A Flow Laboratory Study of an Enhanced Perforating System Designed for Well Stimulation

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Agenda

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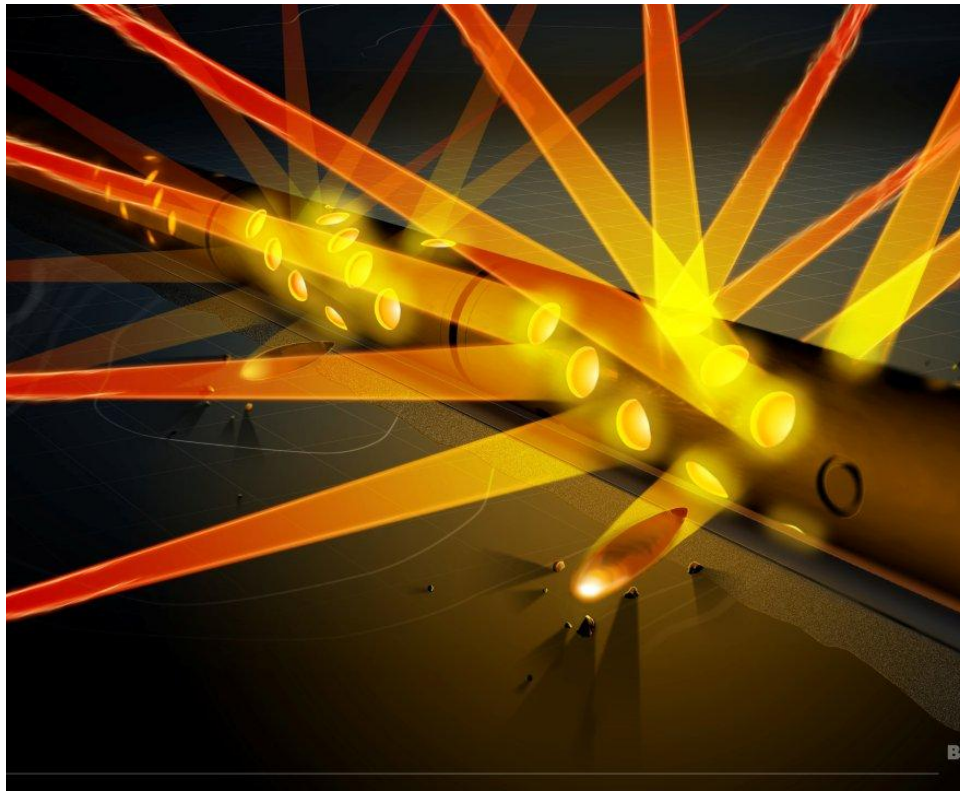
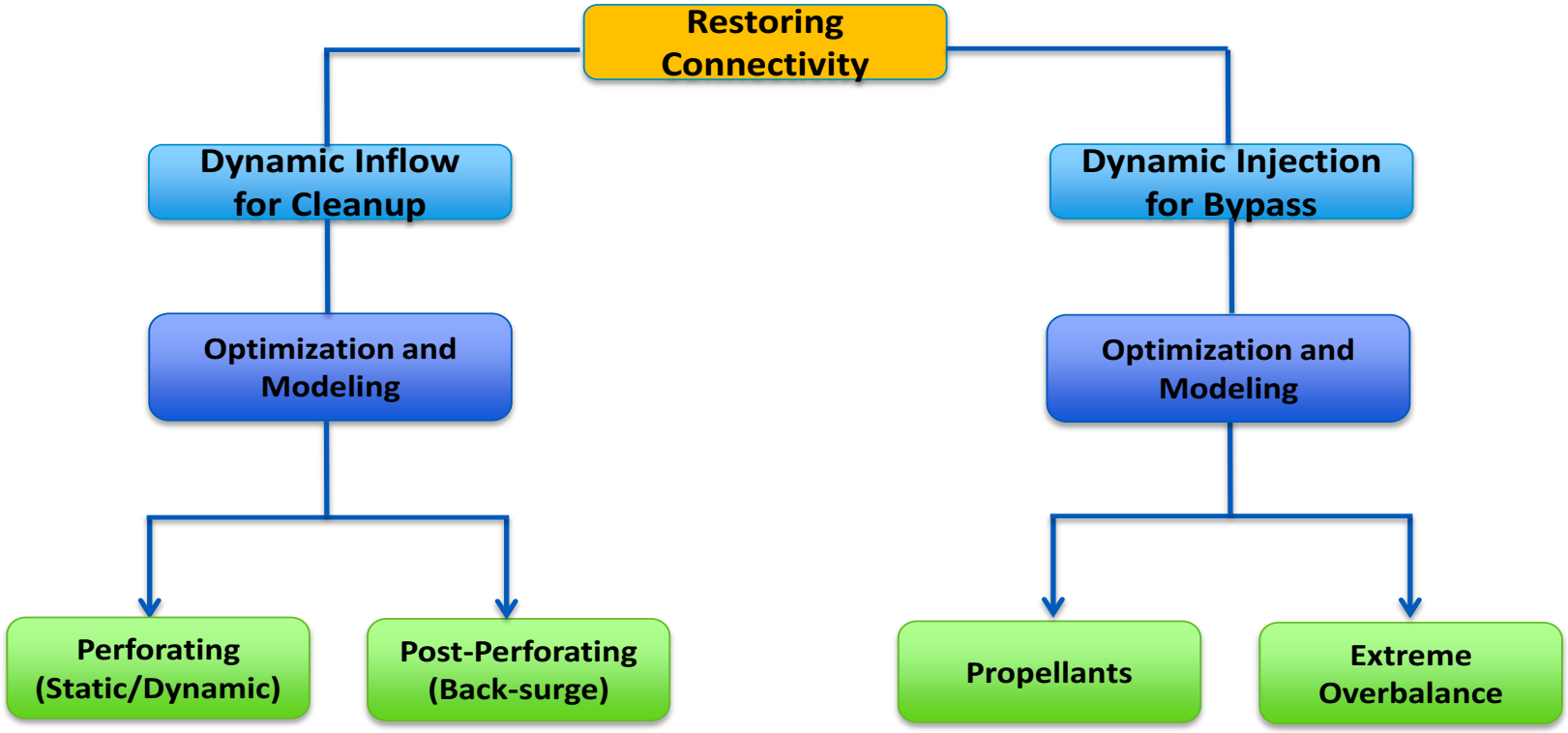
  - ✓ Why propellants ?
  - ✓ Types and Benefits
  - ✓ Internal propellant system
- Objectives of the Study
- Laboratory Test Apparatus: Development
- Results
  - ✓ Transient Pressure
  - ✓ Post-shot analysis
  - ✓ Preliminary Micro-CT evaluation
- Conclusions



Background: Propellants



- During the perforating event, the detonation of the explosive charge inevitably compresses the formation, resulting in "crushed" or "damaged" rock surrounding the tunnel.
- Remediation of formation damage due to shaped charge perforating and subsequent improvement in productivity is critical.
- Bypassing damage, cleaning up the tunnel and initiating fractures.
- Accomplished by propellants and extreme overbalance techniques.

Background: Propellant Types and Benefits

TYPES

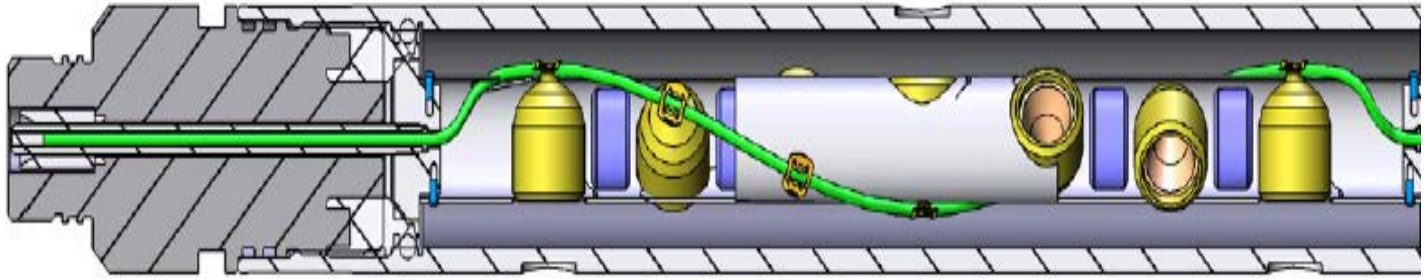
- Propellant sleeve around a perforating gun
- Molded cylinder with propellant-like oxidizing material surrounding an internal steel support tube.
- **Propellants arranged within the perforating system for specific applications to horizontal wells and improve reliability.**

BENEFITS

- Enhance well productivity or injectivity
- Deliver perforation breakdown and cleanup
- Deliver near-wellbore stimulation
- Overcome formation damage created during the perforating event
- Reduce hydraulic fracture initiation pressures and improve proppant placement

Background: Internal Propellant System

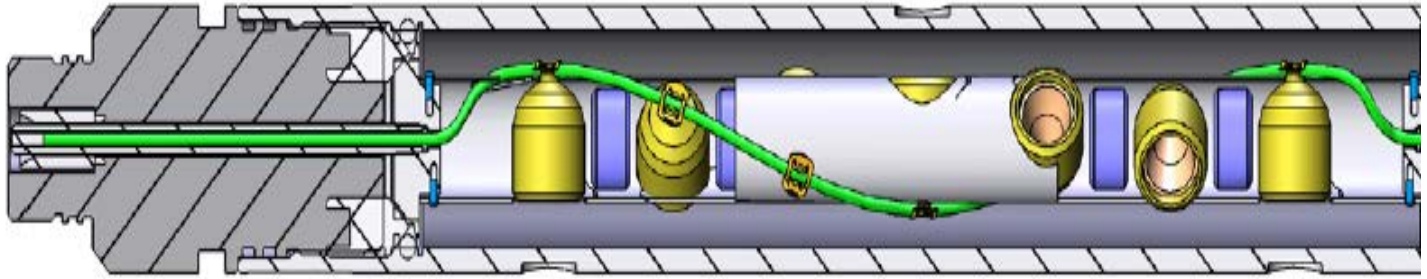
- Combines perforating and well stimulation in one operation.
- The system integrates perforating charges with a proprietary energetic material.
- The detonation of the perforating charges initiates a complex, sequentially burning reaction of the energetic material generating high pressure gas pulse.
- This pulse cleans the tunnel and initiates fractures into the surrounding reservoir improving production/injection performance.



Background: Internal Propellant System

- Successfully run in heavy oil SAGD (steam assisted gravity drainage) wells in Canada. Injection wells showed substantial increases in productivity.

- Tight unconventional reservoirs: West Texas field studies and Woodford shale studies have shown higher inflow performance and decrease in hydraulic fracturing breakdown pressures.

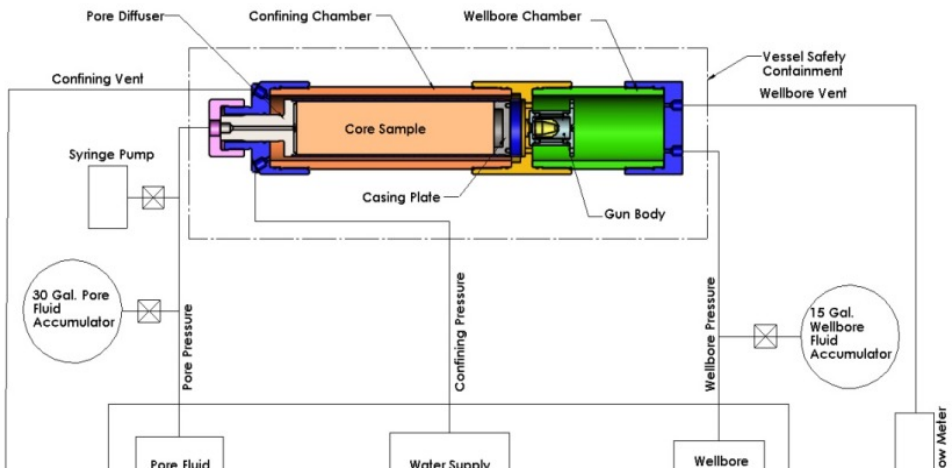


Objectives of the Study

- Quantitative and Systematic Evaluation: Development of a customized flow laboratory apparatus to understand the effect of an internal propellant in conjunction with standard shaped charges.
- A thorough assessment of HSE (Health, safety and environment) was conducted prior to the testing.
- Quantify the complex transient dynamics associated with the enhanced perforating system.
- Measure the physical characteristics of the perforated cores to provide insight into specific features as characterized by the use of propellant disks.

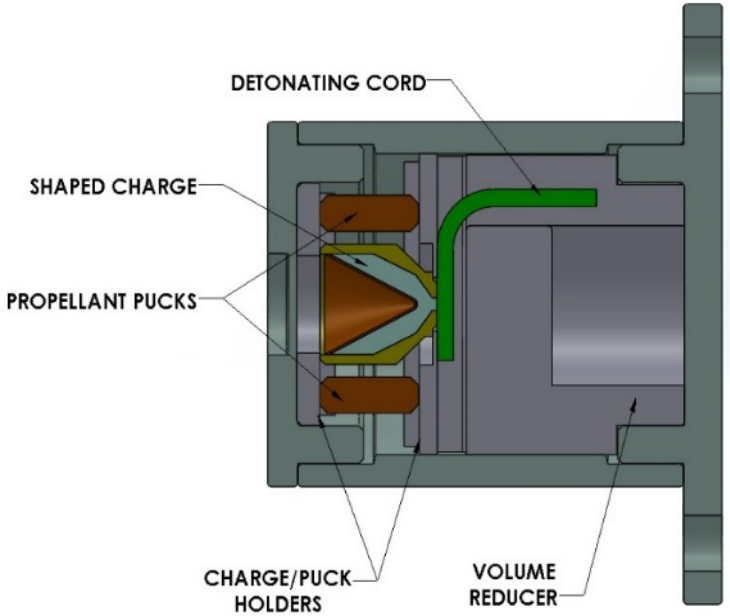
Laboratory Test Apparatus

- Study and qualify the performance of different perforating systems in formation rock at reservoir conditions.
- Study the influence of various factors on well productivity.
- Integrate this knowledge to select the optimal perforating system and clean up strategy for improved productivity.



Laboratory Test Apparatus

- Customized fixture for accommodating propellant disk and shaped charge, appropriate standoff and free gun volume.
- First-of-its kind experiment, specific aspects of HSE were evaluated first.
- 2-7/8” perforating gun with appropriate propellent system modeled for the laboratory scale testing.
- The propellant is typically a cylindrical puck shape that rests in between the perforating charges in the gun system.

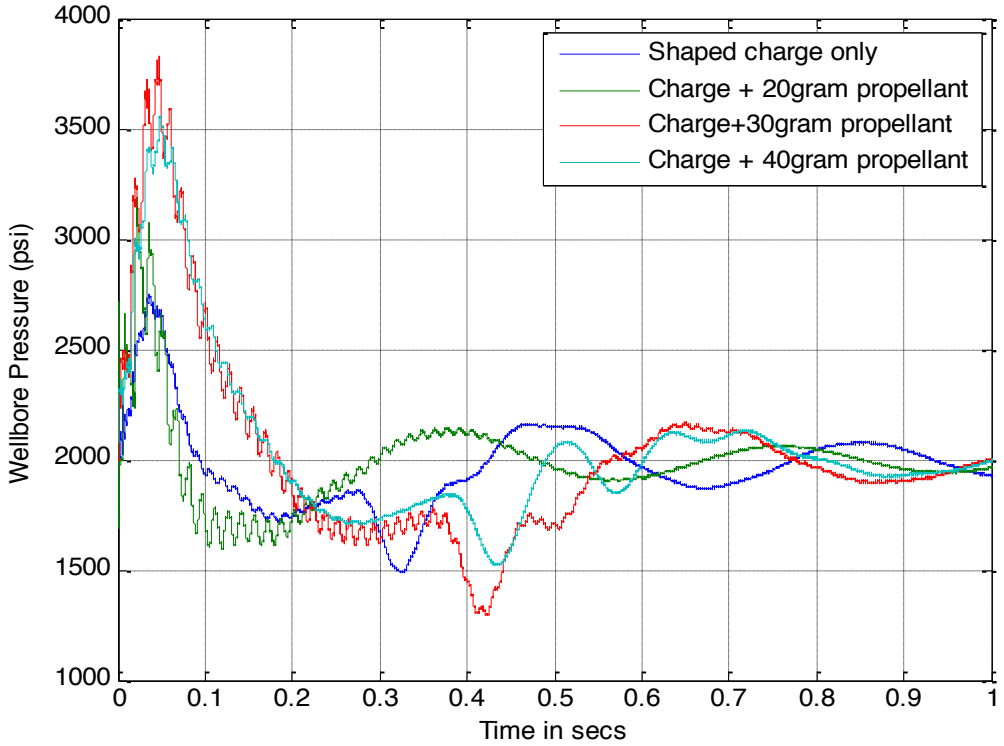


Test Matrix

- Berea sandstone with representative in-situ conditions including overburden, pore and wellbore pressures.
- Shaped charge only, zero gram propellant
- Shaped charge + 20 gram propellant (10 gram on each side)
- Shaped charge + 30 gram propellant (20 gram and 10 gram)
- Shaped charge + 40 gram propellant (20 gram on each side)

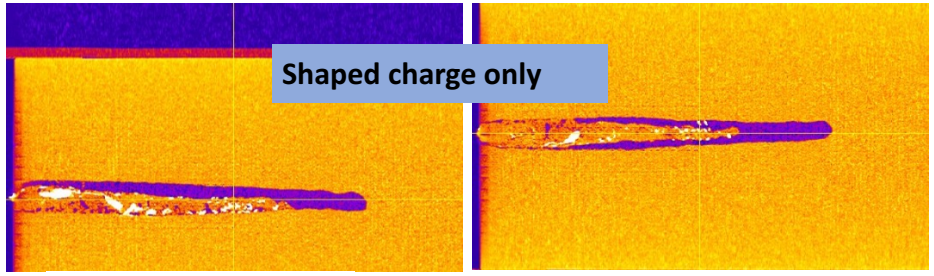
Results: Transient Pressure Data

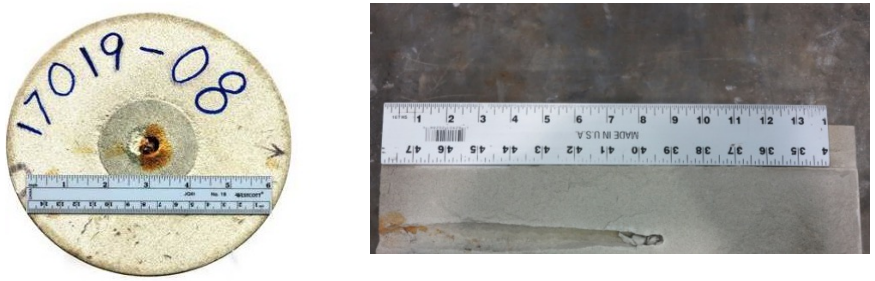
- High-speed transient gage data (100,000 samples / sec) measured within the wellbore.
- Peak pressure measured from the baseline "shaped charge" test is around 2750psi.
- Peak pressure increased to 3100psi (20 gram propellant) and ~3750psi (30 and 40 gram propellant).
- Peak pressure signature extends for a larger time with propellants compared to the case with shaped charge only.
- 35% increase in peak pressure combined with a longer duration peak pressure regime

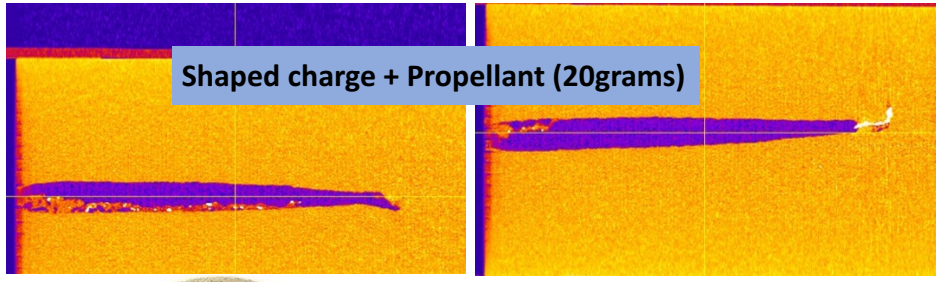


Results: Post-shot analysis

- Significant amount of debris present inside the tunnel with shaped charge only.
- Minimal debris within the tunnel with propellants + shaped charge. Effective clean-up with propellants.
- Extension of the tunnel at the tip-section. This beak-like extension of the tunnel could serve as ideal regime for creating tip-fractures







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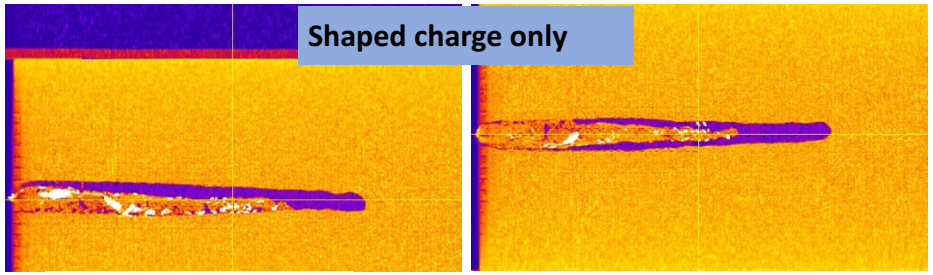
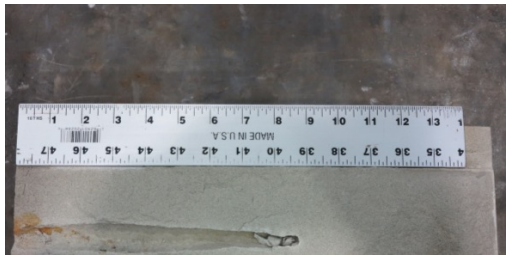
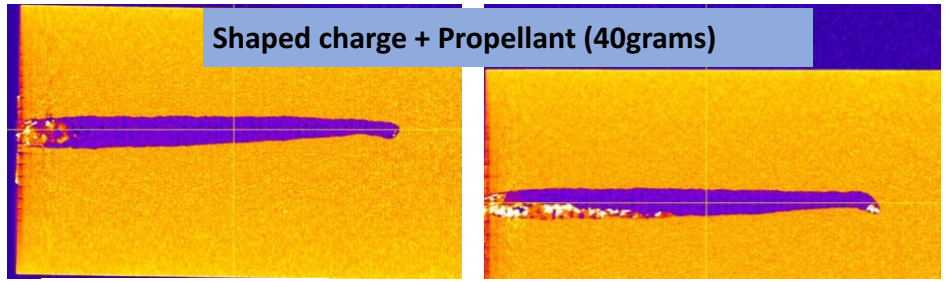






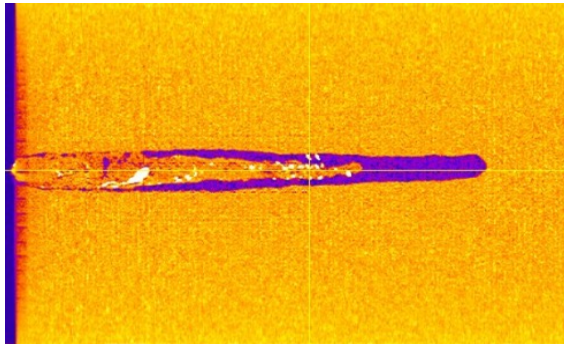
Results: Post-shot analysis

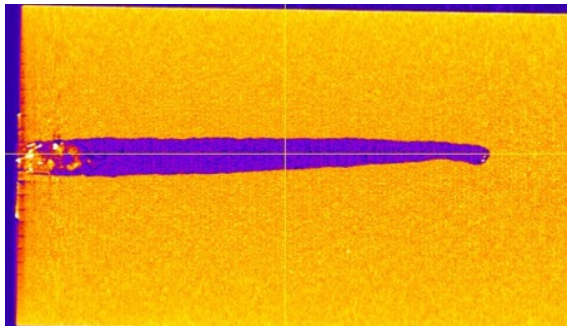
- Tests with the propellant showed a 10% increase in core penetration compared to the test with just a shaped charge.
- Core entry hole size is slightly larger for the tests where propellants were utilized.

Propellant Weight (g)	Core UCS (psi)	Core Penetration (in)	Casing EHD (in)	Core EHD (in)
0	7680	9.1	0.324	0.594
20	7579	10.1	0.300	0.606
40	7589	10.1	0.322	0.657

Conclusions

- Flow laboratory study of an enhanced perforating system designed for well stimulation has been conducted in this study.
- A fit-for-purpose flow laboratory apparatus which combines standard shaped charges along with propellants within a gun system was developed to understand the aspects of clean-up and tunnel efficiencies.
- The results from this study show promising trends with respect to decreased debris, better clean-up, and more importantly, increased surface area when propellants are used in conjunction with shaped charges.
- **Plans for future**: Important aspects including tighter rocks, increased mass of propellant material etc. will be incorporated to better understand the influence of these internal-propellants.
- Use of propellants requires an integrated knowledge of perforating strategy, formation properties, well architecture and well-stimulation techniques. Computer modeling methods that simulate the dynamic behavior of this enhanced propellant/perforating system are critical to a successful job design and optimization and will need to be developed in the near future.





QUESTIONS? THANK YOU