RDECOM

Heating Rate Effect on Slow Cook-Off Response

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Army IM Efforts

- There are many current Army IM efforts attempting to satisfy the arbitrarily difficult standard of the 6˚F/hr heating rate.
- This leads to additional challenges for designers attempting to achieve system requirements, both performance and IM.

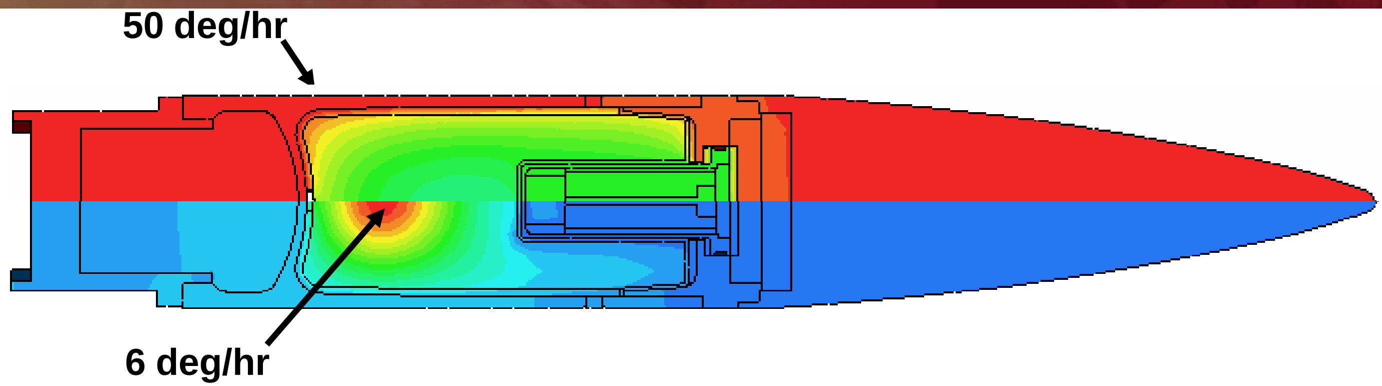
System Design Challenges Examples

- IM solutions for 6˚F/hr can produce overall system failures
  - Larger/more complicated venting schemes reduce structural integrity (e.g. gun launch/ bash-through)
- Designing to pass 6˚F/hr SCO potentially means overlooking solutions for a 50˚F/hr heating rate.
  - If the decomposition rate of an energetic is slower than the rate at which heat can be given off to the environment, there is a potential for a less violent reaction at 6˚F/hr. Conversely utilizing the same design on 50˚F/hr would result in a much more violent reaction.

Slow Cook Off Data

- A large set of data currently exists for a variety of Army systems in development.
- This data set includes both the 6˚F/hr and 50˚F/hr heating rates.
- Experimental data can give direct comparisons of heating rates within a given subset of munitions to illustrate the difference in responses due to cook off.
  - While a single correlation cannot be stated (i.e. slower heating rate : more vent area), there are undeniable differences in responses of munitions when subjected to different heating rates.

XM982 Excalibur Thermal Analysis



- Hotspot = where self-heating occurs, i.e., explosive begins to burn in self sustaining reaction
- 50 deg F/hr
  - Hotspot forms on or near the surface
  - Surface burn allows gases to escape through vents
- 6 deg F/hr
  - Hot spot forms on billet centerline below the surface
  - Hot gases trapped inside the billet

Relevant IM Technologies

- Subsequent data will illustrate the use of various IM technologies.
  - Venting
  - Vent liners
    - Plastic
    - Metal
  - Meltable adapters
- Utilizing analog test setups to illustrate proof of principle of designs

XM982 50ºF/hr vs. 6ºF/hr

XM982 - Excalibur	6ºF/hr	50ºF/hr
Baseline Sub-scale		III
Subscale 2x Liner		V
Subscale Reactive Vent		III
Full Scale 2x liner	I	V/III
Full Scale 1.5x liner		III
Full Scale 1.75x liner		III

XM982 Testing (Sub-scale)

Baseline XM982

TYPE III

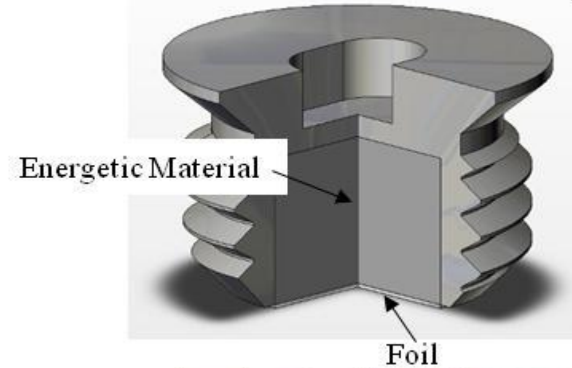
Double Thickness Liner

SETUP

RESULT

TYPE V

Reactive Vent Plug



TYPE III

50ºF/hr

XM982 Testing (Full-scale) Double Thickness Liner

SETUP

RESULT

TYPE V

50ºF/hr

TYPE III

XM982 Testing (Full-scale)

1.5X Liner

1.75X Liner

SETUP

RESULT

TYPE III

50ºF/hr

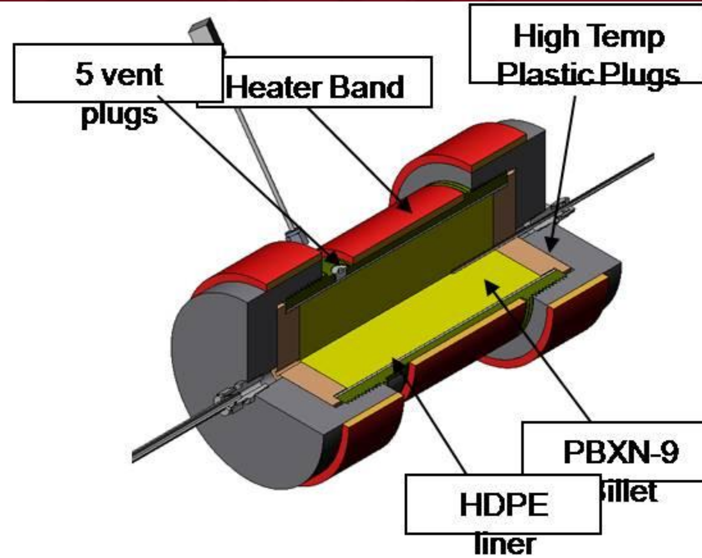
TYPE III

XM982 Controlled Thermal Venting Thicker Melt Liner

- Thicker melt liner venting design demonstrated on sub-scale test fixture (scaled 2/3)
- Thermal modeling conducted to design test and to determine hot spots

Double Thickness Liner (Sub-scale)

TYPE V



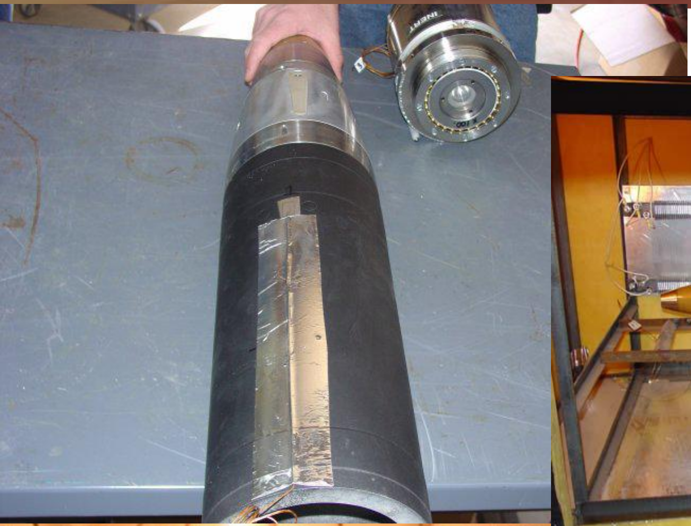
50ºF/hr

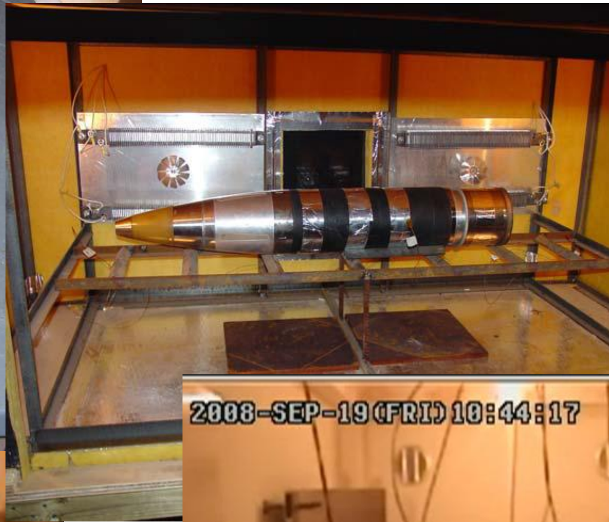
- Liner technology tested in full-scale hardware

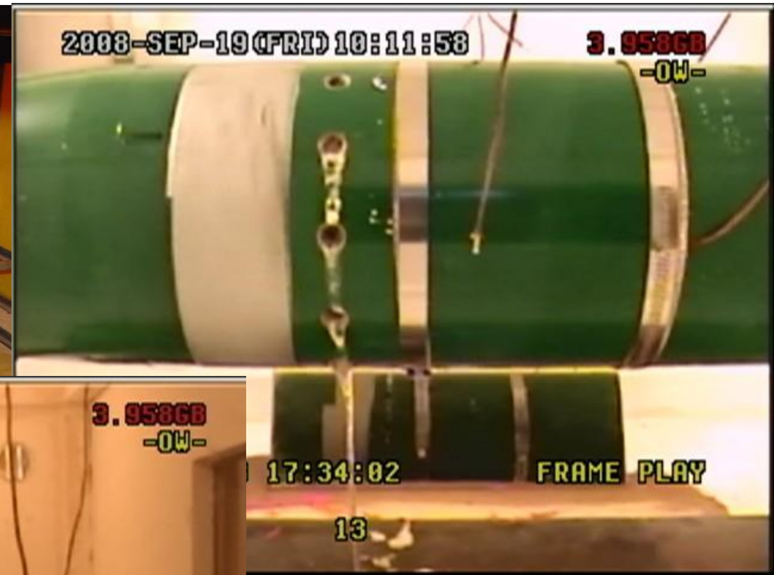
Double Thickness Liner (Full-scale)

TYPE III

XM982 Controlled Thermal Venting Thickest Melt Liner (0.225”)







6ºF/hr

120mm IMX-104 50ºF/hr vs. 6ºF/hr

120mm Mortar (Venting)	6ºF/hr	50ºF/hr
Unfilled Adapter	V	V
Reduced Thread	III	V
Adapter V2	V/III	
Interrupted Thread (0.5)	II	
Interrupted Thread (0.75)	V*	

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120mm Mortar with Unfilled Adapter Ring V2 Test Photos

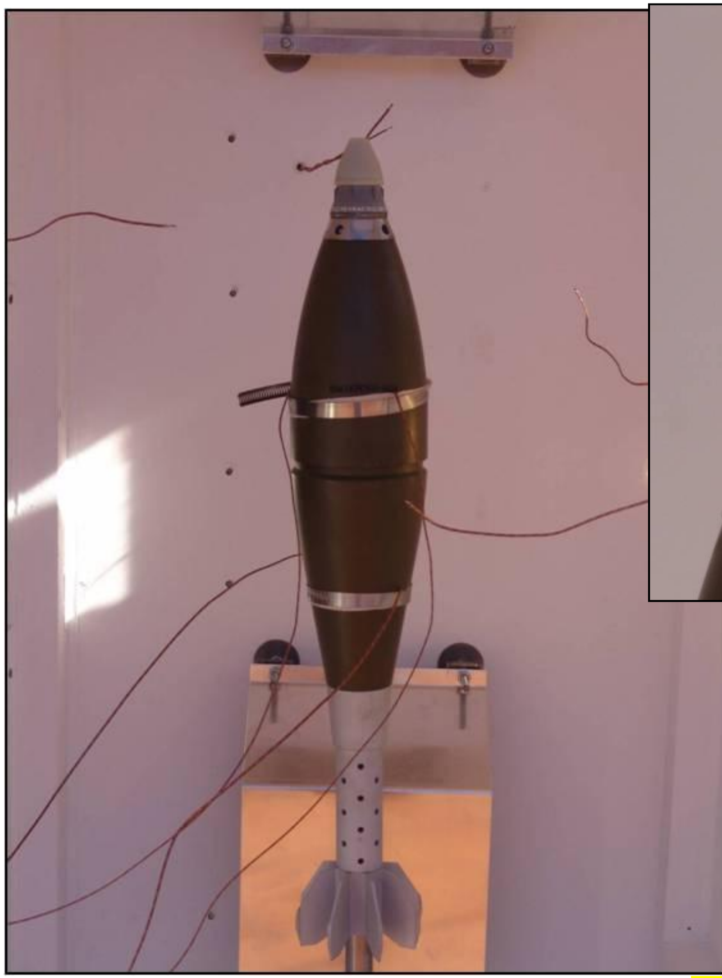



6^{o}F/hr

120mm Mortar with Reduced Thread Adapter PM-CAS Funded (IMX-104)

50°F/hr

120mm Mortar with Filled Adapter Ring V2 Test 1 Photos



6ºF/hr

120mm Mortar with Filled Adapter Ring V2 Test 2 Results

6ºF/hr

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120mm Mortar Reduced Thread Adapter PM-CAS funded (IMX-104)

6ºF/hr

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IMX-104 120mm Mortar

50°F/hr

TYPE V

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IMX-104 120mm Mortar Interrupted Thread 0.75”

6^{o}F/hr

TYPE V

Bangalore Torpedo 50ºF/hr vs. 6ºF/hr

Bangalore Torpedo	6ºFhr	50ºFhr
Baseline		V
Baseline		V
Quad Pack (1 live)		V
Quad Pack (4 live)		V
8 Pack (8 Live)	I	V

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Bangalore Torpedo
Baseline SCO Testing

Test Setup (Bangalore in oven)

Ignition (booster)

Burning

Pre-ignition (much HE runs out)

Post Test

Type 5?

383ºF

50ºF/hr

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Bangalore Torpedo
Baseline SCO Testing (Repeat)

160ºF soak, 50ºF/hr

Test Setup (Bangalore in oven)

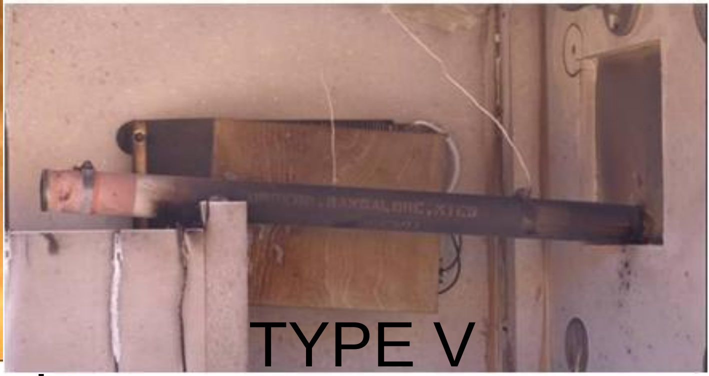
Bulge in Endcap

HE Flows from Endcap

Booster Igniting

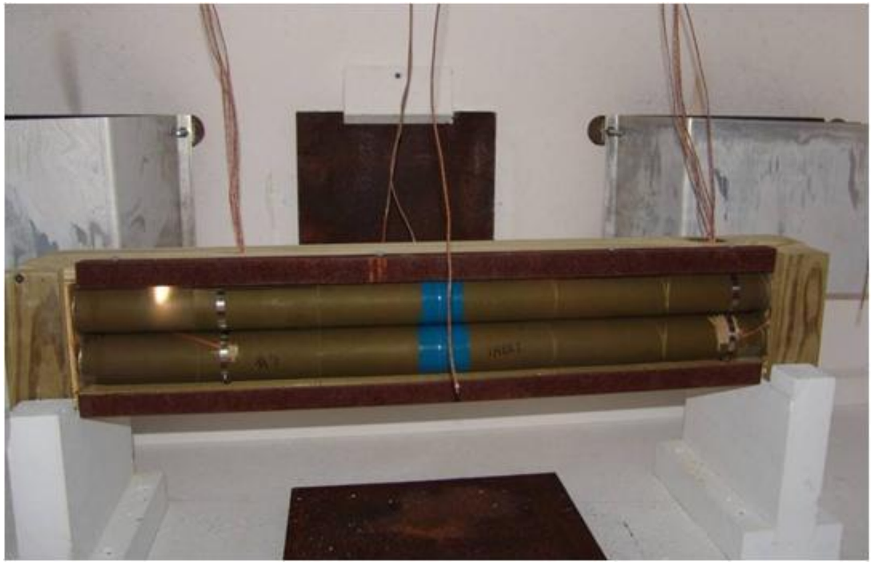
50º F/hr

Item propelled toward camera

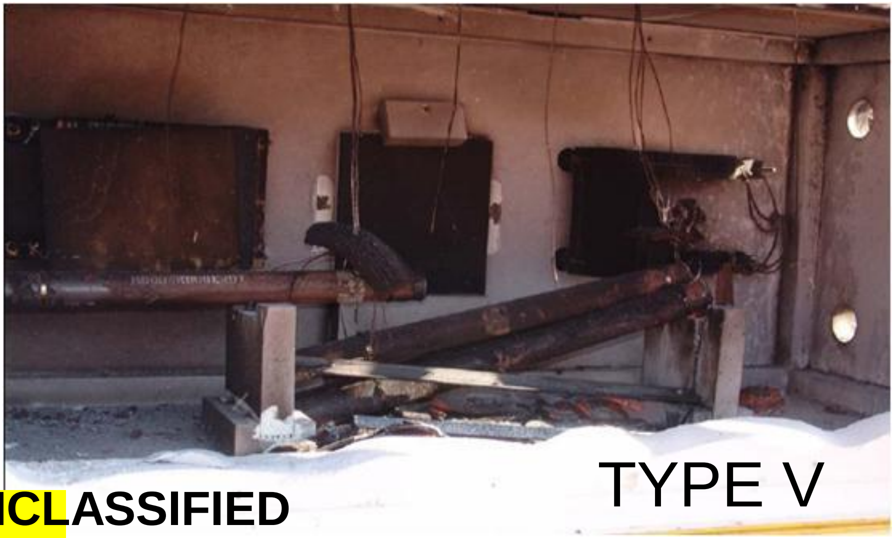


TYPE V

Bangalore Torpedo
Quad pack (1 live, 3 inert)



Test Setup (Bangalore in oven)



TYPE V

50ºF/hr

UNCLASSIFIED

Bangalore Torpedo

TYPE V

50ºF/hr

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Bangalore Torpedo

8-pack (8 live)

Test Setup

6ºF/hr

TYPE I

Overall Comparison

	XM982	120mm	Bangalore
6F/hr	I	III	I
50F/hr	III/V	V	V

Difficulty of 6˚F/hr Prompts Complex Solutions

- Complex solutions are generally necessary to pass the 6˚F/hr requirement
  - Maximum Venting Area
    - Not always a possibility
  - Active Venting
    - Utilizes shaped charges or other techniques to provide venting
  - Thermally Initiated Venting System
    - Utilizes additional energetic that reacts at a lower temperature than main fill to cause surface ignition

We Should be Designing for Realistic Heating Rates

- As can be seen by the preceding data, there exists a real difference in energetic responses from one heating rate to the next.
- Assessments of realistic heating rates and lower bound heating rate estimates for a given munition system could provide important information in order to provide practical real improvements of Insensitive Munitions response.