Construction and Testing of Shell’s Freeze Wall

Shell Exploration & Production

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Outline

• Purpose of freeze wall

• The freeze wall test
  ▪ Test site location
  ▪ Process design
  ▪ Subsurface construction and freezing
  ▪ Freeze wall test layout
  ▪ Current status
  ▪ Future plans

Artistic rendering of the freeze wall.
An Effective Containment System

- Required to protect ground water during oil shale in-situ conversion
- Ideal candidate: A freeze wall
  - Ice forms an impermeable seal
- Shell’s Freeze Wall Test will
  - Confirm freeze wall can be formed across ENTIRE oil shale interval
  - Establish freeze wall’s reparability
Freeze Wall Test Site

• Location
  ▪ Piceance Creek Basin in Rio Blanco County, Colorado
  ▪ On a 15 acre parcel of Shell’s private property

• Test site incorporates
  ▪ The freeze ring covering 1.2 acres
  ▪ Associated monitoring wells
  ▪ 3 refrigeration units and associated circulation systems
  ▪ Control room, process and data acquisition buildings, offices, and warehouse

• Serves as a laboratory to:
  ▪ Establish a freeze wall across the ENTIRE oil shale interval
  ▪ Demonstrate utility of freeze wall as a containment system
  ▪ Establish reparability of freeze wall containment system
The Freezing System

- Combined cooling capacity:
  - 3,242 tons (15,288 HP) of cooling
  - 7,500 gpm circulation rate
- Circulation pumps rated at 3,500 gpm each
- Chilled aqua ammonia circulated through 136 freeze holes
  - Total cooled subsurface length: 212,800 feet
Subsurface Construction

• Accurate well placement
  ▪ Tight well spacing (8’)
  ▪ Exceptional directional tolerance
  ▪ Required to ensure closure

• The results
  ▪ Successfully drilled all freeze holes within 2’ radius circular cylinder
  ▪ Successfully installed freeze equipment
    • Confirmed by temperature logs
Freeze Wall Construction

• Circulation of chilled fluid through each freeze hole
  ▪ Aqua ammonia at 25 to 50 gpm
    • Higher rate at start-up
  ▪ Freeze hole inlet temperatures as low as –54 degrees F
• Freezes water in formation
  ▪ Ice creates impermeable seal across entire frozen interval
The Freeze Wall Test Layout
Current Status

• Actively freezing
  ▪ All freeze holes on line
  ▪ Freeze wall closure over 86% of interval being frozen
  ▪ A few holes remain in the wall in the hottest, deepest zones

• Wall thickness varies from about 16 feet to more than 40 feet
  ▪ Zone dependent
  ▪ Established based on
    • Temperature logs in freeze temperature and other monitoring holes
    • Numerical simulations

Temperature in Freeze Temperature Monitor Well
About 9 Feet from Freeze Wall Center Line

Temperature (deg F)
Depth (ft)
Field Data Confirms Simulations

The graph shows the comparison of field data and simulations over time. The x-axis represents time in days, ranging from 0 to 900 days. The y-axis represents temperature in degrees Fahrenheit, ranging from -20 to 80 degrees Fahrenheit. The graph includes two sets of data: field data and simulations. The field data is represented by blue dots, while the simulations are represented by orange lines. The graph visually confirms that the field data aligns well with the simulation results, indicating a strong correlation between the two datasets.
Freeze Wall Closure in Shallow Zones

- Confirmed by:
  - Pressure rise within containment area relative to that outside
  - Lack of external pressure response when changing water level inside the containment area
  - Lack of internal pressure response inside the containment area to external pressure transients
Observations to Date

- Confirmed freeze wall can be constructed over 86% of oil shale interval we are freezing
  - Anticipate closure over remaining intervals in near term
- Confirmed activities that increase flow velocities subsurface adversely affect freeze wall construction
- Calibrated models using subsurface temperature data and freezing behavior
- Demonstrated leak tightness of wall by
  - Lowering or raising of fluid level within test cell
  - Saw no response outside test cell
Future Plans

• Complete freezing
  ▪ Establish freeze wall across entire oil shale interval
    • Monitor progress via temperature and pressure data
    • Closure expected in near future
  • Test various containment system configurations
  • Establish freeze wall performance
    ▪ Break wall and repair