Cook-Off Mitigation Scaling Effects

(RDECOM-ARDEC)

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Outline

• Background
• Comp B Geometric Scaling
  – Small/Large Scale Hardware
  – Single hole
  – Multiple Vent Holes
• Full Scale Generic Hardware
  – Inert and Comp B Modeling
  – PBXN-109 Analytic Burn Modeling
  – Cast cure liner material investigation
• Conclusions
Background

• PEO Ammunition and RDECOM-ARDEC:
• Developing and Applying IM Warhead Venting Technology
• Maintaining structural requirements and warhead performance
• Lacking standard explosives venting characterization and quantification
Small Scale Laboratory Fixture

- Vent Disc
- Explosive
- Gaskets
- Steel Confinement

- Assembled fixture
- Heating bands
- Thermocouple leads
- Vent location
- Adjusted Vent Hole

25.4D X 101.6L (mm)
Large Scale Laboratory Fixture

Explosive Heating Bands
Large and Small Scale Hardware

Assembled fixture
Composition B - Geometric Scaling
Single Vent Hole

Small Scale
- 0.45

Large Scale
- 1.15 (0.45 eq)

Go

No Go
Composition B
Multiple Vent Hole

5 vent holes
0.512”/hole (0.45 eq) - Go

10 vent holes
0.506”/hole (>0.45 eq) - No Go
<table>
<thead>
<tr>
<th>Scale</th>
<th>Go/No Go</th>
<th>Vent Size</th>
<th>Notes</th>
<th>T(°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Scale</td>
<td>Go</td>
<td>0.1</td>
<td>Throttle Plate Blown Out</td>
<td>370</td>
</tr>
<tr>
<td>Small Scale</td>
<td>Go</td>
<td>0.2</td>
<td>Exploded</td>
<td>400</td>
</tr>
<tr>
<td>Small Scale</td>
<td>Go</td>
<td>0.2</td>
<td>Fixture on Side, Violent, Bolts sheared, Center Burst</td>
<td>379</td>
</tr>
<tr>
<td>Small Scale</td>
<td>Go</td>
<td>0.4</td>
<td>Explode, top end plate came off</td>
<td>376</td>
</tr>
<tr>
<td>Small Scale</td>
<td>No Go</td>
<td>0.4</td>
<td>Burn Off</td>
<td>390</td>
</tr>
<tr>
<td>Small Scale</td>
<td>No Go</td>
<td>0.4531</td>
<td>Burn off, Fixture in one solid piece</td>
<td>362</td>
</tr>
<tr>
<td>Small Scale</td>
<td>No Go</td>
<td>0.5</td>
<td>Burn Off</td>
<td>415</td>
</tr>
<tr>
<td>Small Scale</td>
<td>No Go</td>
<td>0.5</td>
<td>Burn Off</td>
<td>375</td>
</tr>
<tr>
<td>Small Scale</td>
<td>No Go</td>
<td>0.5</td>
<td>Burn Off</td>
<td>400</td>
</tr>
<tr>
<td>Small Scale</td>
<td>No Go</td>
<td>0.8</td>
<td>Fixture on Side, Burn Off, Fixture in one piece</td>
<td>378</td>
</tr>
<tr>
<td>Large Scale</td>
<td>No Go</td>
<td>1.15</td>
<td>Scaled up Vent hole as a function of total surface area</td>
<td></td>
</tr>
<tr>
<td>Large Scale</td>
<td>No Go</td>
<td>1.15</td>
<td>0.45 eq (Comp B small scale cutoff point) Deflagration, fixture intact</td>
<td>350</td>
</tr>
<tr>
<td>Large Scale</td>
<td>Go</td>
<td>0.894</td>
<td>0.35 eq, Full Detonation</td>
<td>425</td>
</tr>
<tr>
<td>Large Scale</td>
<td>Go</td>
<td>1.025</td>
<td>0.40 eq, Transition to Detonation</td>
<td>430</td>
</tr>
<tr>
<td>Large Scale</td>
<td>Go</td>
<td>1.15/5</td>
<td>0.45 eq. Surface area divided into 5 same size holes (0.512 in)</td>
<td>430</td>
</tr>
<tr>
<td>Large Scale</td>
<td>No Go</td>
<td>1.15*2/10</td>
<td>1.15 dia vent x 2, Vent area divided by 10 same size holes (0.506 in) Burn. Initiated on heater band</td>
<td>440</td>
</tr>
<tr>
<td>Large Scale</td>
<td>No Go</td>
<td>1.15*2/10</td>
<td>1.15 dia vent x 2, Vent area divided by 10 same size holes (0.506), Burn</td>
<td></td>
</tr>
</tbody>
</table>
Inert and Comp B Modeling

Inert Hardware Baseline Modeling

Composition B Generic Hardware Modeling
Modeling results predict that a very small vent area is required
- Assumes clear vent path for gas products to escape
- Indicates liner material viscosity is important
Cast Cure
Liner Material Investigation

PBXN-109 – AHM Liner Testing

AHM=Asphaltic Hot Melt
Very low viscosity when melted!

Identical single hole vent:
AHM liner: not violent
HDPE liner: violent

HDPE=
High Density Polyethylene
(Higher viscosity than AHM)
Conclusions

• Melt Pour High Explosives:
  – Direct Scaling based on billet surface area for the required vent area determination
  – Required vent area increased with increased number of vent holes
  – Vent area requirement using subscale and large scale fixtures used to develop venting solutions for full sized ordnance systems

• Solid High Explosives
  – Analytic burn modeling indicates that very small vent areas can be successful, but a clear path for gas products is required
  – Melt liner viscosity is a critical factor in reducing vent area required

• Variety of melt pour, cast cure and pressed explosives testing
  – Comp B, PAX-28, PBXN-109, PBXN-9 have been vent tested with and without liners
  – Very little data exists for the burning behaviors at high temperature