Design Considerations for Natural Gas Storage in Gulf Coast Salt Caverns

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Why We Need GC Storage

• New Production from Offshore
  • 15% of Production in 2007
  • Expected to be 21% in 2030
  • More if more Offshore Drilling is allowed

• Potential for LNG Imports
  • Imported a record 771 BCF in 2007
  • Dropped to 352 BCF in 2008
    • Low Price
    • High transportation cost vs. Europe
    • Lack of storage in Gulf Coast
Why We Need GC Storage

Gas Production in Offshore Fields, Lower 48 States

Source: Energy Information Administration based on data from NMS, HPDI, CA Dept of Oil, Gas & Geothermal
Updated: April 8, 2009
Why We Need GC Storage

Annual U.S. Natural Gas Salt Underground Storage Activity - Injects

- Source: U.S. Energy Information Administration

Annual U.S. Natural Gas Salt Underground Storage Activity - Withdraw

- Source: U.S. Energy Information Administration

From EIA
Why We Need GC Storage

United States
LNG Imports vs. Total Imports

From EIA
• Mother salt is about 5 – 6 miles deep
• Temp. and pressure extrudes the salt upward
• Caprock is formed from insolubles in the salt
• Some domes have penetrated the surface
A Geologic Characterization is a must, methods include:

- Well Control
- Seismic, if
  - Well control is not available, or
  - Too few wells or information is sketchy
- Use old seismic data, and/or
  - Have old seismic data re-modeled
- Analysis of core samples
Drilling and Casing Program

- Desired Injection/Withdrawal Rate
- Maximum/Minimum Pressures – Storage
- Leaching, De-watering Rates (Re-watering?)
- Intermediate Gas Service?
- Minimum of 2 cemented strings in salt
- Maximum deviation requirement
- Design final casing for Lithostatic outside and atmospheric inside
Drilling and Casing Program

Intermediate Gas Service

Leach to Completion
Geo-Mechanical Stability

- Shape
- Size
- Separation
- Span
- Depth
Geo-Mechanical Stability
(4 S’s – Size, Shape, Span & Separation)

• Size
  • Size is dependent on the desired storage capacity and the depth to the casing shoe
  • All things equal, if capacity is 8 BCF, then:
    • Cavern volume for casing shoe of 2500’ is about 11 MMB
    • Cavern volume for casing shoe at 3500’ is about 8 MMB
  • What is the “right” depth?
Geo-Mechanical Stability
(4 S’s – Size, Shape, Span & Separation)

• Shape
  • Must resist salt “spalling”
  • Must resist “creep”
  • Must support cavern “span”
  • Must resist influence from adjacent caverns
  • Must allow for volume recovery (due to creep)
What is the Best Shape?

Overburden

Caprock

\[ \approx 1.2 \text{ to } 1.5 \times X \]

Gas

Salt

Pressure Differential Increases with Depth
Geo-Mechanical Stability
(4 S’s – Size, Shape, Span & Separation)

• Span
  • Roof should be tapered or dome shaped
  • Radius of roof should not exceed distance from roof to casing shoe.
  • Roof radius should be modeled for stability
    • Rock Mechanics analysis
    • Avoid large unsupported (flat) roof spans!
Geo-Mechanical Stability
(4 S’s – Size, Shape, Span & Separation)

• Separation
  • Natural gas storage caverns should have a minimum Pillar/Diameter ratio of 2 to 3
    • Pillar is separation between caverns
    • Diameter is the effective cavern diameters of adjacent caverns
  • Use finite element study to determine
Geo-Mechanical Stability

Rock Mechanics Analysis

- Establishes safe maximum & minimum operating pressures
- Sets maximum roof spans at minimum pressure
- Sets safe separation distance for adjacent caverns
- Predicts “creep closure” rates
Min/Max Operating Pressure

- Minimum pressure gradient is NOT regulated
- Minimum allowable pressure gradient should be around 0.15 - 0.25 psi/foot
- Maximum pressure gradient IS regulated by the States
- Maximum is typically 0.80 to 0.90 psi/foot
- Good idea to check fracture pressure when drilling
Creep Closure
What is Creep Closure?

- Salt at the depth of storage is plastic, therefore can flow with differential pressure
- Weight of overburden causes a differential pressure with the cavern
- Overburden is assumed to be ≈ 1 psi/ft in the Gulf Coast
- At a cavern MAOP of ≈ 3,000 psi, the differential at TD for a 2000’ tall cavern is about 1,500 psi
- At cavern minimum pressure ≈ 600 psi, differential is almost 4,000 psi!
- Formation/Cavern differential pressure causes creep/closure
- Closure mostly occurs at cavern bottom where differential is greatest
Creep Closure
Can it be stopped?

• NO, When the cavern has completed leaching, the cavern will start getting smaller

• However, rate of creep closure can be affected by:
  • Storage pressures
  • Period of time at a particular pressure
  • Cavern shape
  • Cavern depth
Additional Considerations

- Leaching Program
  - Two Step; One Workover
  - Nitrogen Blanket (initially)
  - Control Salinity to Limit Backwashing
- NG Moisture Content
  - Set Dewatering String on Bottom
- Use Centralizers for De-Watering String
- Downhole Pressure/Temperature Probes
2 Step Solution Mining Program

- **Sump Building** Near Completion
  - BRINE RETURN
  - WATER INJECTION

- **Partially Developed Cavern**
  - RAW WATER INJECTION
  - BRINE RETURN
  - TOP OF INSOLUBLES

- **Cavern** Near Completion
  - BOTTOM OF CEMENTED CASING
  - BLANKET LEVEL
  - DEPTH OF ORIGINAL HOLE

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• RESEARCH COMMITTEE
  • Ron Benefield – North America (Fall 2011)
  • Patrick De Laguérie – Outside N. A. (Fall 2011)
  • Jeff McCartney – North America (Spring 2010)
  • Paul Grönefeld – Outside N. A. (Spring 2010)
  • Jeff Langlinais – North America (Spring 2009)
  • Fritz Wilke – Outside N. A. (Spring 2009)
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Solution Mining Research Institute

• ACTIVE PROJECTS
  • “Three Cavern Abandonment Field Tests”
  • “Upgrade the SALT_SUBSID Software”
  • “Standard Gas Cavern Practices”
  • “Deformation of Cemented Casings”
  • “High Frequency Cycling of Salt Storage Caverns”
  • “Flow-induced Vibration of Hanging Tubulars”

• NEXT USA MEETING SPRING 2010 – GRAND JUNCTION, CO
Conclusions

• Additional Gulf Coast cavern storage is needed in the future

• Certain design considerations should be made, Remember

DON’T THINK OUTSIDE THE BOX;
BUILD A BIGGER BOX!

• SMRI has ongoing research that will aide our industry
QUESTIONS?