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PREDICTION OF GUN-STRING DYNAMIC FAILURE RISKS DURING PERFORATING: Partially-Loaded Gun Failures

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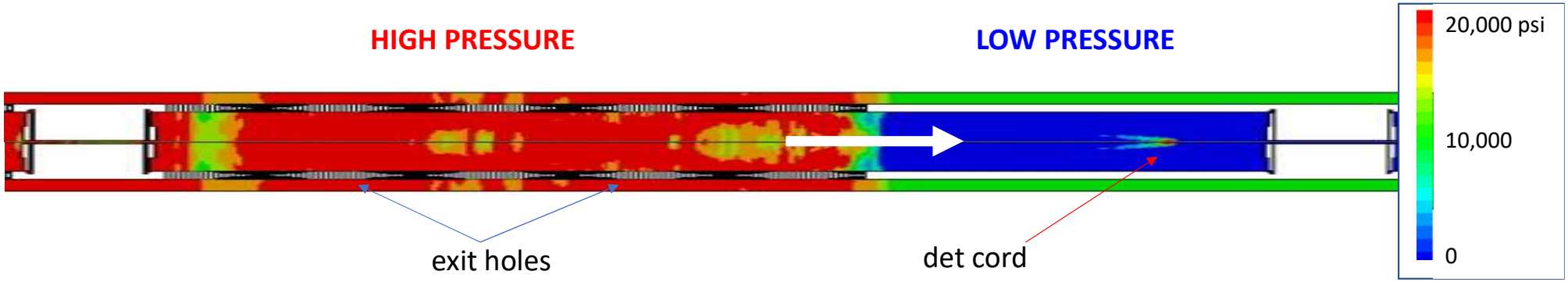
Gun Burst Failures

- Structural failure of perforating guns can be very costly to a job
- If the gun parts, the problem can be even greater
- Gun wall ruptures can often be tied to overpressure, or burst differential pressure
- This is evident where the gun wall is pushed outward and a crack propagates longitudinally
- When a crack occurs near the end of the gun, it can propagate around machined features and result in gun parting
- High pressure at the end of the gun is a telltale for a possible fluid hammer event

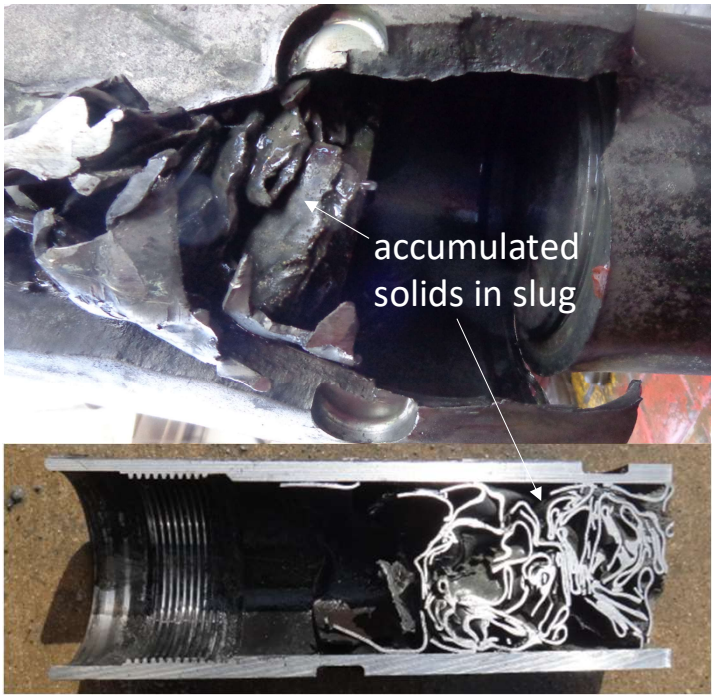
Why Partially-Loaded Guns Are Special

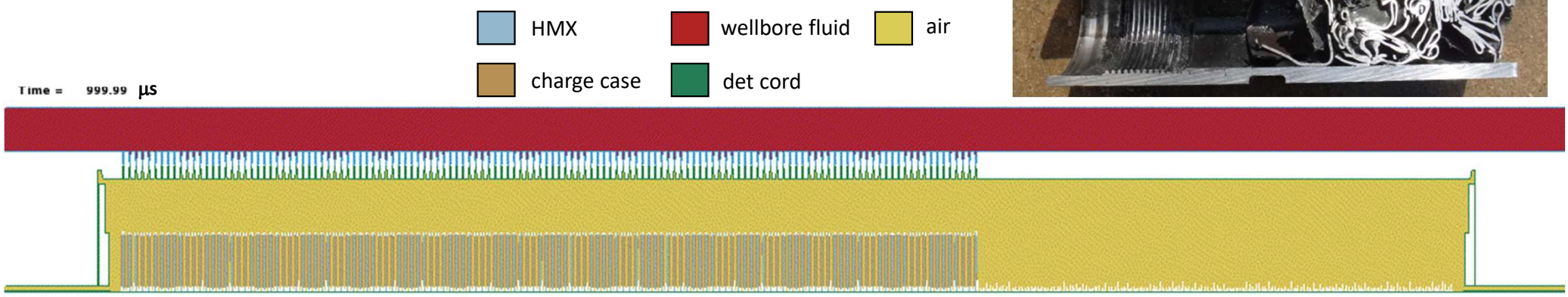
- As a partially-loaded gun detonates, one side of the gun starts at very high pressure, the other side remains at atmospheric pressure
- This creates a drive from high to low pressure
- And this can move fluids and solids in the direction of the low pressure
- If the fluids and solids move fast enough, a fluid hammer effect can be created at the end wall



Dynamics of Partially-Load Gun Detonation

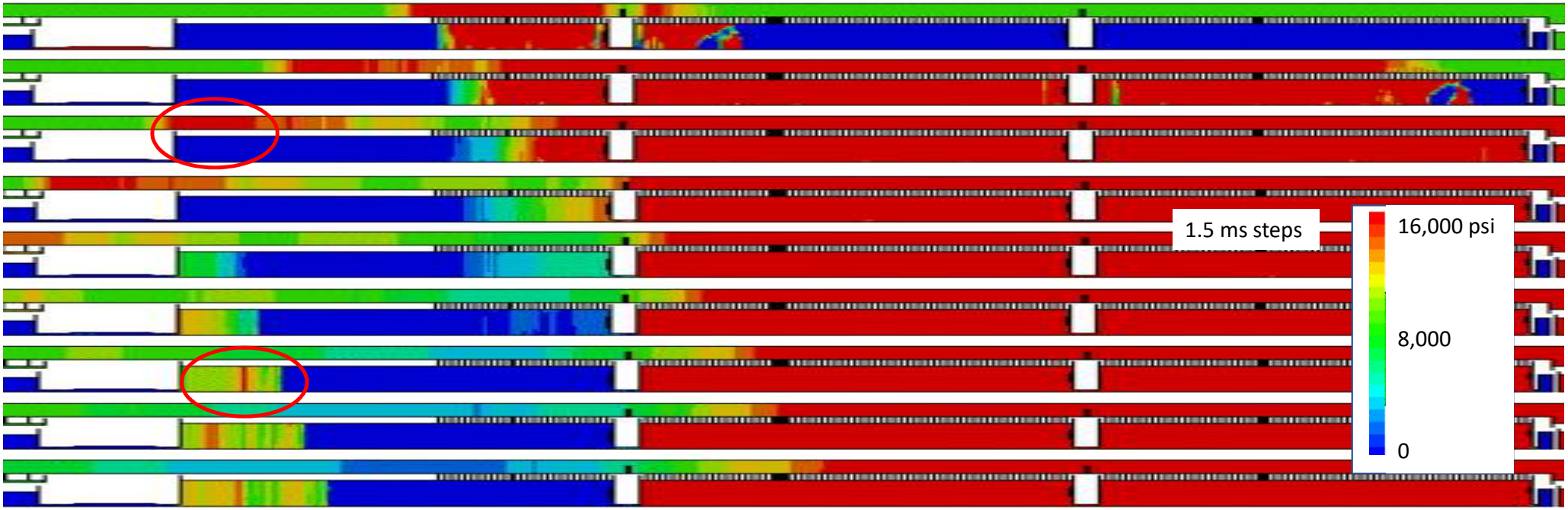
- The fluid and solids can form a slug of material that travels into the blank section at high speed
- How fast the slug travels will depend on how fast explosive gases and wellbore fluids can fill in behind it to drive it forward
- Many factors including hydrostatic pressures, % loading, explosive mass, and wellbore fluid can effect the behavior





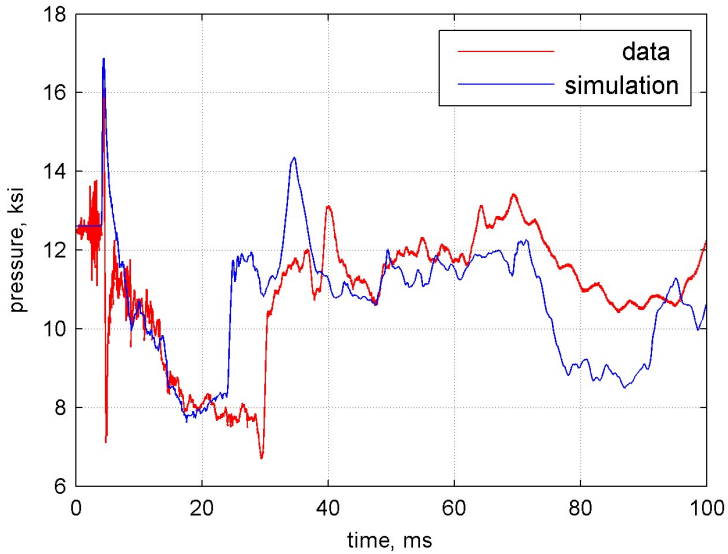
Simulation of Partially-Loaded Guns

- 4.625 inch 12 SPF guns, 28 g LD charges
- 12,000 psi hydrostatic pressure
- Top gun is 40% loaded
- Moderate collapse and then burst differential develops at blank end



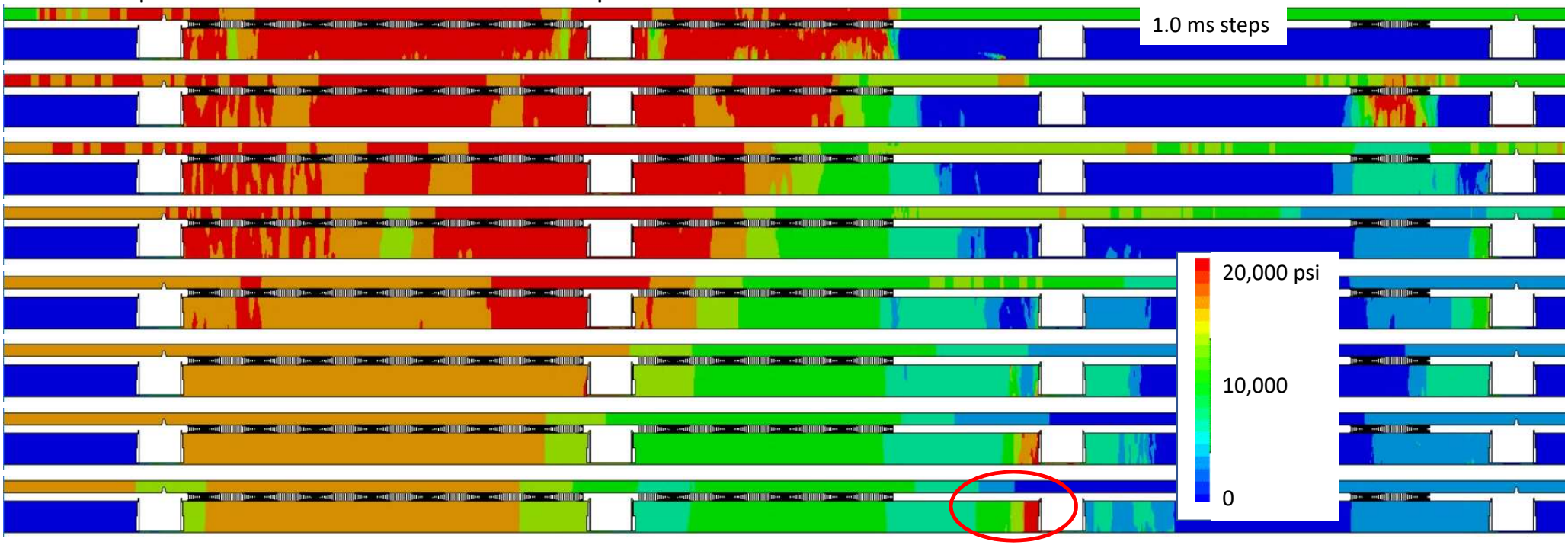
Collecting Data on Partially-Loaded Guns

- Data collected adjacent to partially-loaded gun detonation has provided direct observation of the dynamics within the gun
- Sloshing or internal reflections within the partially-loaded top gun resulted in oscillations in pressure
- Reflections are visible in data as well as in simulations



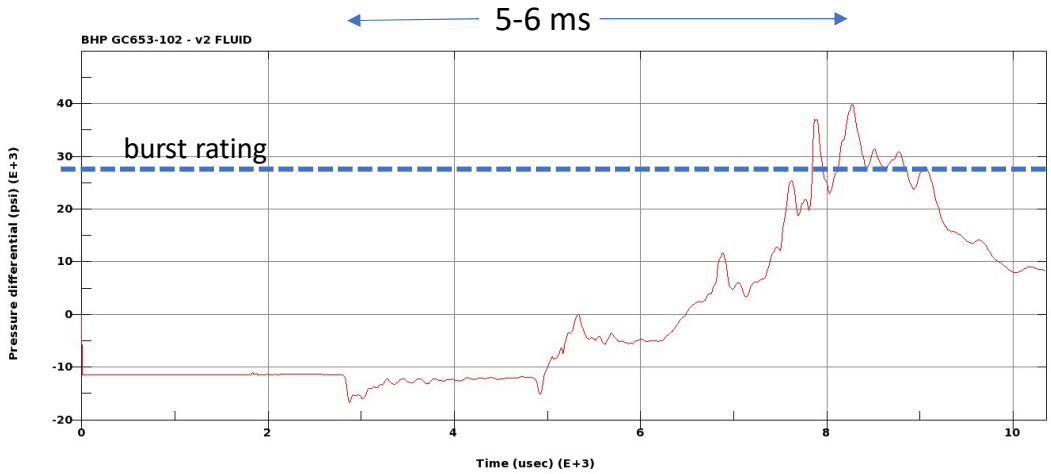
Simulation of Partially-Loaded Guns

- 6.5 inch 14 SPF guns, 47 g LD charges
- 11,000 psi hydrostatic pressure
- upper gun is 65% loaded with lightly loaded 20% gun below
- High burst differential develops at blank end when internal high pressure combined with annulus low pressure



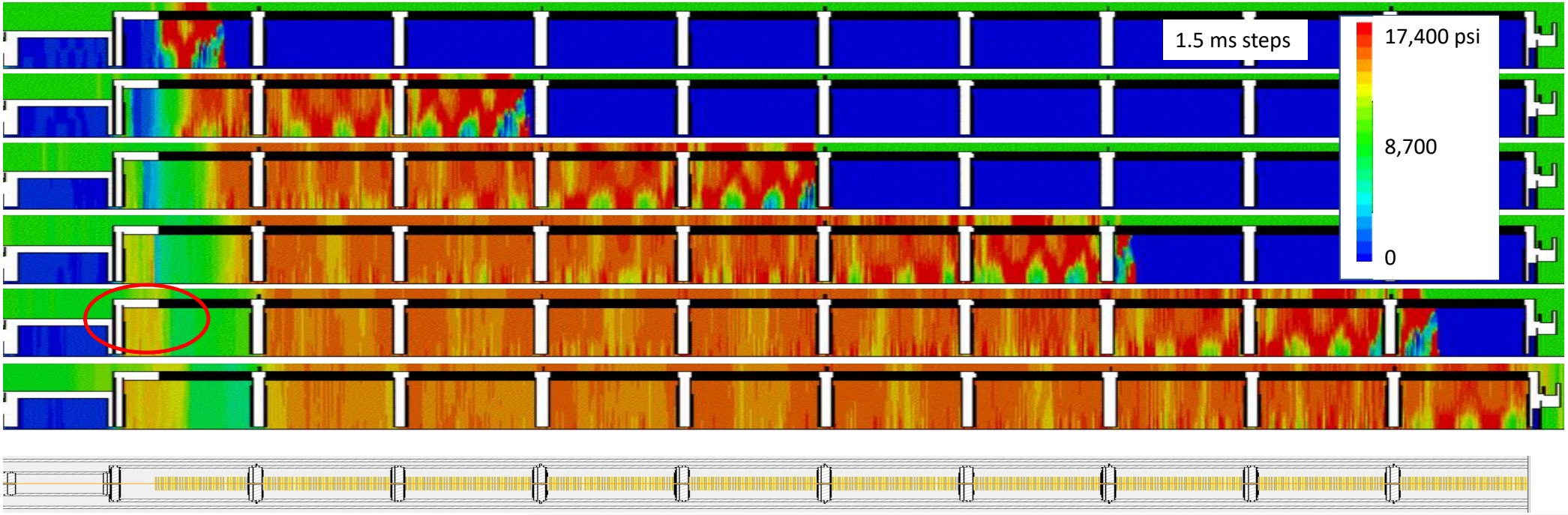
Differential Pressure on Gun Wall

- The combination of high pressure from the fluid hammer inside the gun and low pressure in the annulus results in high differential
- Gun rating is exceeded resulting in rupture of the gun wall



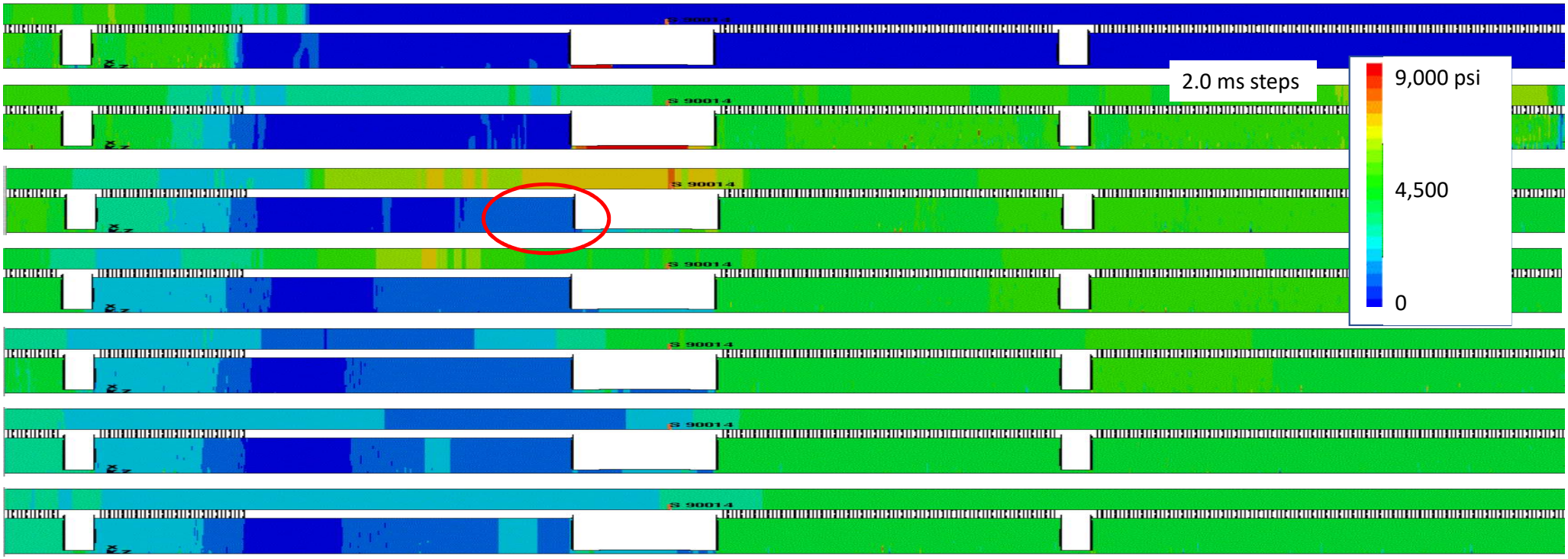
Simulation of Partially-Loaded Guns

- 7 inch 18 SPF guns, 40 g LD charges
- 8,000 psi hydrostatic pressure
- Top gun is 80% loaded
- Moderate burst differential develops at blank end



Simulation of Partially-Loaded Guns

- 4.625 inch 5 SPF guns, 39 g charges
- 200 psi hydrostatic pressure
- Upper gun is 40% loaded
- Minimal collapse differential develops at blank end



Factors That Exascerbate the Resulting Dynamics

Factors that cause guns to flood more rapidly:

- High wellbore pressures
- Propellants

Factors that increase the differential pressure across the gun wall:

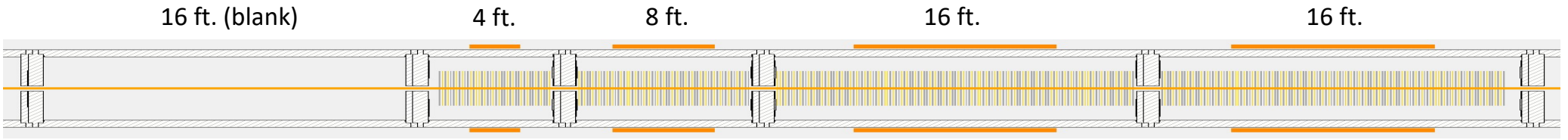
- Charge energy
- Low pressure sinks nearby such as other lightly-loaded guns or vented spacers

Length of gun and % loading:

- Longer guns have the potential to build up more inertia which can amplify the fluid-hammer effect
- The magnitude of the effect will also vary with % loading and wellbore pressure

Mitigating Risks of Failures

- Take precautions with high pressure wells or with propellant jobs
- Using shorter guns to better match perforated intervals, thus minimizing the need for partial loading
  - e.g. replace a 50% loaded 16-foot gun with two 8-foot guns
  - Avoid guns loaded ~25% to 75% at least in high risk conditions
- Pre-job simulations identify potential risks and allow for changes to the string design (early in planning stage to allow for changes to be made)



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QUESTIONS?
THANK YOU

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