December 5-6, 2018

Norris Conference Centers -
City Centre, Houston, Texas
ShaleTechConference.com

SHALETECH™

Enhancing perforation efficiency using rate pulses; a step change in Hydraulic fracturing

Debotyam Maity

Senior Engineer

Gas Technology Institute

SHALETECH™

Overview

- Perforation inefficiency
- Proposed solution – Variable Rate Fracturing (VRF)
- Selected field case studies
  - Marcellus
  - Permian
- Design
- Diagnostics
- Conclusions

Problem: Low perf. efficiency

- Perforation breakdown efficiency can be low:
  - Centralization
  - Rock composition
  - Pore pressure
  - Stress

Variations in perforation breakdown pressures can exceed 1000's of psi*

- Few tools are available to tackle the issue
  - Ball sealing: no control, time, challenge in horizontals
  - Diverters: no control, time
  - Specialized perf. guns: perf. pattern & gun placement does not guarantee perf. opening.

*Waters, G. (2017). Fracture Initial Pressures and Near-Well Hydraulic Fracture Geometries in Cemented, Perforated, Horizontal Wells, *Hydraulic Fracturing Journal*, **4** (3).

SHALETECH™

Perforations are key!

Figure 13—Post-Fracturing perforation image showing no indication of erosion.

Figure 12—Post-Fracturing perforation image clearly showing significant erosion.

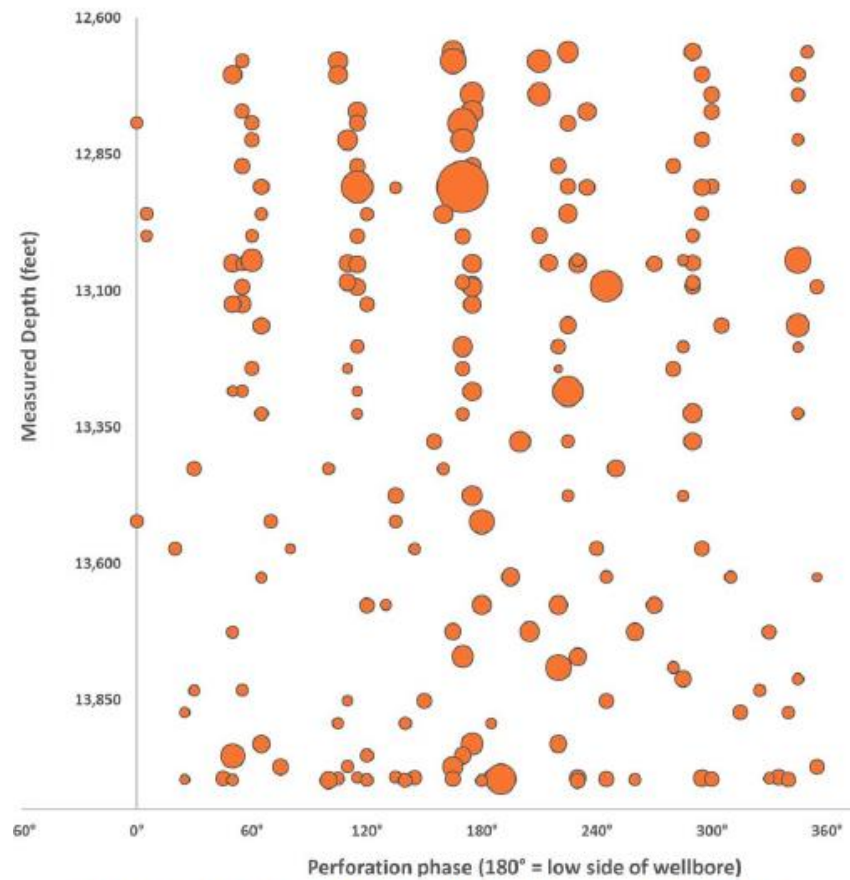
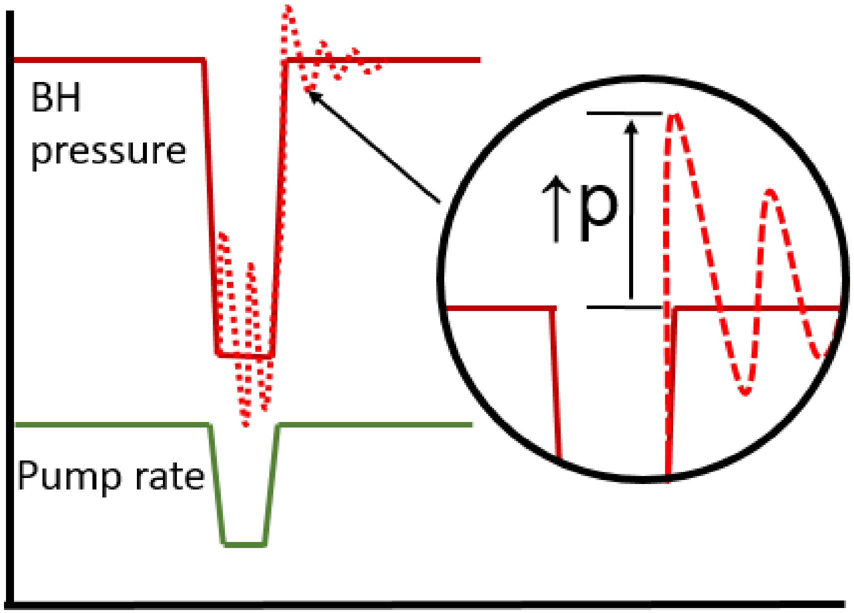


Figure 15—Spatial plot of perforation depth against phase. Bubble size represents measured area.

Roberts, G., Lilly, T. B., Tymons, T. R. (2018). Improved Well Stimulation Through the Application of Downhole Video Analytics. SPE HFTC. The Woodlands, TX. https://doi.org/10.2118/189851-MS

SHALETECH™

Variable Rate Fracturing (VRF)

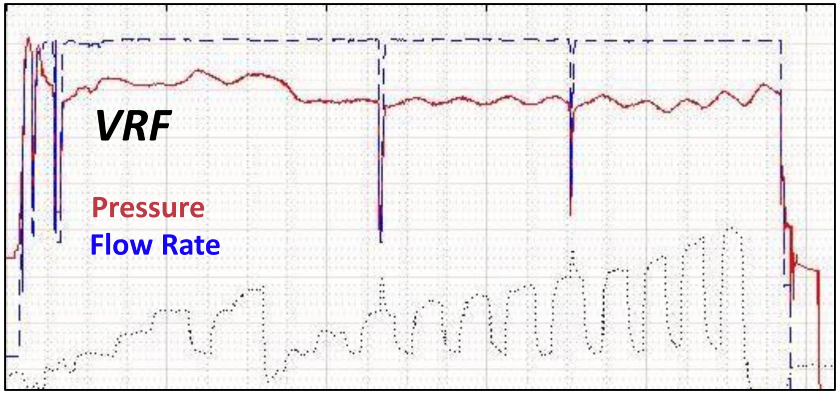


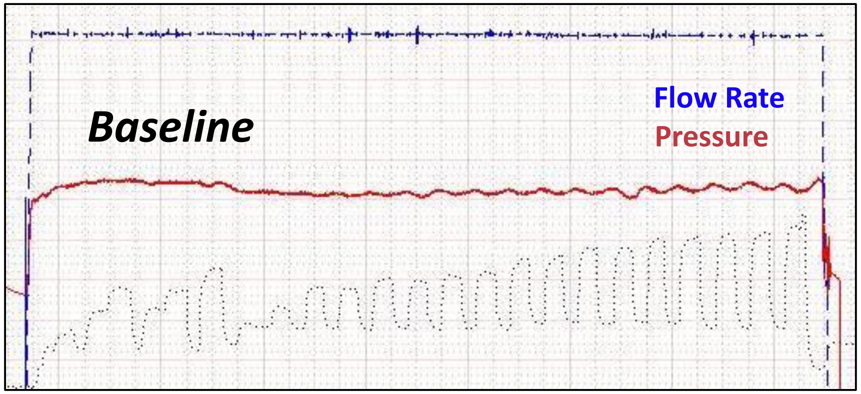
- Engineered rate changes
  - Induced pressure pulse within wellbore.
  - Pressure pulse along with original limited entry fracturing pressure can be significant & can open additional perforations.
  - Transient generated either with a drop or a rise in rate.

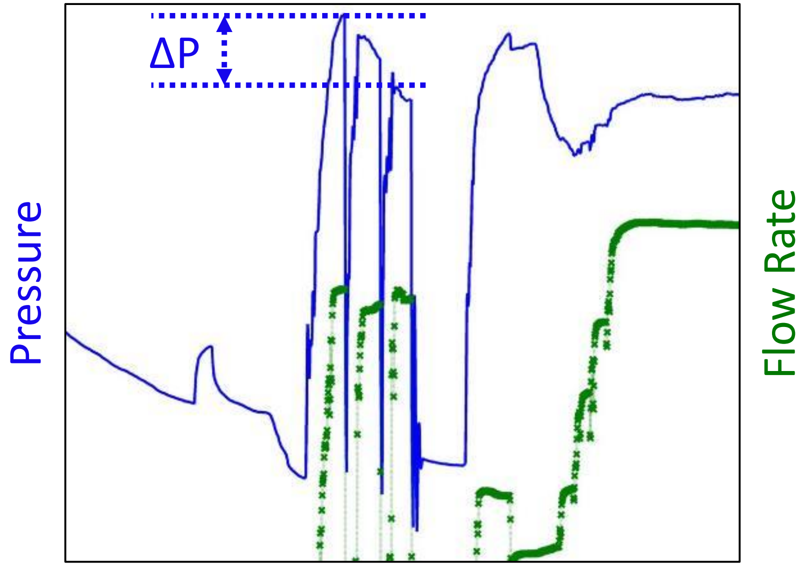
US Patents 9,581,004, 9,879,514, 9,982,523, 10,018,025 + others pending

SHALETECH™

Example VRF field implementation





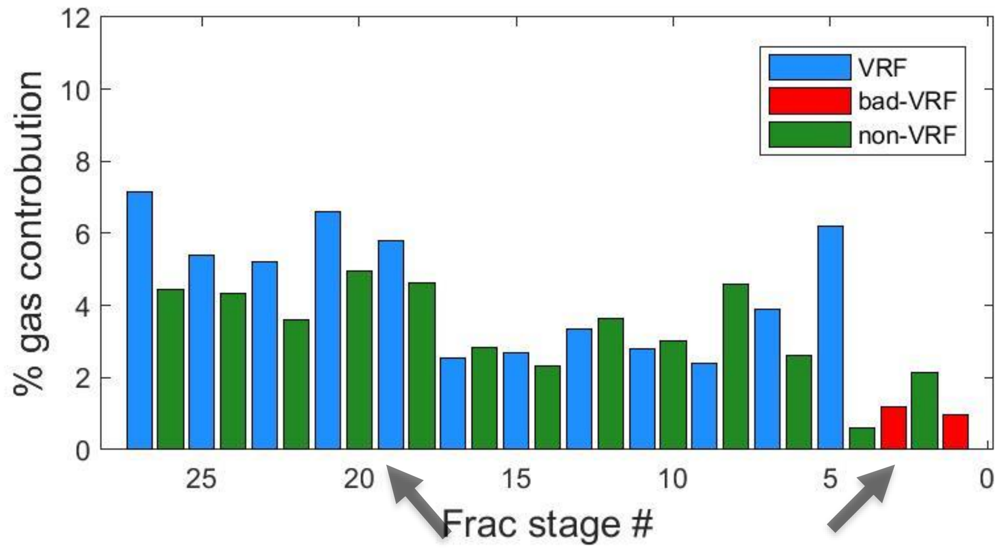


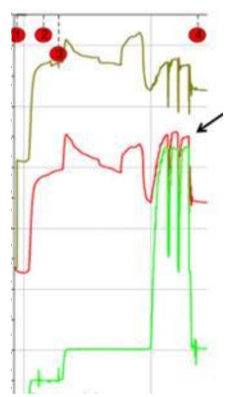
- Engineered rate changes
  - Very rapid engineered change of pump rates.
  - No extra equipment or materials needed.

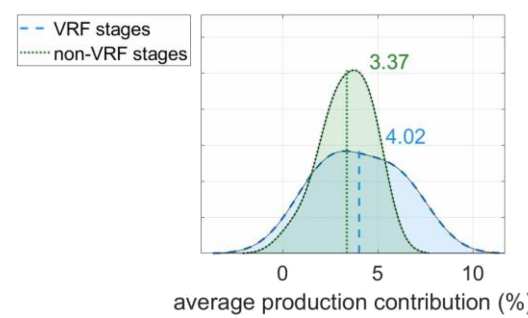
SHALETECH™

Initial field test results - Marcellus

- VRF performed on odd frac. stages.
- Design kept same (same proppant/ fluid loads).
- Open perfs. increased 14% on average
- PLT measured 19% higher average rate vs. control stages.



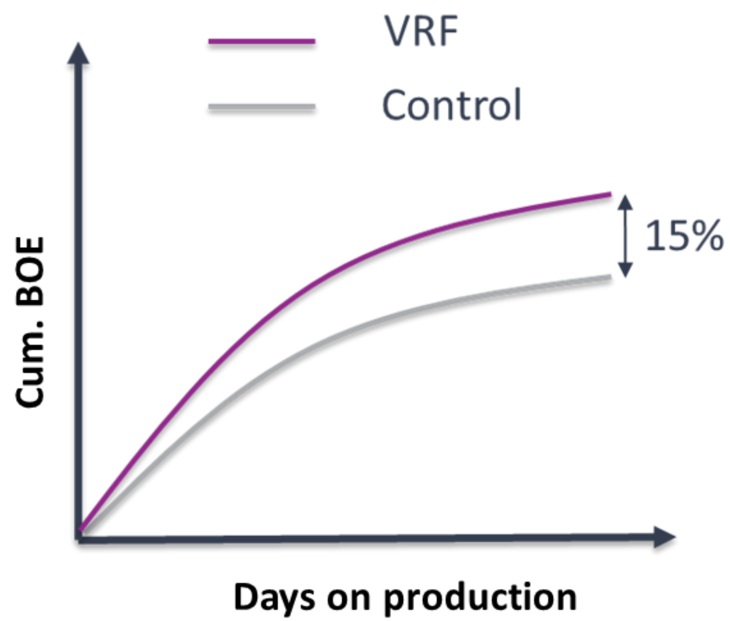




SHALETECH™

Permian test

- Approach
  - VRF on all stages.
  - Measured perf. opening before & after pumping (rate step tests).
  - On average, 20% additional open perfs were observed.



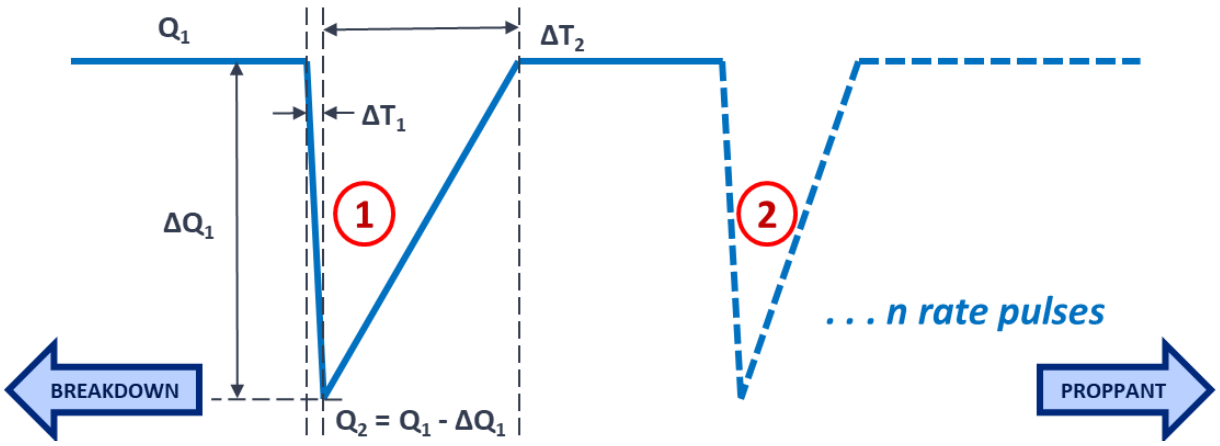
- Both accelerated recovery & higher EOR were observed.

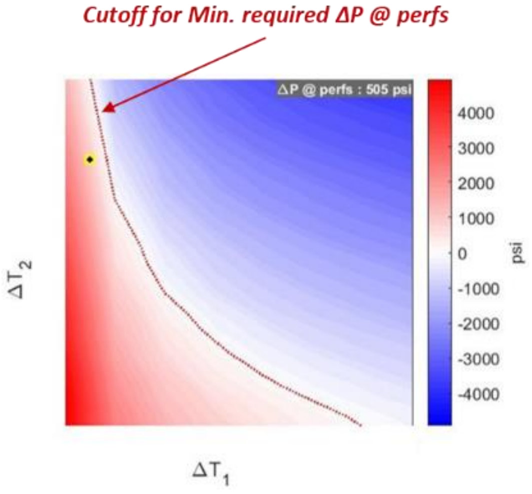
Ciezobka et al. (2018). Hydraulic Fracturing Test Site (HFTS) - Project Overview and Summary of Results. URTeC. https://doi.org/10.15530/URTEC-2018-2937168

SHALETECH™

VRF design - FD modeling

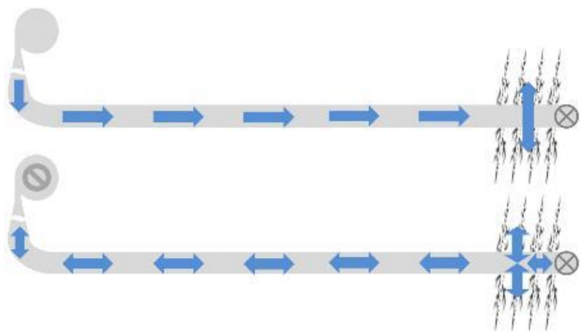
- We model pressure response @ perforations based on transient conditions, i.e., initial rate drop [ΔQ_1] & corresponding time [ΔT_1] for drop as well as the time to get back to rate [$\Delta T_1 + \Delta T_2$].





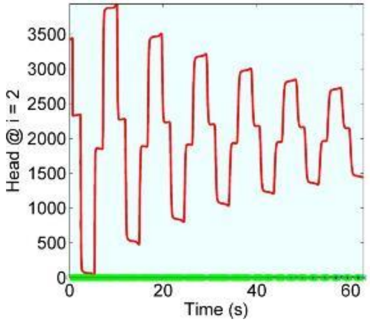
SHALETECH™

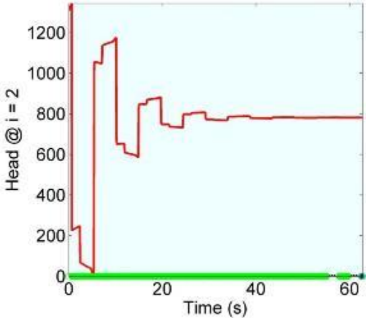
Modeling - theoretical basis



$$\frac{dV}{dt} + \frac{1}{\rho a}\frac{dP}{dt} + g\frac{dz}{dx} + \frac{f}{2D}V|V| = 0$$

$$\frac{dV}{dt} - \frac{1}{\rho a}\frac{dP}{dt} + g\frac{dz}{dx} + \frac{f}{2D}V|V| = 0$$

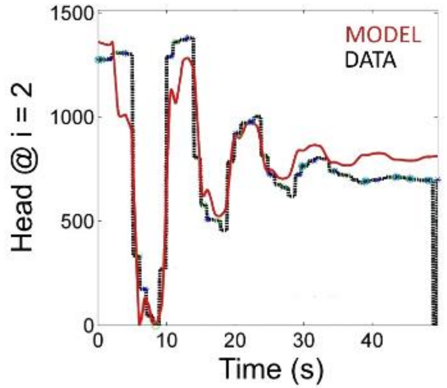


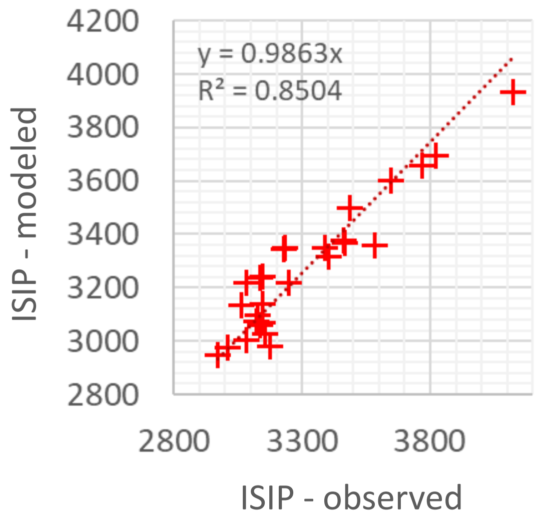


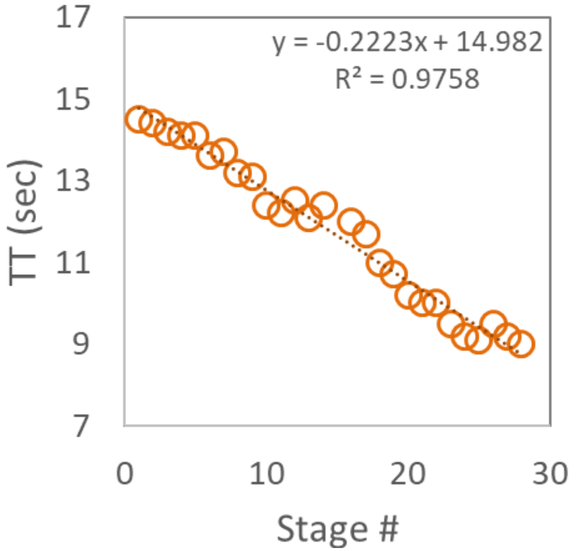
- Use equation of continuity & equation of momentum to model ΔP with ΔQ.
- Account for wellbore trajectory & friction.
- Use predicted ΔP behavior with historic VRF data to identify optimal VRF parameters & expected ΔP associated with actual treatment.

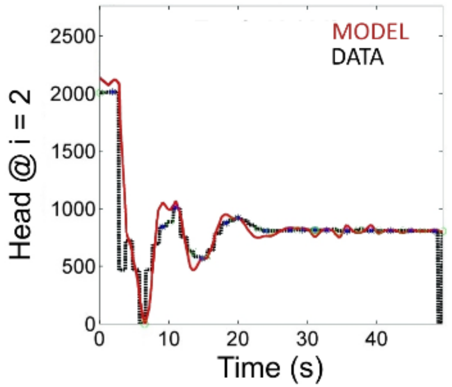
SHALETECH™

Modeled vs. actual ΔP behavior









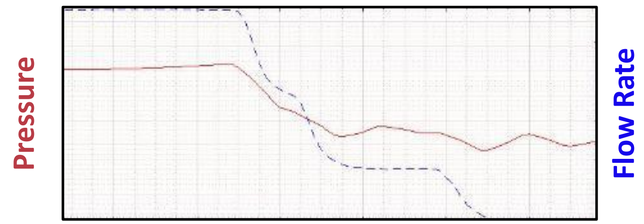
- Pressure transient modeling is validated using various measurements.

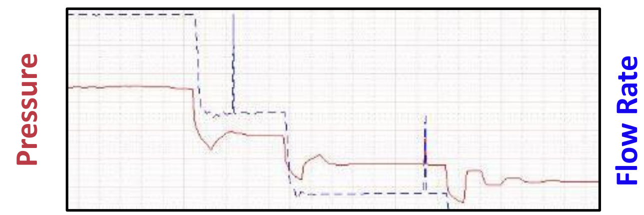
- These include actual response in wellbore to transients, actual & synthetic travel times, etc.

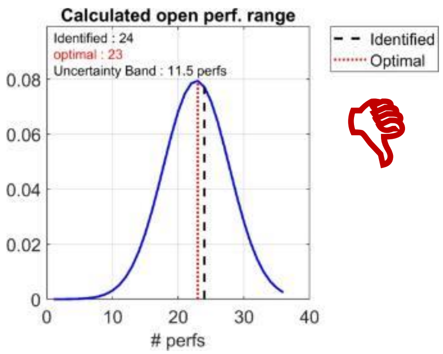
SHALETECH™

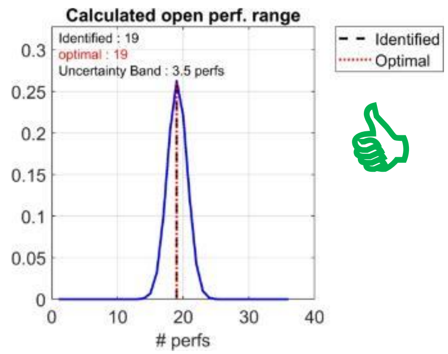
Calculating perforation efficiency

- Classical stepdown test as well as VRF drops as data points for open perf. estimation.
  - Initial open perforations (baseline)
  - # open perfs. during VRF drops
  - Identify progression
  - Design subsequent rate pulse



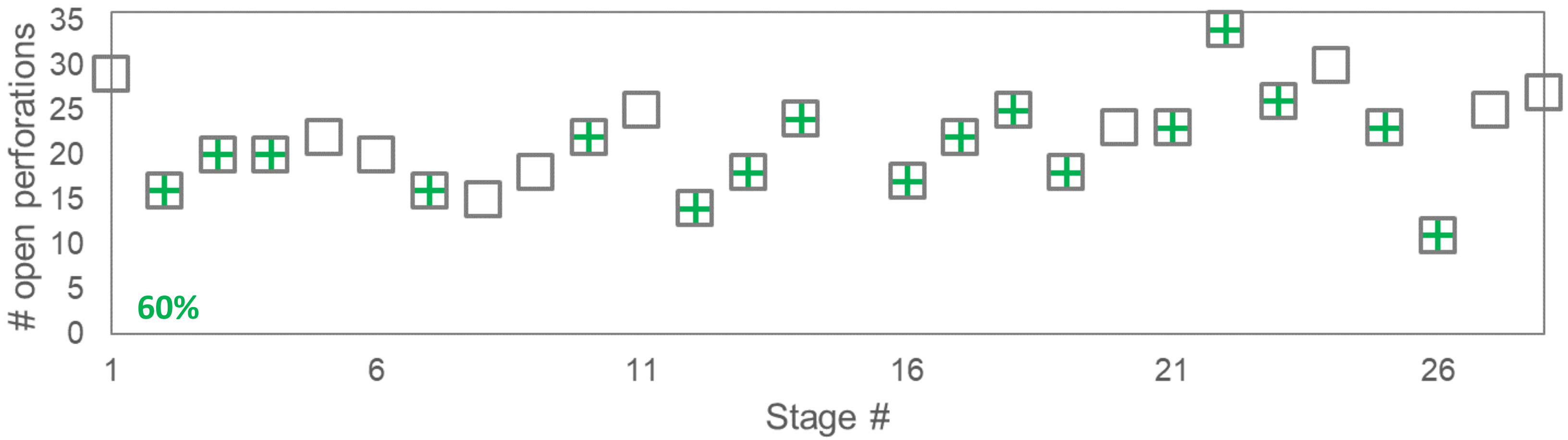


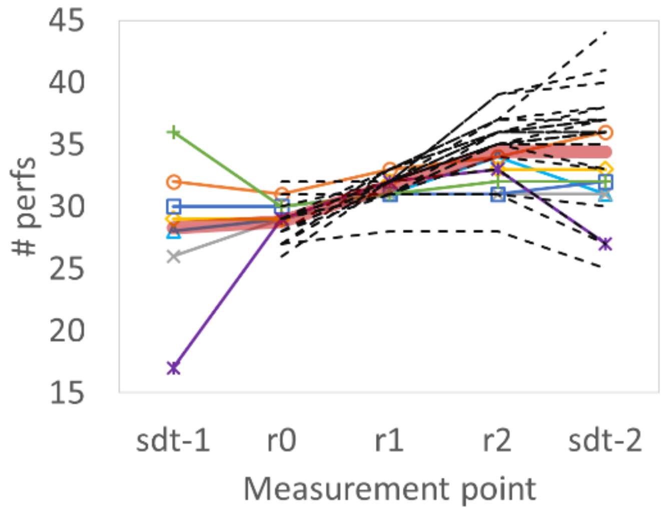




SHALETECH™

Estimate efficiency upside

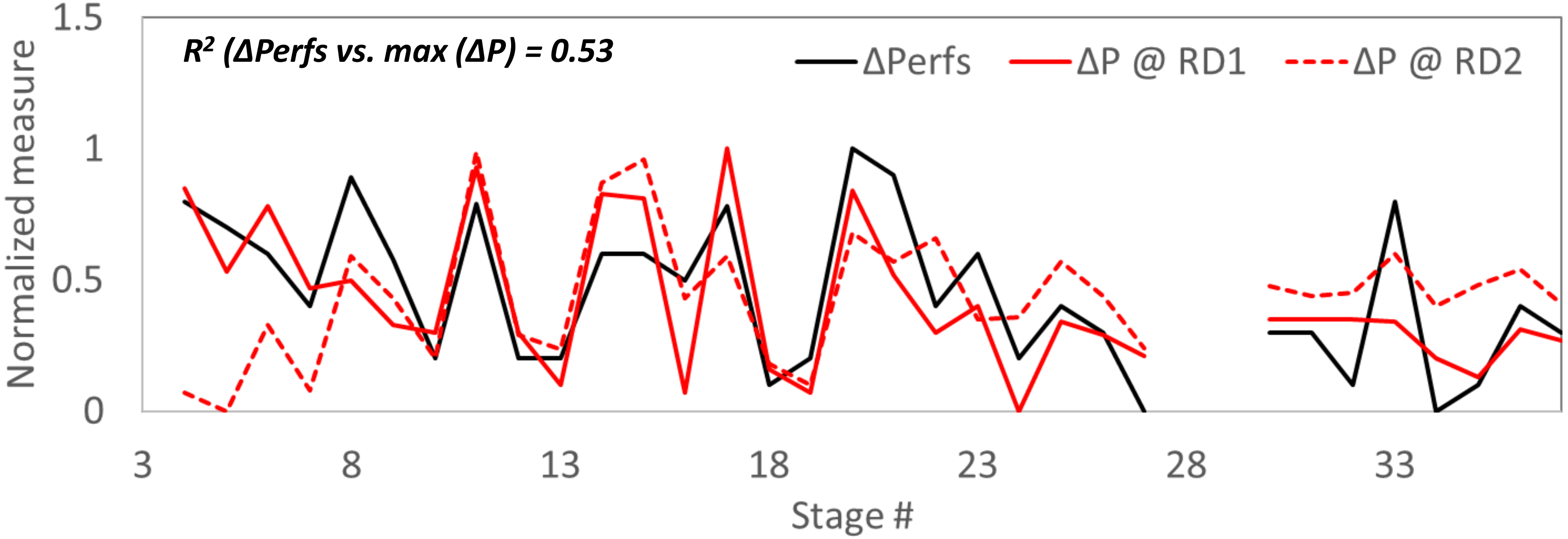




- Benchmarking existing perforation efficiency used to predict VRF performance in analogous wells.
- Results validated independently.

SHALETECH™

VRF design parameters are key

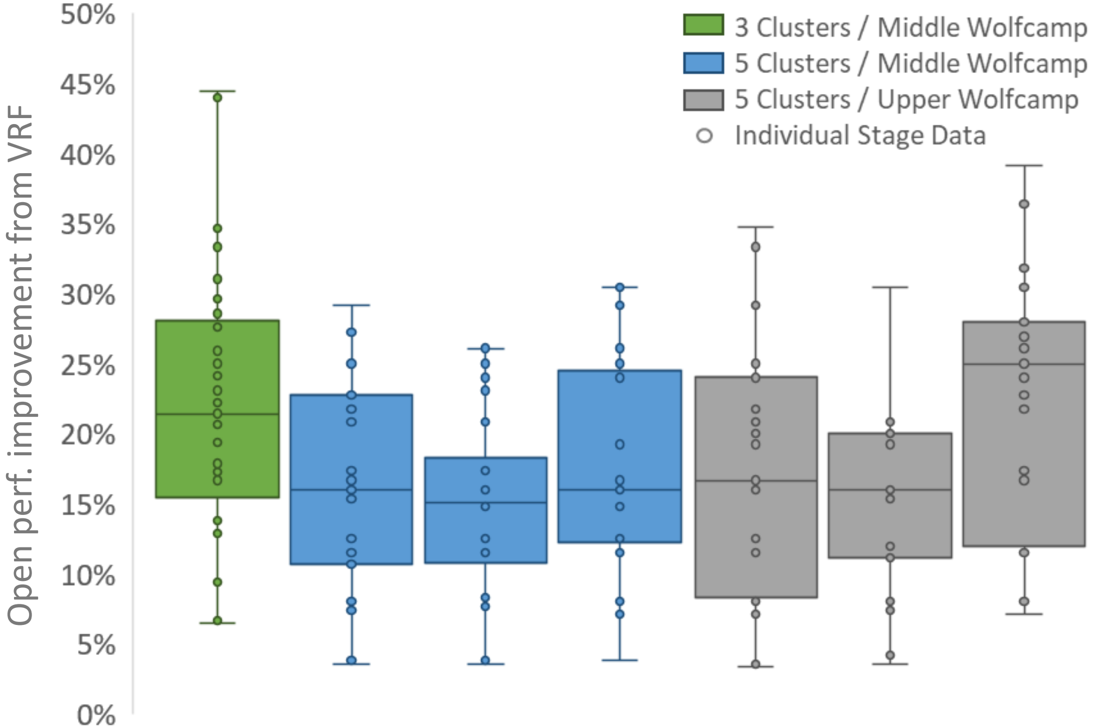


- VRF parameters such as ΔP shown here is critical for maximized efficiency gains.
- There is a close correlation between ΔP & actual additional opening of perforations achieved during VRF treatments.

SHALETECH™

Better completion

More perforations → More fractures → uniform slurry distribution.



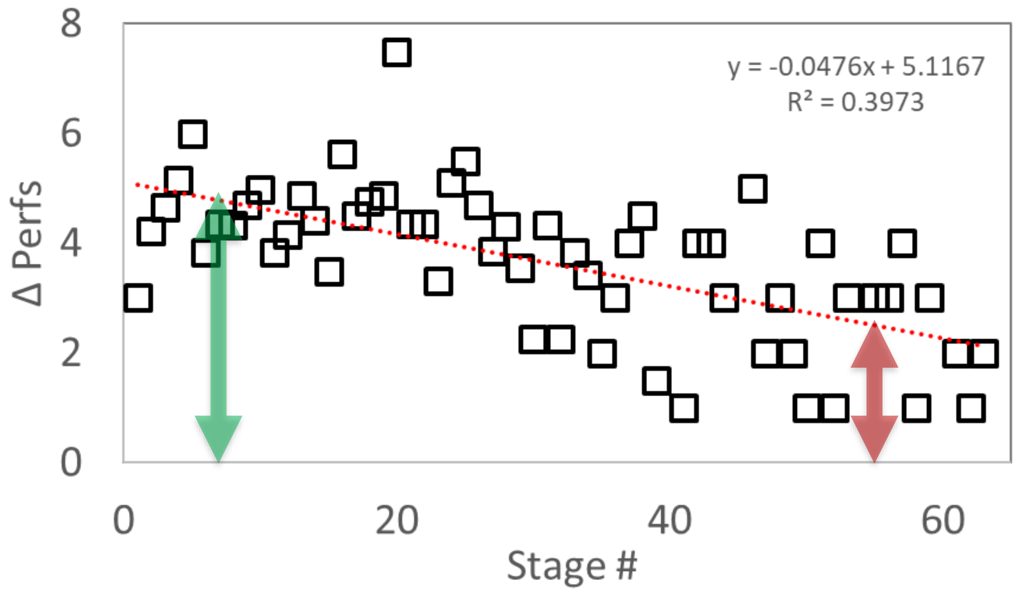
More perforation should lead to reduced near-wellbore skin (tortuosity).

It should reduce chances for screen-outs.

SHALETECH™

Need for accurate design!

- VRF is easier for toe stages as the wellbore lengths are longer.
- Shorter wellbores result in smaller ΔP. Proper design allows for maximized gains.



Operational issues can place constraints on some VRF parameters. In such situations, design parameters are recomputed for effective rate drops.

Blind rate drops are suboptimal

SHALETECH™

Conclusions

- VRF helps ***enhance perforation efficiency*** by opening additional perforations before proppant is pumped. Significant improvement in well productivity!
- VRF has been ***implemented*** under license in over ***40 wells***. Additional wells are pending.
- The approach is valid for any play, as long as the completions are ***plug & perf*** type.
- VRF creates ***lower tortuosity*** around perforations & reduced chances of screen-outs.
- ***No*** additional ***material*** or ***equipment*** is needed for implementation in field settings.

SHALETECH™

Question ?

Debotyam.Maity@gastechnology.org: (847) 418-6273
Jordan.Ciezobka@gastechnology.org: (847) 768-0924

http://www.gastechnology.org/news/Pages/PerfExtra-Technology-for-Hydraulic-Fracturing.aspx

SHALETECH™