



# Annulus Monitoring & Control

Deep, High-Pressure Class I Wells

Stephanie Hill, P.G.

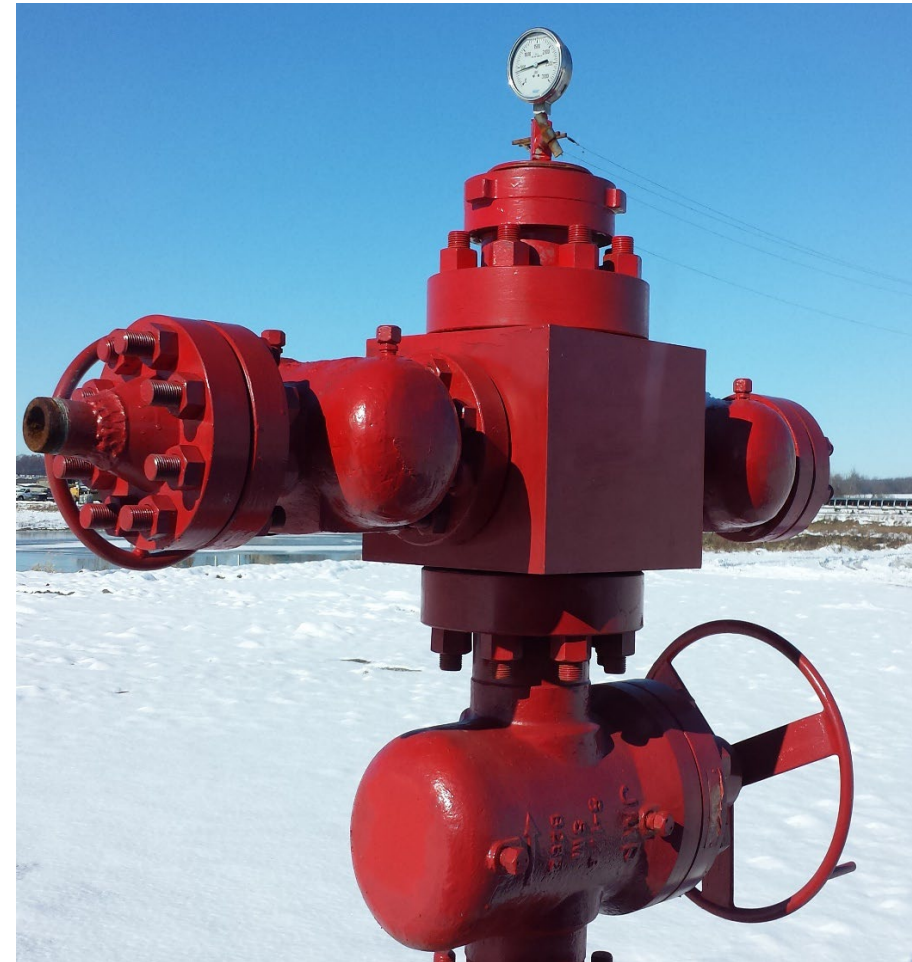
**SCS ENGINEERS**

**GROUNDWATER**  
PROTECTION COUNCIL

# Project Background

## New Geologic Area for Class I Wells

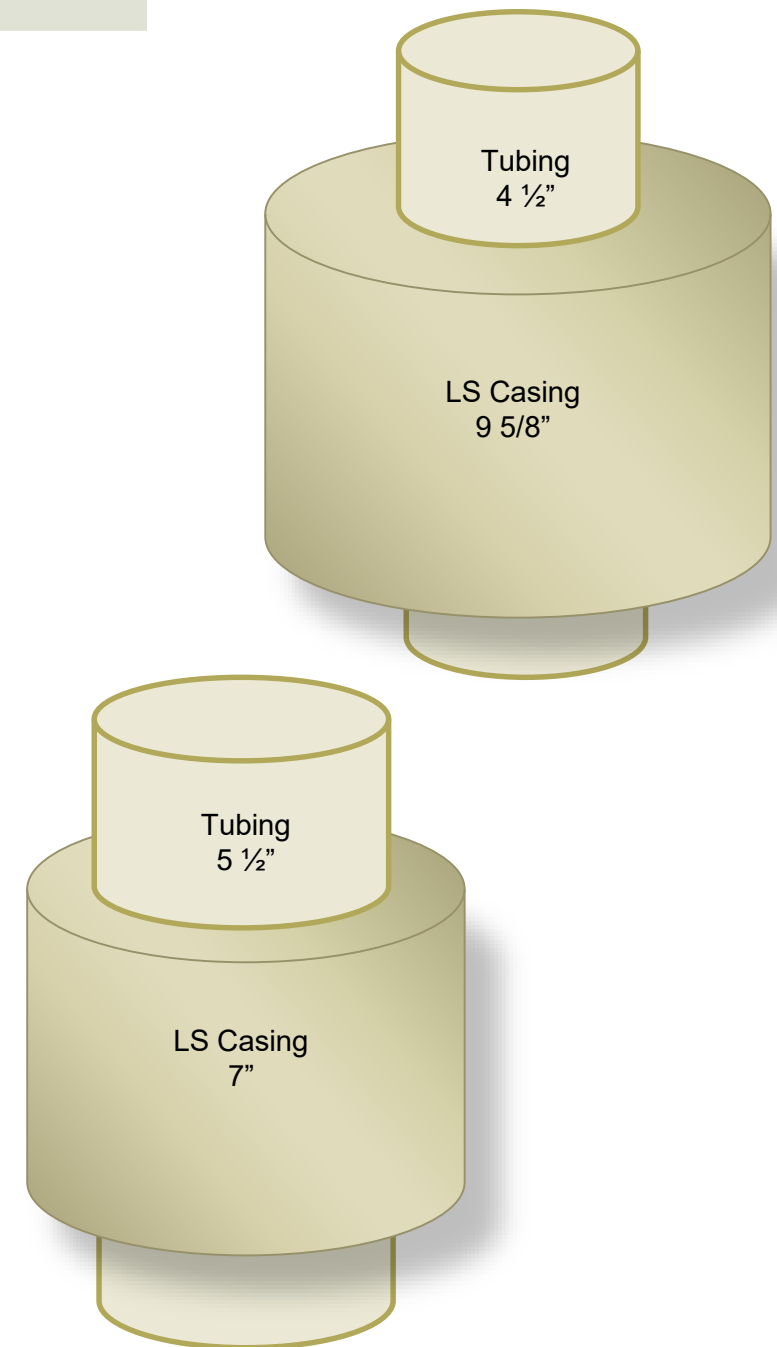
- “Wildcat” Wells
- No Operator Experience
- Limited Regulatory Experience
- No Program Guidance



# 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

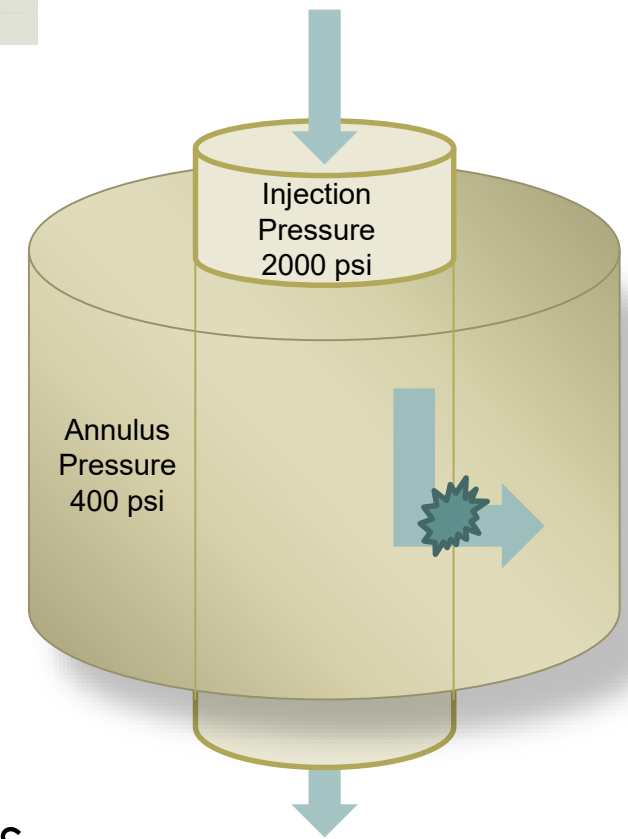
Typical Low Pressure Seal  
Pot with Nitrogen Blanket



# Project Background

## Operating Constraints/Conditions

- Permit Limits
  - Injection Pressures ~1700 psi
  - Annulus Pressures ~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

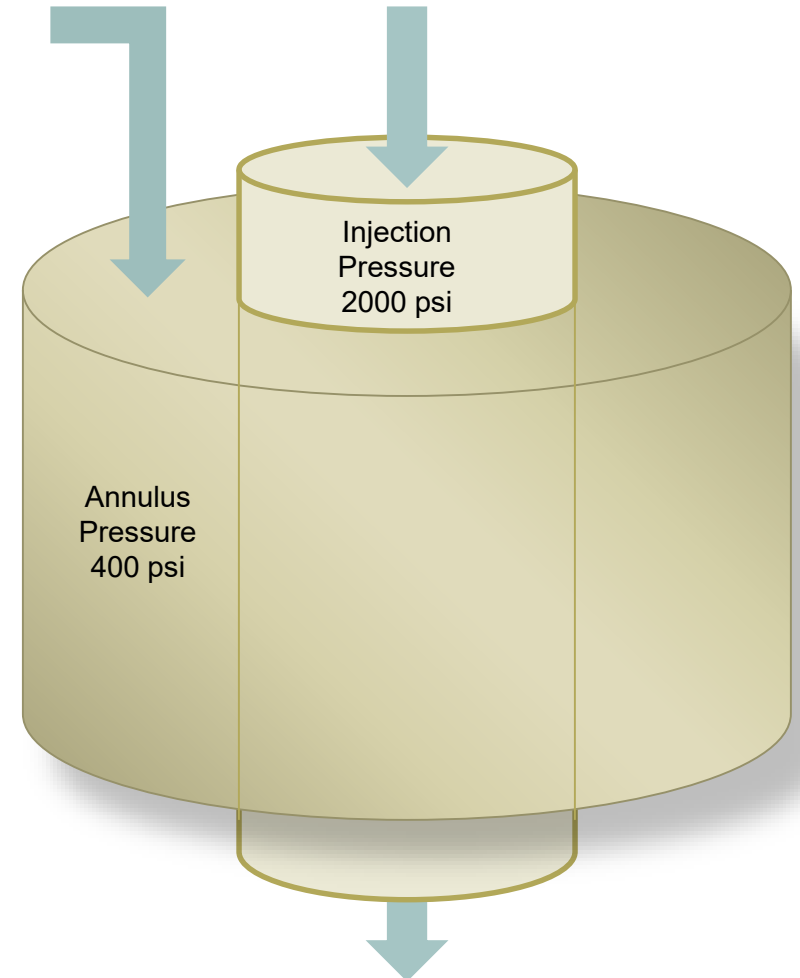
1. Injection Under Pressure & Adding fluid
2. Injection Under Pressure & Removing Fluid
3. Post Injection Shut-in



# Challenges

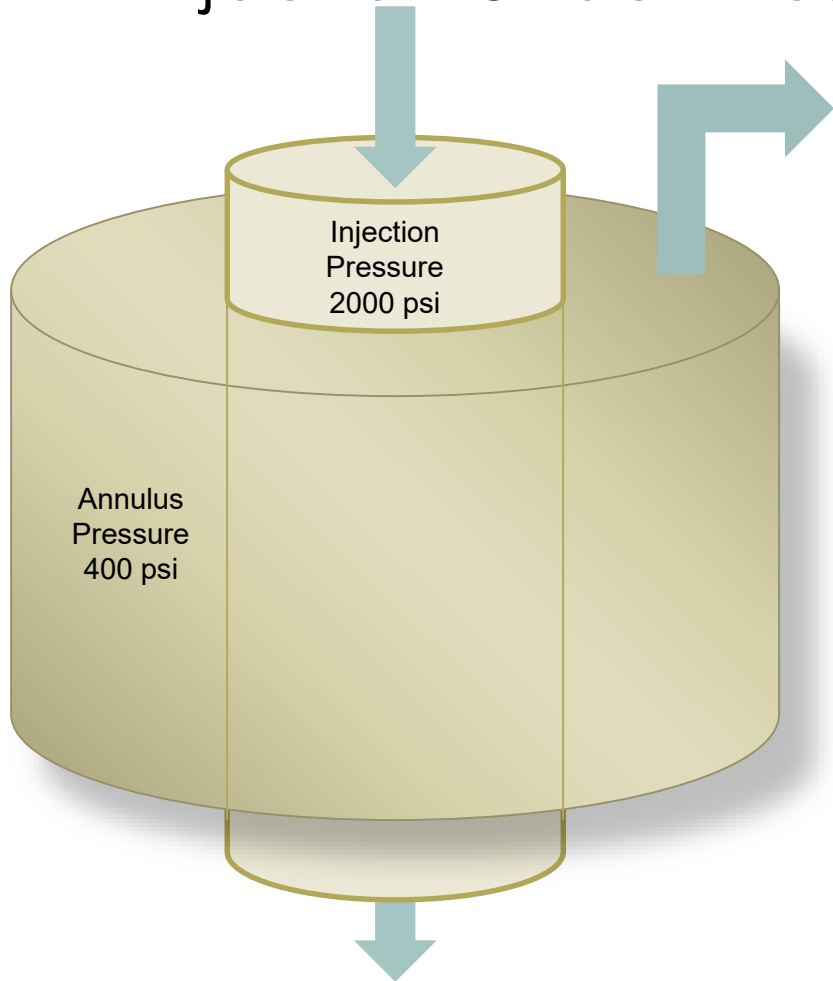
## 1 - Injection Under Pressure, Adding Fluid

- Injectate Temp  $70^{\circ}\text{F} < \text{Annulus Temp}$
- 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



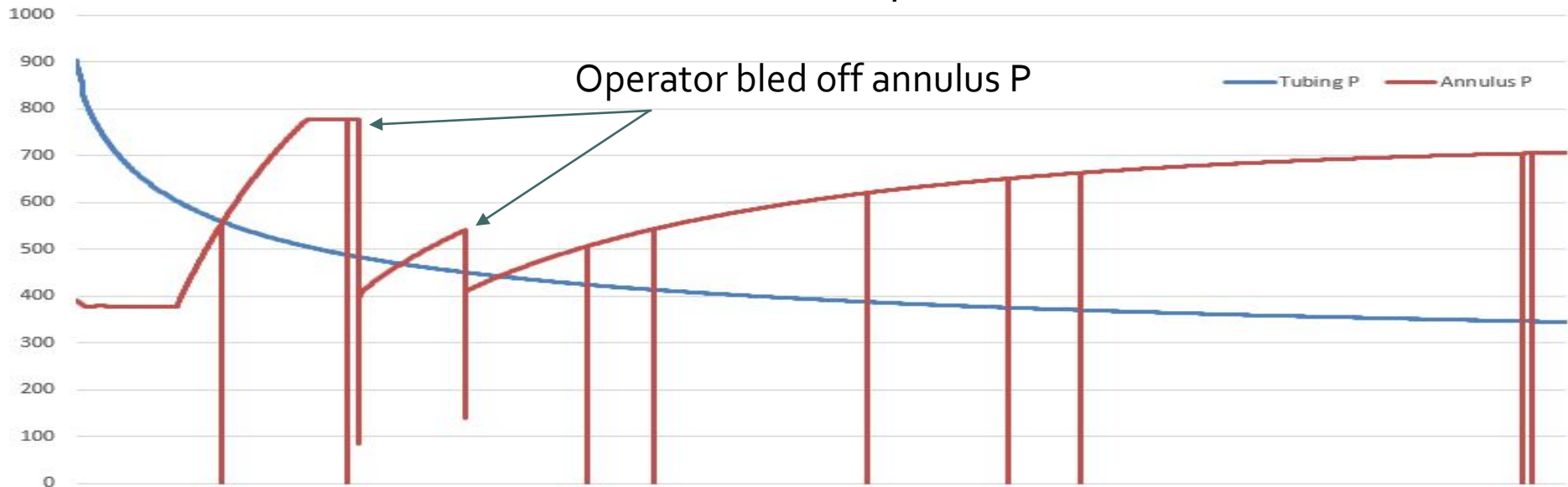
- Injectate Temp Warms
- Dynamic Tubing Conditions Create One-Way Micro Leak
- Must Remove Fluid from Seal Pot due to Volume Change



# 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



# 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

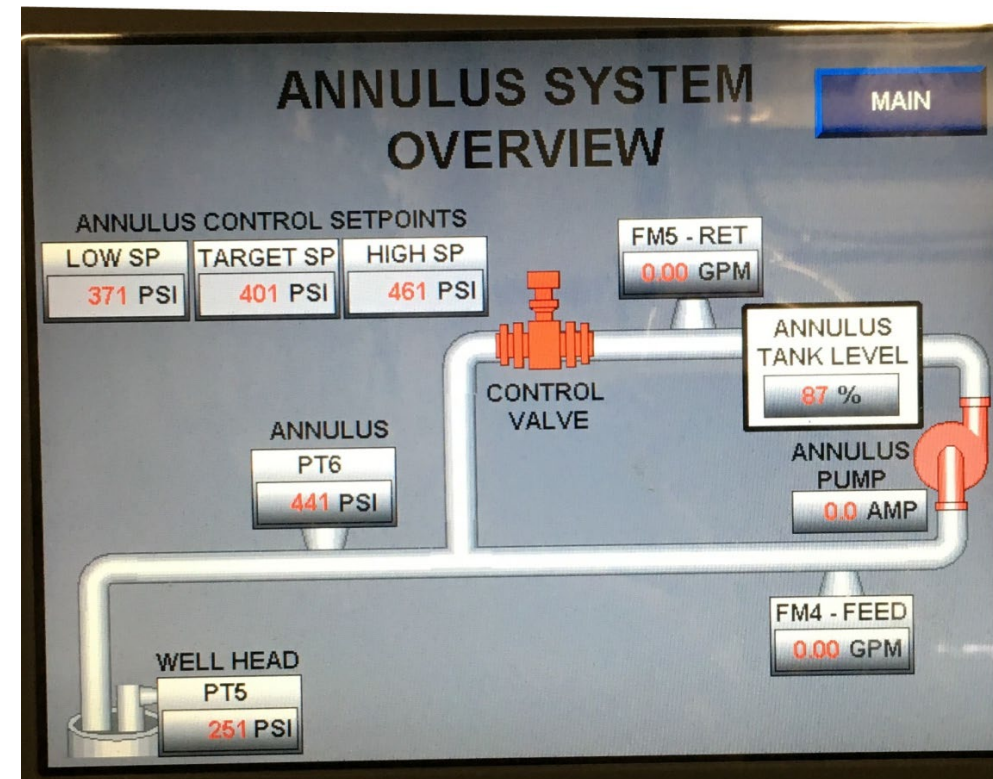




# Solution

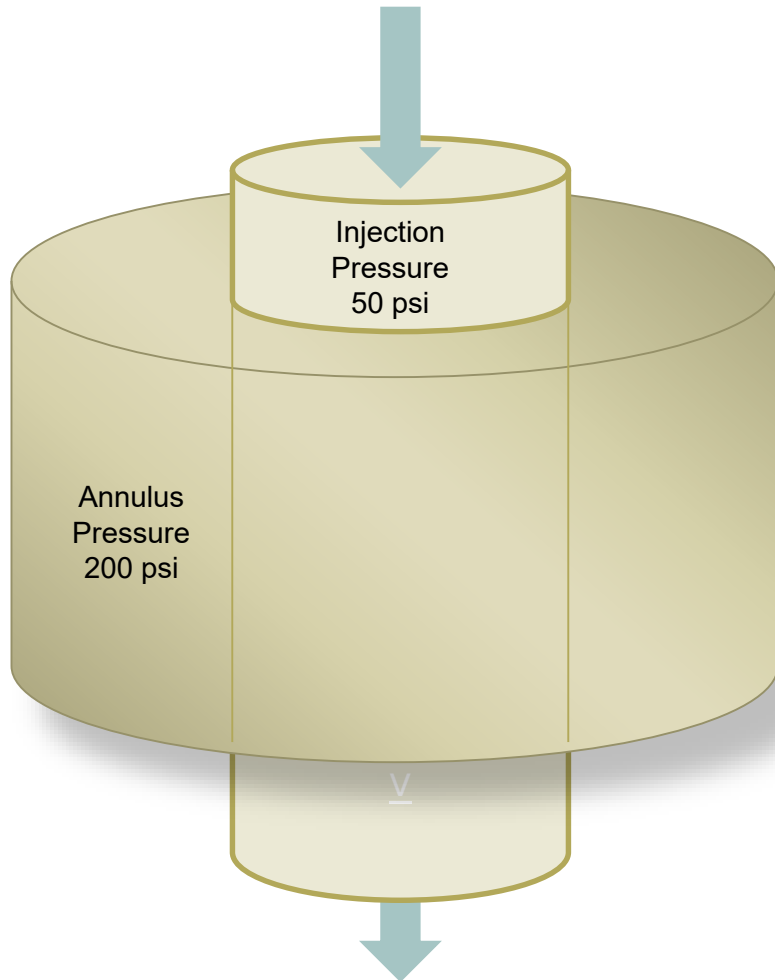
## New Scenario - Injection Under Pressure

- 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

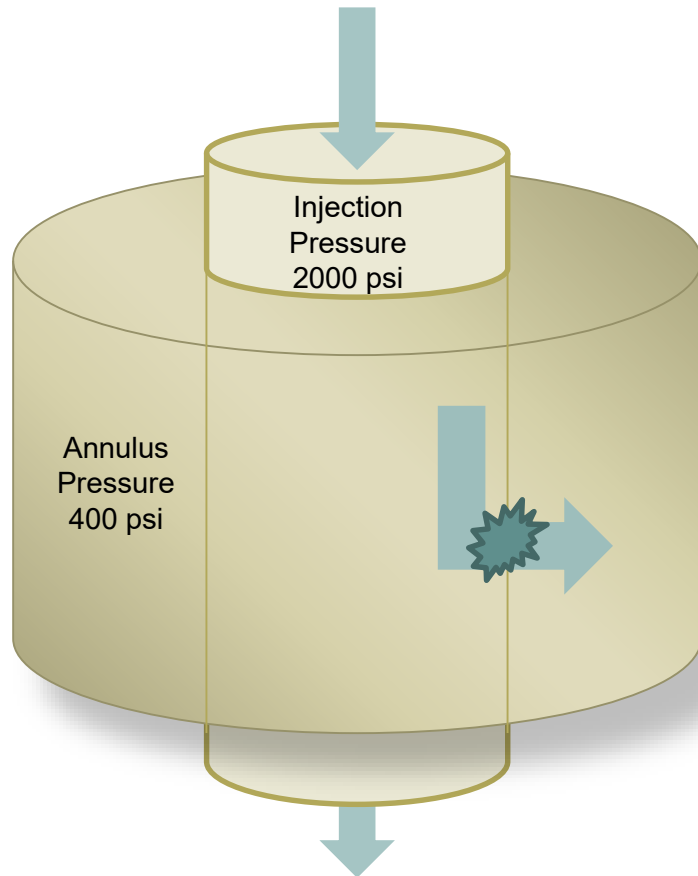
## New Scenario – Post Injection Shut-In



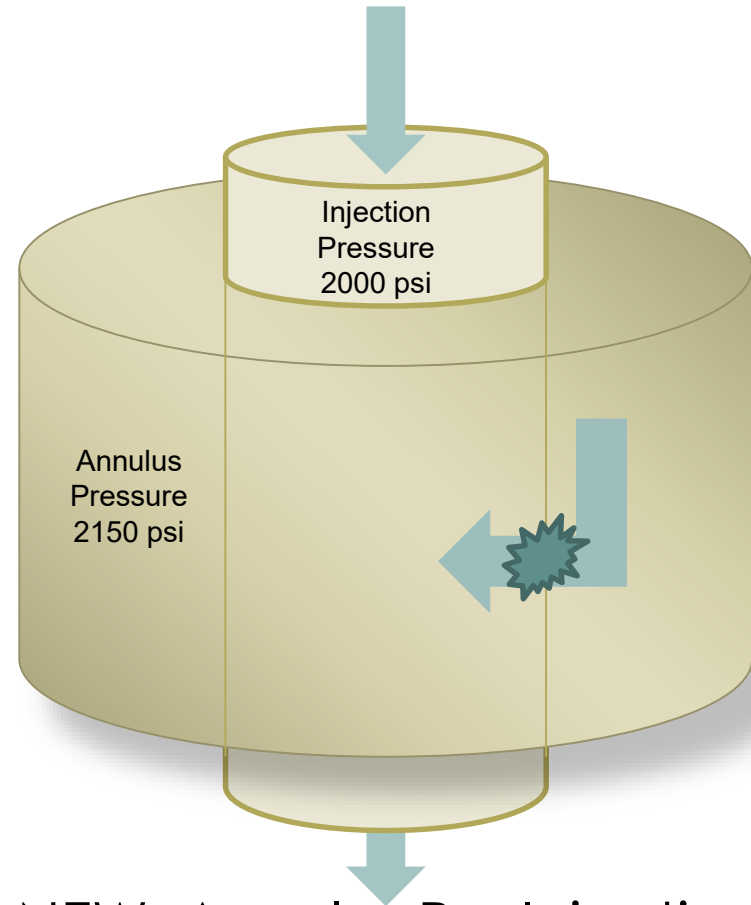
- Fluid in Tubing Cools
- Annular Fluid Contracts as it Cools
- Skid Automates Pressure Decrease to Track Tubing Pressure

# Positive Impacts on Operation

## Protection of USDW



OLD: Annulus  $P <$  Injection  $P$



NEW: Annulus  $P >$  Injection  $P$



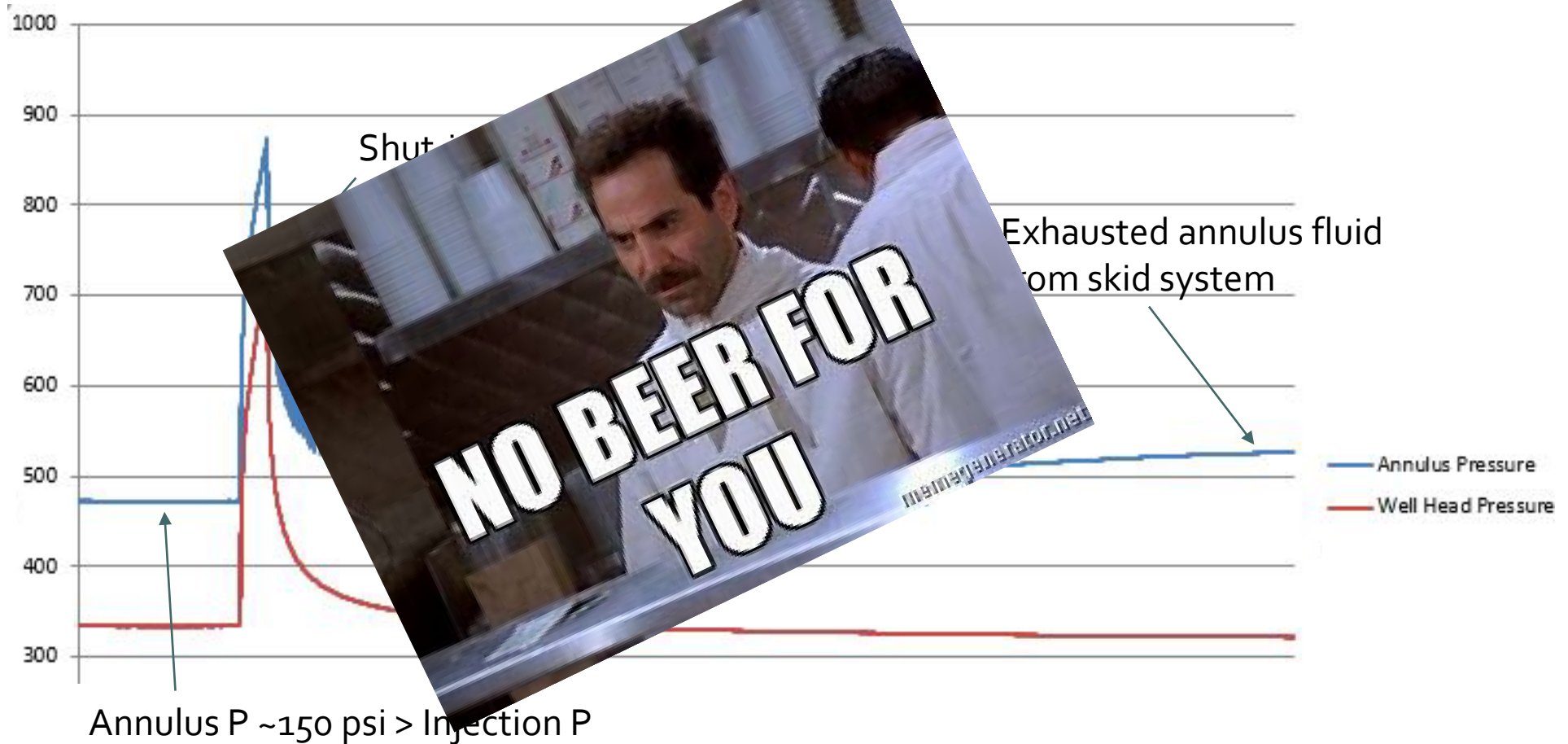
# Positive Impacts on Operation

- 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



# 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

Stephanie Hill, P.G.  
(618) 444-0307  
shill@scsengineers.com

The background image shows an outdoor industrial site. On the left is a tall, white, vertical cylindrical tank with various pipes and valves. In the center, there's a complex assembly of pipes, a blue pump, and electrical control boxes mounted on a metal frame. To the right, a large horizontal pipe runs across the frame, with a large red handwheel valve visible. The ground is gravel, and a corrugated metal building is in the background under a cloudy sky.

**SCS ENGINEERS**