EXPERIMENTAL RESULTS OF THE CONVECTIVE COMBUSTION OF AN HD 1.3 MATERIAL

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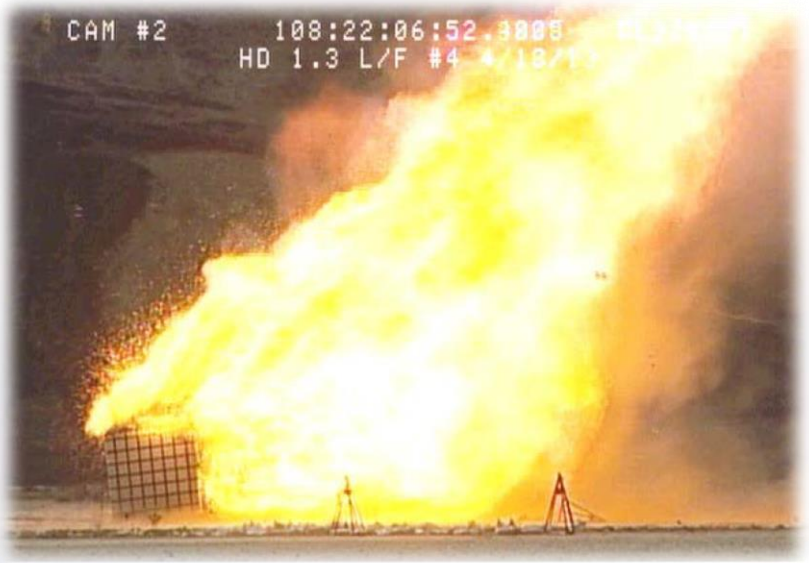
Overview

- Improving computer models
  - Predict outcome of combustion-driven events
- Experimental Results
  - Flame propagation throughout gun propellant bed
  - Resulting pressurization rate



Background

- Current siting methodologies for energetics other than HD 1.1 may not be adequate
- Previous testing on HD1.3 M1 gun propellant
  - Modeling and simulation tools are needed
  - Accurately describe initial transient convective combustion conditions

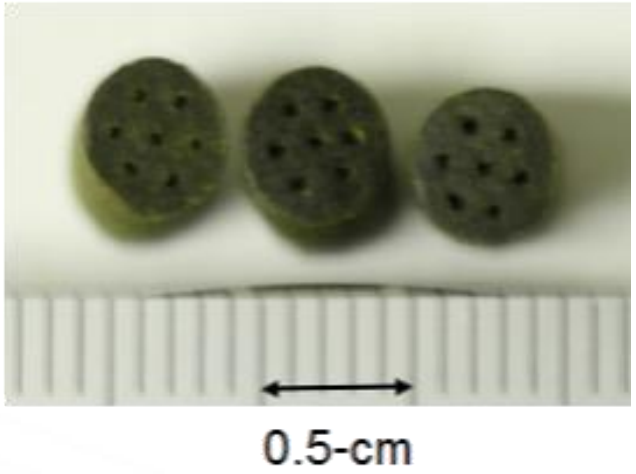
General Objective

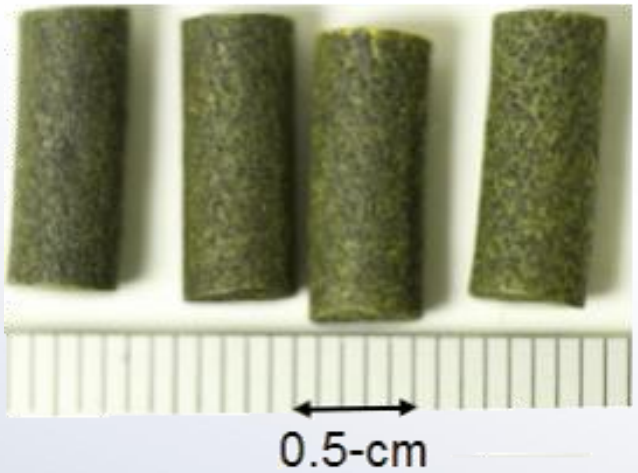
- Continuation of convective combustion experiments presented at JANNAF (Dec 2017, Newport News, VA)
  - Understand flame propagation and pressurization rate of M1 during transient combustion events
  - Thin-wall vs thick-wall polycarbonate tubes
- Support and improve computer models
  - Predict combustion-driven events in concrete structures

Sample

- Main Charge
  - M1 Propellant
  - 7 Perf pellets
    - 4.77 mm, 10.765 mm, and 0.451 mm perf

Ingredient	Weight %
Nitrocellulose	85.00 ± 2.00
Dinitrotoluene (DNT)	10.00 ± 2.00
Dibutylphthalate (DBT)	5.00 ± 1.00
Diphenylamine (DPA)	1.00 ± 0.10
Lead carbonate	1.00 ±0.20
Potassium sulfate	1.00 ±0.30





- Ignitor
  - Reynolds SQ-80 (450 mg Thermite)
- Aide
  - Red Dot Smokeless Powder

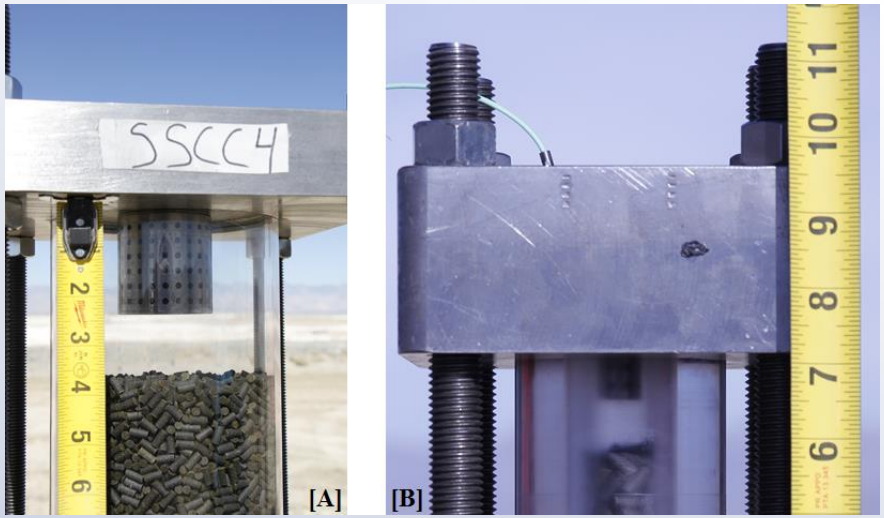
Confinement Configurations

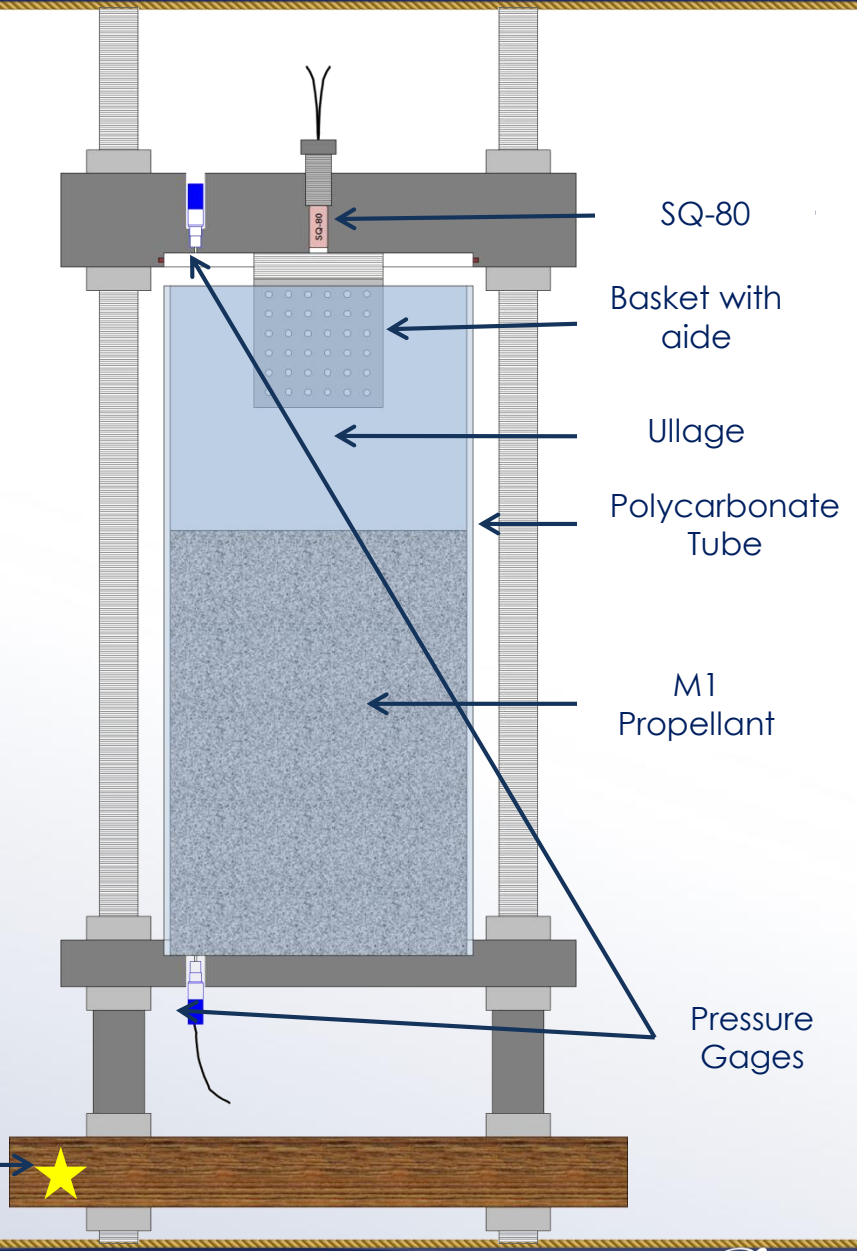
- Thin-walled container:
  - 5.75" ID
  - 6" OD
  - 0.125" wall thickness
  - 13" height

- Thick-walled container:
  - 1" ID
  - 3" OD
  - 1" wall thickness
  - 8" height

Equipment and Instrumentation

- High Speed Cameras
- Pressure gages
- Data Acquisition System
- Temporal Fiducial





Range Test Configuration

- M1 propellant is loaded into polycarbonate tube
- Tube is secured between base plate and top plate
- Igniter and ignition aide are housed in a basket

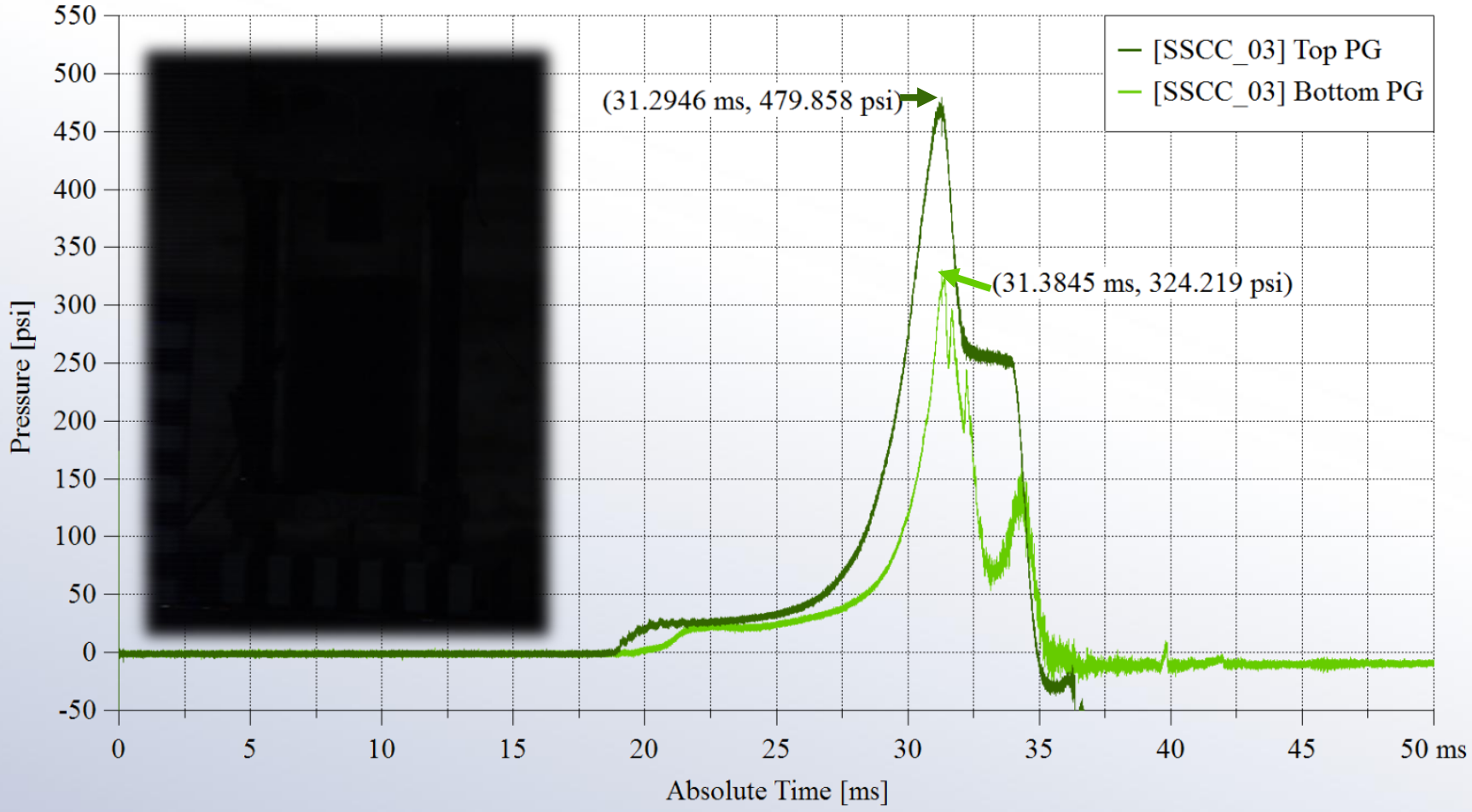
Test Details

- Six tests performed
  - 4 thin-wall, 2 thick-wall
- Thin-wall: interaction of flame with porous bed
- Thick-wall: allow additional video recording time

Test Number	Ignition Aide [g]	M1 Weight [g]	Bed Height [cm]	%TMD
SSCC_01	20.005	3186.364	21.285	57.054
SSCC_02	60.036	3186.364	20.955	57.953
SSCC_03	65.002	3186.364	20.955	57.952
SSCC_04	65.004	3204.545	21.590	56.569
SSCC_05	1.416	65.400	16.805	47.633
SSCC_06	1.416	65.480	16.538	50.781

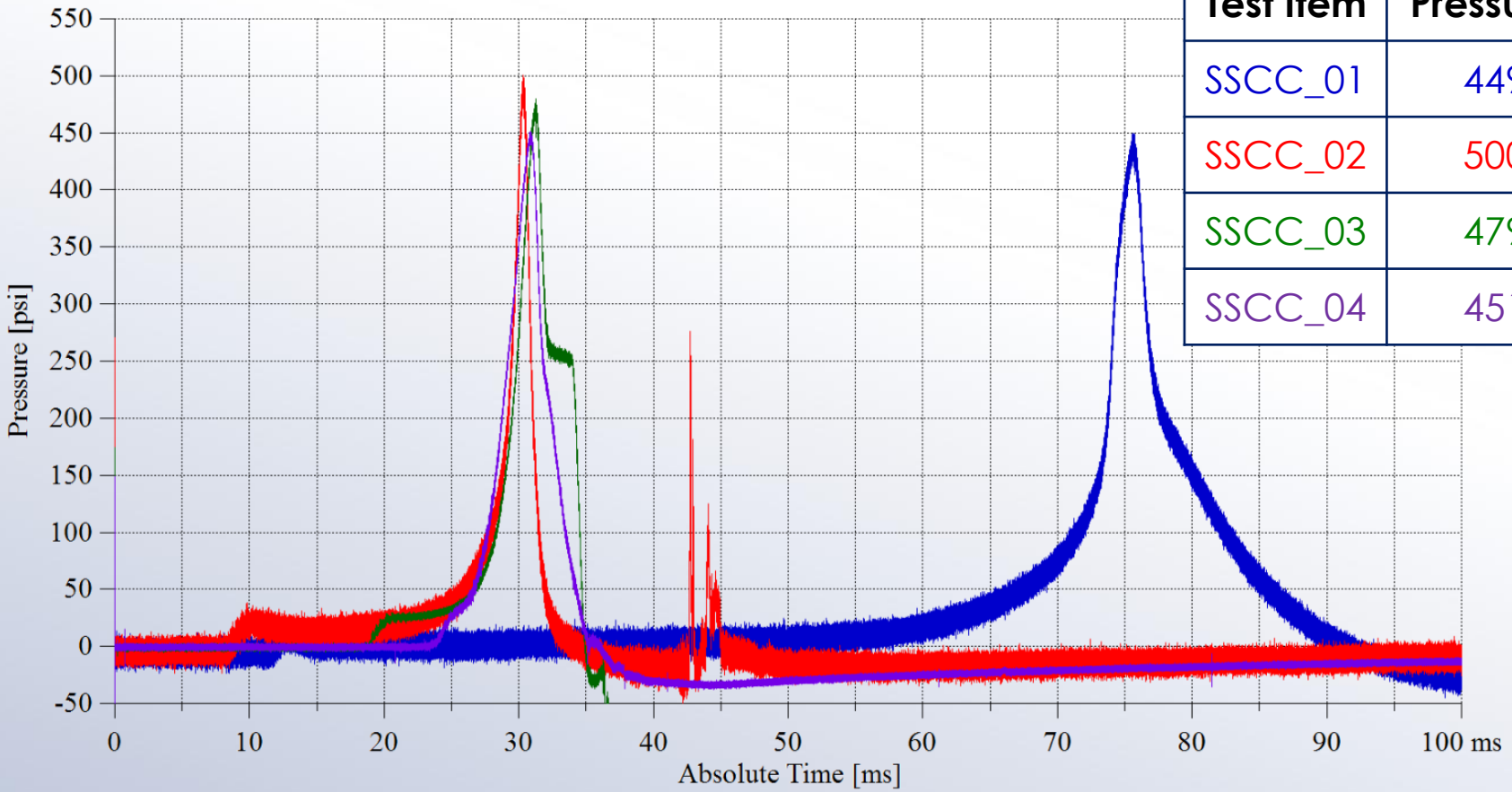
Pressure Trace Sample – SSCC_03

65.0018 g of Red Dot aide and 7.01 lbs (3179.68 g) of M1 Propellant in a polycarbonate tube



Thin-wall Tests – Pressure Results

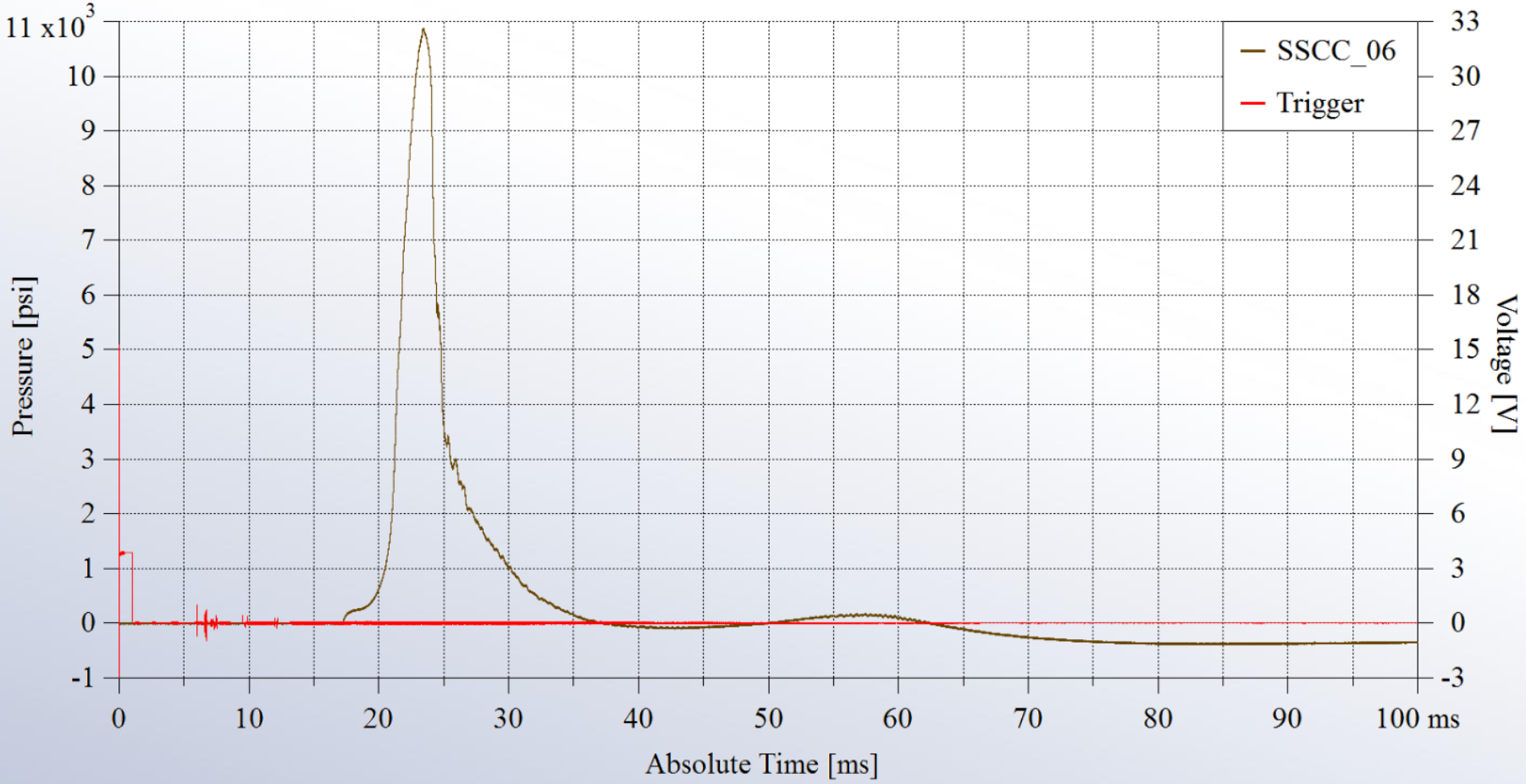
- Containers rupture/vent around 450 psi
- Amount of ignition aide present determines delay
- Data shows good repeatability



Test Item	Pressure (psi)
SSCC_01	449.524
SSCC_02	500.488
SSCC_03	479.858
SSCC_04	451.538

Thick-wall Test – Pressure Results

- Data for SSCC_05 – No pressure recorded
- Tube vented at about 23 ms
- Maximum pressure prior to failure 10,880 psi



Peak Pressure Comparison

- Ignition delays closer for SSCC_02 – 06
  - Scaled down amount of igniter
  - Thick-walled case – rupture 7 ms earlier

Test Number	Ignition Aide [g]	M1 Weight [g]	Bed Height [cm]	%TMD
SSCC_01	20.005	3186.364	21.285	57.054
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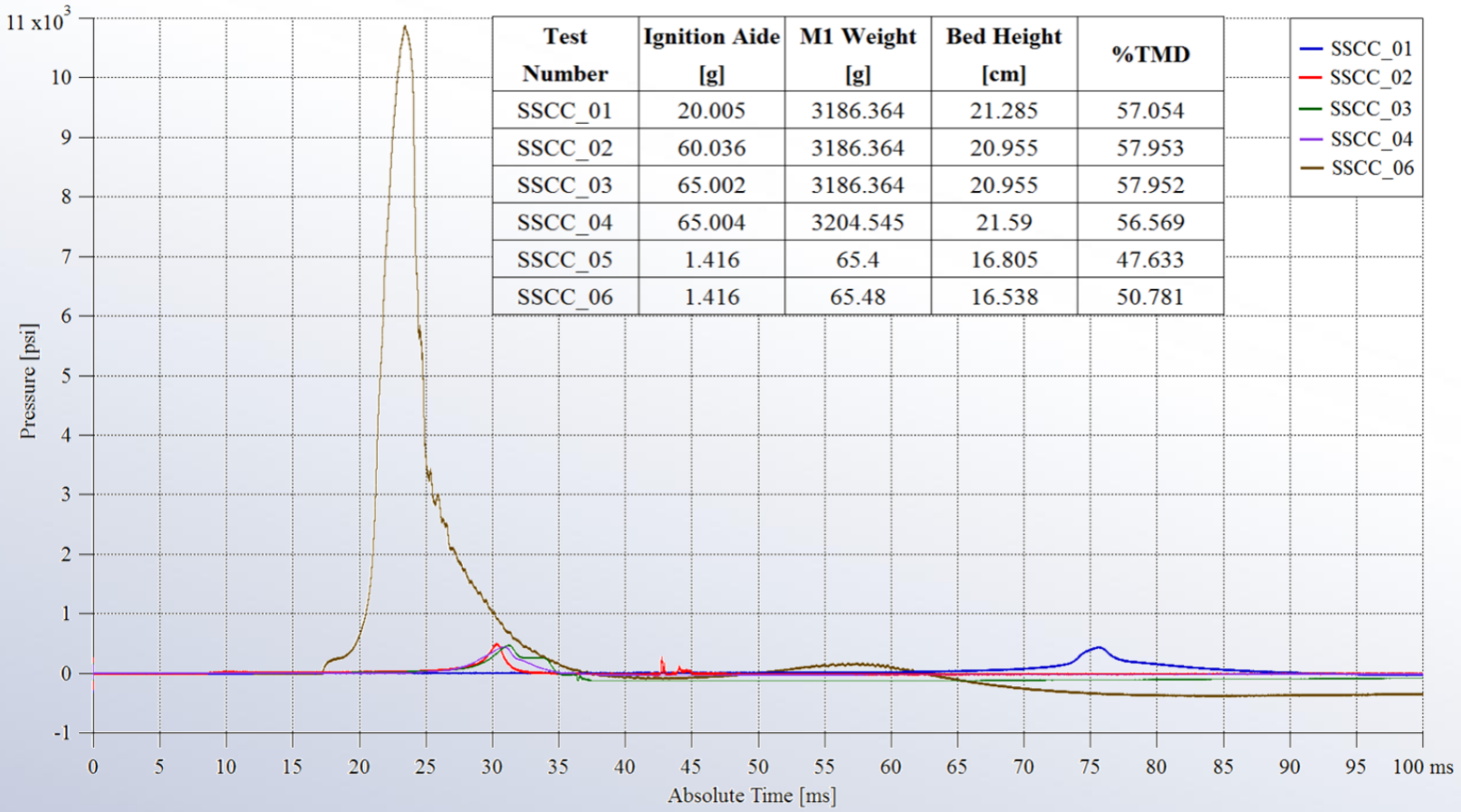
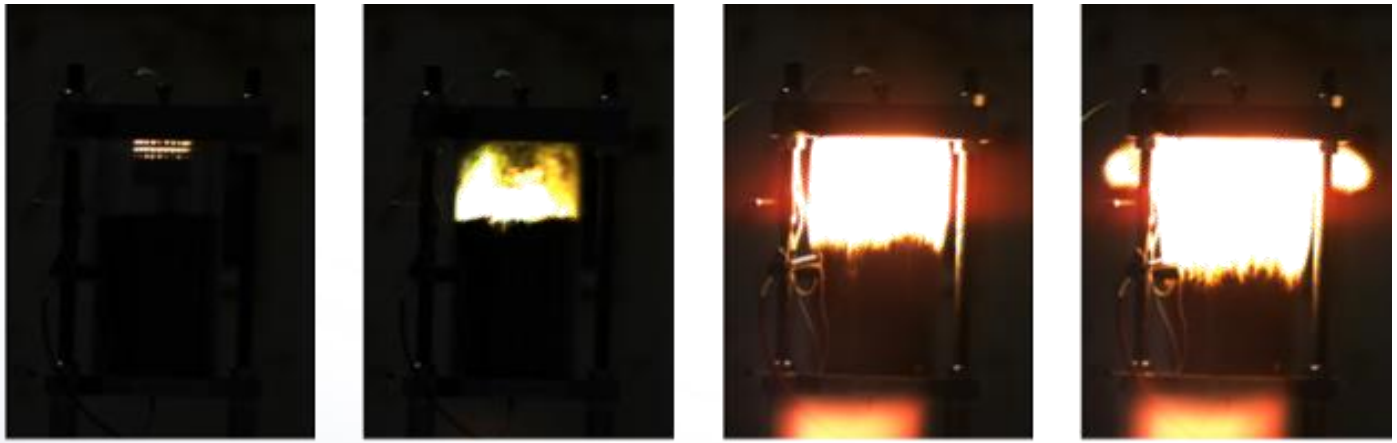
SSCC_06	1.416	65.48	16.538	50.781



Flame Front Tracking

[A]



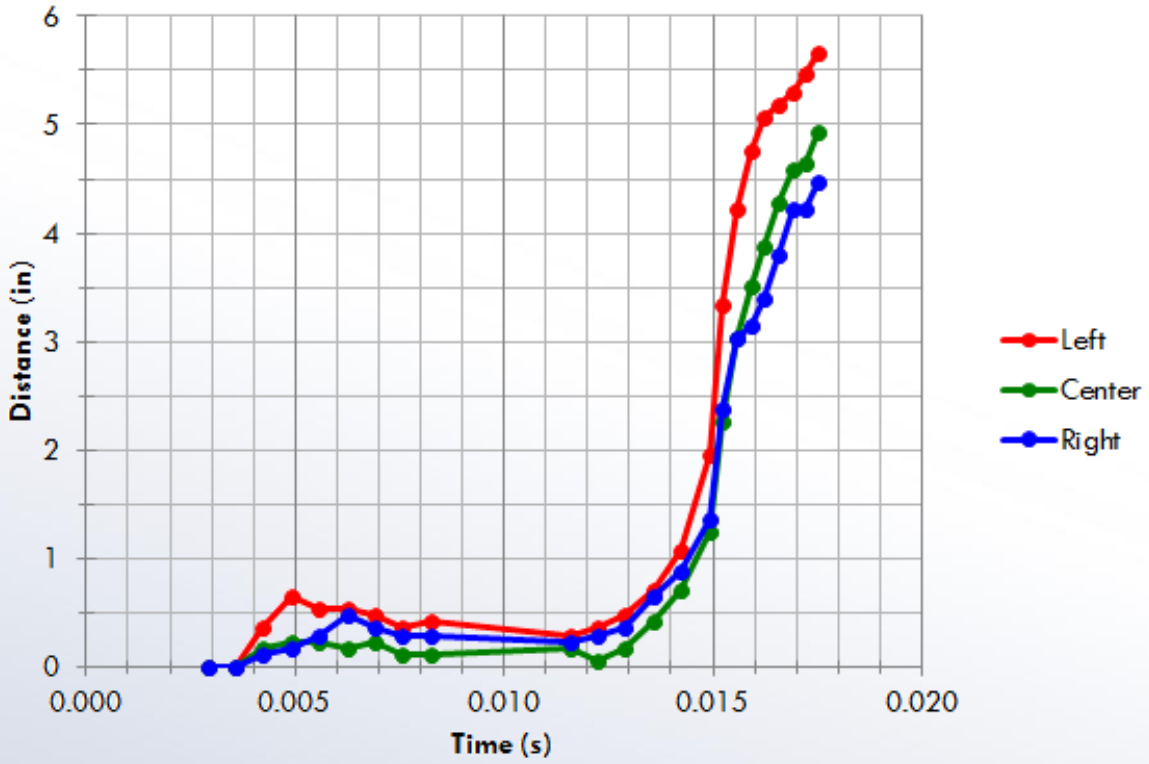
[B]

Camera 1
South View

Time from trigger 0.0172 s 0.0189 s 0.0208 s 0.0212 s

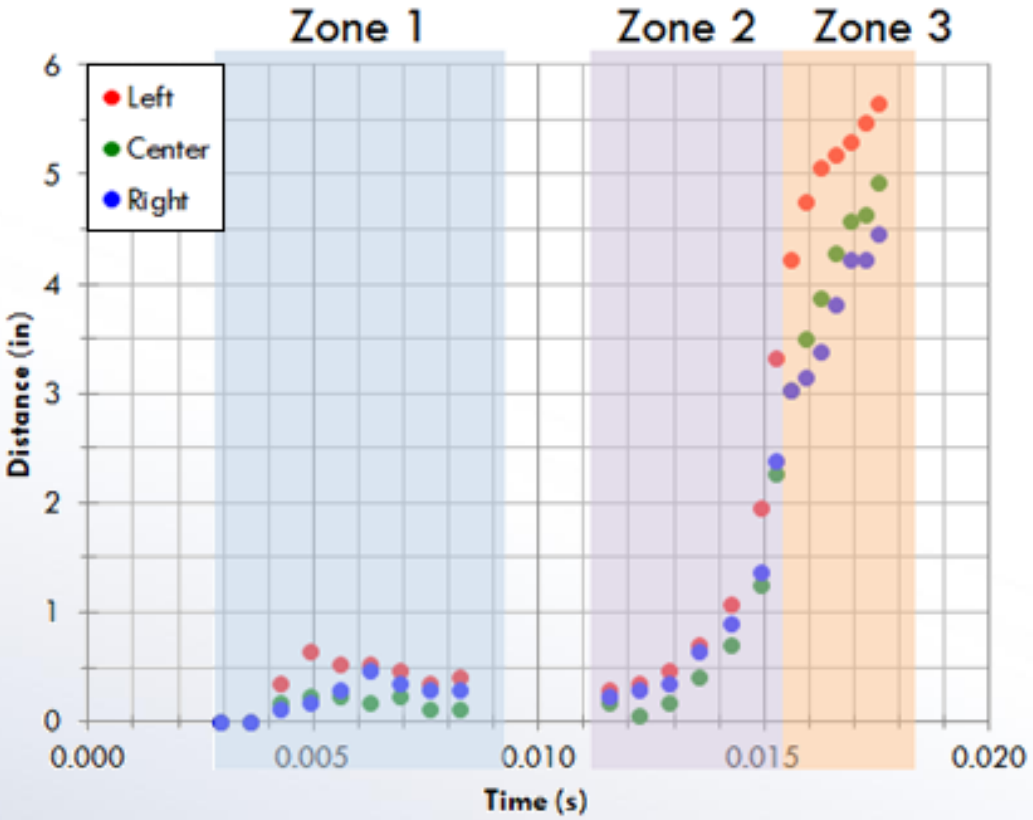
Average Flame Traces

Values calculated from 3 areas using high speed videos of every shot



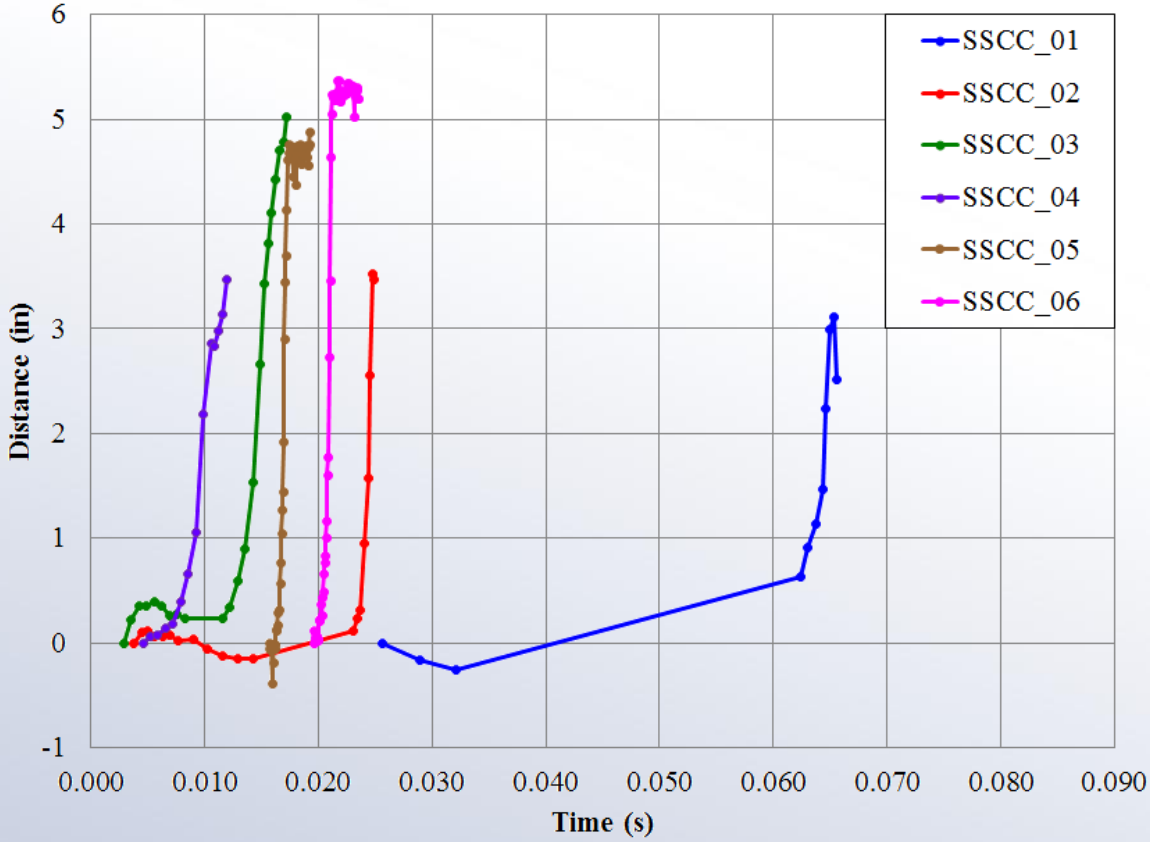
Transient Zones

- 1: Pre-Ignition
  - Thermal profile in porous bed established
- 2: Acceleration
  - Early gasification of propellant occurred.
- 3: Deceleration
  - Volume increase or tube failure.



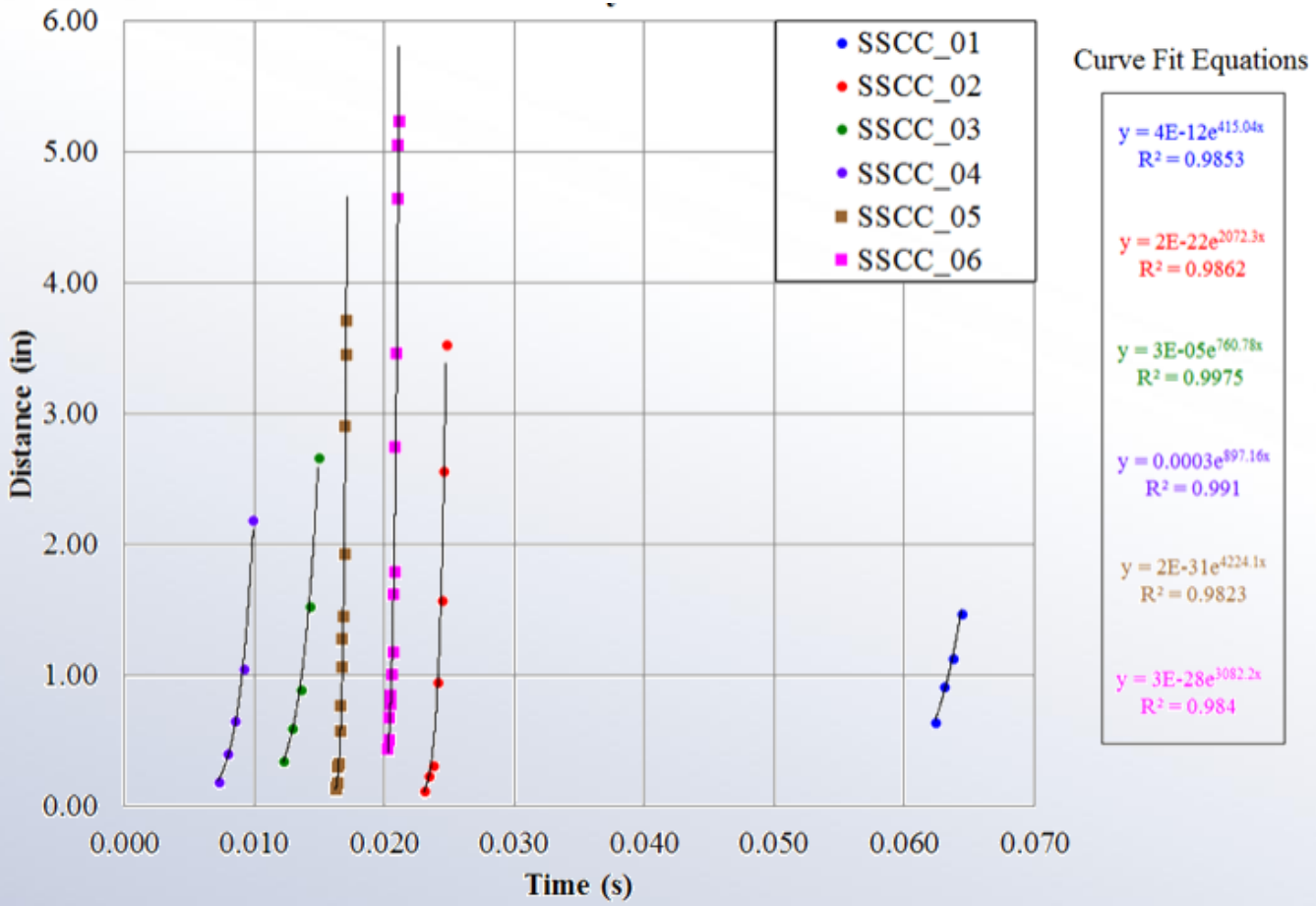
Flame Propagation For All Tests

- Flame displacement with respect to time of each test
- No pre-ignition zone for SSCC_05 and SSCC_06
  - Clear visibility required for code to run – Fireball/smoke blocked view
  - Assumed pre-ignition zone starts between that of SSCC_02 and SSCC_03



Acceleratory Zone: Burning Rates

- Exponential curvefit applies to acceleratory zone
- Non-linear rate – convective burning
- 3x higher burning rate for thick-wall tests



Summary and Conclusions

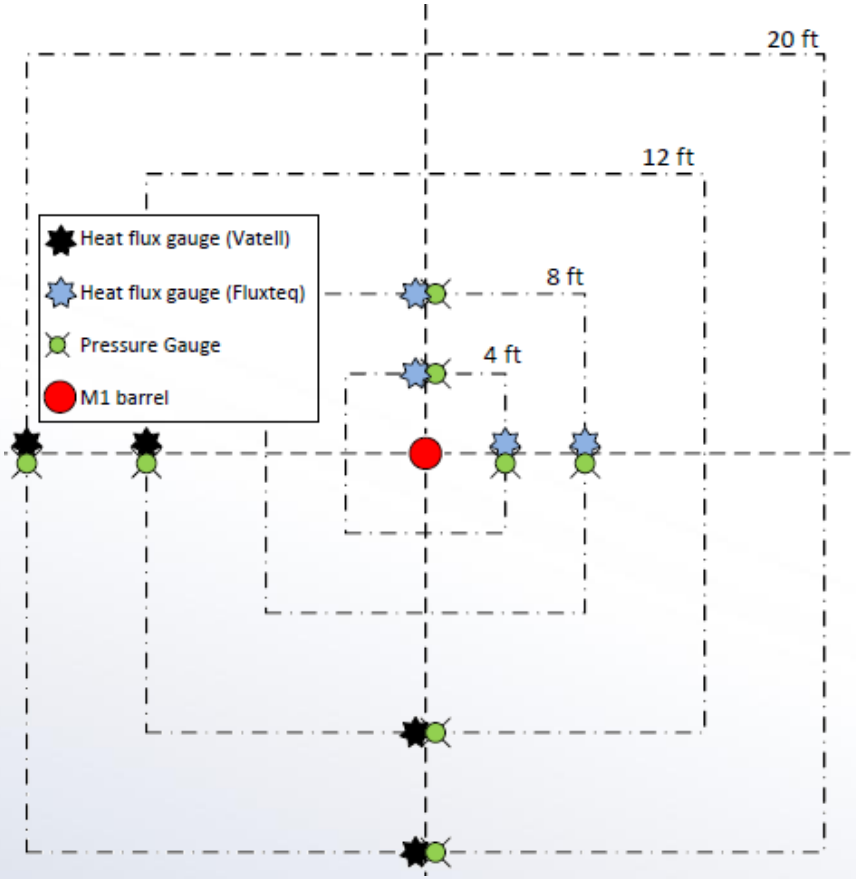
- Better characterize flame propagation, combustion, and pressurization rates
- Experimental values applied to models to determine combustion characteristics of HD 1.3 materials
- Thin-walled tests – Partial ignition of propellant bed
- Thick-walled tests – propellant bed fully ignited and consumed
- Additional data points collected with thicker confinement
- Pressure profiles for thin-walled tests – pressure tolerance of the confinement between 400 to 500 psi
- Thick-walled test – 10,880 psi max pressure
  - Repeatability of results not confirmed

Summary and Conclusions

- Scaling of aide-to-propellant was accurate
- Flame rate profiles followed the same trend
  - Pre-ignition, acceleration, and deceleration zones
  - Material underwent convective combustion, not linear combustion
- Influence of quantity of aide used
  - Reaction delay time
    - More aide → faster the reaction
  - Contribution to pressure rise still unknown
  - Acceleration zone uniformity
    - More uniform with more aide

Future Work

- Ongoing modeling effort
- Planned tests at NAWCWD
  - Calibration shot 1: 1 barrel unconfined
    - Determine output of a single barrel
  - Calibration shot 2: 2 barrels unconfined
    - Observe sympathetic reaction of barrels
  - Calibration shot 3: ISO container with 16 barrels
    - Test effect of confinement on reaction
  - Main shot: ISO container with 32 barrels



Questions

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