Confined Energetic Cook-off Mitigation as a Function of Heating Rate

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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2007 Insensitive Munitions and Energetic Materials Technology Symposium
15th-18th October, 2007

Outline

- Background
- Focus
- Venting Concept
- Testing
- Experimental Results
- Modeling
- Conclusions

Background

- Lack of Insensitive Munitions (IM) compliance has caused the loss of hundreds of lives as well as the loss of material (greater than $250M) and/or reduced operational capability
- Most warheads behave violently when subject to various external insults such as cook-off
- Mil-STD 2105C governs IM related testing
  - 5 levels of severity; Type I Detonation – Type V Burning
- STANAGs supplement Mil-STD 2105C
  - STANAG 4240 – Liquid Fuel/External Fire
  - STANAG 4382 – Slow Heating

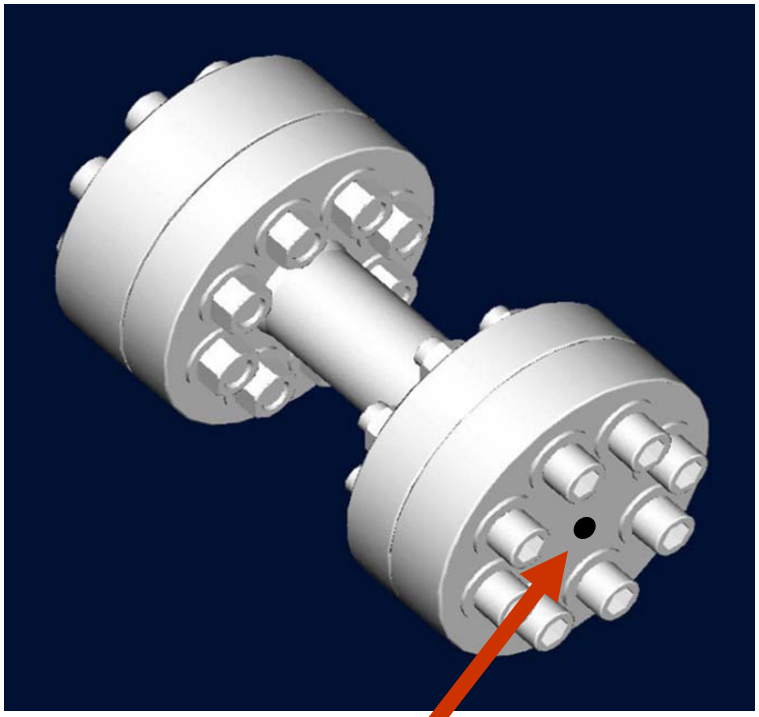
Focus

- Emphasis on IM Technology Development
- IM warhead venting technology: survive unplanned stimuli produced by fires (slow & fast cook-off)
  - Venting technology and venting concepts demonstrations developed for melt pour, cast cure, and pressed formulations
- Although heating rate is specified, other heating rates are useful in order to design robust venting solutions (6, 50, and 500 °F/hr)

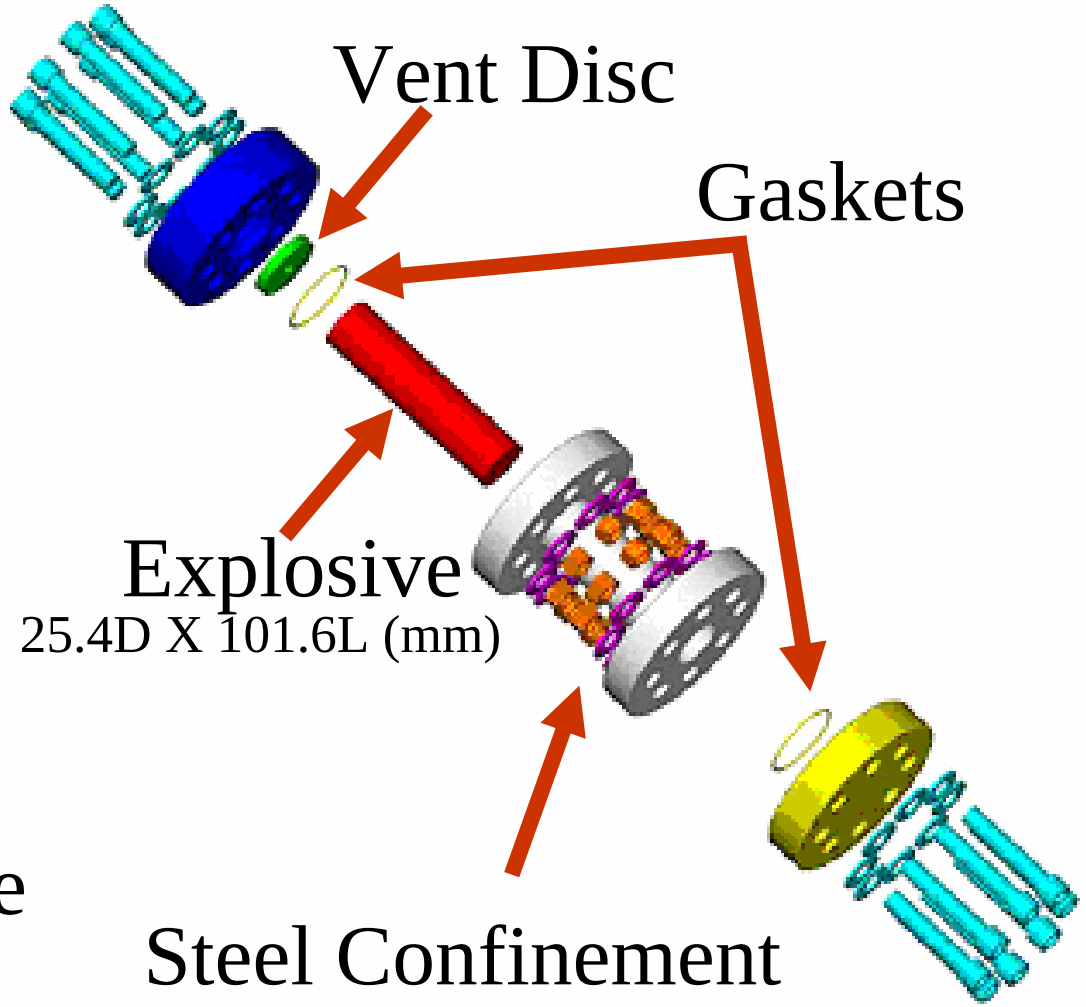
Venting Concepts

- Warhead venting is not a new concept [T. Swierk, 1993]
- Prevent high pressures and temperatures that lead to violent response during cook-off
- Passive venting: thermal or pressure based venting, melt liners
  - Active venting: sensor produces a chemical or mechanical venting response
- Lack of technology: explosive venting characterization and design technology
- Small scale hardware – variable heating rates and HE type
- HE Formulations
  - Composition B
  - PBXN-109
  - PAX-3

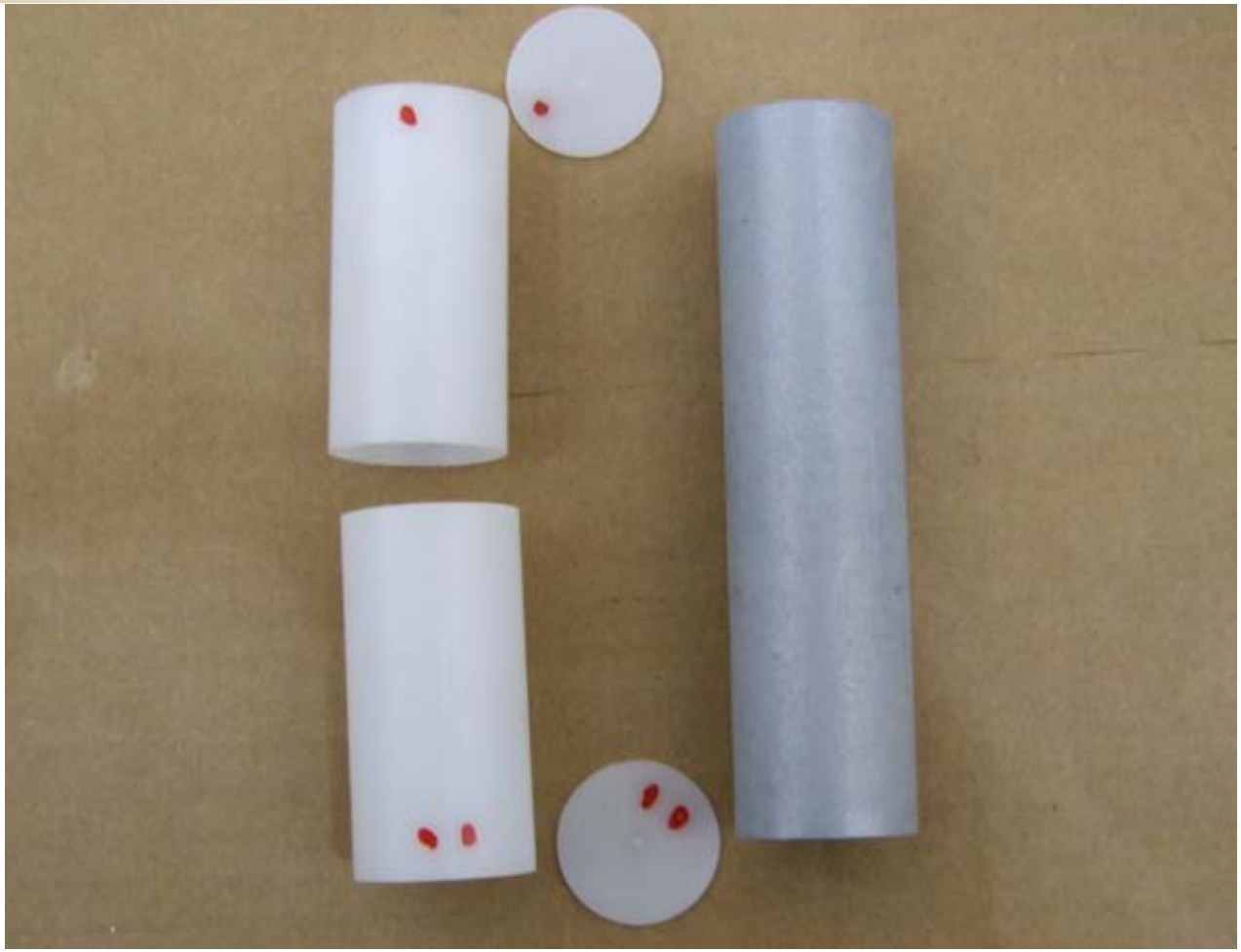
Small Scale Laboratory Fixture



Adjusted Vent Hole

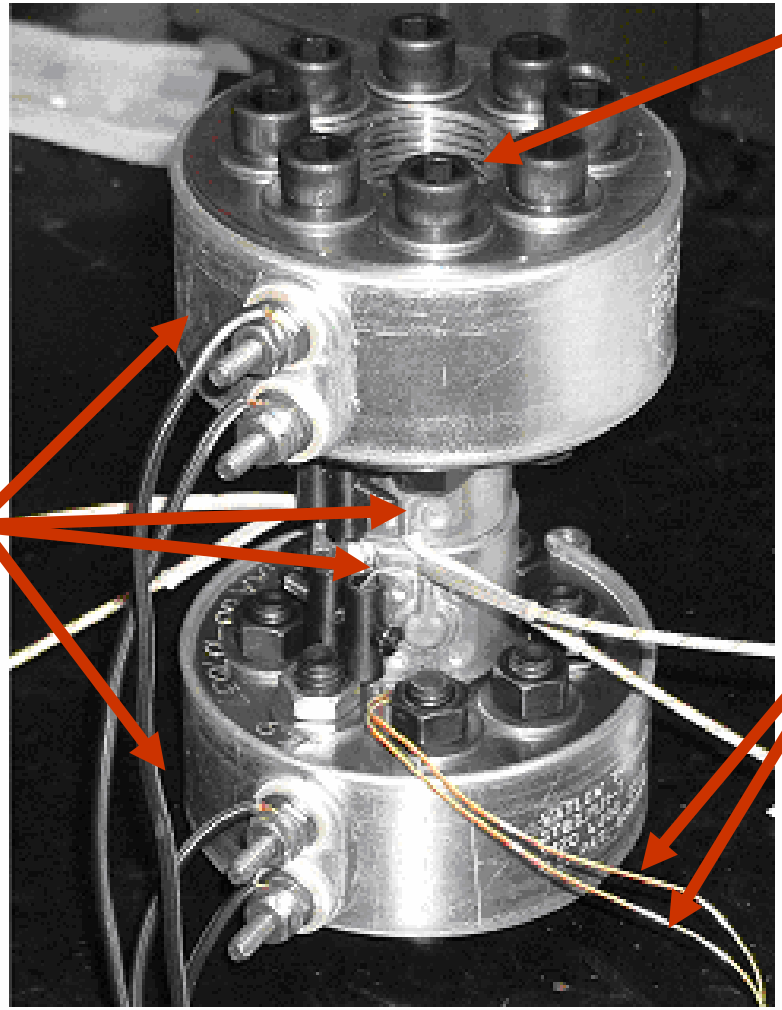


Small Scale Laboratory Fixture



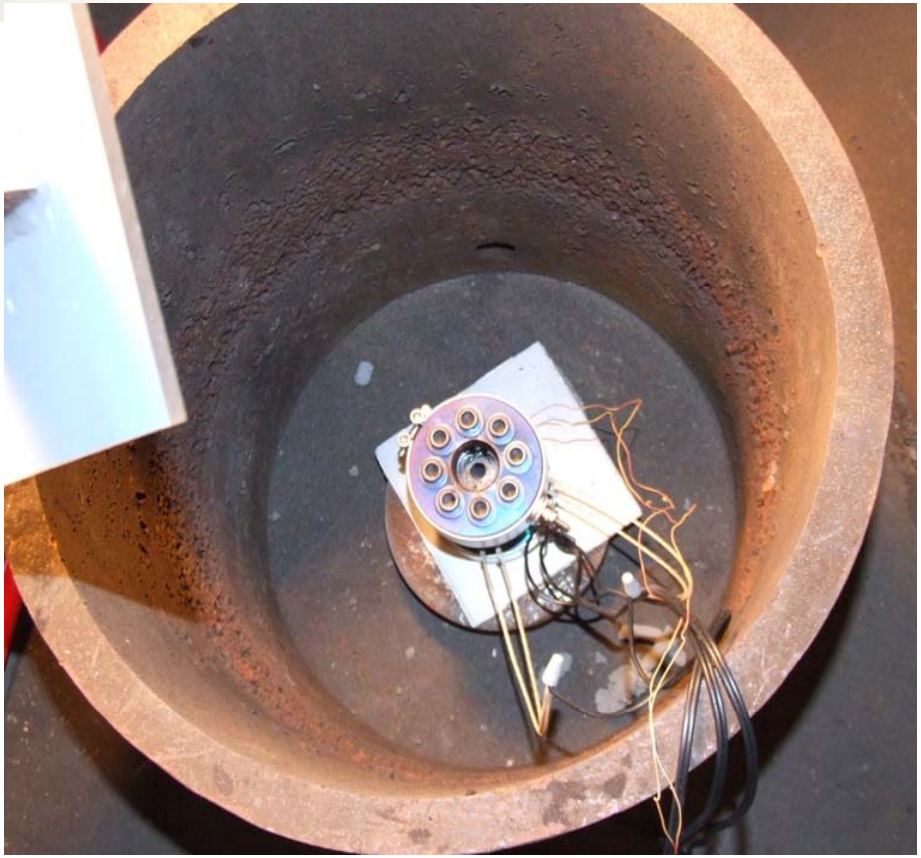
Matched HE pellet and liner

Small Scale Laboratory Fixture



Assembled fixture

Small Scale Laboratory Fixture

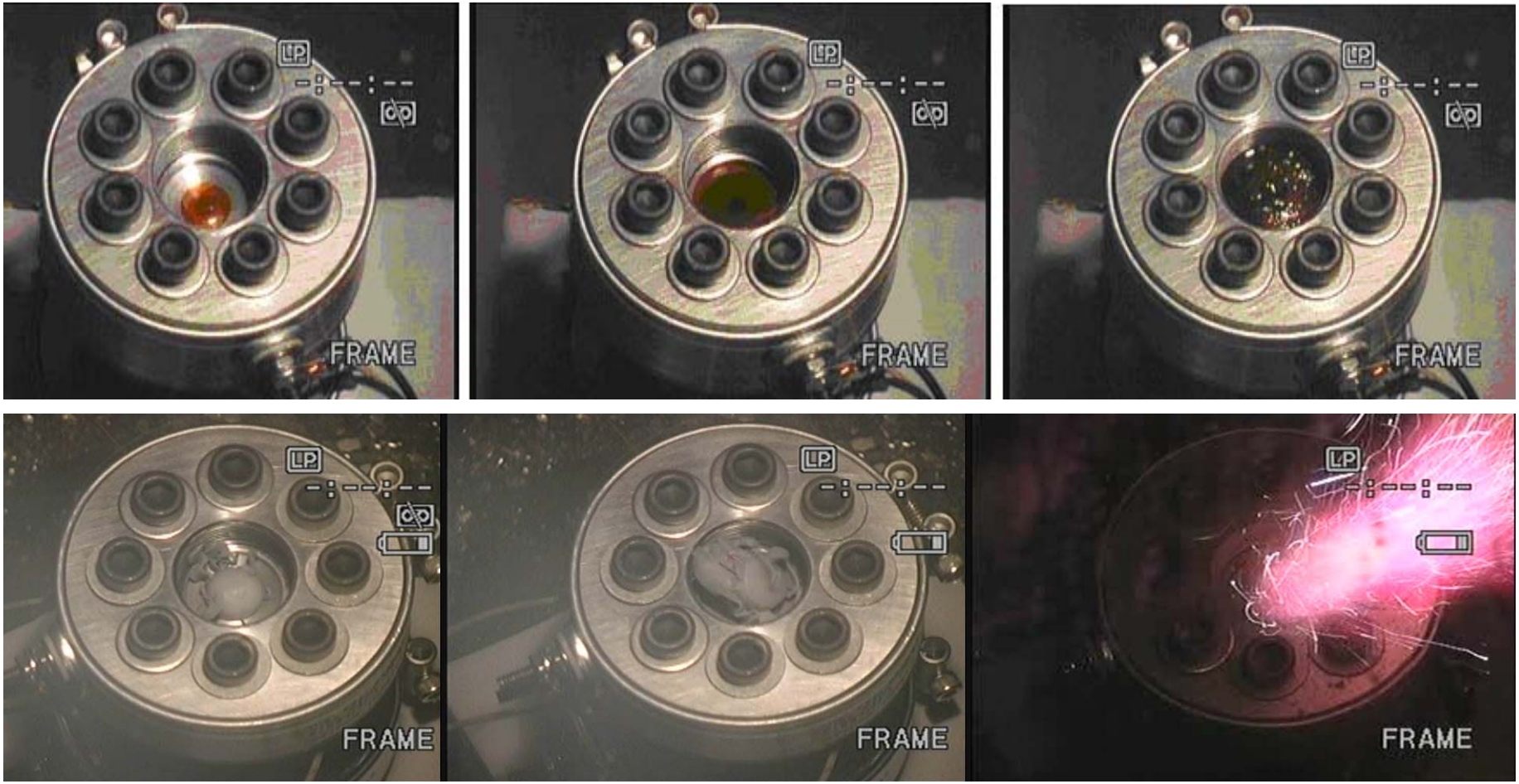


Small hardware loaded in the firing chamber

Small Scale Testing –Typical Results

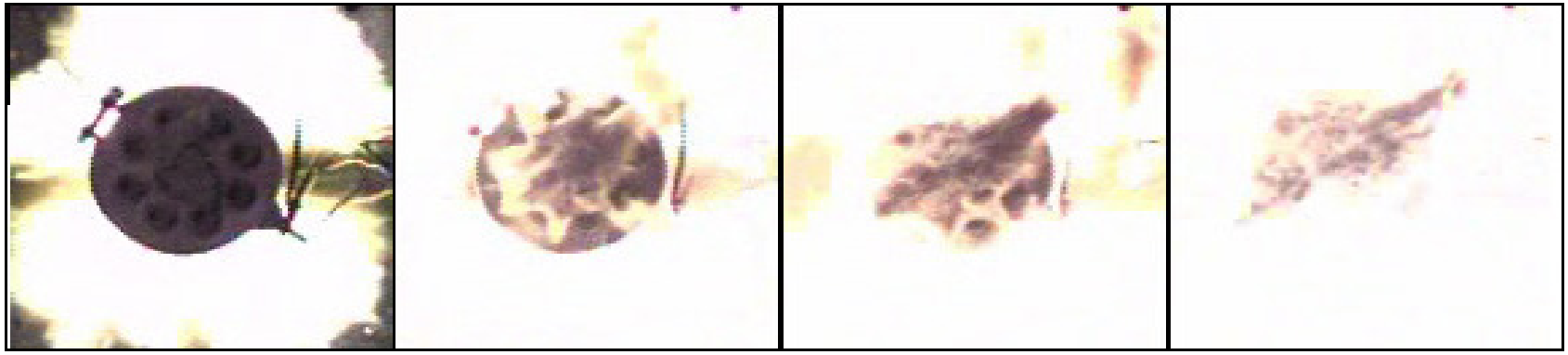
Small hardware (from l to r – untested, no go, go)

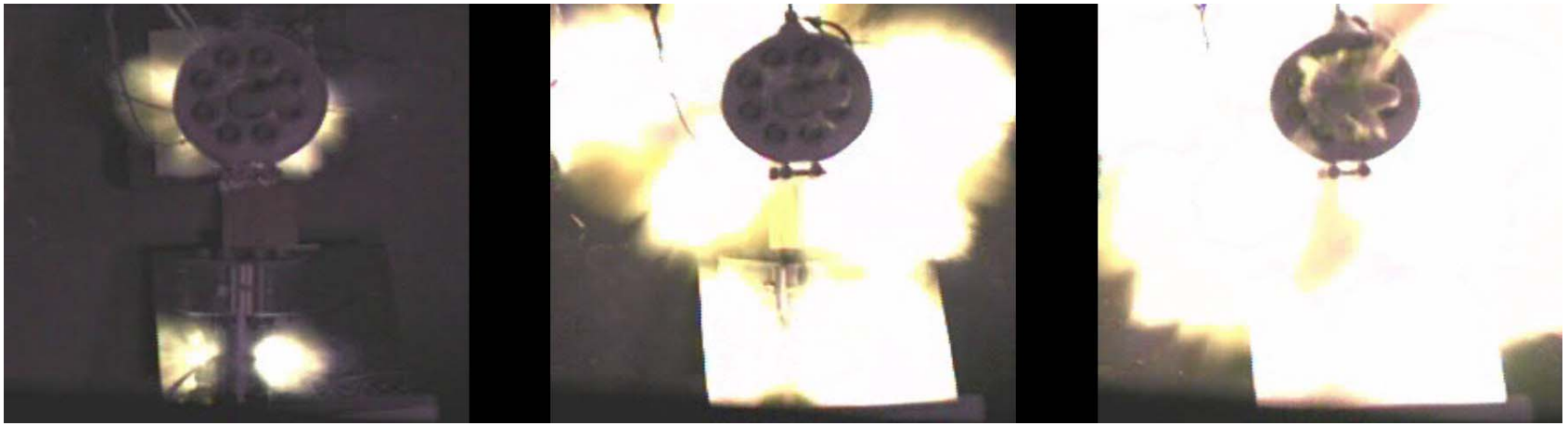
Small Scale Testing –Typical Results



Standard video

Small Scale Testing –Typical Results





High speed photography during testing

Experimental Results

Explosive	Ht Rate (°F/hr)	G/NG	Diam (in)	Reaction Notes	Rxn T (°F)
Comp-B	6	Go	0.4	Violent reaction	355
Comp-B	6	No Go	0.45	Ignited in vent disk, fast burn	362
Comp-B	6	No Go	0.5	External ignition propagated inside, mild burn	376
Comp-B	6	No Go	0.6	Ignited in vent disk, expelled material, fast burn	Unkn
Comp-B	50	Go	0.1	Vent disk blown out	370
Comp-B	50	Go	0.2	Explode	400
Comp-B	50	No Go	0.4	Burn	390
Comp-B	50	Go	0.4	Explode, top end plate came off	376
Comp-B	50	No Go	0.4	Burn Off	376
Comp-B	50	No Go	0.4531	Burn off, Fixture in one solid piece	362
Comp-B	50	No Go	0.5	Burn Off	415
Comp-B	50	No Go	0.5	Burn Off	400
Comp-B	500	Go	0.1	Violent, bolts sheared, center burst	438
Comp-B	500	Go	0.15	Violent, bolts sheared, center burst	458
Comp-B	500	No Go	0.2	Burn Off	467
Comp-B	500	No Go	0.3	Burn Off	425

6°F/hr - .4/.45

50°F/hr - .4/.45

500°F/hr - .15/.2

Comp B results

Experimental Results

Explosive	Ht Rate (°F/hr)	G/NG	Diam (in)	Reaction Notes	Rxn T (°F)
PBXN-109	6	Go	0.3	w/HDPE Liner, Exploded center section	336
PBXN-109	6	No Go	0.4	w/HDPE Liner, Burn Off	320
PBXN-109	6	No Go	0.5	w/HDPE Liner,	330
PBXN-109	50	Go	0.2	w/HDPE Liner, Exploded	357
PBXN-109	50	No Go	0.2	No HDPE Liner, Burn Off	375
PBXN-109	50	No Go	0.228	w/HDPE Liner, extrusion and burn off	370
PBXN-109	50	Go	0.266	w/HDPE Liner, exploded but not all HE reacted	363
PBXN-109	50	No Go	0.3	w/HDPE Liner, Burn Off	377
PBXN-109	50	No Go	0.4	w/HDPE Liner, Burn Off	352
PBXN-109	50	No Go	0.5	w/HDPE Liner, Burn Off	367
PBXN-109	50	Go	0.5	No HDPE Liner, Exploded	370
PBXN-109	50	No Go	0.5	No HDPE Liner, Burn Off	390
PBXN-109	50	No Go	0.7	No HDPE Liner, Burn Off	374
PBXN-109	500	Go	0.1	w/HDPE Liner, Exploded	417
PBXN-109	500	Go	0.3	w/HDPE Liner, Exploded	401

6°F/hr -.3/.4

50°F/hr -.266/.3

500°F/hr ->.3

PBXN-109 results

Experimental Results

Explosive	Ht Rate (°F/hr)	G/NG	Diam (in)	Reaction Notes	Rxn T (°F)
PAX-3	6	No Go	0.7	0.1" HDPE Liner, Bum off	420
PAX-3	50	Go	0.4	No HDPE Liner, Explode	392
PAX-3	50	Go	0.5	No HDPE Liner, Explode	398
PAX-3	50	Go	0.5	w/.05" HDPE Liner, Explode	374
PAX-3	50	Go	0.5	w/.1" HDPE Liner, Explode	415
PAX-3	50	Go	0.6	No HDPE Liner, Explode	396
PAX-3	50	Go	0.6	w/.1" HDPE Liner, Explode	395
PAX-3	50	No Go	0.7	w/.1" HDPE Liner, Burn Off	405
PAX-3	50	Go	0.8	No HDPE Liner, Explode	391
PAX-3	50	Go	0.8	w/.05" HDPE Liner	416
PAX-3	50	No Go	0.8	w/.1" HDPE Liner	430
PAX-3	500	Go	0.5	0.1" HDPE Liner, varied heating profile	Unkn
PAX-3	500	No Go	0.575	0.1" HDPE Liner, varied heating profile	355
PAX-3	500	Go	0.631	0.1" HDPE Liner, Explode	483
PAX-3	500	No Go	0.7	0.1" HDPE Liner, Bum Off	488

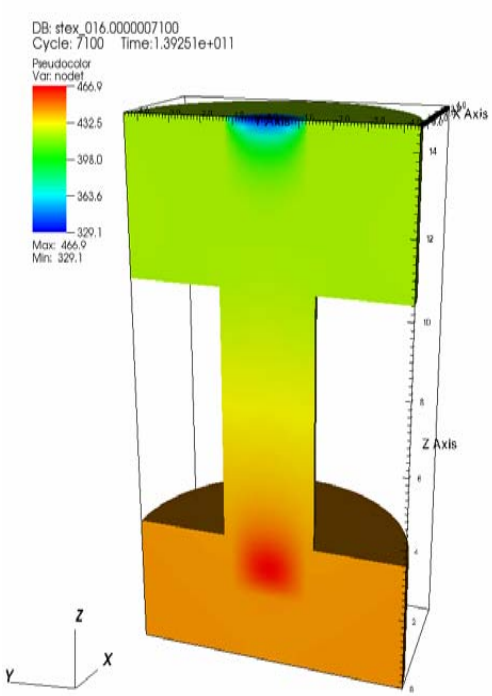
6°F/hr - <.7

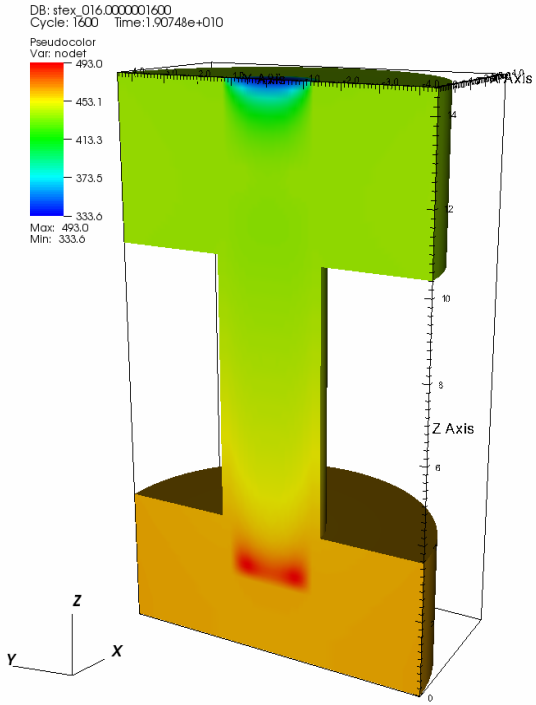
50°F/hr -.6/.7

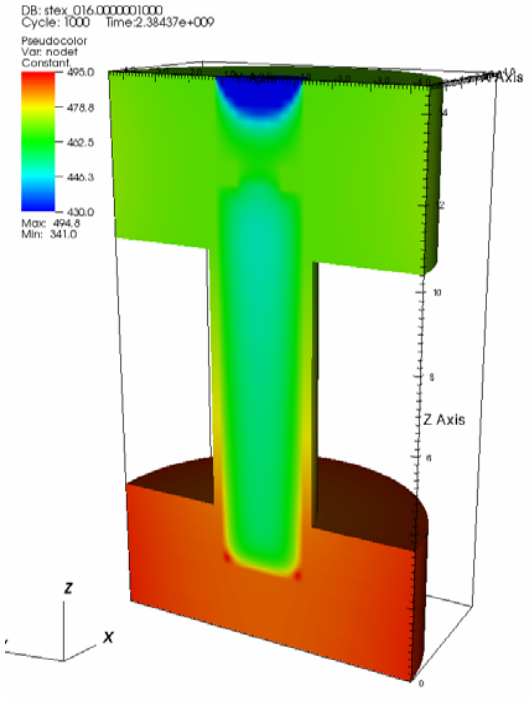
500°F/hr -.631/.7

PAX-3 results

Modeling







6 °F/hr 50 °F/hr 500 °F/hr

- Initial modeling of inert fixture to match thermal profile
- Good agreement with time and temperature at reaction
- Not such good agreement with location of reaction
- Ongoing material model development

Conclusions

1. Venting as a function of heating rate changes vary from one HE to the next
   - Composition B remains flat and then decreases after a certain point
   - PBXN-109 remains relatively flat
   - PAX-3 remains relatively flat throughout
2. Liners seem to add consistency (at least for PBXN-109)

Questions?