COE CST Sixth Annual Technical Meeting

Task 299: Nitrous Oxide Composite Case Testing

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Center of Excellence for Commercial Space Transportation

Agenda

- Team Members
- Task Description
- Schedule
- Results
- Conclusions

Team Members

- PI: Seokbin (Bin) Lim (NMT)
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Task Description

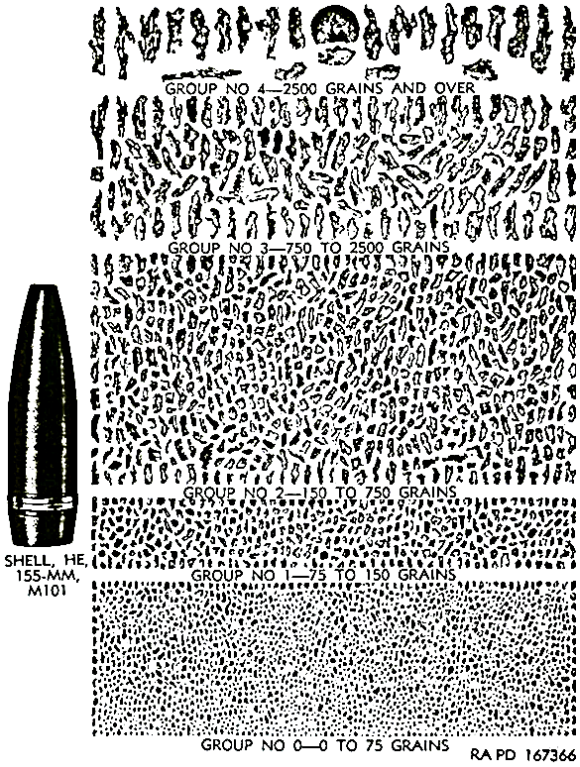
Objectives

- Develop an understanding of fragmentation hazards from composite tanks used for fuel/oxidizer storage
- Construction of hypothesis and experimental validation of how cracks form in test samples

Tasks

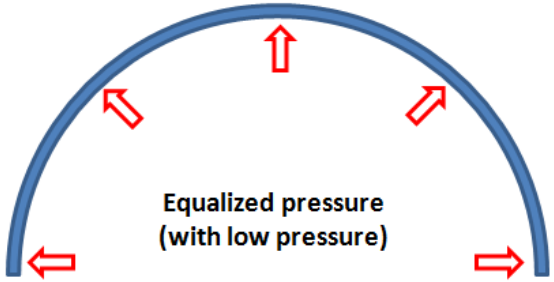
- 5 tests each of Al 6061 & composite tubes to understand the crack opening behavior (10 tests total)
- 5 Al liner with composite wrapped tanks (space application grade)
- Develop methods to predict crack opening behavior
- Develop standard test procedures for composite materials under a high-rate loading
- Numerical simulations to predict the fragmentation (in progress)

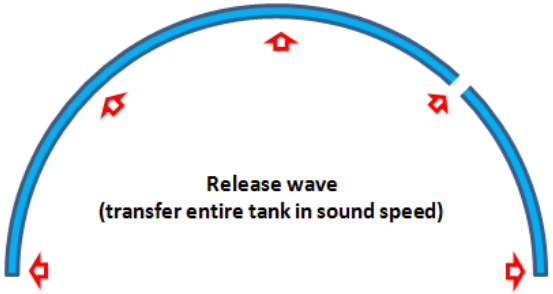
Hypothesis



Static vs. Dynamic
(Very slow loading Vs. Fast-Continuous loading)

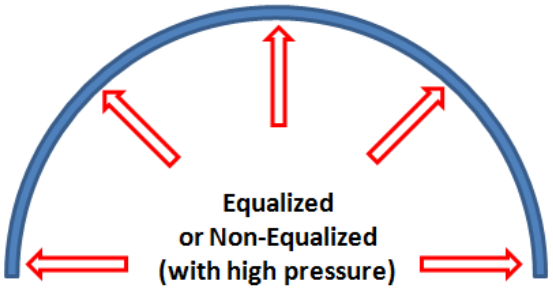
Equilibrium
(low strain-rate)

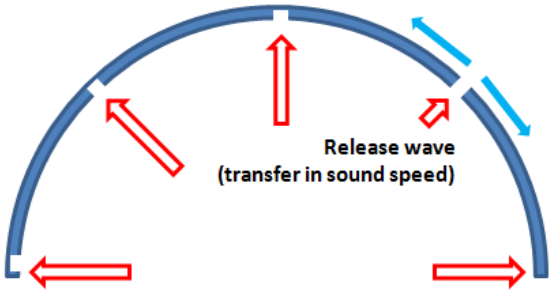




A weak point of the tank will be ruptured, and the subsequent release wave from the ruptured area will lower the stress in entire tank

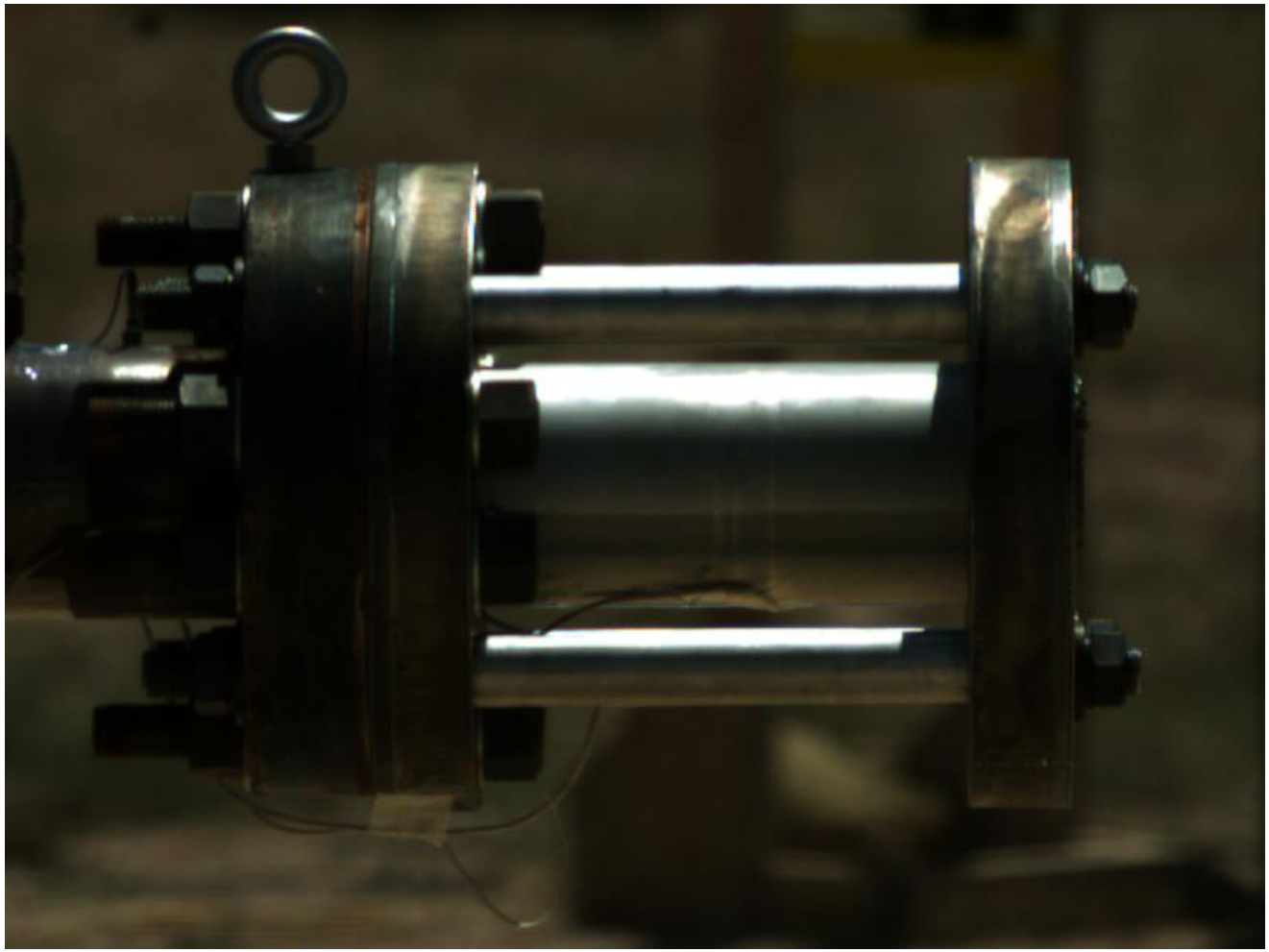
Non-equilibrium
(high strain-rate)



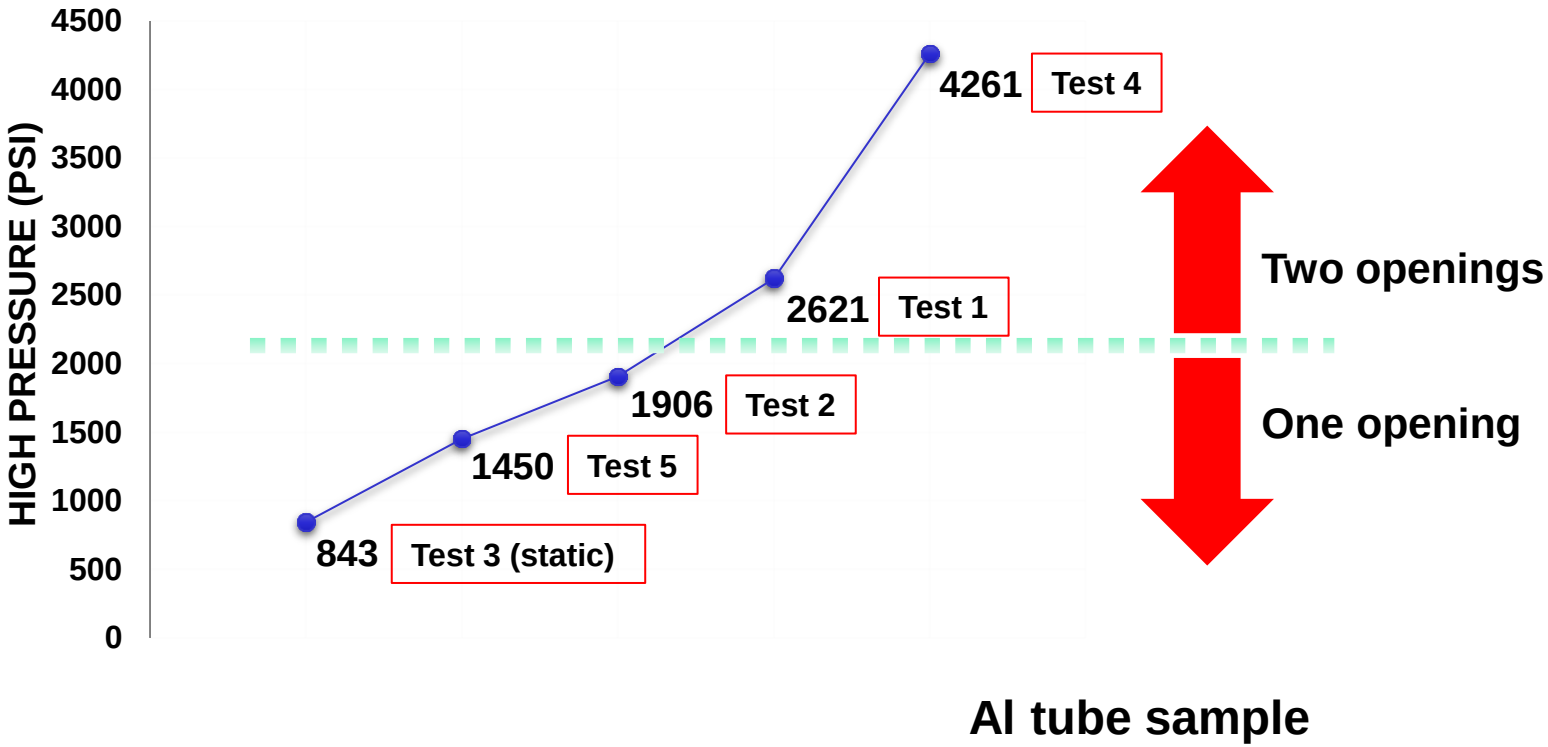


A weak point of the tank will be ruptured initially, and the subsequent release wave forms but the speed of release wave is not fast enough to prevent extra initiations of ruptures nearby

Test from ATM5



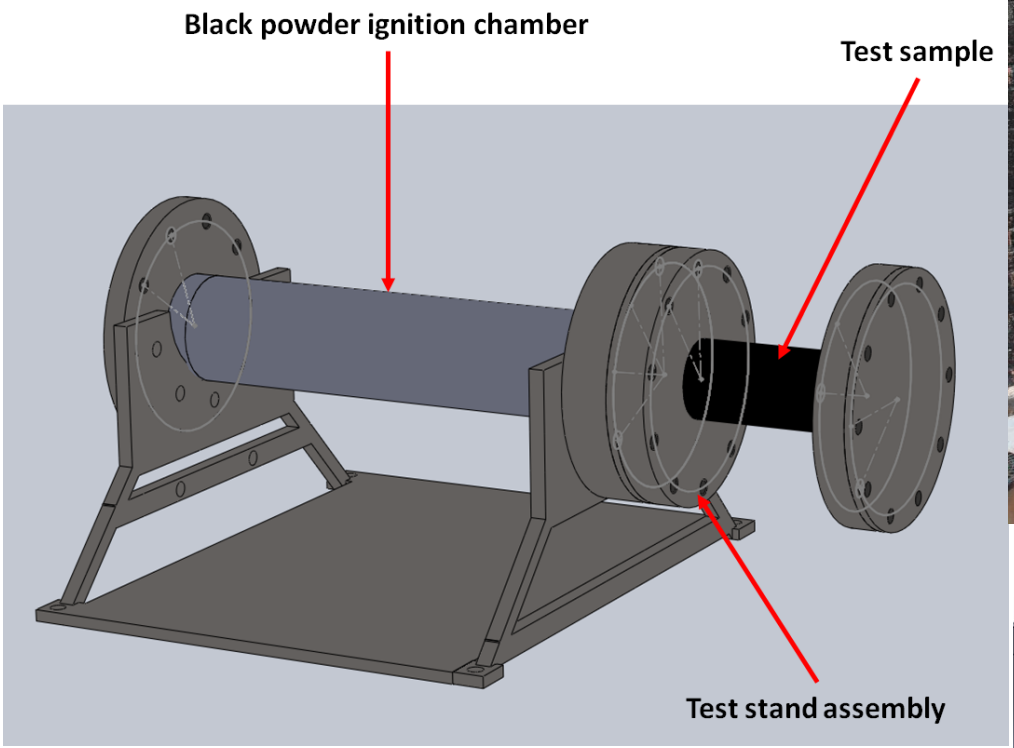
Results from ATM5

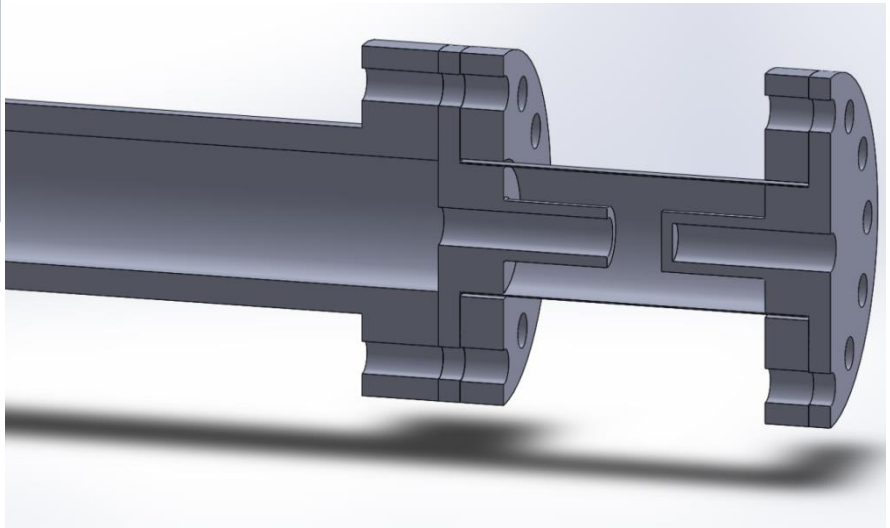


Test Matrix

Date	Loading Source	Sample Material	Type	Success
8/19/2015	Nitrogen Tank Farm	Aluminum	Cylinder	Yes
9/10/2015	Nitrogen Tank Farm	Aluminum	Cylinder	Yes
9/10/2015	Nitrogen Tank Farm	Aluminum	Cylinder	Yes
9/23/2015	Nitrogen Tank Farm	Aluminum	Cylinder	Yes
9/30/2015	Nitrogen Tank Farm	Aluminum	Cylinder	Yes
4/13/2016	Nitrogen Tank Farm	Carbon Fiber	Cylinder	No
4/14/2016	Nitrogen Tank Farm	Carbon Fiber	Cylinder	No
6/16/2016	Nitrogen Tank Farm	Carbon Fiber	Cylinder	No
6/21/2016	Nitrogen Tank Farm	Carbon Fiber	Cylinder	No
7/10/2016	Nitrogen Tank Farm	Carbon Fiber	Cylinder	No
9/29/2016	Black Powder Chamber	Carbon Fiber	Cylinder	Yes
10/7/2016	Pyrodex Cavity	Carbon Fiber / Aluminum	Tank	No
10/10/2016	Pyrodex Cavity	Carbon Fiber / Aluminum	Tank	Yes
10/10/2016	Pyrodex Cavity	Carbon Fiber / Aluminum	Tank	Yes

Test Fixture

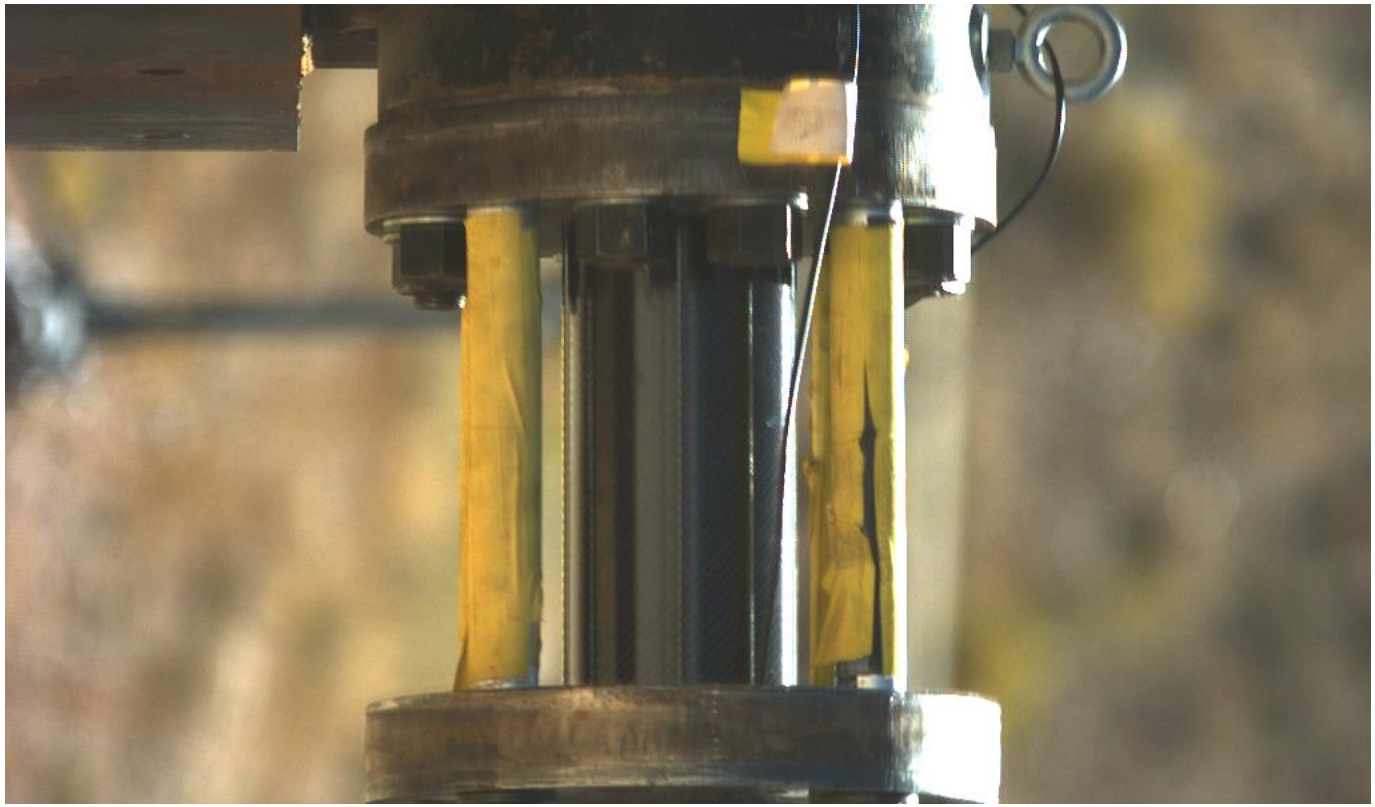


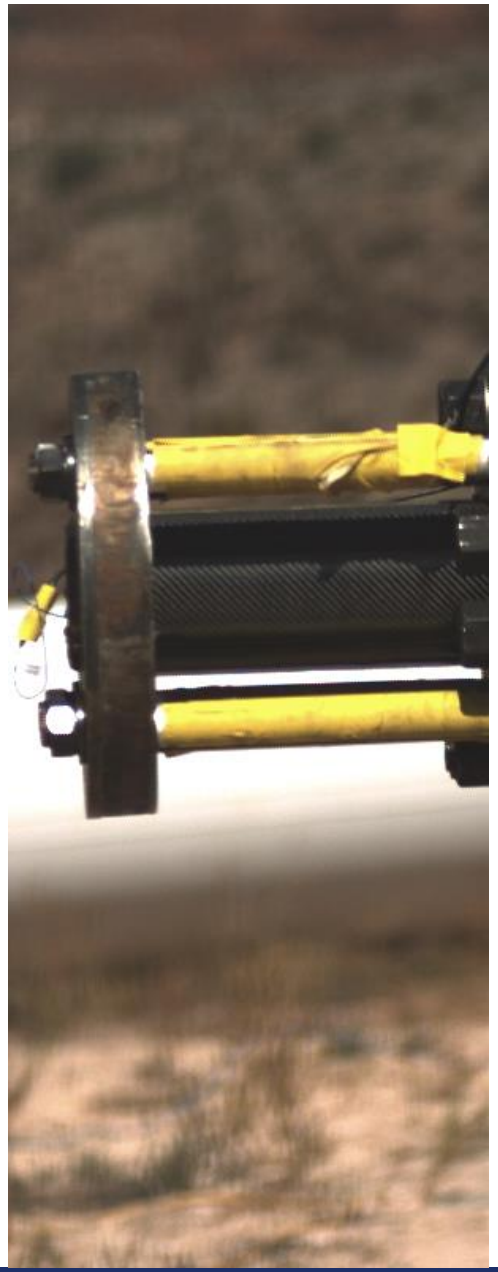


1/16 in. Wall thickness,
12 in. Long,
6 in. Diameter,
Carbon Fiber Composite Tube (commercial)
The tube is pre-pressurized to 700psi

Test Results

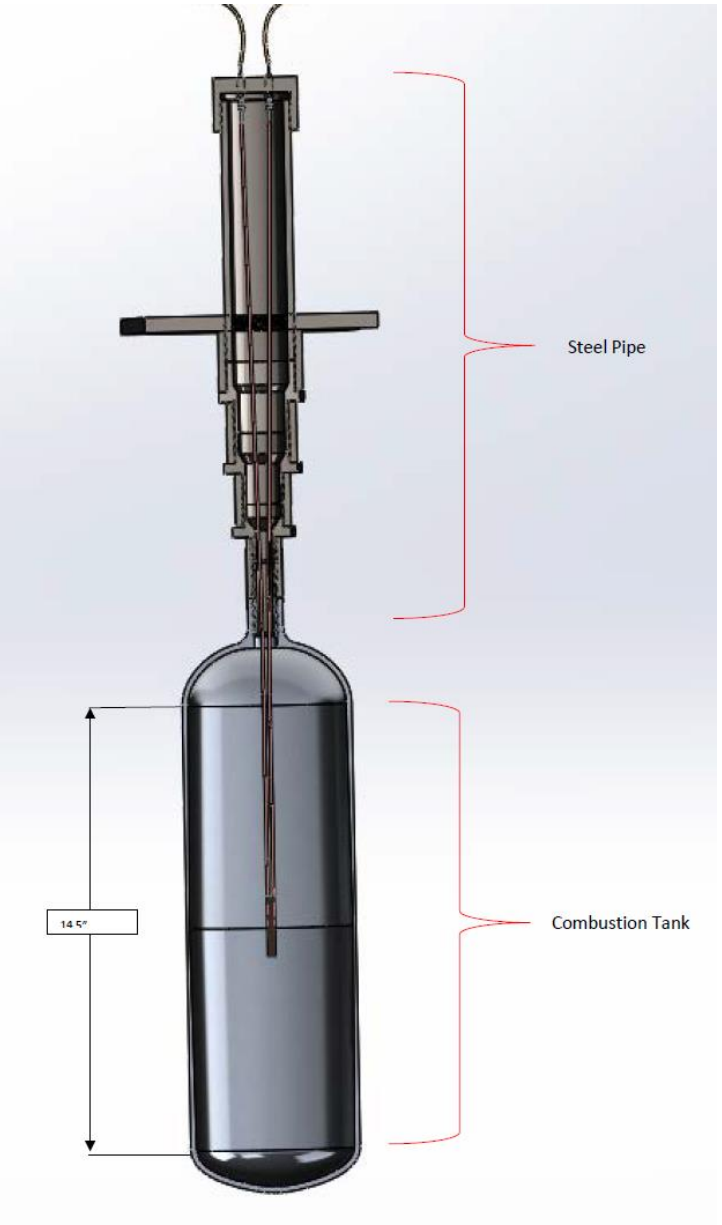
4000 Psi (expected)
(4.3 lbs Black Powder)





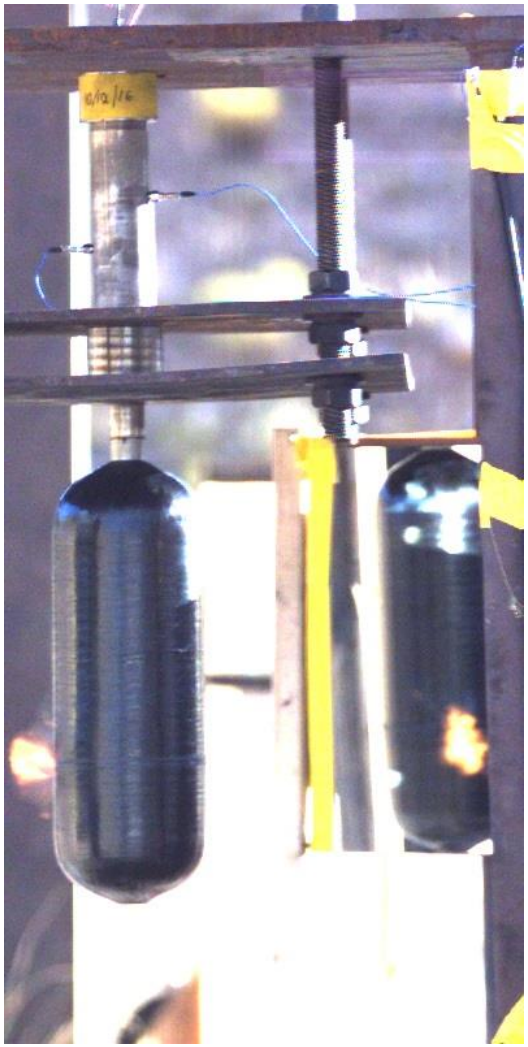
Secondary fractures after single opening

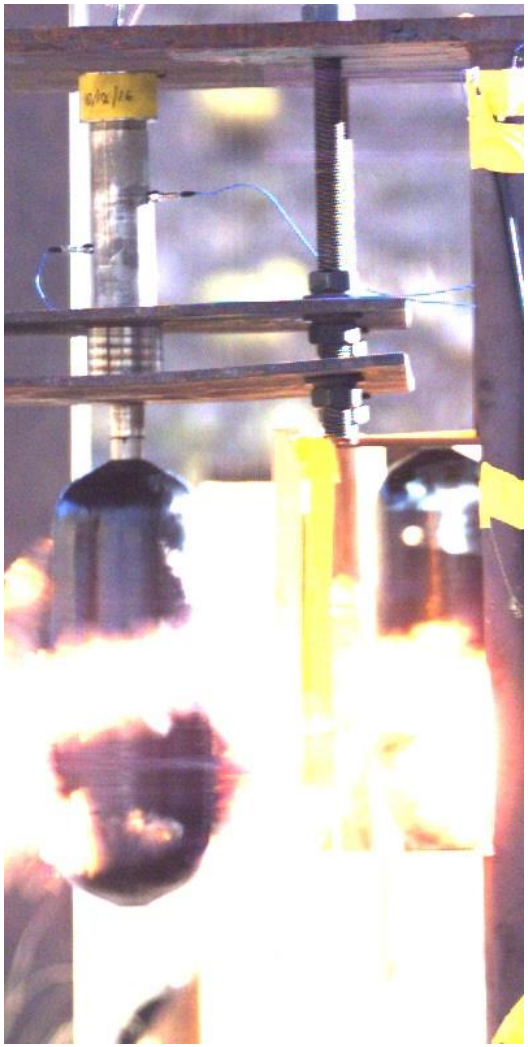
Test Fixture

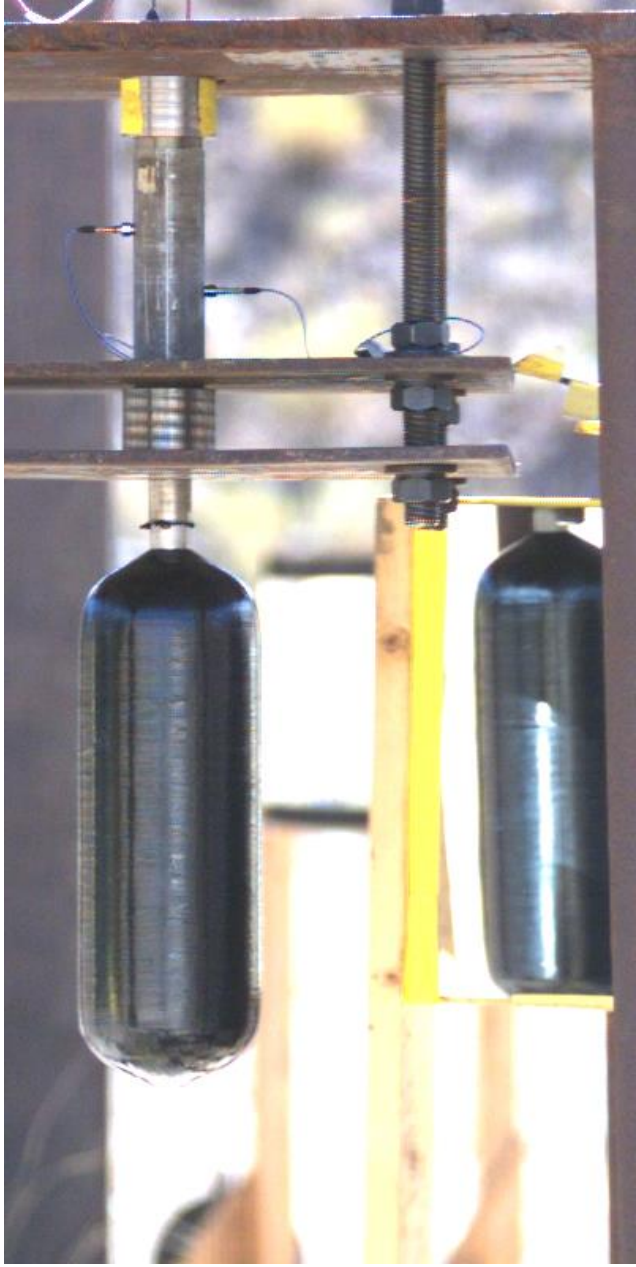


~1/4 in. Al liner with ~1/4in composite (3lbs) wrapped wall
~16 in. Long,
6 in. Diameter, 203 cu in.
Space grade tanks (material properties are not available)
3lbs Pyrodex
20,400 Psi (expected)

Test Results







Secondary fractures after single opening

Results

- Two different types of crack/fracture pattern
- Brittle vs. Non-brittle fractures

Type	Non-brittle fracture (ATM5)	Brittle fracture (ATM6)
Shrapnel	Large pieces	Small/Many pieces
Origin	One or Two openings	Single opening (so far)
Material	Aluminum	Carbon fiber and Composite
Pattern	Tend to maintain initial openings	Multiple crack formation after the initial opening
Approach	Shock/Release wave speed in the sample (gas)	Extreme dynamic event

Conclusions

- The number of openings depends on the initial pressure loading (one or two openings)
- The size of fragments gets smaller as they impact to nearby objects
- The number of opening predicts the size of initial fragment (in non-brittle)
- The number of opening provides a way to determine the initial velocity/size of fragments after explosion
- Two different approaches are needed depending on the type of sample (Brittle vs. Non-brittle) fracture patterns and the crack formation

Non-brittle

Pressure loading → **Opening** (**With large fragments**) → **Secondary impact** → **Shrapnel** (**Few/Large**)

Brittle

Pressure loading → **Opening** (**Single**) → **Secondary cracks** (**& Secondary impact**) → **Shrapnel** (**Many/Small**)