Oil & Gas Industry Activity Today
Transition to Unconventional Reservoirs

- The Shale Revolution
  - Sandstones and carbonates to source rock reservoirs

- Horizontal Drilling
  - Increased reservoir contact

- Hydraulic Fracturing
  - What it is and is not
Resource Triangle

Conventional Reservoirs
Small Volumes
Easy to Develop

Unconventional Reservoirs
Large Volumes
Difficult to Develop

Low Perm Oil
Tight Gas Sands
Low – Medium Quality

Gas Shales
Heavy Oil

Gas Hydrates

Coalbed Methane

Oil Shale

Improved Technology

Increased Cost

Reference: OTC 20267 Stimulation of Tight Gas Reservoirs Worldwide
Stephen A. Holditch, Texas A&M University
Benefits - Horizontal Wells and Reservoir Contact

- Increase contact area of formation
- Improve efficiency and economic viability
- Reduce surface footprint
Hydraulic Fracturing
What it is ...

Hydraulic Fracture Mechanics

\[ \sigma_{\text{min}} = \left[ \frac{\nu}{1-\nu} \right] \left[ \sigma_z - \alpha_1 P_R \right] + \alpha_2 P_R + \sigma_{\text{tec}} \]

\( \sigma_v > 1 \text{ psi/ft} \)

Fracture Design
Treatment Schedule

<table>
<thead>
<tr>
<th>Stage #</th>
<th>Flow Path</th>
<th>Fluid System</th>
<th>Prop Type</th>
<th>Stage Time (min)</th>
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<tbody>
<tr>
<td>1 – 1</td>
<td>Shut-In</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1 – 2</td>
<td>In</td>
<td>20# Water Frac G</td>
<td></td>
<td>39.3</td>
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<td>1 – 3</td>
<td>In</td>
<td>20# Water Frac G</td>
<td>SAND – PREMIUM – 20/40, BULK, SK (100003678)</td>
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<td>In</td>
<td>20# Water Frac G</td>
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<td>6.39</td>
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<tr>
<td>1 – 5</td>
<td>In</td>
<td>15% Hydrochloric Acid</td>
<td></td>
<td>1.06</td>
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<td>1 – 6</td>
<td>In</td>
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<td>16.46</td>
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<td>1 – 7</td>
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<td>SAND-CRC PREMIUM-20/40, BULK (101357961)</td>
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<td>1 – 8</td>
<td>In</td>
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<td>SAND-CRC PREMIUM-20/40, BULK (101357961)</td>
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<td>1 – 9</td>
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<td>SAND-CRC PREMIUM-20/40, BULK (101357961)</td>
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<td>1 – 10</td>
<td>In</td>
<td>20# Water Frac G</td>
<td>SAND-CRC PREMIUM-20/40, BULK (101357961)</td>
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<td>1 – 11</td>
<td>In</td>
<td>20# Water Frac G</td>
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<td>10.37</td>
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<tr>
<td>1 – 12</td>
<td>Shut-In</td>
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<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Total 124.01
Well Construction
Why do we need to cement wells?

- Protect fresh water and other formations from well fluids
- Protect the well casing from damaging formation conditions
- Ensure a durable and competent casing string throughout the life of the well
- Possibly the most critical phase in well construction or completion
Typical casing strings

- Conductor Casing
- Fresh Water Aquifer
- Surface Casing
- Lost Circulation Zone or High Pressure Zone
- Intermediate Casing
- Production Casing
- High Pressure Reservoir
- Cement
- Cement
- Cement
- Cement
How Did We Get Here?
How Did We Get Here

- Concept development and understanding
- Chemical system development
- Equipment development
- Engineering understanding
Velma, Oklahoma

The First Commercial Hydraulic Fracturing Treatment

March 17, 1949
The “Hydraulic Fracturing” Process

• The Use of Fluids To Apply Hydraulic Pressure to Create A Fracture in a Rock Formation

• The Continued Injection of Fluids Into The Created Fracture To Develop the Geometry

• The Placement of Small Granular Solids Into The Fracture To Insure It Remains Open After The Hydraulic Pressure Is No Longer Being Applied
The Objective of The “Hydraulic Fracturing” Process

• Increase The Rate At Which The Well Is Capable of Producing Oil or Gas

• Increase The Economically Recoverable Reserves For A Well
Principal Stress And Fracture Orientation

\[ \sigma_V \]
\[ \sigma_{H1} \]
\[ \sigma_{H2} \]

Lowest
Propping Agents
Chemical Development
Reservoir Characterization
Engineering and Testing
Performance Testing – Fracture Conductivity
Reservoir Understanding - Rock Mechanics
Software Development
History of Halliburton Frac Fluids - 1

- **The Industry**
  - 1949 Oil Frac
  - 1950’s Viscosified Water
  - 1960’s Crosslinked Fluids
  - 1970’s Foamed Fluids

- **Halliburton**
  - 1969 HyGel™/LoGel™
  - 1972 VersaGel™
  - 1974 Kleer-Gel™ II
  - 1977 AcidGel Frac II™
  - 1982 VersaGel™ HT
Massive Hydraulic Fracturing – late 1970’s through the 1980’s

- **Targets**
  - Low permeability reservoirs
  - Natural gas production
  - Deeper
  - Hotter
  - Higher pressure

- **Technology**
  - Complex chemical fluid systems
  - Long pump times
  - Computer designs
The Rise of Unconventional Reservoirs

- Source Rock Reservoirs
  - Shale Gas
  - Shale Oil

- Horizontal Wells and Hydraulic Fracturing
  - Accelerated development
  - Increased productivity
Evolution of Fracturing – 1990’s to Today

- Engineering understanding of the fracturing process
  - Ultra-low permeability reservoirs
  - Coal Bed Methane (CBM)
  - Source Rock Reservoirs

- Alteration of design based on the reservoir
  - Computational improvements
    - Fracture Design Simulators
    - Reservoir Simulators
  - Hybrid treatment designs
Equipment
Equipment
History of Halliburton Frac Fluids - 2

- **The Industry**
  - 1980 Improved Breakers
  - 1990 Reduced Polymer Fluids
  - 2000 Reduced Residue Fluids
  - 2010 Guar-Free, Green Fluids
  - 2012 High TDS Crosslink Fluids

- **Halliburton**
  - 1986 Pur-Gel™
  - 1986 Thermagel™
  - 1987 BoraGel™
  - 1991 HyborGel™
  - 1997 Delta Frac
  - 2001 HMP
  - 2002 SilverStim® LT
  - 2002 Sirocco®
  - 2003 SeaQuest®
  - 2004 DeepQuest®
  - 2005 pHaserFrac®
  - 2008 OmegaFrac®
Concerns for the Industry
Concerns for the Industry

- Water resources
- Environmental pollution
- Sustainability
## Overarching US Debate - Federal Versus State Oversight

<table>
<thead>
<tr>
<th>Federal</th>
<th>Legislators and regulators vie to regulate oil and gas industry at the federal level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Regulation</td>
<td>Waxman inquiry prompts EPA to expand regulatory guidance on diesel use in frac fluids</td>
</tr>
<tr>
<td>Federal Lands</td>
<td>BLM reviewing operations and revising oil and gas regulations on federal lands</td>
</tr>
<tr>
<td>EPA Study</td>
<td>EPA HF study to include water withdrawals, storage, treatment, disposal and recycling</td>
</tr>
<tr>
<td>SEAB</td>
<td>Natural Gas Subcommittee recommendations on improved safety &amp; environment in shale development</td>
</tr>
<tr>
<td>State</td>
<td>State regulators seeking to maintain primacy over oil &amp; gas regulation</td>
</tr>
</tbody>
</table>
## State Regulation - Under Review

<table>
<thead>
<tr>
<th>State</th>
<th>Regulations and Legislation</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>De facto moratorium awaiting final SGEIS ruling in 2014?</td>
</tr>
<tr>
<td>Wyoming</td>
<td>Chapter 3 regulations address well construction and completions – Lawsuit over disclosure</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>Chapter 78 regulations address well construction and completions</td>
</tr>
<tr>
<td>Colorado</td>
<td>Rule 205-A ruling sets new standards for HF chemical disclosure – April 1st</td>
</tr>
<tr>
<td>Texas</td>
<td>HB 3328 regulation sets new standards for HF chemical disclosure – Feb. 1st</td>
</tr>
<tr>
<td>California</td>
<td>SB 4 proposes new legislation on upstream activities including HF disclosure</td>
</tr>
</tbody>
</table>
Water Use Comparison

*Shale Gas Development < 1%*

Source: USGS
Fracture Location Determination - Barnett Study

Bottom of deepest aquifers

Thousands of feet of separation

Top of fractures

Kevin Fisher, “Data Confirm Safety of Well Fracturing,”
The American Oil & Gas Reporter – July 2010
Frac Fluid Composition

0.49% ADDITIVES*

99.51% WATER AND SAND

FracFocus – Chemical Disclosure Registry

- Publicly available information on a well by well basis
- Standardizes reporting for all fracturing operations
- Supports multiple state disclosure efforts
- Provides information on state regulations and educational material

www.FracFocus.org
Environmentally Focused Energy Development
Environmental Advancements In Fracturing

Chemistry Scoring Index (CSI)

- Assess Health, Safety and Environmental hazards of products
- Considers relative hazards in formulating new products
- Can be adopted by entire industry
Comprehensive Environmental Stewardship

CleanStream®
Ultra-violet light to control bacteria

CleanWave™
Electrocoagulation to recycle water for fracturing process

ADP™ Blender
Dry powder gelling agent to eliminate carrier fluids

SandCastle®
Solar energy and gravity rather than diesel power

Dual fuel technology
Powering equipment with a blend of diesel and natural gas

- Treated > 860 million gallons of water eliminating 129,000 gallons of biocide
- Recycled > 31 million gallons water saving 7,400 truck loads
- Eliminated > 30 million gallons of mineral oil from fracturing operations
- Saved > 1.4 million gallons of diesel and avoided 31 million pounds of CO₂

2012 Statistics
## Sources of Information

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRONGER</td>
<td>In-depth peer review of the regulatory programs in OH, PA, OK, LA and CO</td>
<td><a href="http://www.strongerinc.org">www.strongerinc.org</a></td>
</tr>
<tr>
<td>API</td>
<td>Detailed guidance documents and recommended practices for industry</td>
<td><a href="http://www.API.org">www.API.org</a></td>
</tr>
<tr>
<td>IOGCC/GWPC</td>
<td>FracFocus website providing well by well hydraulic fracturing information to the public</td>
<td><a href="http://www.FracFocus.org">www.FracFocus.org</a></td>
</tr>
<tr>
<td>Energy In Depth</td>
<td>E.I.D. launches new grassroots initiatives in northeast PA, southern NY and eastern Ohio</td>
<td><a href="http://www.Energyindepth.org">www.Energyindepth.org</a></td>
</tr>
<tr>
<td>Halliburton</td>
<td>HF microsite contains detailed fluid information and educational material</td>
<td><a href="http://www.Halliburton.com/HydraulicFracturing">www.Halliburton.com/HydraulicFracturing</a></td>
</tr>
</tbody>
</table>
Additional Information

Gradient Report – National Human Health Risk Evaluation for Hydraulic Fracturing Fluid Additives

SPE 166142 – Environmental Risk Arising From Well Construction Failure: Difference Between Barrier and Well Failure, and Estimates of Failure Frequency Across Common Well Types, Locations and Well Age

Vicki Vaughan Article – Water for fracking is dwarfed by other usage

Chesapeake Energy Overview – Water Use in Deep Shale Gas Exploration

SPE 151597 Paper – Measurements of Hydraulic-Fracture-Induced Seismicity in Gas Shales

University of Texas Methane Study:
http://www.utexas.edu/news/2013/09/16/understanding-methane-emissions/

Kevin Fisher Article, Oil & Gas Reporter – Data Confirm Safety Of Well Fracturing
Where Are We Going?
Where are we going

- Frac of the Future

- Subsurface Visualization
Tomorrow’s Fracturing Location

- Industry leading reliability
- Highly efficient operations
- Safe and easy to the wellhead
- Effective land usage
- Environmental responsibility
- Remotely operable
CYPHER™ Earth Model Properties
3D Framework with Lateral Wells
Conclusions

- Across the US, abundant natural gas and oil is being enabled by hydraulic fracturing and other technologies.
- Well construction and sound engineering practices are the keys to protecting ground water.
- Hydraulic fracturing is a safe and well understood process with a long and proven track record.
- With scientifically based and balanced regulations shales can be developed in an environmentally sensitive and cost effective manner.
- Technological advancements are making real impacts in reducing the industry’s overall footprint.

Source: EIA Annual Energy Outlook 2011
Thank you