Annulus Monitoring & Control
Deep, High-Pressure Class I Wells

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Project Background

New Geologic Area for Class I Wells

• “Wildcat” Wells
• No Operator Experience
• Limited Regulatory Experience
• No Program Guidance
Project Background

Downhole Construction

- >10,000 ft TD Wells
- Manage Coal Mine Wastewater
- >7,500’ Packer Seat
- Packers set under Compression
- New P110 Tubing (~200 joints)
  - Torqued on Joints to API Specs
  - Pressure Tested during Installation
- Large Annular Volumes
  - 7,000 – 14,000 Gallons
Project Background

Typical Low Pressure Seal Pot with Nitrogen Blanket
Project Background

Operating Constraints/Conditions

- Permit Limits
  - Injection Pressures $\sim$1700 psi
  - Annulus Pressures $\sim$300 psi
- Annulus Pressures < Injection Pressures
  - Large Pressure Differential on Downhole Components
    - $>1600$ psi
  - Large Temperature Differentials
    - 70 - 90 °F
- Potential Fluids Migration not Protective of USDW
Challenges

Operating Scenarios

1. Injection Under Pressure & Adding fluid
2. Injection Under Pressure & Removing Fluid
3. Post Injection Shut-in
Challenges

1 - Injection Under Pressure, Adding Fluid

• Injectate Temp 70°F < Annulus Temp
• Tubing and Annular Fluid Contracts, Pressure Decreases
• Must Add Fluid to Seal Pot due to Annular Volume Change
Challenges

2 - Injection Under Pressure, Removing Fluid

- Injectate Temp Warms
- Dynamic Tubing Conditions Create One-Way Micro Leak
- Must Remove Fluid from Seal Pot due to Volume Change
Challenges

3 – Post Injection Shut-In

- Injectate Temp Cools after Shut-In
  - Injection P Decreases to <100 psi
- Tubing/Annular Fluid Continues to Expand
  - Annulus P Increases to > 3,000 psi

Operator bled off annulus P
Defining the Solution

• Few Comparable Situations
• Inquired with Academia, UIC Industry & Operators

• Need to Limit Pressure Swings in Annulus
• Need to Allow for Monitored Fluid Movement
• Need Real Time Measurement and Monitoring
Solution

Skid-Mounted Annulus Monitoring & Control System

• Non-Pressurized Vessel
• Operates Delta P: Annulus > Injection
• Small Piston Pump w/ VFD
  • Meters Flow in/out of Annulus
• Low Volume Flow Meters
• Level Sensors
• Pressure Relief Valves
Solution

New Scenario - Injection Under Pressure

• Injectate Temp 70°F < Annulus Annulus

• PLC Set Points Track Annular Pressure to Operate 150 psi Above Injection Pressure

• Piston Pump Adds/Removes Fluid to Annulus to Maintain Delta P Above Injection Pressure
Solution

New Scenario – Post Injection Shut-In

- Fluid in Tubing Cools
- Annular Fluid Contracts as it Cools
- Skid Automates Pressure Decrease to Track Tubing Pressure
Positive Impacts on Operation

Protection of USDW

OLD: Annulus P < Injection P

NEW: Annulus P > Injection P
Positive Impacts on Operation

• No Labor Intensive Fluid Additions or Removals
• Eliminates High Pressure Micro Leaks at Joints
• No Costly Workovers
• Reduces Differential Stresses on Well Components
• Protection of USDW from Potential Fluids Migration
• Clients Love it!
Positive Impacts on Operation

Leak Detection

Shut-in

Exhausted annulus fluid from skid system

NO BEER FOR YOU

Annulus P ~150 psi > Injection P
Results

• New Permit Conditions
  • Annulus Pressure 100 - 200 psi > Injection Pressure
• No More Micro Leaks at Tubing Joints
• Strict Control of Annular Fluid Volumes
• Well can Operate Continuously
  • Skid System Cycles on/off at Start-Up
  • Settles once Temperatures and Pressures Stabilize
• Annular Pressure Tracks ~150 psi > Injection Pressure
Conclusions

• ~200 Tubing Joints can Experience Significant Stress under Wide Operational Temps/Pressures
• Micro Leaks can be One Way
• High Pressure Wells Require Alternate Annulus Monitoring Approach
• Solution Relatively Straight Forward
• Avoided Costly Workover/Compliance Issues
Discussion
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