Well Construction and Cementing Practices in Shale and Salt Water Disposal Wells

2017 Shale Network Workshop
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Why Well Construction?

Fact: A drill bit passes through strata containing fresh water on its way to Marcellus or Utica Shale!
Well Construction
Planning/engineering requires a drilling prognosis

• Information needed
  – Depths to all fresh water zones
  – Depth to coal
  – Depths to tops of all major formations
  – Pore pressures
  – Mud weight (or air)
  – Frac gradients
  – Geologic features – faulting, high perm matrix
Well Construction
Casing Design Considerations

• Casing Design
  – Internal (burst) yield
  – Collapse pressure
  – Joint strength
  – Axial loading
  – Connections
  – API 5T specs
Well Construction
Primary Modes of Pipe Failure

• Internal yield (burst)
  – \( P_B = 0.875 \left( \frac{2Ypt}{D} \right) \)

• Collapse pressure
  – External pressure exceeds internal pressure (radial)
Well Construction
Primary Modes of Pipe Failure

• Joint strength – body failure

• Connection failure
  – Cross-threading
  – H2S – rarely in NE

The strength of the casing string is expressed as pipe body yield strength and joint strength.
Well Construction
Shale Well vs. Salt Water Disposal

• Shale Well
  – Higher injection pressures (frac)
  – Higher pore pressures
  – Cased hole completions
  – Production casing based largely on frac pressures

• Salt Water Disposal
  – Lower injection pressures (MAIP)
  – Lower pore pressures (depletion)
  – Cased and open hole completions
  – Production casing/tubing larger to avoid friction losses
Well Construction
Shale Well vs. Salt Water Disposal

- Shale Well
- SWD Well

Courtesy of Seahorse Operating, LLC
Well Construction
Primary Containment

Sub-base - soil cement and rolled stone

Berming

Primary – textured composite liner with 6 x 6 wood and 6 x 15# steel frame rig mats
Well Construction
Secondary Containment
Well Construction

Cellars
Well Construction
Conductor Pipe – 0 – 300’

• Purpose
  – Prevent sides of hole collapsing
  – Restricts drilling returns
  – Stops artesian water flow and lost circulation
Well Construction
Surface Casing - to 800’

• Purpose
  – Prevent contamination of fresh water zones
  – Isolates coal seams
  – Supports BOPs and other casing strings
Well Construction
Intermediate Casing - to 9500’

• Purpose
  – Prevents corrosion of production casing
  – Protects against hole caving of weak zones
  – Helps resist high pressure zones below
Well Construction
Production Casing - to 20,000’+

• Purpose
  – Selectively allows for oil & gas production
  – Isolates and prevents gas and brine migration
  – Provides well control
Well Cementing
Primary Cementing Planning

• Critical Factors
  – Wellbore
  – Drilling Fluid
  – Casing
  – Rig Operations
  – Cement Properties
  – Cement Service Equipment
  – Personnel
  – Lab Testing
Well Cementing
Cementing Chemistry

- Hydration
  - Complex Reaction
  - Accelerators
  - Fluid Loss
  - Retarding Agents
  - Lost Circulation
  - Dispersants
  - Friction Reducers
  - Specialty Chems
    - Gas Migration
    - Zero Free Water

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<th>API Class</th>
<th>ASTM Type</th>
<th>Official Description</th>
<th>C₃S</th>
<th>β-C₂S</th>
<th>C₃A</th>
<th>C₃AF</th>
<th>Minimum Fineness Sq cm/g</th>
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<td>1,600</td>
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SA (surface area) = # blocks x SA of each block

1. area of each face = 1 x w - 3' x 3' = 9 in²
   total SA = 8 faces x 9 in² = 72 in²
2. area of each face = 1 x w = 1.5' x 1.5' = 2.25 in²
   total SA = 6 faces x 6 blocks x 2.25 in² = 108 in²
3. area of each face = 1 x w = 1' x 1' = 1 in²
   total SA = 8 faces x 27 blocks x 1 in² = 152 in²
Gas and Oil Well Cementing
Fluid & Gas Migration/Sustained Casing Pressure

• Why?
  – Early time failures (hours/days)
    • Borehole enlargement/poor mud removal
    • Equipment failure/unplanned job shutdowns
    • Slurry design – horizontal wells – free water
    • Unknown factors – overpressured shallow rocks
  – Late time failures (weeks/months/years)
    • Bulk volume reduction of cement
    • Pressure cycling
Gas and Oil Well Cementing
Fluid & Gas Migration/Sustained Casing Pressure

- Prevention
  - Drilling practices – reduce washout hole size
  - Rethink casing program
  - Strict adherence to job standard practices
  - Lab testing with all critical test parameters
  - Gas migration additives
  - Packer collars or mechanical seals
  - Flexible cement
  - Cement expanding agents

Remediation: Tubing workovers are easy; cement sheath failure is difficult to fix and is very expensive
Gas and Oil Well Cementing
Fluid & Gas Migration/Sustained Casing Pressure

• What about backside or annular pressure?
  – Plumb annuli up with piping to ground level
  – Monitor pressure or open to stock tank
  – Poses minimal risk with a deeper intermediate casing set below properly cemented naturally fractured strata$^{21}$
Hydraulic Fracturing

Fluid & Gas Migration/Sustained Casing Pressure

The Hydraulic Fracturing Process (HF): Real Concern or Misdirected Focus Concerning Threats to Drinking Water Supplies (DWS)

Introductions

The hydraulic fracturing process, alternative to traditional drilling techniques, involves injecting water, sand, and chemicals into the ground to create fractures in the rock layers beneath the surface. These fractures allow the natural gas or oil to be released and recovered. However, concerns have been raised regarding the potential impacts of hydraulic fracturing on drinking water supplies and the environment.

Key Questions:

1. How accurately are these subsurface representations of natural gas migration relative to the volume and what are the reasonable pathways to air and downwind?
2. When a sandstone becomes overpressured, can significant amounts of methane gas be released into the groundwater stream? As a result, are the boundaries of the groundwater stream altered by the hydraulic fracturing process?
3. If venting is the preferred measurement technique to prevent borehole annulus from overpressuring, what quantity of methane is being released into the atmosphere by the hydraulic fracturing process?

Conclusions

Hydraulic fracturing, as practiced in the United States, has been shown to result in the migration of gas from the formation to the borehole annulus. This gas migration can be significant, particularly in areas where the formation has a high permeability or where the hydraulic fracturing process has led to overpressuring of the formation. The potential impacts of hydraulic fracturing on drinking water supplies and the environment require further research and monitoring to understand fully.
Summary

- Water wells and oil & gas wells drill into strata containing fresh drinking water
- Well construction planning is critical to success of both shale and salt water disposal wells
- Well cementing is of primary importance but doesn’t get the attention it deserves
- Long term zonal isolation and prevention of fluid and gas movement
Bibliography - References

• Slide 3
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  – Cabot Oil & Gas, Life of a Natural Gas Well, 2010?
    – https://water.usgs.gov/edu/earthgwaquifer.html

• Slide 5 – personal photo
Bibliography - References

• Slide 6
• Slide 6 - http://casingcollapse.com/
• Slide 7 - https://www.slideshare.net/akincraig/petroleum-engineering-drilling-engineering-casing-design
Bibliography - References

• Slide 9 – Schematics property of Seahorse Oilfield Services, LLC
• Slide 6 - http://casingcollapse.com/
• Slide 7 - https://www.slideshare.net/akincraig/petroleum-engineering-drilling-engineering-casing-design
• Slides 8 – 19 – Personal photos and slides from personal archives
Bibliography - References

• Slide 20 – Removal of Sustained Casing Pressure by Gravity Displacement, E. Demirci, LSU, 2014, Master’s Thesis

• Slide 21,22 –