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Underbalance Optimization Using a Laboratory-Based Fast Computational Model

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POSTER PRESENTATION

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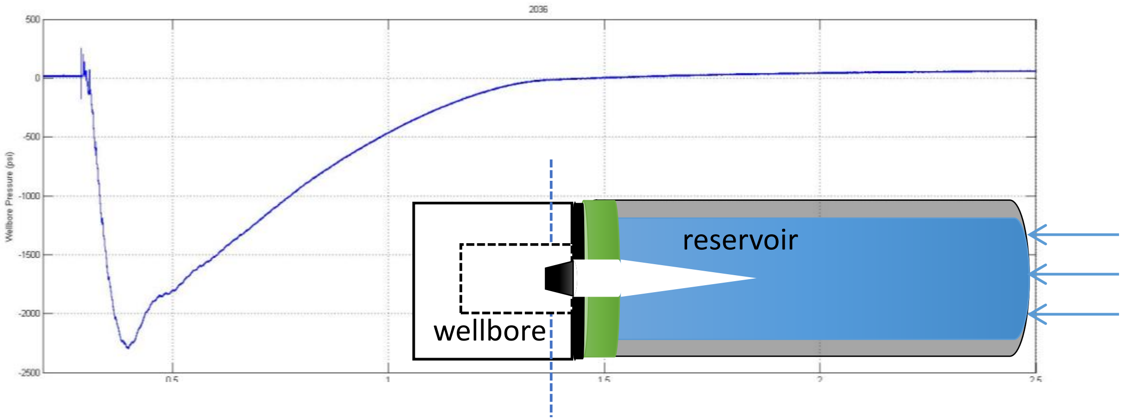
AGENDA/INTRODUCTION

- Perforation Laboratory and Modeling
- Objectives of the Study
- Our Design Philosophy
- Fast-Physics
  - Model Development
  - Components
  - Results
- Conclusions

Perforation Flow Laboratory



- Flow laboratory: Clear vehicle to study and understand the coupled effects between transient dynamics and job design parameters.

- Measurements from a Section-IV test:
  - Pre- and post-flow permeability
  - Core flow efficiency
  - Productivity
  - Dynamic high-speed pressure
  - Perforation tunnel characteristics
  - Clean-up and underbalance optimization

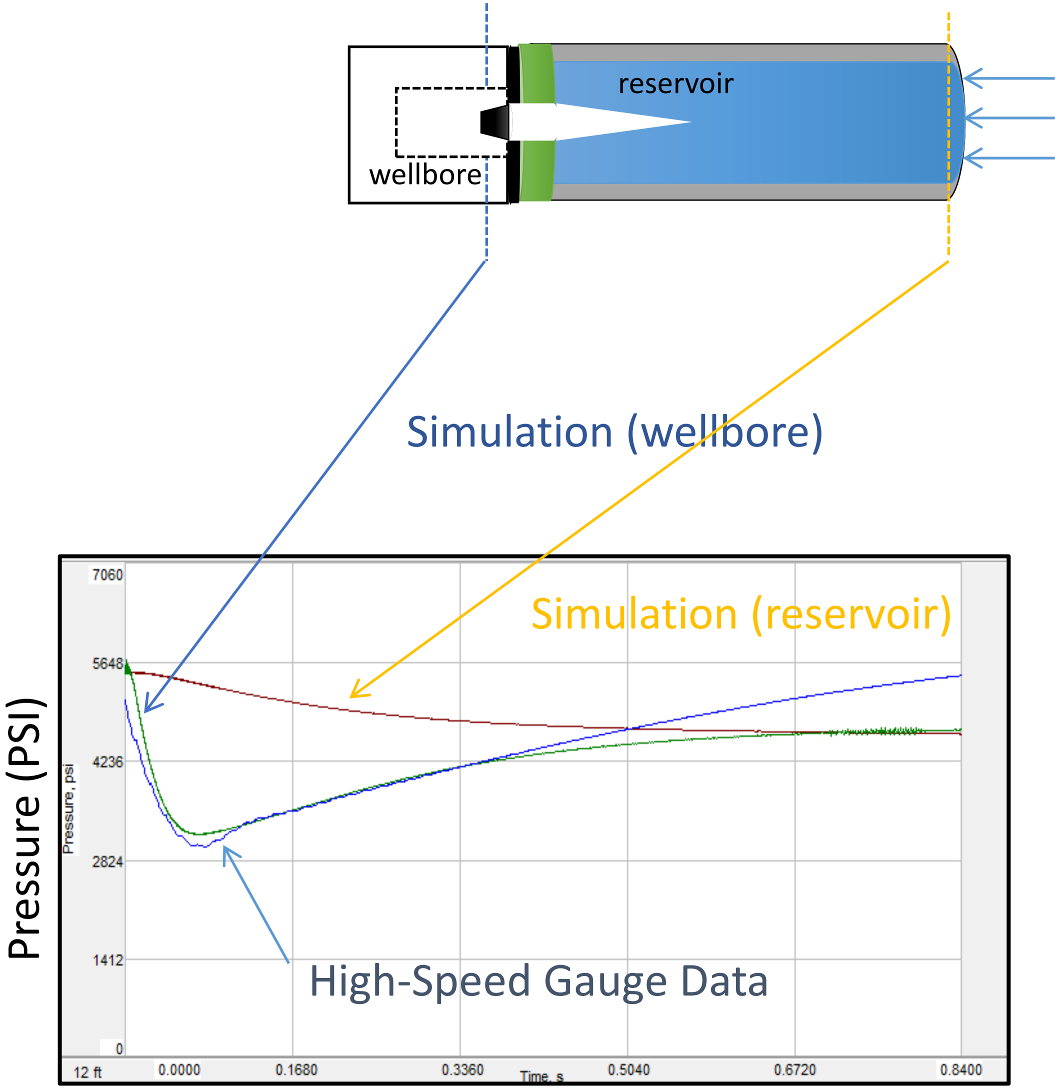
- Dynamic pressure data provides insight into the perforation process.

- Though the details of the pressure curve look complicated, the general trends of the dynamics are dominated by only a few physical processes.

- Challenges: Experimental costs, Limited data, Impractical when DOEs are required

Laboratory Event Modeling

- Laboratory simulator:
  - Useful tool to aid in experimental data analysis and interpretation
  - Helps in planning and optimizing experiments
  - Can reduce the size of meaningful DOEs ***(saves $$$)***
  - Modeling can be upscaled to field-scale analysis ***(improves perforating jobs)***
- Existing models:
  1. Limitations in representing flow lab geometry
  2. Too many “free parameters” unrelated to the flow physics
  3. A decent fit requires multiple ~30 min. runs for tuning



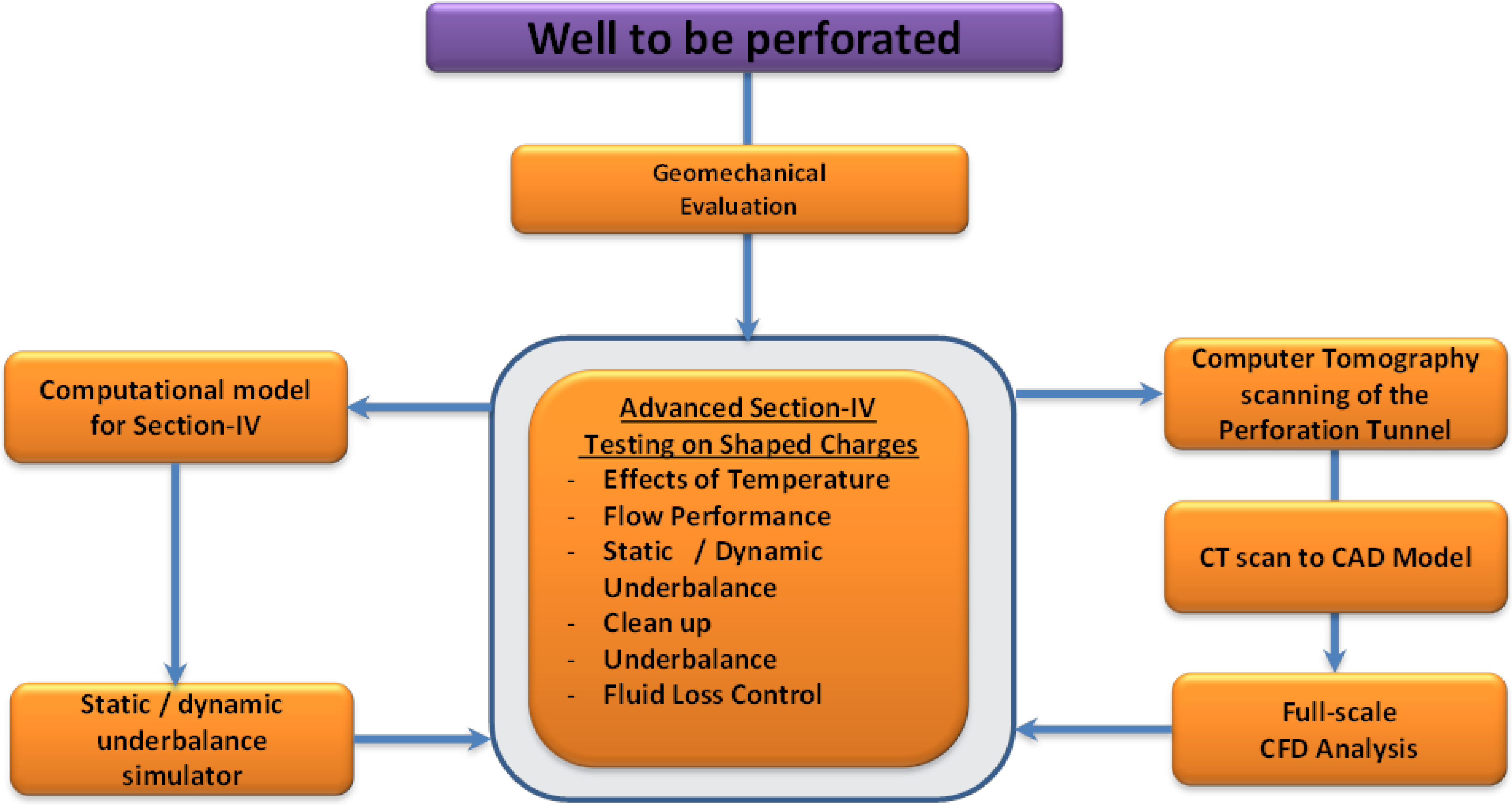
Objectives of the Study

- ✓ Understand and analyze the complex transient dynamics obtained from an API Section-IV experiment.

- ✓ Develop one-of-its-kind ***fast computational model*** based on ***simplified dominant processes*** that play an important role during the Section-IV test.

- ✓ Predict the **complex pressure transients** that are generated using a dynamic perforating event.

Our Design Philosophy



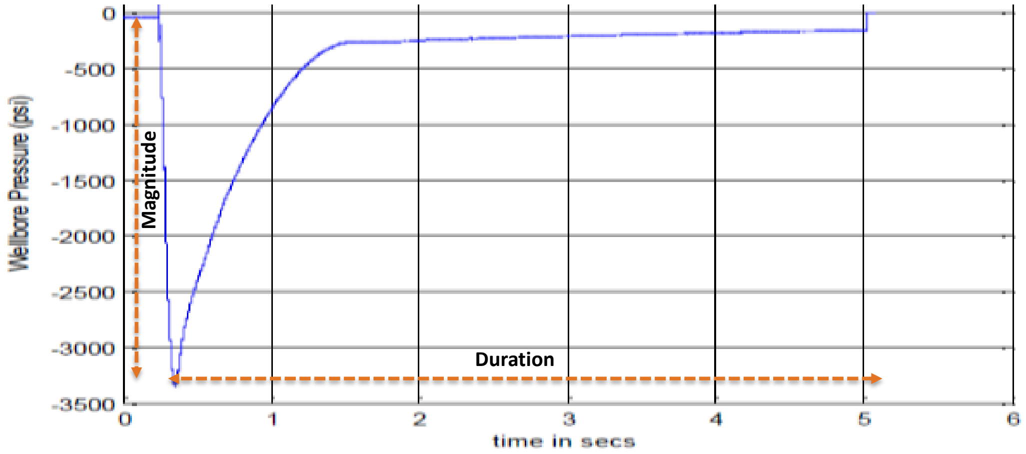
Fast Physics: Underbalance Management

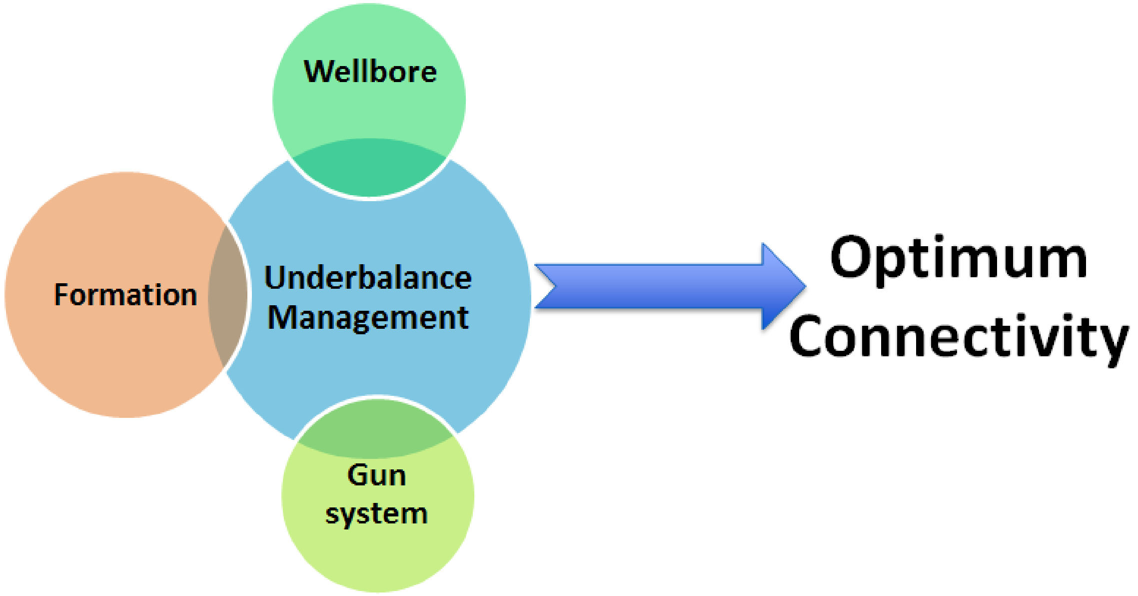
- ***An engineered process that considers the interaction among the wellbore, gun system and formation to design and optimize underbalance processes for optimal clean-up.***

- Classical transient pressure curve from an API Section-IV test characterizes the underbalance mechanism.

- Physics of transient pressure is dependent on:
  - Wellbore (static effect)
  - Perforating guns (dynamic effect)
  - Formation properties

- While both the static effects (wellbore system) and the dynamic effects (gun system) have an influence on the magnitude and duration, the coupled effect of the static and dynamic system (referred to as "*total underbalance*") truly drives the overall cleanup and productivity enhancement.





Fast-Physics – Model Development

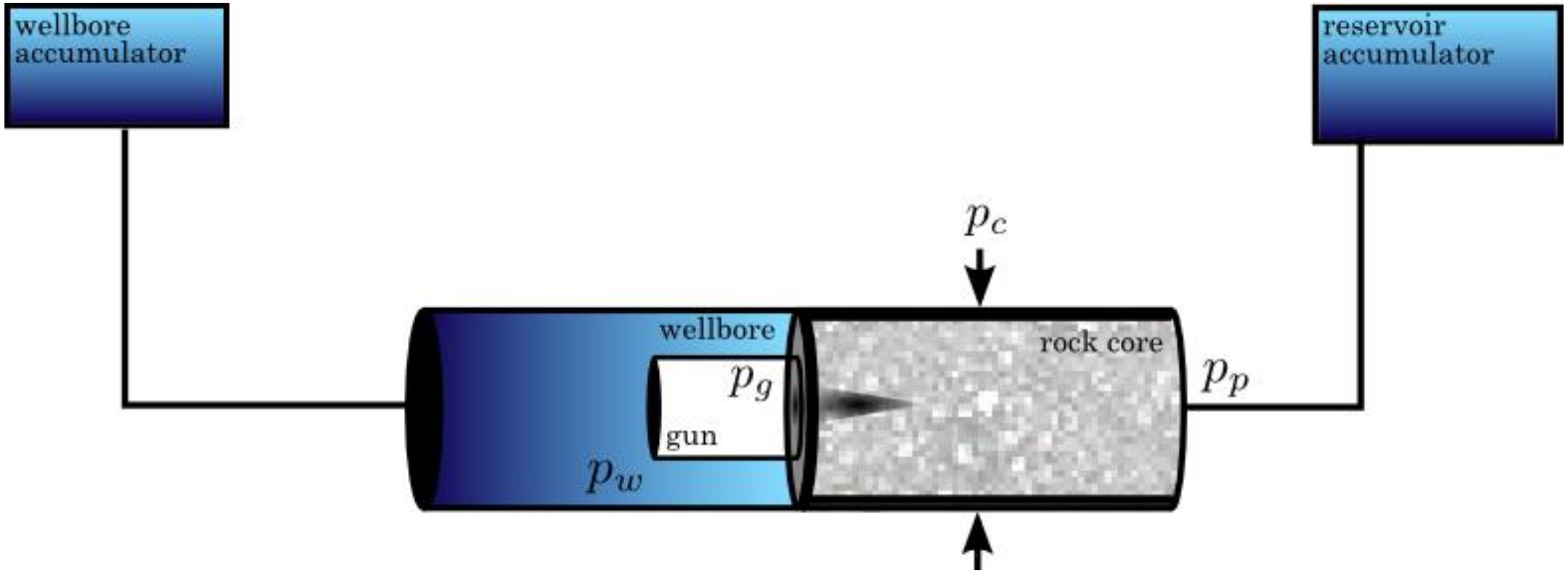
Conceptual
- Simple shape of the pressure transients hint at two dominant physical processes
- Test of time scales as rough estimators.

Full Numerical
- Develop full models for gun, wellbore, and reservoir.
- Implement them in a bench-top environment.

Fast Physics
- Use full numerical simulation to understand dominant processes.
- Recast full model into simplified "dominant physics" model.

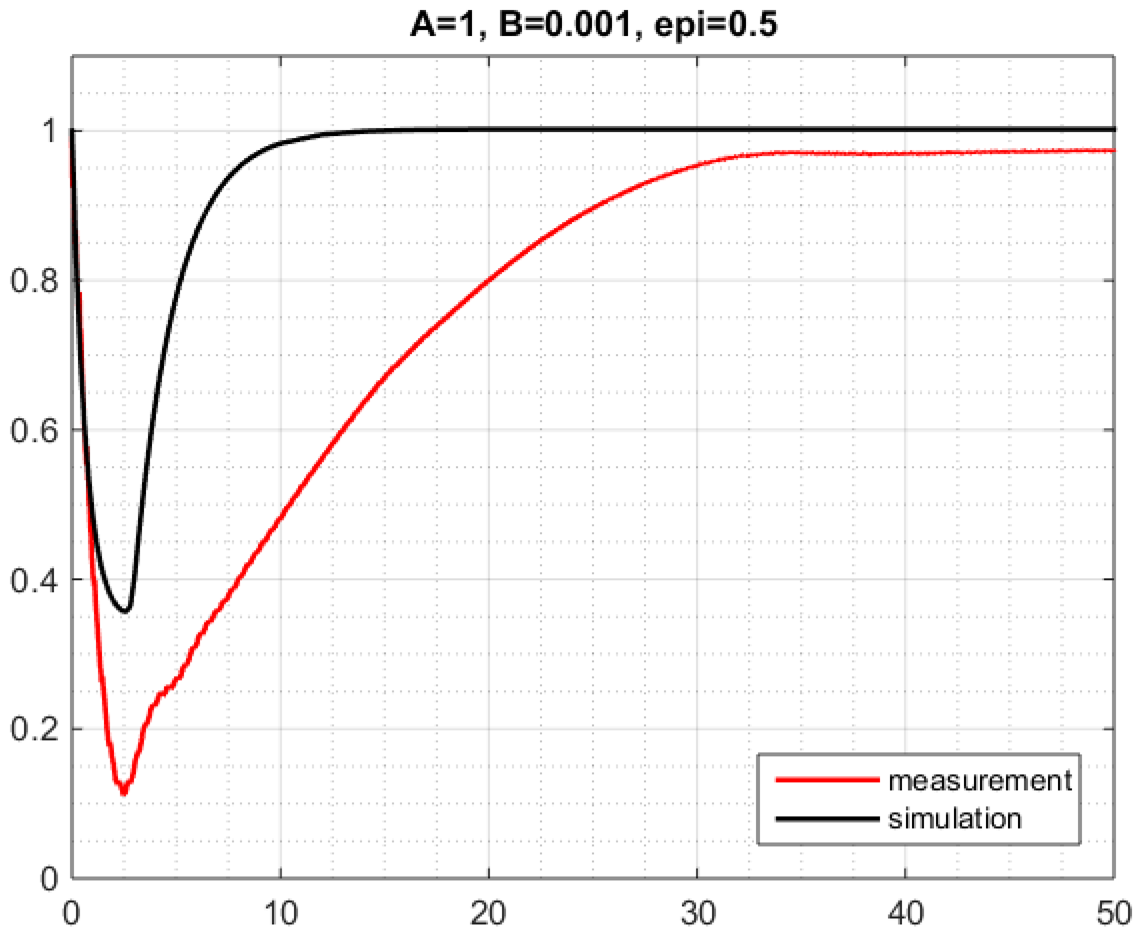
Proof of Concept
- Comparison of measured pressure transients with computed values.

Fast-Physics – Model Components



- Wellbore
- Gun chamber
- Rock core
- Connectivity to accumulators
- Perforation tunnel

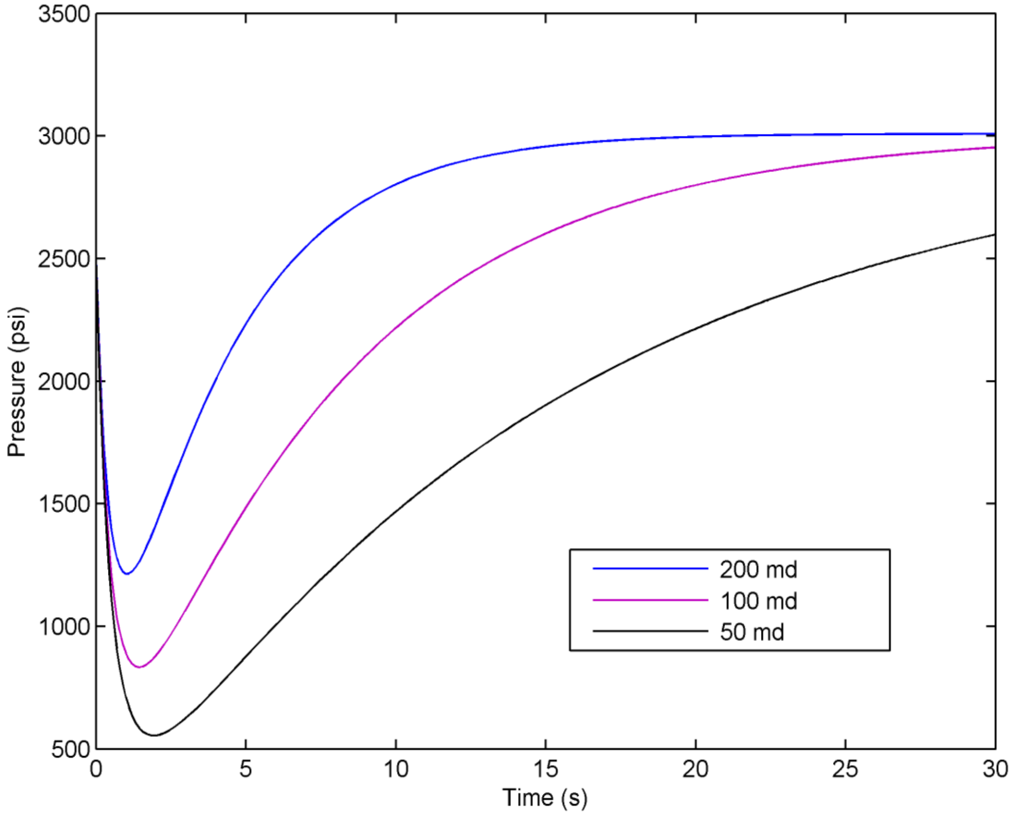
Fast-Physics – Results



- ✓ A model optimization routine in conjunction with fast-physics model is implemented.
- ✓ Model fit to measurement data is very good.
- ✓ No parameter "fudging", all parameters are physics-based and their values lend insight into the physical flow
- ✓ **Each run takes <100 ms to run → a fitting tool will be simple and feasible**
- ✓ Efficient tool to understand
  - underbalance conditions
  - overbalance conditions
  - influence of damage zones
  - clean up dynamics

Fast-Physics – Parametric Study

Gun	Wellbore	Rock Core
geometry (volume)	fluid properties (compressibility)	permeability (volume and non-uniformity)
gas constant	geometry (volume)	Porosity
external conditions	initial state (static underbalance)	Viscosity
shape charge characteristics		



Plot shows an example where the model can be quickly used to understand the influence of core permeability on the dynamics of the pressure curve.

As permeability is increased from 50md to 200md,

- The magnitude of dynamic underbalance is reduced
- The time required to reach equilibrium is reduced with increasing permeability

Conclusions

- A new model and simulation tool has been developed for interpretation of the pressure transients of an API-RP 19B Section IV flow test.
  - Model is based on simplified dominant physics
  - Each simulation runs in < 1 second
  - Its simple form enables interpretation based directly on physical parameters.

- Preliminary results show good agreement between measured high-speed data and computed dynamic pressure data.

- As part of our future plans, we are working on
  - Extending the fast-physics to include details effects of perforation tunnel characteristics (true size/shape and crushed zone)
  - Comprehensive validation using gauge and CFD data
  - Incorporate clean-up and upscaling models

QUESTIONS? THANK YOU!