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Reservoir and Completion Considerations for the Refracturing of Horizontal Wells

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Poll Question

Slide 3

How many years industry experience do you have?

Poll Question

How many re-frac treatments have you been involved in designing, executing, or evaluating?

Poll Question

How do you judge success of the re-frac?

Poll Question

How do you “condition” the well before the re-frac?

Poll Question

How do you improve job placement or achieve full coverage?

Poll Question

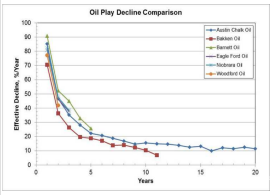
What percent of the re-fracs you are aware of were economically successful?

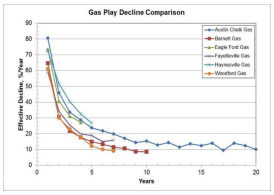
Why Re-Frac Wells?

To correct or repair inefficient initial completions
To compensate for rapid early decline
To replace damaged conductivity
To contact more reservoir
To increase reserves

What works, and what doesn't, and why?
How do we evaluate results honestly?

Is it the reservoir? The completion? Or…?





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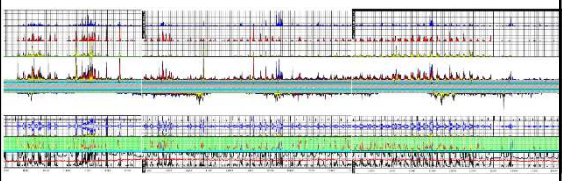
Successful Re-Frac to Contact New Reservoir



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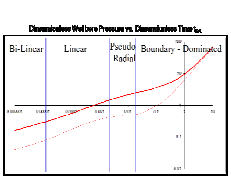
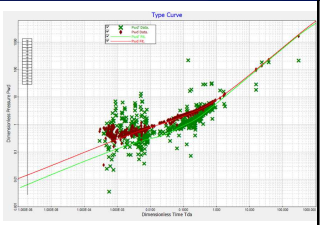
Problems to Solve??





Limited drainage area, but boundary influenced flow.
Why???

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Causes of Rapid Early Decline

- Mechanical issues:
  - Cleanout to the toe to remove plugs and sand bridges
  - Verify not sand, salt, scale plugs, paraffin, asphaltenes
  - Check for collapsed pipe
- Operational Issues:
  - Liquid loading, poor tubing placement
  - Inefficient artificial loft
  - Well trajectory (porpoising)

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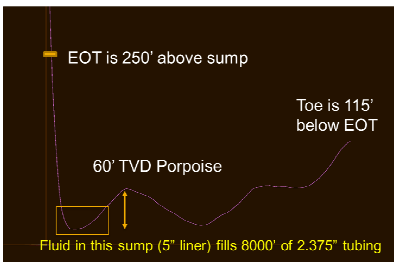
Example of Extreme Loading Potential



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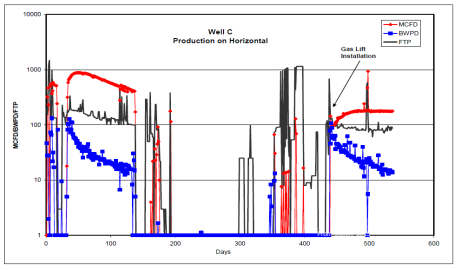
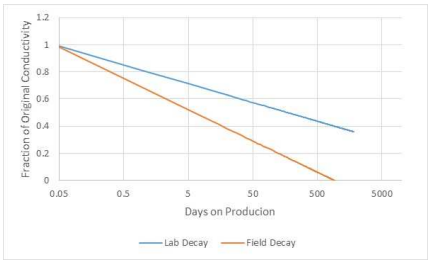
Operating Conditions: Effective Gas Lift



See SPE 130256 for reference

Loss of Conductivity Over Time



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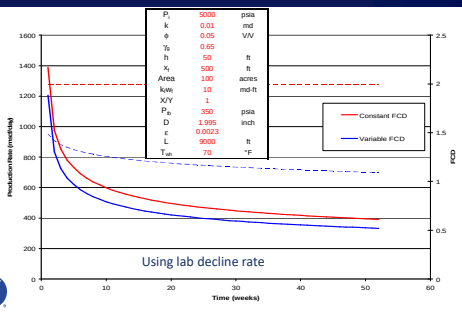
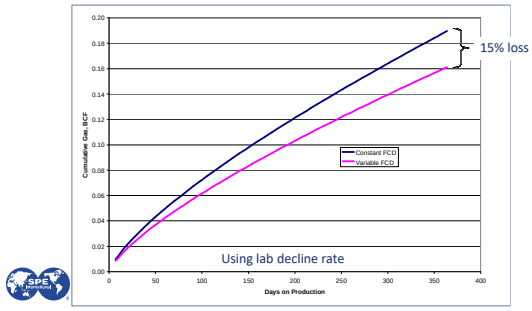
Conductivity Loss Mechanisms

- Pressure solution and re-precipitation of silica
- Long-term creep of proppant grains and formation face
- Fines invasion from failed and spalled surface
- Fines migration from formation
- Chemical scale and salt deposition
- Deposition of waxes and asphaltenes
- Saturation and hysteresis effects

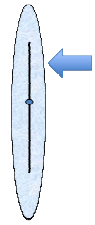
Impact of Variable Conductivity on Well Performance



Impact of Variable Conductivity on Well Cumulative Production

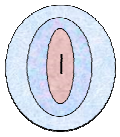


When is Conductivity Loss Critical? Reservoir Transient Response



Early time:
- Linear flow into fracture
- Very high rate with hyperbolic decline
- Fracture conductivity is critical

Late time:
- Pseudo-radial or boundary flow
- Rate is reduced to about 10% of initial rate
- Fracture conductivity no longer controls production



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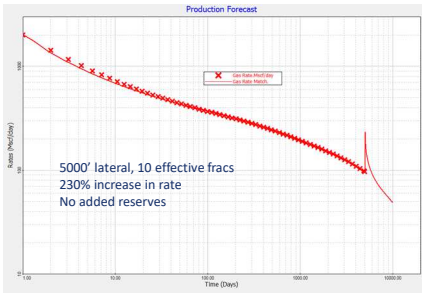
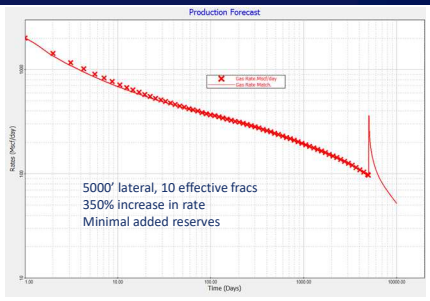
Transient Effects Mask Benefits

- Re-frac candidates are often “conditioned” prior to re-treatment
- During any workover the well will be shut-in for some time
- Wells may be shut-in due to high water cut or poor production prior to being re-fractured
- Short term production after such a shut-in can be mistaken for improved completion

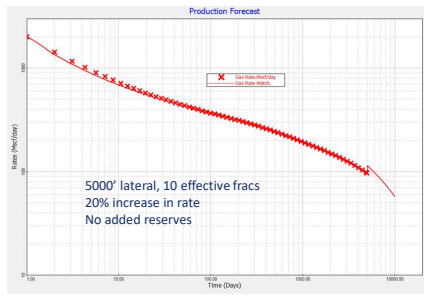
Shut-In with No New Fracture



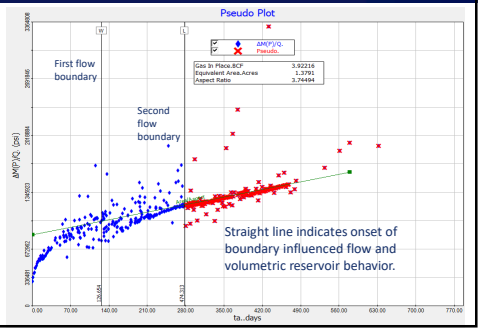
Shut-in and Double Effective Frac Length



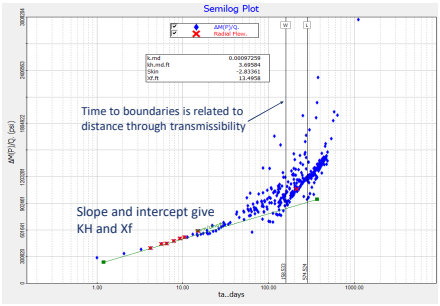
Double Effective Frac Length



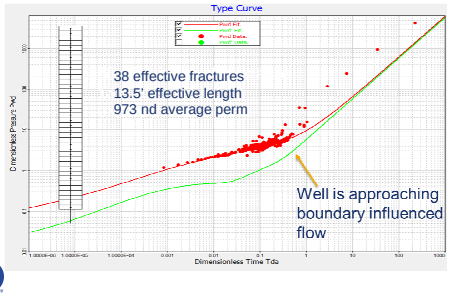
Actual Well in Boundary Flow



Actual Well KH and XF



Actual Well Type Curve Model



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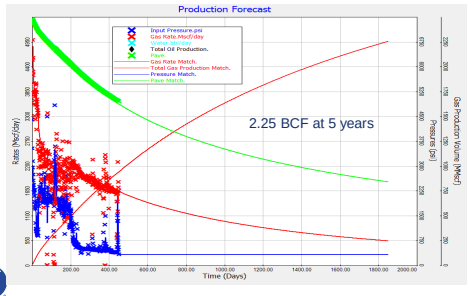
Production Forecast for 5 Years



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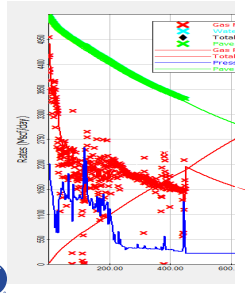
Re-Frac to Double Xf



First 180 day after re-frac:
- 27% rate increase
- Appears to lift decline curve

How long does the increased production last?

How much does it increase reserves, vs. accelerate production?

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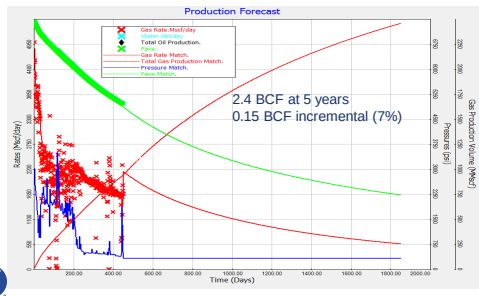
Re-Frac to Double Xf



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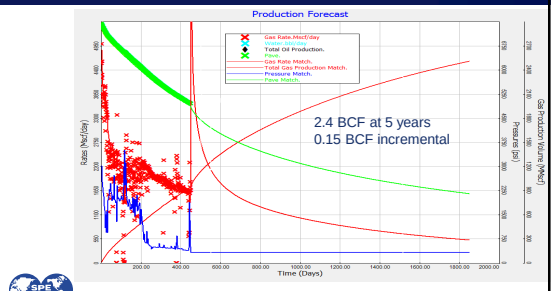
Re-Frac to Double Xf with Shut-in



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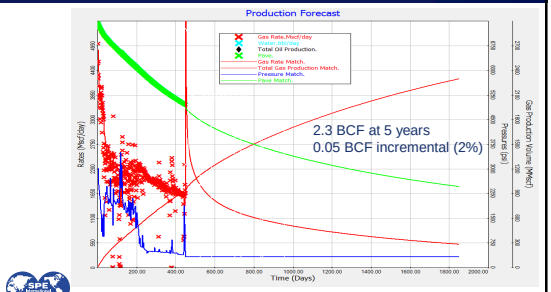
No Re-Frac (Same Xf) with Shut-in



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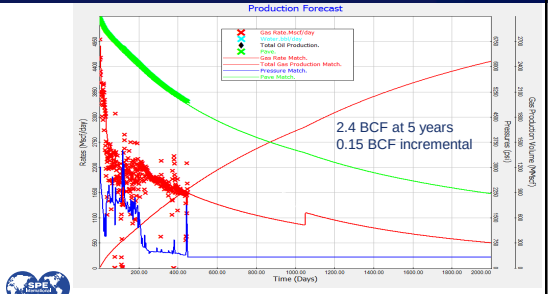
Re-Frac (Double Xf) after 3 yrs



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Conductivity Replacement: Conclusions

- Loss of conductivity is severe and inevitable
- Conductivity is critical in the early life of the well
  - Linear flow around fracture requires high conductivity to deliver to the well
- Once in boundary influenced flow, conductivity loss is no longer critical as production is controlled by the reservoir transient
  - Much less flow through the fracture, so less conductivity is needed
- Expect 5-8% incremental reserves, at best, if the only result of the re-frac is to replace the conductivity in the same fracture

If original frac conductivity is severely damaged, re-frac as soon as practical for maximum value

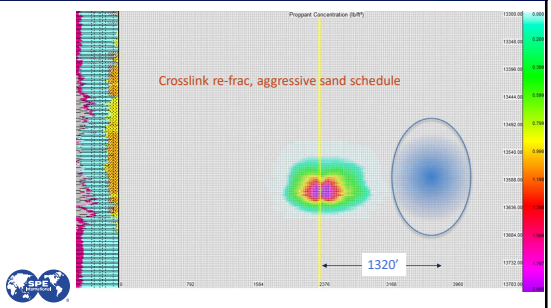
Designing the Re-Frac to Contact New Reservoir

- Conditions for fracture re-orientation
  - Low original horizontal stress bias
  - Depletion tends to favor more longitudinal fracture growth
- Avoid selecting re-frac candidates that are already in boundary influenced flow
  - Unless the indicated drainage area is a small fraction of that contacted by the well
- Increasing effective fracture height or net pay using higher rate, viscosity or job volume
- Potential use of diverters
  - Stimulate previously undrained sections of well

Offset Pore Pressure Depletion

- Well spacing of 1320 ft (~400 m)
- Refrac the new well with slickwater or XL gel?
  - Slickwater (per entry): 34,000# 30/50 sand @ 20 BPM
  - XL gel (per entry): 50,000# 30/50 sand @ 20 BPM
- Offset (parent) well has produced long enough to generate 2200 psi (15.2 MPa) pore pressure depletion at offset well
  - Same pore pressure distribution for all cases

Pore Pressure/Total Stress Depletion (1320 ft (400 m) offset)



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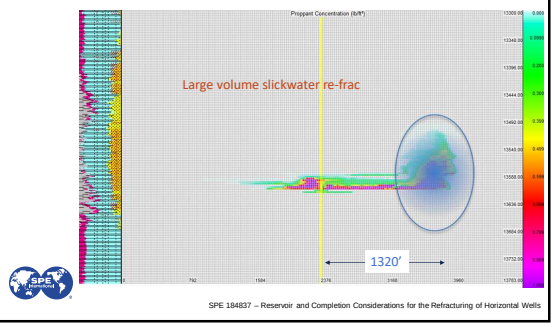
Pore Pressure/Total Stress Depletion (1320 ft (400 m) offset)



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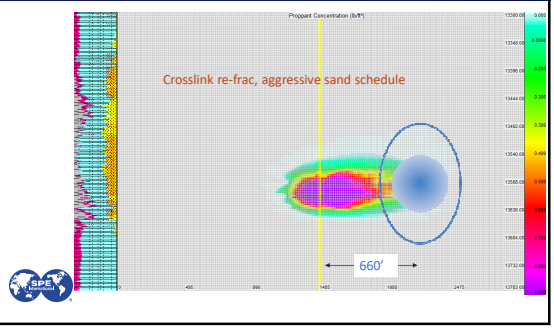
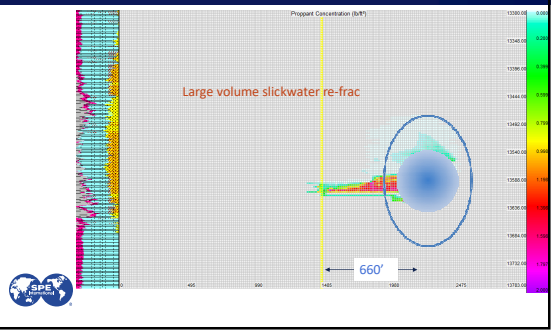
XL Gel, 2000 psi Depletion, 660' Offset Spacing



Slick, 2000 psi Depletion, 660’ Offset Spacing

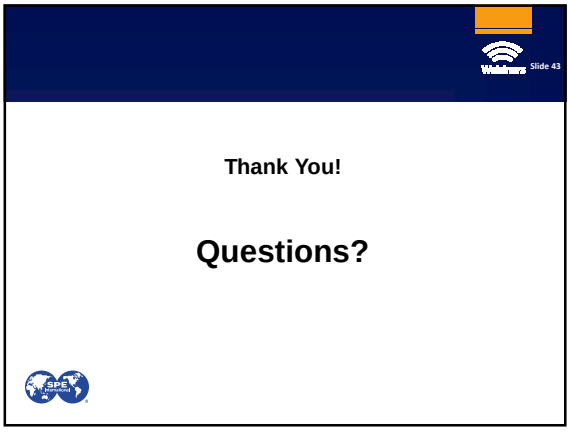


Bashing Effects

- Mostly negative production effects on impacted wells
  - Saturation hysteresis, inability to unload
- Can lead to:
  - Workovers/cleanouts
  - Collapsed/buckled casing or tubing
  - Large surface pressures in impacted well
    - reports of 5000 psi (34.5 MPa) hits at offset wellheads
  - Reserve impacts/write-off
  - Surface facility impacts
- Mitigation
  - Pressure defense (“protection fracs”)
    - Marginal chance of success
  - Shut-in and/or pressure up offset wells

Concluding Remarks

- A short term increase in rate may not translate into increased reserves, or indicate the success of a re-frac
- The cost of the re-frac must be offset by acceleration of production and addition of new reserves to add value
- Re-fracs that do not contact new, previously undrained reservoir volume will typically not add reserves but may yield some acceleration
- Re-fracturing to replace damaged conductivity usually only has value early in the life of the well or if the original treatment was badly flawed
- The effect of offset well depletion and spacing must be considered when deciding on job size and fluid type as well bashing can severely damage offset production
- Re-fracturing to increase recovery factor depends heavily on existing well spacing, fracture geometry, and reservoir heterogeneity


Slide 43
Thank You!
Questions?