HYDRAULIC FRACTURING IN CALIFORNIA

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California Department of Conservation
Division of Oil, Gas, and Geothermal Resources

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- DIVISION AUTHORITY
- DIVISION HISTORY
- PETROPHYSICS
- HYDRAULIC FRACTURE STIMULATION
- WELL CONSTRUCTION
- GEOLOGY
- WELL STIMULATION REGULATIONS
DIVISION MANDATES

...SUPERVISE THE DRILLING, OPERATION, MAINTENANCE... OF WELLS...

TO PREVENT...DAMAGE TO LIFE, HEALTH, PROPERTY, AND NATURAL RESOURCES...
Division Mandates

...TO PERMIT THE OWNERS...

TO UTILIZE ALL METHODS...AND PRACTICES KNOWN TO THE INDUSTRY FOR THE PURPOSE OF INCREASING THE ULTIMATE RECOVERY.
Division Mandates

TO BEST MEET OIL AND GAS NEEDS IN THIS STATE, THE SUPERVISOR SHALL ADMINISTER THIS DIVISION SO AS TO ENCOURAGE THE WISE DEVELOPMENT OF OIL AND GAS RESOURCES.
Fig. 1. Sketch showing entrance of water into oil sand due to imperfect seating of casing and to lack of cement around bottom of outer casing.
Fig. 3. Sketch showing entrance of water into oil sand and its migration to a properly drilled well. Due to use of only one string of casing in first well,
FLUID FLOW AND ROCK PROPERTIES (PETROPHYSICS)

POROSITY

PERMEABILITY

ROCK MECHANICS
POROSITY – Percentage of pore space between grains of rock. “Open space” between grains occupied by fluid and/or gas.

SHALE  SANDSTONE  LIMESTONE
PERMEABILITY – The ability of a material to transmit fluid.
Darcy’s Law

\[ q = KA \frac{h_2 - h_1}{l} \]
Permeability Relationships

Loose, well-sorted gravel
- 100,000,000 to 1,000,000,000 md

Clean beach sand
- 10,000 to 1,000,000 md

Typical California reservoir rock
- 10 to 10,000 md

Shale
- .01 to 1 md

Granite
- .0001 to .001 md
How a rock fractures is based on the laws of physics and geology, such as…

- Reservoir pressure and temperature
- Poisson’s Ratio
- Young’s Modulus
- Formation compressibility
- In-situ stress
- Fracture toughness
- Pore Pressure
- Lithology
WHAT IT IS NOT:
- A drilling process.
- A new technology.
- Underground injection of chemicals.

WHAT IT IS:
- A well “completion” process employed after a well has been drilled.
- A well “stimulation” process used to maximize the extraction of underground resources; including oil, natural gas, geothermal energy, and even water. (US EPA)

- Fluids, commonly made up of water (~99.5%) and chemical additives (~0.5%), are pumped into a geologic formation at high pressure during hydraulic fracturing. When the pressure exceeds the rock strength, the fluids open or enlarge fractures that can extend several hundred feet away from the well. (US EPA)
Hydraulic Proppant Fracturing
wide but short fracture

multiple proppant stages
fully propped fracture

Water Fracturing
small but long fracture

settling of proppants at fracture bottom
narrowing of fracture / arch zone
After the fractures are created, a propping agent (sand) is pumped into the fractures to keep them from closing when the pumping pressure is released.

Surface water discharges of the flowback are regulated by the National Pollutant Discharge Elimination System (NPDES) program, which requires flowback to be treated prior to discharge into surface water or underground injection prior to discharge.

Underground injection of flowback is regulated by either EPA Underground Injection Control (UIC) program or a state with primary UIC enforcement authority.
- **Short-term Process**
  - Unconventional resource (shale gas), horizontal multi-stage procedures may take several days.
  - Conventional resource (sandstone) minutes to hours.

- **Water Usage**
  - Unconventional Well (shale): \(~1.5 \text{ to } 5 \times 10^6\) gals
  - Conventional Well (sandstone): \(~1 \text{ to } 4 \times 10^5\) gals
  - Typical Golf Course in CA: 312,000 GPD

- **Flowback**
  - Most of the fluid injected to create fractures is produced back shortly after the fracture treatment is completed.
  - This is the point at which fluid storage, treatment, and reuse or disposal is critical.
Constituents of HF “Fluid”

http://fracfocus.org/water-protection/drilling-usage
<table>
<thead>
<tr>
<th>Type of Additive</th>
<th>Function</th>
<th>Typical Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocide</td>
<td>Kills bacteria</td>
<td>Gluteridehyde carbonate</td>
</tr>
<tr>
<td>Breaker</td>
<td>Reduces fluid viscosity</td>
<td>Acid, oxidizer, enzyme breaker</td>
</tr>
<tr>
<td>Buffer</td>
<td>Controls pH</td>
<td>Sodium bicarbonate, fumaric acid</td>
</tr>
<tr>
<td>Clay stabilizer</td>
<td>Prevents clay swelling</td>
<td>KCL, NH CL, KCL substitutes</td>
</tr>
<tr>
<td>Diverting agent</td>
<td>Diverts flow of fluid</td>
<td>Ball sealers, rock salt, flake boric acid</td>
</tr>
<tr>
<td>Fluid loss additive</td>
<td>Improves fluid efficiency</td>
<td>Diesel, particulates, fine sand</td>
</tr>
<tr>
<td>Friction reducer</td>
<td>Reduces surface friction</td>
<td>Anionic copolymer</td>
</tr>
<tr>
<td>Iron controller</td>
<td>Keeps iron in solution</td>
<td>Acetic and citric acid</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Lowers surface tension</td>
<td>Florocarbon, nonionic</td>
</tr>
<tr>
<td>Gel stabilizer</td>
<td>Reduces thermal degradation</td>
<td>MEOH, sodium thiosulfate</td>
</tr>
</tbody>
</table>
# TYPICAL RESERVOIR CHEMISTRY

<table>
<thead>
<tr>
<th>Gas</th>
<th>Hydrocarbon Liquids</th>
<th>Connate Water Ionic Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethane</td>
<td>Gasoline</td>
<td>Sodium</td>
</tr>
<tr>
<td>Methane</td>
<td>Kerosene</td>
<td>Magnesium</td>
</tr>
<tr>
<td>Propane</td>
<td>Gas condensates</td>
<td>Calcium</td>
</tr>
<tr>
<td>Pentane</td>
<td>Paraffin</td>
<td>Potassium</td>
</tr>
<tr>
<td>Hexane</td>
<td>Asphaltene</td>
<td>Magnesium</td>
</tr>
<tr>
<td>Heptane</td>
<td>Coke</td>
<td>Calcium</td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
<td>Potassium</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td></td>
<td>Manganese</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td></td>
<td>Strontium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Barium</td>
</tr>
</tbody>
</table>
The study of the mechanical behavior of rocks goes back to the 1700’s.

The first successful hydraulic fracture treatment in an oil well was done in 1947.

By 1955, over 100,000 wells in the US were hydraulically fractured.

Hydraulic fracture stimulation is a relatively common practice employed in “conventional” reservoirs to increase productivity of oil, gas, geothermal, and water wells.

Hydraulic fracturing of SHALE for “unconventional” gas production was discovered by accident in the early 1990s.
Organic Shales - Deep Water, Anaerobic / Clay Matrix

Organic Rich Source Rock
Extremely Low Permeability
Depth of Affected Region Affected by Hydraulic Fracturing

Barnett Mapped Frac Treatments/TVD

Fisher (2010)

http://nwis.waterdata.usgs.gov/nwis/inventory
Producing Oil from Shale?

Methane
0.4 nm

Typical Pore
40 nm

Oil

Courtesy: Stanford University
Oil Field Cross Section

Production Sandstone Formation

Non-Productive Formation
Horizontal Drilling
Multi-Stage Hydraulic Fracturing Works!

Horizontal Drilling and Multi-Stage Slick-Water Hydraulic Fracturing Induces Microearthquakes (M ~ -1 to M ~ -3) To Create a Permeable Fracture Network

Courtesy: Stanford University
Risk Associated with Injection and Triggered Seismicity

Microseismic Events Associated with Hydraulic Fracturing
- Very Low Risk to Public
  - Limited rock volume, limited pumping volume/time
  - Very few events > M 2 in ~1 million frac stages

Seismic Events Associated with Wastewater Injection
- Low Risk to Public
  - Much Larger Pumping Volumes
  - Can be Effectively Managed by Effective Site Characterization, Monitoring and Proactive Planning
  - Minimize Injection by Water Recycling
WELL CONSTRUCTION IN CALIFORNIA

- Laws and regulations address the protection of underground and surface water.
- Specific regulations address the integrity of the well casing.
- Specific regulations address cement to secure the well casing inside the bore hole.
- Specific regulations address cement and equipment used to seal off the well from underground zones bearing fresh water and other hydrocarbon resources.

See California Public Resources Code sections 3106, 3203, 3211, 3220, 3222, 3224, 3255; Title 14 of the California Code of Regulations, sections 1722.2, 1722.3, 1722.4, etc.

For more information about oil and gas well drilling and well completion techniques, please refer to, “California’s Oil, Gas, and Geothermal Resources, An Introduction,” Chapters 6 and 7, pp. 35-43.
California’s requirements for the protection of underground resources and well construction standards provide a first line of protection from potential damage caused by hydraulic fracturing.

However, California’s regulations do not currently require notification to the Division when hydraulic fracturing occurs.

Information provided to the Division about hydraulic fracturing operations and steps taken to protect resources and the environment are lacking.

Therefore…

Department’s draft regulations and SB4.
7 Workshops Throughout State 2012

Discussion Draft Hydraulic Fracturing Regs released December 2012

5 Day-long Workshops 2013

Rulemaking begins late 2013
Regulations Include

- Nearby Geologic Review
- Pre-Fracturing Well Testing
- Advance Notification to Division, Property Owners, and Tenants
Regulations Include

- Monitoring During and After Fracturing Operations
- Disclosure of Materials Used in Fracturing Fluid
- Trade Secrets
- Proper Storage of Hydraulic Fracturing Fluids
Senate Bill 4 (SB 4) (2013)

Creates: “Article 3. Well Stimulation” in state law

Purpose:

- To increase transparency of CA well stimulation techniques;

- Provides framework for a comprehensive study, environmental review, and regulation of well stimulation.
REQUIRES:

• A study on well stimulation
  • [Public Resources Code Section ( ) 3160]

• A Statewide Environmental Impact Report
  • [ 3161(b)]

• The Division to adopt well stimulation regulations
  • [ 3160 (b) (1) (A)]

• Permits for well stimulation
  • [ 3160 (d) (2) (A)]
REQUIRES:

- Groundwater monitoring plans
  - [ 3160 (d) (1) (F)]
- Public disclosure
  - [ 3160 (g) (2) (A)]

ESTABLISHES:

- Notification requirements
  - [ 3160 (d) (6) (A)]
- Trade secret procedures
  - [ 3160 (j) (1)]

PROVIDES:

- Amendments to the oil and gas fee structure
  - [ 3401 (a)]
MORE INFO

http://www.conservation.ca.gov/dog/general_information/Pages/HydraulicFracturing.aspx

http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydrowhat.cfm

http://www.usgs.gov
Questions?

www.conservation.ca.gov