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Evaluation of the Transportable Detonation Chamber for Processing Recovered Munitions

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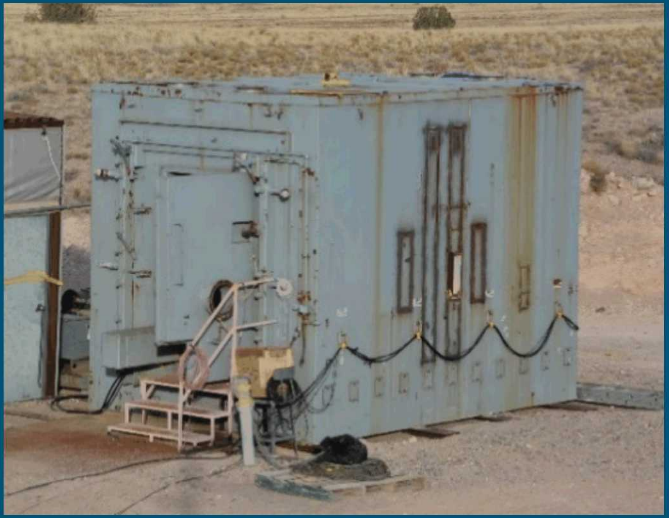
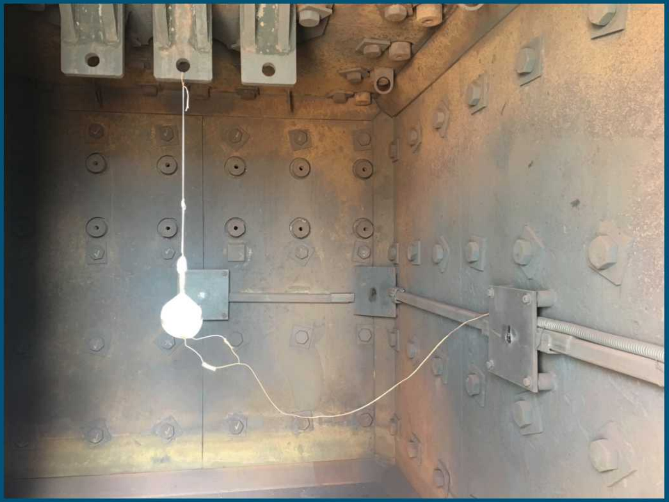
Background

Transportable Detonation Chamber (TDC) Background

- Munition destruction system designed by CH2M HILL
- Consists of Donovan TC-60 blast chamber (shown), expansion chamber, air pollution abatement system, and various support systems/utilities
- 88-ton welded steel chamber
- Rated at 40 lb TNT NEW
- Inner and outer walls separated by wide-flange beams and sand
- Inner blast door and outer vapor door
- Chamber is lined with replaceable AR-500 armor steel plates that are bolted to the inner walls





TDC Background

- Chamber was acquired by the US Army Recovered Chemical Materiel Directorate (RCMD) in 2014
- Planned to use the chamber for chemical munition demilitarization at large burial sites
- Used previously for chemical demilitarization, but with reliability issues and unsatisfactory throughput
- RCMD requested that SNL evaluate the fitness of the TDC for chemical weapon demilitarization and recommend improvements

Set-up and Instrumentation

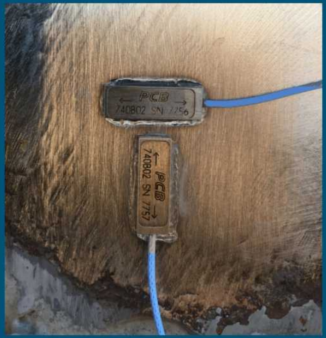
Explosive Testing

- Performed 29 total shots (4 of which were in open air)
- All charges used bulk Composition C-4 and RP-83 EBW detonators
- Studied chamber dynamic response and effects of interstitial sand and water bags

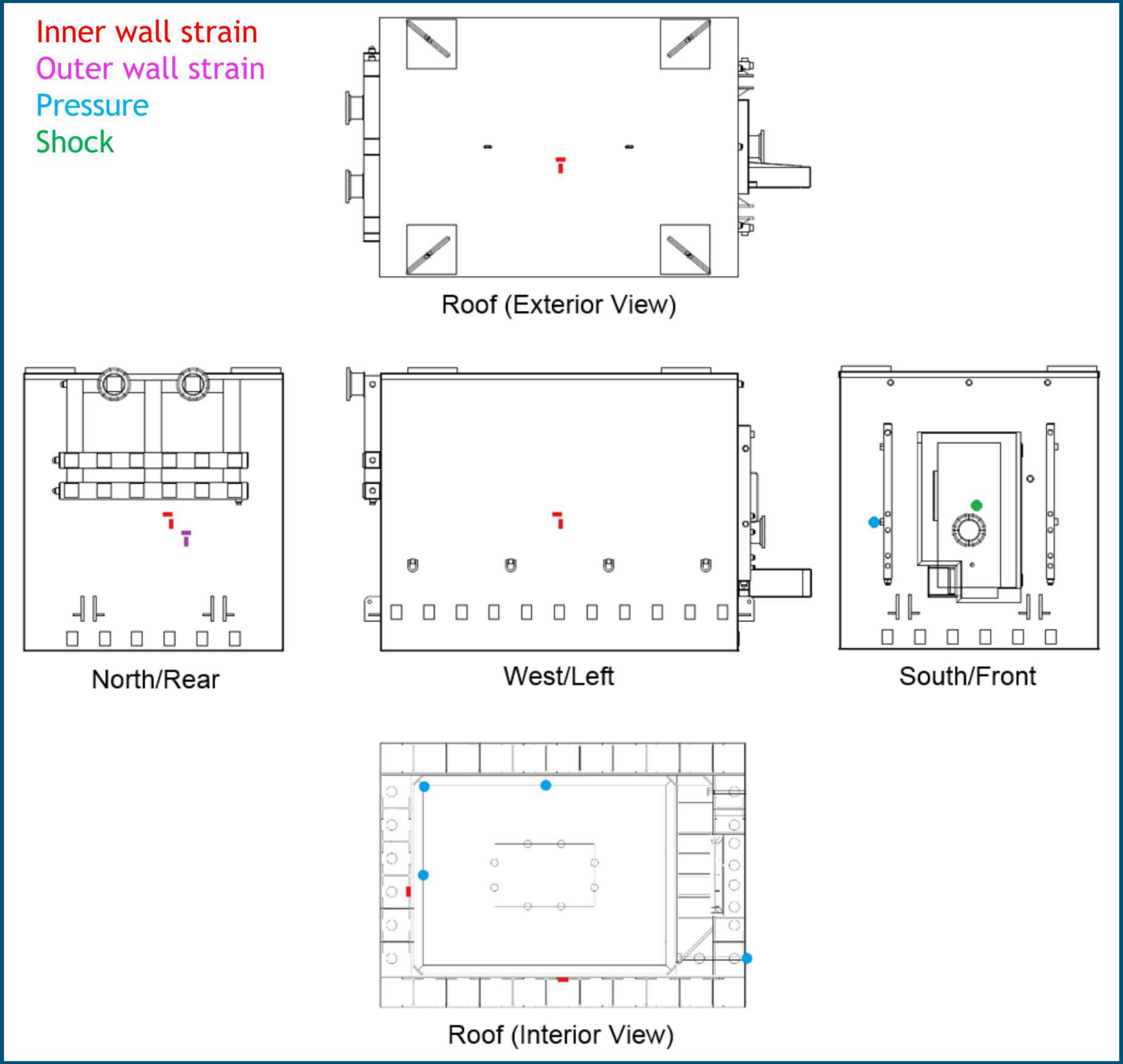
Shot No.	NEW	Open/Plugged Exhaust	Sand	Water Bags
1	1.25	OPEN		
2	1.25	OPEN		
3	1.25	OPEN		
4	1.25	OPEN		
5	1.25	OPEN		
6	1.25	OPEN		
7	1.25	OPEN		
8	1.25	OPEN		
9	1.25	PLUGGED		
10	5	PLUGGED		
11	1.5	OPEN		
12	1.25	OPEN		
13	5	OPEN		
14	5	OPEN		
15	5	OPEN		
16	5	OPEN	✓	
17	5	OPEN	✓	
18	5	OPEN	✓	
19	5	OPEN	✓	✓
20	5	OPEN	✓	✓
21	5	OPEN	✓	✓
22	5	PLUGGED	✓	
23	5	N/A - Open air, not in TDC	N/A	✓
24	5	N/A - Open air, not in TDC	N/A	
25	5	N/A - Open air, not in TDC	N/A	✓
26	5	N/A - Open air, not in TDC	N/A	✓
27	5	PLUGGED	✓	
28	5	PLUGGED	✓	
29	20	OPEN	✓	

Instrumentation

- Piezoelectric strain
  (exterior surfaces of inner and outer walls)
- Piezoelectric pressure
  (internal quasi-static and reflected pressures)
- Piezoelectric shock
  (not discussed in this presentation)



Instrumentation Layout

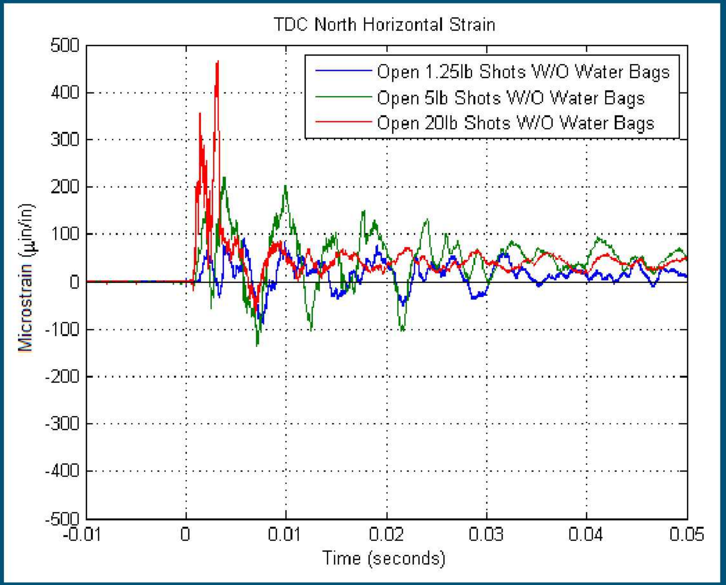


Results

Strain: General Observations

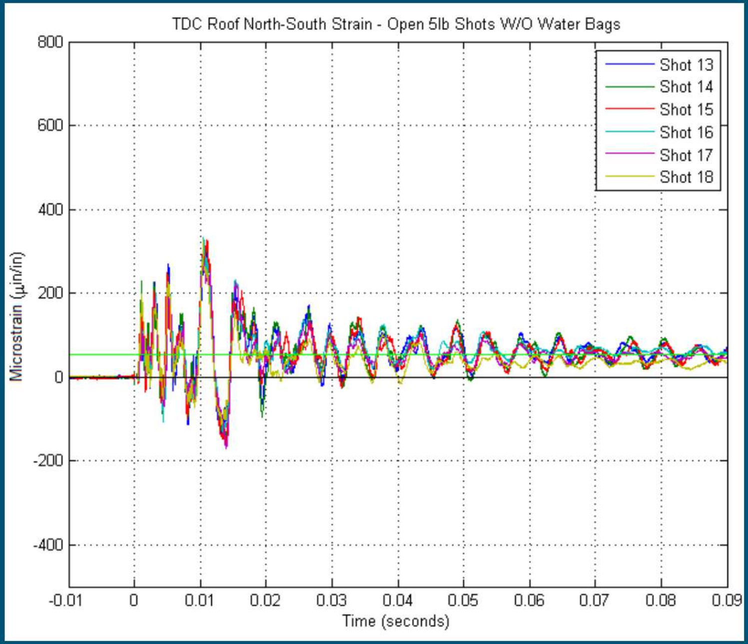
- Weaker direction (perpendicular to beam) on each face exhibited higher strain than the beam-strengthened direction
- The highest peak strain for the north horizontal inner wall strain gauge was 93, 222, and 463 outward microstrain for 1.25lb, 5lb, and 20lb shots, respectively
- If these points follow a linear trend, the expected strain at 32 lb (the CH2M HILL rating of the vessel for Composition C-4) is about 694 microstrain

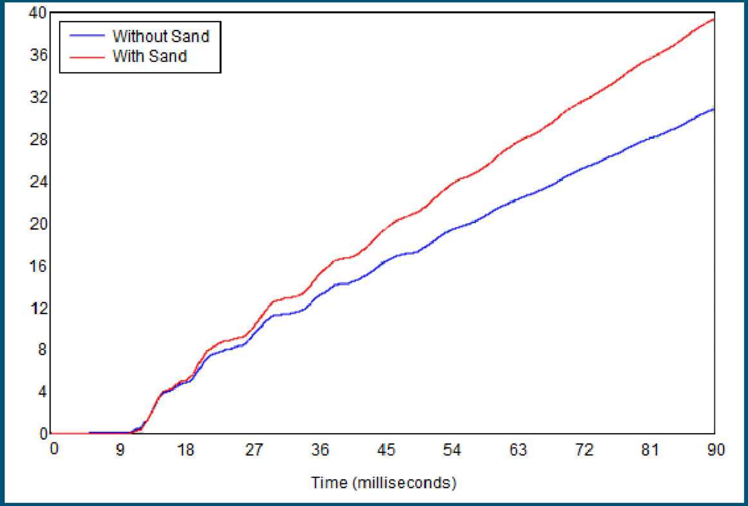
Face	Peak Strain (μstrain) Parallel to Beam	Peak Strain (μstrain) Perpendicular to Beam
North	100	200
West	60	220
Roof	60	310



Strain: Effects of Interstitial Sand

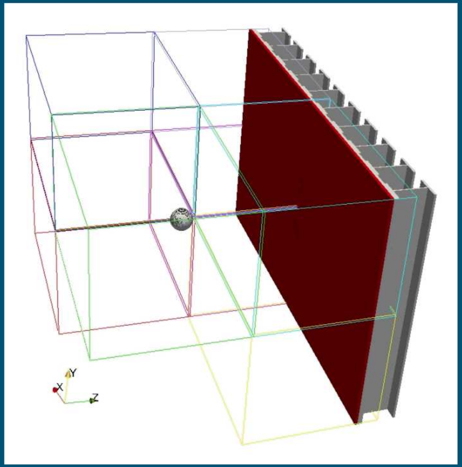
- Designers claimed the sand helped to dampen shocks associated with the explosive events
- Shots 13-15 were performed *without* sand, Shots 16-18 *included* sand
- No obvious changes in frequency or magnitude of strain oscillations
- Running integration of the strain signals indicates that the sand couples *more* impulsive load to the inner wall

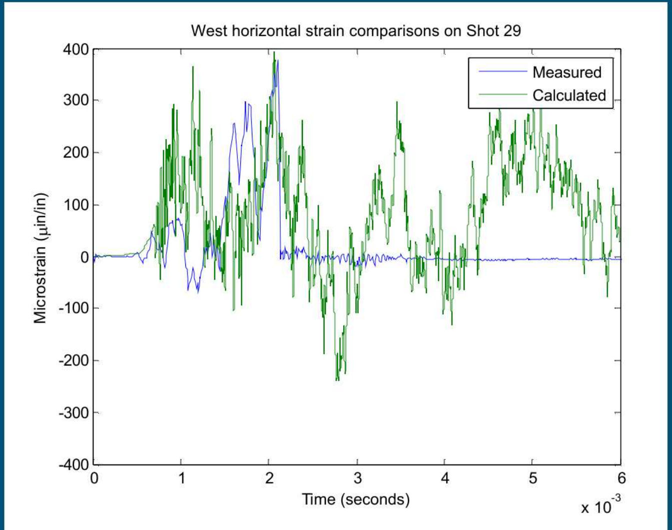


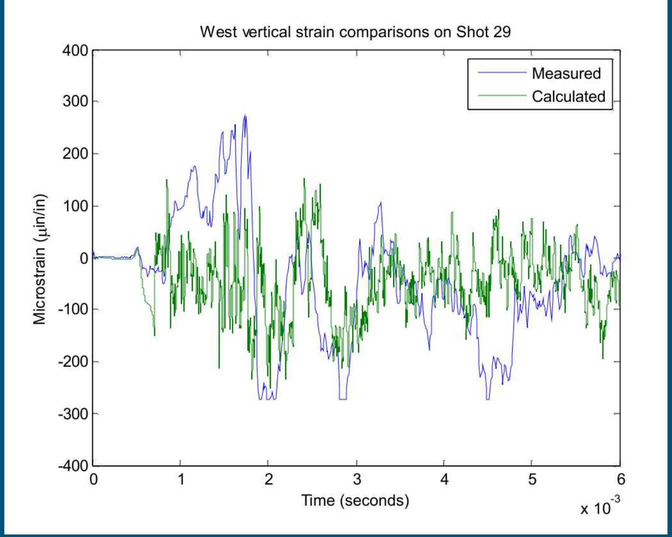


Strain: ASME Code Case 2564

- Inner wall/beam assembly was modeled in a combined Eulerian/Lagrangian code (hydrocode/FEA)
- Subjected to a 20 lb explosive event
- Similar amplitudes and times of arrival as real signal
- Simulated again at 40 lb NEW
- No equivalent plastic strain occurred in the wall – code case is met in this aspect (peak equivalent plastic strain averaged through the chamber thickness must not exceed 0.2%)
- Full analysis of the rest of the chamber would need to be done to meet code case

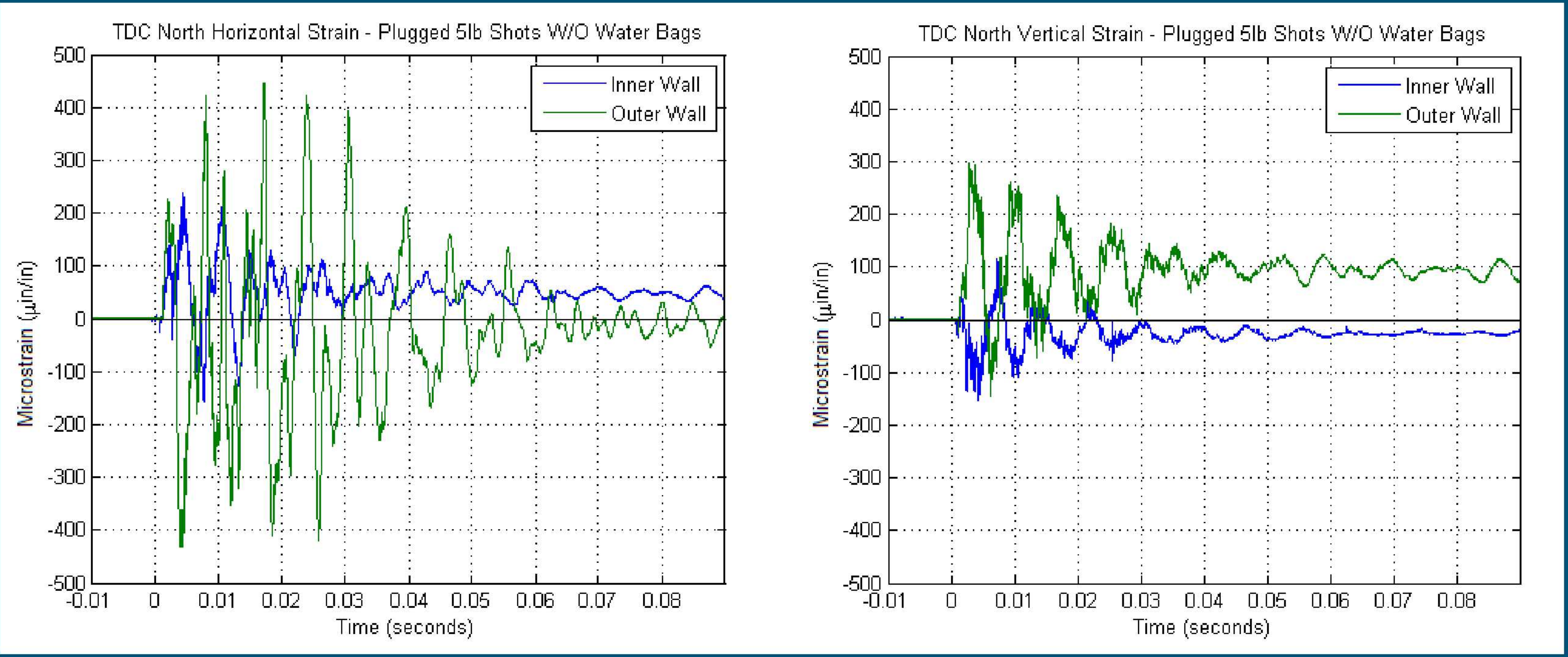






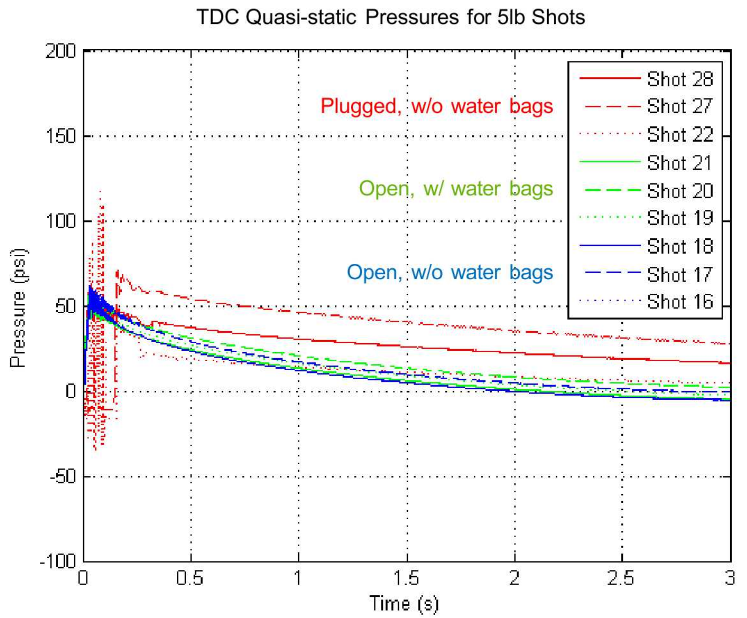
Strain: Comparison of Inner and Outer Walls

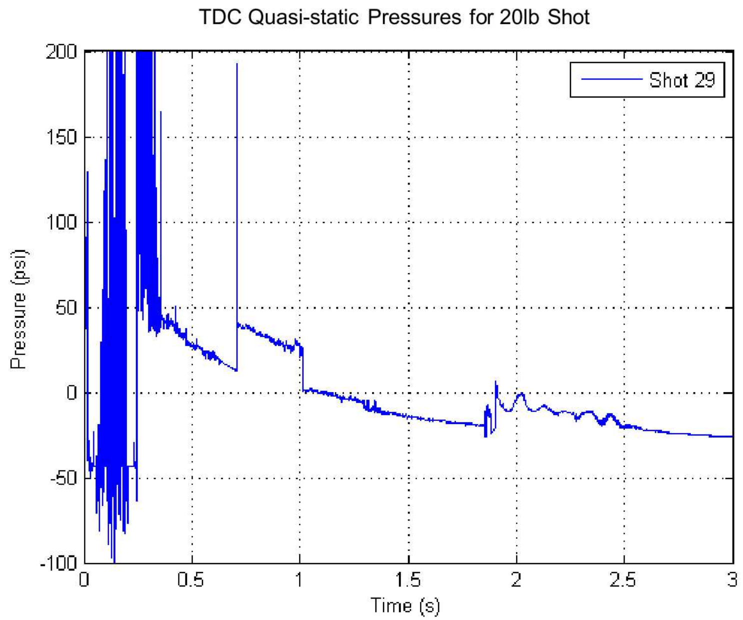
- Inner wall dampens more quickly than the outer wall (more mass)
- About the same vibrational frequency
- The inner and outer walls vibrate opposite each other in both directions—when one bows outward, the other bows inward



Static Pressure

- Water bags do not have any effect on the static pressure
- Plugging the exhaust merely slows the depressurization of the vessel, but the initial peak static pressure does not appear to be highly affected
- Peak pressure at 5 lbs is just over 50 psi, while 169 psi was measured for the 20 lb shot. For an NEW increase of 4 times, the peak static pressure increased 3.4 times.

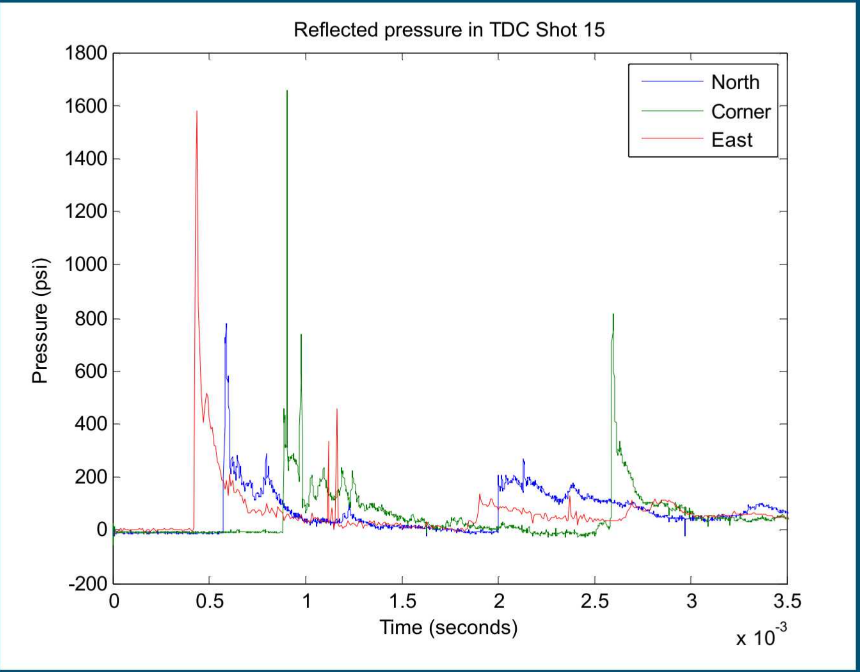




Reflected Pressure

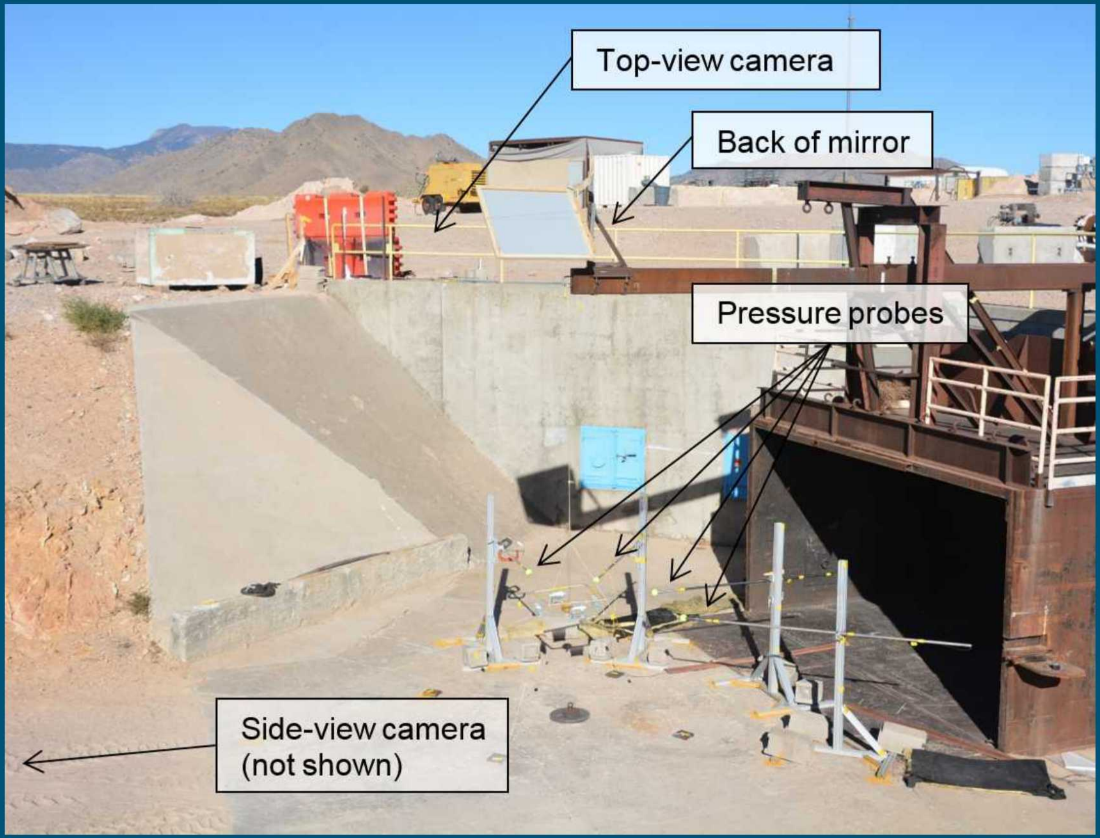
- Reflected pressure was measured at three known distances away from the charge inside the chamber
- Distances and times of arrival were used to estimate pressure wave speeds, which were later compared to the open-air tests

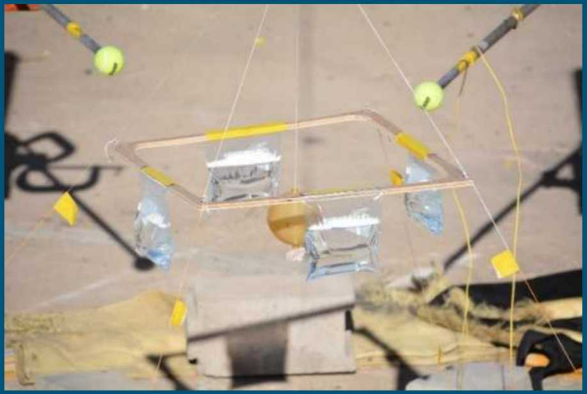
Charge Weight (lb)	North Speed (km/s)	East Speed (km/s)	Corner Speed (km/s)
20	2.7	3.0	2.5
5	2.2	2.3	1.9
1.25	1.5	1.6	1.3



Open-Air Shots

Open-air Shots: Layout



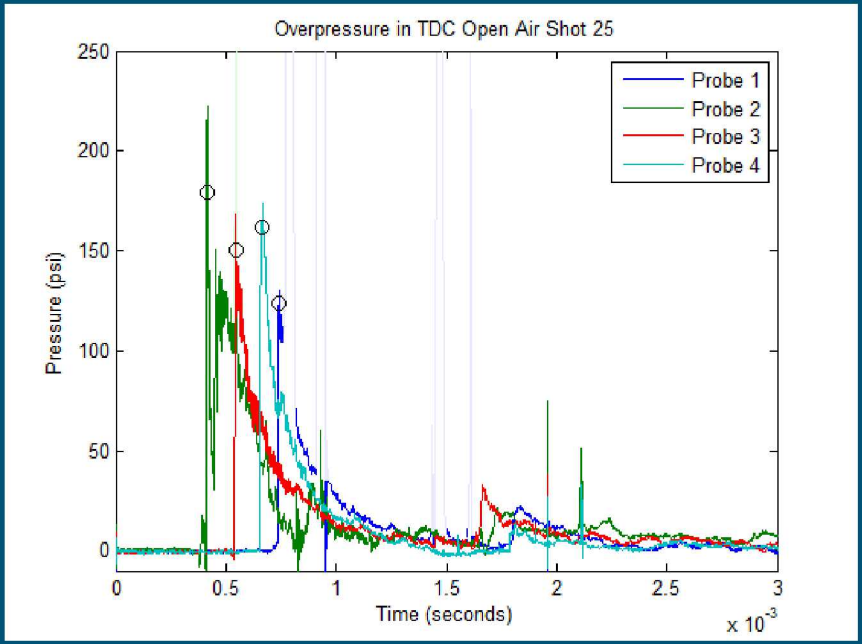


Tests were set-up to simulate event inside chamber (pressure sensors at the same distances)

Measured overpressure (static pressure) and captured high-speed video

Water Bag Effect on Peak Overpressure

- Higher pressures are observed between water bags
- Peak overpressure decreases behind water bags (about 24 psi for the 43-inch gauges and 68 psi for the 54-inch gauges)



Gauge	Shot 23 (psi)	Shot 24 (psi)	Shot 25 (psi)	Shot 26 (psi)	Distance from charge (in)	Aim w.r.t. water bags
1	131.1	171.0	127.3	116.0	54	Through
2	275.0	215.8	177.8	250.0	43	Between
3	246.4	234.2	150.0	234.2	43	Through
4	N/A	248.3	160.8	210.4	54	Between

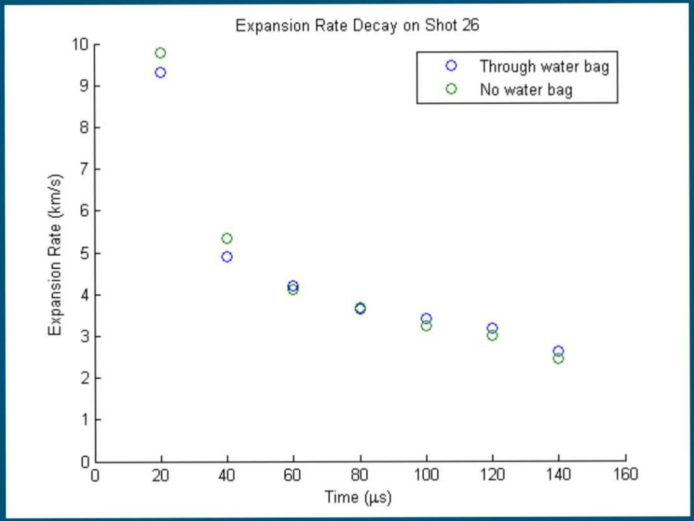
Comparison of Time of Arrival of Pressure Wave

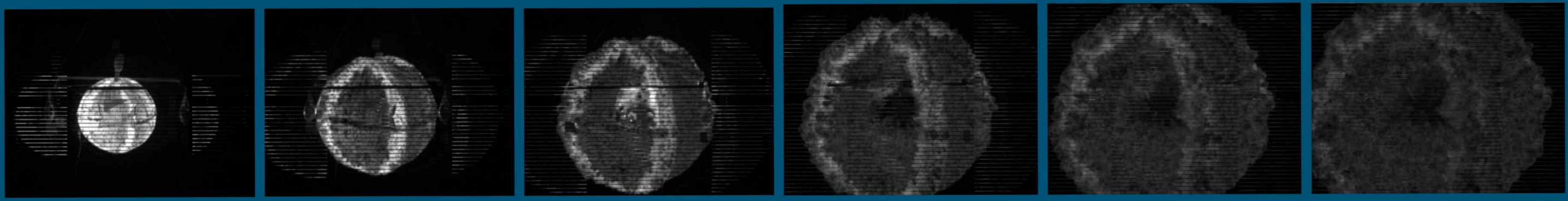
- Times of arrival at each pressure gauge was used in conjunction with known distance from the charge to determine pressure wave speed
- The wave speeds calculated in both types of events compared well to each other
- Based on the times of arrival of peak pressure, the presence of water bags slows down the arrival of peak overpressure—about 84 µs later at the 43-inch (east) location and about 142 µs later at the 54-inch (north) location

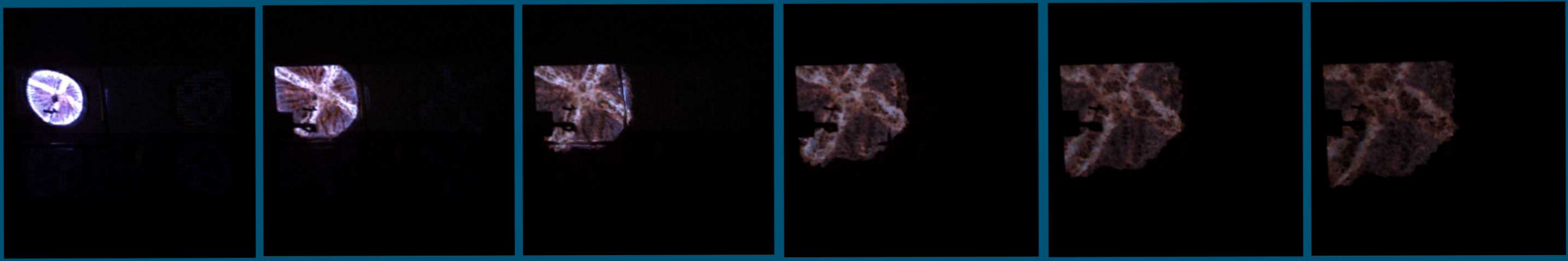
Measurement Location	Average Speed (km/s) Reflected pressure in chamber	Average Speed (km/s) Overpressure in open-air
North gauge	2.2	1.891-2.449
East gauge	2.3	2.189-2.597

Visual Effect of Water Bags on Fireball

- Images from the top-view video were examined to determine the fireball expansion rate (plot) with and without a water bag
- No effect on fireball expansion rate from the presence of water bags
- High speed video shows no alteration of the fireball shape due to water bags







Issues Encountered During Testing

Broken Bolt Cup Welds

- Three bolt cup welds failed or were discovered incomplete
- First failure was discovered on a plugged 5 lb test
- The second two were discovered through pressurization of the chamber
- Bolt cups were inspected by cutting into outer wall
- The third failure looked to have been pre-existing—more corrosion
- In the intended use, these failed welds would allow chemical agent to leak outside of the chamber and into the sand
- The large armor plates rely on these welds to stay in place





Recommended Path Forward

Recommended Path Forward

- SNL *does not* recommend using the TDC for demilitarization of chemical munitions
  - Widespread weld failures (difficulty inspecting the bolt cups)
  - Design of the welded penetrations is not robust to the dynamic flexing of the vessel walls during weapons destruction
- This failure mechanism was experienced during operations in Columboola, Australia in 2011—a quarter were found to be suspect upon inspection
- No formal inspection of the bolt cup welds during fabrication or repair
- An unintended release would slow throughput, increase cost, and increase risk
- SNL *does* recommend using the chamber for demilitarization of non-chemical (conventional) munitions, given that the chamber is regularly monitored for structural and weld integrity
- The primary hazards associated with conventional demilitarization are fragments and pressure –the TDC handles these two hazards within its rated capacity

Questions?