Shale Gas Development: Leaks and Vents

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Outline of Presentation

• Geology Rules!: What Is Unconventional Development of Methane/Oil from Clustered, Multi-well Pads Via High-Volume Frac’ing from Long Laterals?

• The Fluid Migration Problem: Why and How Often Do Wells Leak?

• The Methane Emission Problem: Where, When?

• Is Shale Gas a Clean Fossil Fuel?
Why Is Shale Gas Development “Unconventional”? 

- Because it requires **4 technologies only recently combined** to make gas production from impermeable shales technically and economically feasible.
- **Directional drilling**: needed to access a thin layer of shale with long laterals.
- **High frac fluid volumes**: needed to stimulate gas release from many existing fractures.
- **Slickwater**: needed to control the amount of power needed to pump large volumes of frac fluids, at high pressures, quickly, over long distances, through small diameter casing.
- **Multi-well Pads and Cluster Drilling**: needed to access as much of the gas inventory as possible, under constraints of leasing and capital.
High Volume, Slickwater Fracing from Long Laterals: The Concept

Cap rock

~ 5000 ft

Cap rock

Shale Layer

~ 100 ft
Pay zone

Well is turned horizontal

The Lateral, >5000 ft

Not to scale

Hydrofrac Zone
Early Joints at Taughannock Falls

Geneseo-Burket (Devonian black shale)

Taughannock Falls State Park, Trumansburg, N.Y.

Gas Producing Shales are Heavily Fractured Naturally

Photo Courtesy T. Engelder
3D Imaging of the Sub-Surface

From *National Geographic*, December 2012
Targeting the Shale Layer Via Multiple, “Horizontal” Wells from Clusters of Pads

From Cody Teff, Shell Appalachia, WELL CONSTRUCTION PRACTICES IN THE MARCELLUS
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Leaks and Vents: Impact on Drinking Water

VIDEO of
Methane Bubbling
At Head of Leaking Well
Industry-Reported Data On Loss of Wellbore Integrity: Offshore Wells

SCP=Sustained Casing Pressure. Also called sustained annular pressure, in one or more of the casing annuli.

- About 5% of wells fail soon
- More fail with age
- Most fail by maturity

Wells with SCP by age. Statistics from the United States Mineral Management Service (MMS) show the percentage of wells with SCP for wells in the outer continental shelf (OCS) area of the Gulf of Mexico, grouped by age of the wells. These data do not include wells in state waters or land locations.

Brufatto et al., Oilfield Review, Schlumberger, Autumn, 2003
Industry-Reported Data On Loss of Wellbore Integrity: Onshore Wells

Watson and Bachu, SPE 106817, 2009.
Industry well integrity outlook

- Industry will drill more wells in the next decade than have been drilled in the last 100 years.
- Global well population is +/- 1.8 million, of which +/- 35% has sustained casing pressure.
- Public awareness and concern of zonal isolation requirements is increasing (USA / Australia / Europe).
- Geothermal wells and CO2 sequestration wells are on the increase.
- Subsidence is a risk in some depleting reservoirs.
- Life cycle extension of aging assets is becoming a pre-requisite of legislators.
- Zonal isolation challenges and assurance does need push in technology.
- Abandonment of legacy wells is becoming more of a focus.
- Industry collaboration is an inevitable pre-requisite on all topics.
Some Mechanisms of Gas Migration

- Gas Migration Through Cement: percolation during curing
- Cement Sheath Failure: high temp, high pressure, perforation
- Improper Cement Design and Placement: poor chemistry, poor mud cleanup, low cement top
- Casing Failure: Corrosion, joint failure, fracture
- Cross Flow Between Adjacent Wells

Figure 4: Incomplete displacement of drilling mud and resulting cement and drilling fluid channels. Over time, the gels in the drilling fluid well shrink, forming a gas flow path in the annulus.\(^3\)

From Watson, PAPER 2004-297 Petroleum Society’s 5th Canadian International Petroleum Conference
GOOD MECHANICAL INTEGRITY
INSUFFICIENT CEMENT COVERAGE

PRESSURE BUILDS UP

CONDUCTOR PIPE

SURFACE CASING

PRODUCTION CASING

FRESH WATER AQUIFER ZONE

SHALLOW PRODUCING ZONE

INTERMEDIATE PRODUCING ZONE

TARGET PRODUCING ZONE
• Access Pennsylvania Department of Environmental Protection Violations Database online.

• First Pass: Count wells with violations for “leak” codes; eliminate duplicate wells in database.

• Second Pass: Count wells with leakage noted via inspection but which had not been issued violations.

• Divide total number of wells found leaking per year by number of wells drilled that year.
Recent Operator Performance in the Pennsylvania Marcellus Play: Results of Survey

1,609 wells drilled in 2010.
97 well failures.
6% rate of failure.

1,972 wells drilled in 2011.
140 well failures.
7.1% rate of failure.

1,346 wells drilled in 2012
120 well failures.
8.9% rate of failure.

Consistent with previous industry data, and not improving.

200,000 Marcellus Wells Expected
You do the math....
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• **The Methane Emission Problem: Where, When?**
• Is Shale Gas a Clean Fossil Fuel?
Methane Can Be Purposely Vented and Accidentally Leaked, Upstream/Midstream/Downstream

- During drilling
- During initial frac fluid flow-back period
- Routinely and continuously at the well site
- During liquid unloading
- During gas processing
- During transmission, storage, and distribution
Upstream Example: Gas Is Supposed to Rise Inside the Production Casing, Not Outside

VIDEO of Methane Bubbling At Well Head
Upstream Example: Bubbling form Gas Migration in Muncy Creek, Lycoming County, PA:

Video Courtesy of Ralph Kisberg, Responsible Drilling Alliance

Photo and FLIR Methane-Tuned Video Courtesy Frank Finan

Video courtesy of Frank Finan
Upstream+Midstream Methane Emission Measurements are Coming in Very High

Uinta Basin, Utah:
Up to 9% of total production
*Nature* 493, 12 (03 January 2013) doi:10.1038/493012a

Denver–Julesburg Basin, Colorado:
2.3% to 7% of total production

Note: Howarth, Santoro, Ingraffea predicted TOTAL (UPSTREAM+MIDSTREAM+DOWNSTREAM) emission range of 3.6% to 7.9%.
*Climatic Change Letters*, 2011
Downstream Methane Leakage from Aging Urban Distribution Pipelines: Boston MA

Natural background level is about 1.9 ppm
“**A 2.86%** leakage of all the natural gas handled by ConEd in Manhattan alone…”

“…8.6 billion cubic feet per year methane emissions from Manhattan…”

“Over 70% of the cast iron pipe in the ConEd system is over 100 years old, and almost all was installed before 1930, i.e., is more than 80 years old.”

Payne and Ackley, Gas Safety Inc., 2013
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CO$_2$ Concentration in the Atmosphere

RECENT MONTHLY MEAN CO$_2$ AT MAUNA LOA

Seasonal fluctuation

http://www.esrl.noaa.gov/gmd/ccgg/trends/
Methane Concentration in the Atmosphere: Historical Record

Figure 1: Methane content in the atmosphere obtained from measurements in glaciers in Antarctic and Greenland and in environmental samples collected in Tasmania.

Measured Methane Concentration in the Atmosphere: Recent Record

DATA FROM NOAA: http://www.esrl.noaa.gov/gmd/dv/iadv/graph.php?code=MLO&program=ccgg&type=ts
Methane Is a Much More Potent Greenhouse Gas Than Carbon Dioxide

• Up to 33 times more potent over 100 years*
• Up to 105 times more potent over 20 years*
• Therefore, even small leakage rates important:
  Each 1% lifetime production leakage from a well produces about the same climate impact as burning the methane twice.

A DAUNTING CLIMATE FOOTPRINT

Over 20 years, shale gas is likely to have a greater greenhouse effect than conventional gas or other fossil fuels.

Howarth, Ingraffea, NATURE, 477, 2011
Why Is Controlling Methane (CH$_4$) Emission So Important?

Burn-Offs at MarkWest Gas Processing Plant, Houston, PA: THIS Is Black Carbon

9/18/11
2:03pm

Photos courtesy of Robert Donnan
Burn-Offs at MarkWest Gas Processing Plant, Houston, PA: THIS Is Black Carbon

9/28/11
7:28pm
NO to HVHF, YES to a Much Better Plan

Convert New York State’s (NYS’s) all-purpose -- electricity, transportation, heating/cooling, industry -- energy infrastructure to one derived entirely from wind, water, and sunlight (WWS), by 2030.

We the people own the sun. We own the wind. We own the water. Those fuel costs are $0.00.

Or, NYS can have 50,000 to 100,000 Marcellus and Utica Wells;
• 8,000 to 16,000 pads;
• 500 to 1,000 compressor stations;
• Thousands of miles of new pipelines;
• Thousands of incidents of well water contamination;
• Increase New York’s contribution to global warming;
• Continue illness and morbidity from pollution;
• Sequester forever twice the tonnage of the US Navy in non-recyclable steel casing.
Our Energy Plan for New York State

Wind, water and solar energy will provide a stable, renewable source of electric power not subject to the same fuel supply limitations as fossil fuels and nuclear power. Due to the eventual depletion of coal, oil, natural gas, and uranium resources, their prices will continue to rise.

We Own the Wind, the Sun, the Water: They Make Us Energy Secure and Independent
“Natural gas is a delaying tactic…There is no time to waste… We have to decide whether we are in the business of delaying bad outcomes or whether we are in the business of preventing bad outcomes.”

Ken Caldiera, Senior Scientist
Department of Global Ecology,
Carnegie Institution, Stanford, CA
April 15, 2012
Physicians, Scientists, and Engineers for Healthy Energy is dedicated to supplying objective, evidence-based, scientific information and resources on unconventional gas development (high-volume hydrofracking) and other novel energy production methods. PSE's mission is to bring transparency to the important public policy issues surrounding such methods, helping to level the playing field for citizens, advocacy groups, media, policy-makers and politicians.

http://www.psehealthyenergy.org/
Where Can You Find Reliable Information?

http://www.earthworksaction.org/oil_and_gas.cfm