2012 Insensitive Munitions & Energetic Materials Technology Symposium

SOLID ROCKET MOTOR VENTING SOLUTIONS

Peter J. Cahill
Aerojet
Culpeper, VA

Kenneth J. Graham
Aerojet
Culpeper, VA

J. Rob Esslinger
U.S. Army AMRDEC
Huntsville, AL

Outline

- Background
  - Description of the problem
  - Historical review
- Aerojet Propellant Testing
- A Shape Memory Alloy Venting Solution
- Description of a Standard Test Motor
- Test Results
- Summary and Conclusions
- Acknowledgements

System Background

- Man-portable (small, light-weight)
- Low-cost, lightweight case which provides reliable pressure capability.
- The propellant is a cross-linked, double-base formulation containing nitramine and a mixed energetic plasticizer.

Modes	IM Reactions		
	Component	FCO	SCO
Field Handling	Propulsion Unit	IV	N/A
Transportation and Storage	Propulsion Unit	IV	III

Type I Detonation
Type II Partial Detonation
Type III Explosion
Type IV Deflagration/ Propulsive
Type V Burning

- State-of-the-art, lower-sensitivity propellants fall short of performance goals.

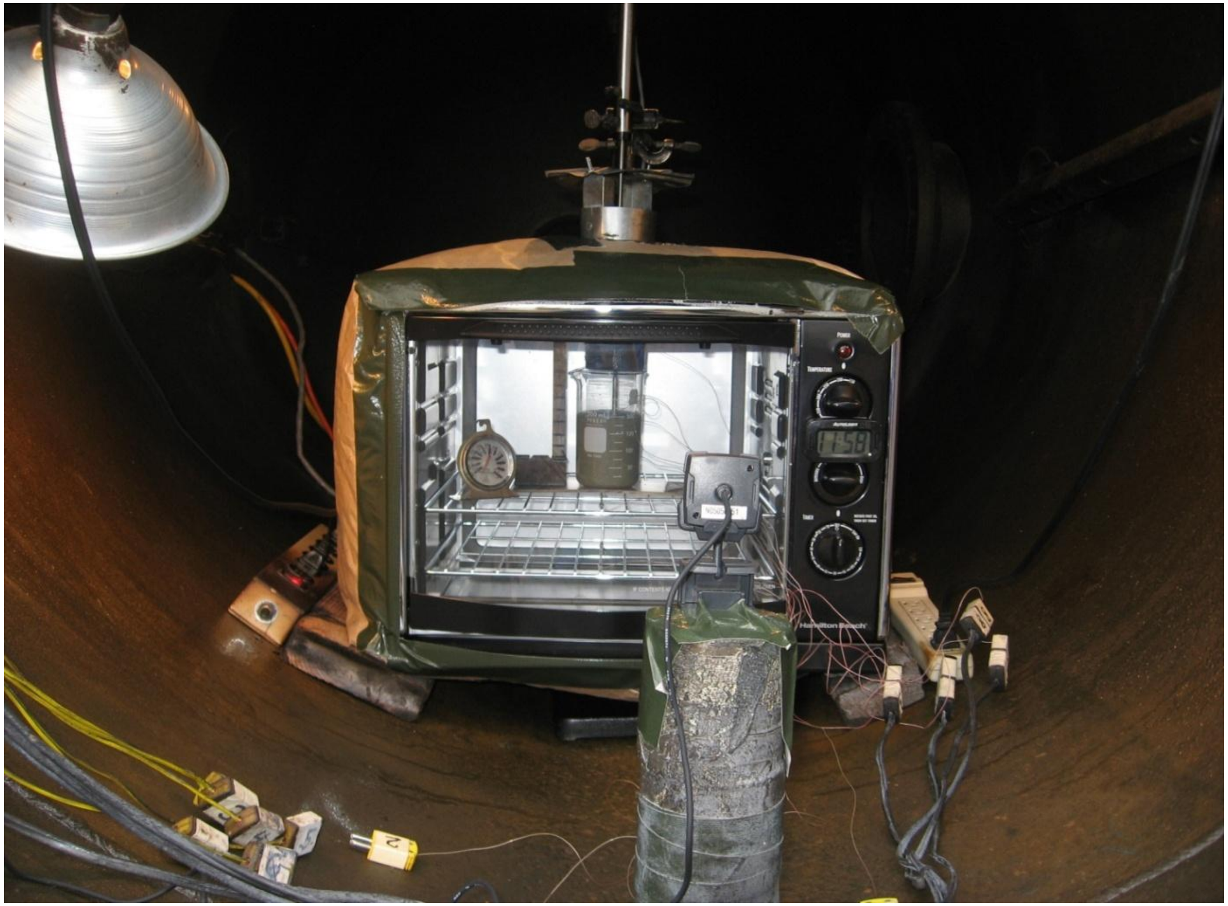
The Cookoff Problem

- **Energetic materials are not meant to survive long durations in high heat environments without undergoing thermal decomposition.**
  - **Faster heating (fuel fire) usually causes a surface ignition of the energetic material.**
    - **Most of the material remains in an undamaged state prior to burning.**
    - **Confinement at the ignition location can lead to drastically different results.**
  - **Slow heating often results in extensive damage prior to ignition.**
    - **Ignition occurs in the bulk, due to self-heating.**
    - **Hardness of the material in this damaged state can influence reaction by adding to confinement.**

Why Venting?

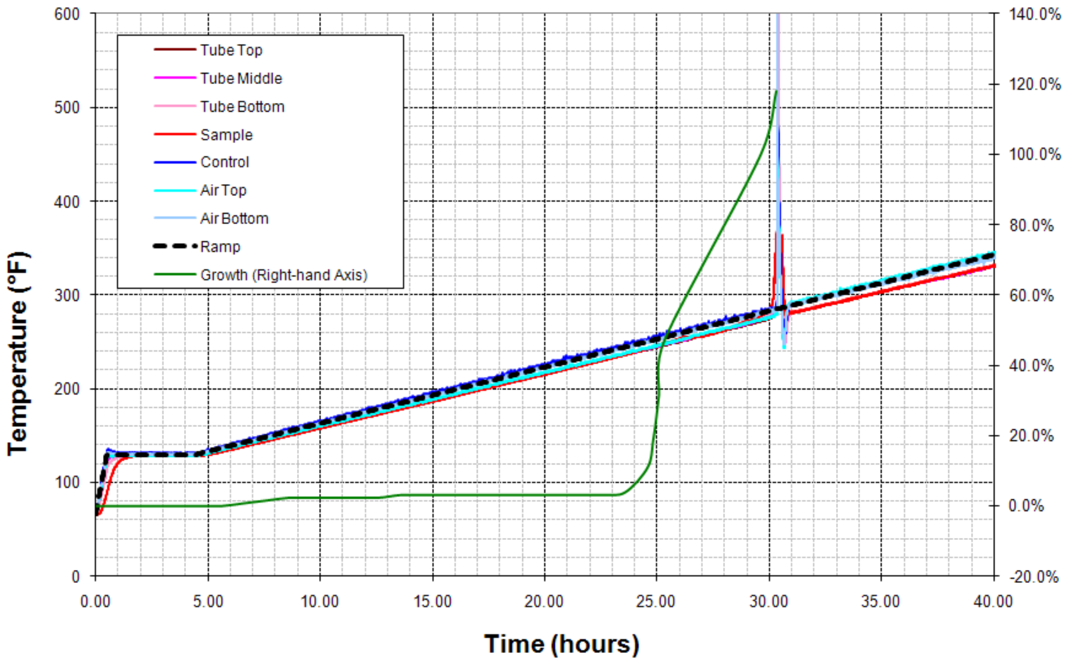
- **The burn time of a rocket motor is controlled by:**
  - **Propellant quantity**
  - **Burning surface area**
    - **dependent on grain design and surface regression of the propellant**
  - **Ballistic properties of the propellant**
    - **dependent on operating pressure & temperature**
- **Product gases increase the pressure in a feedback loop unless they can be removed from the system at an adequate rate.**
  - **Critical vent area where gases produced by decomposition can be effectively released to the surroundings without increasing pressure;**

Aerojet Propellant Testing



Aerojet Propellant Testing

- **Phase changes and decomposition result in void formation and swelling in the propellant.**
  - **Non-CTE growth began 118°C-121°C (245°F-250°F) in three Slow Cookoff Visualization (SCV) Tests, 3.6-6.5 cm (1.4-2.5-inch) diameter.**
  - **Unconfined propellant growth exceeds 100% in SCO heating.**
  - **Propellant softens, non-violent burning when vented.**

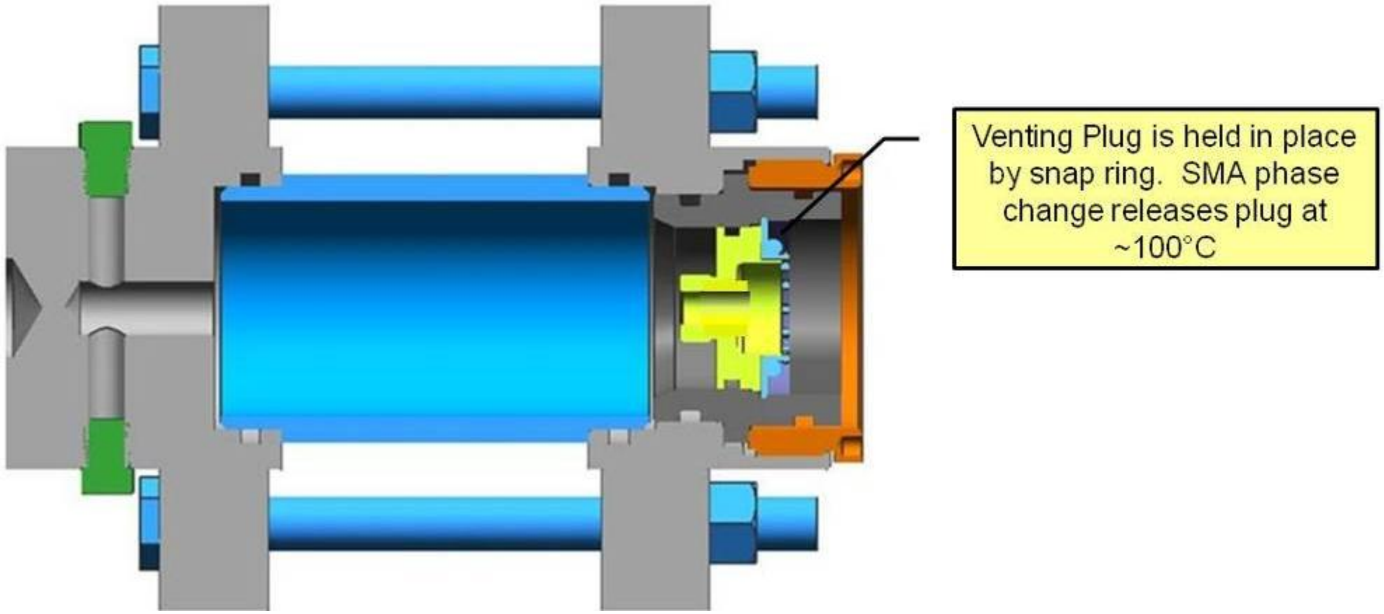


Determining Critical Vent Area

- Aerojet performed burning rate measurements as a function of pressure at various temperatures from 21°C and 115.6°C (70°F to 240°F).
- Burning rate dependence used with rocket motor design tools to determine the critical vent area.
  - This method of analysis and the justification for use in fast cookoff mitigation has been reported previously.
  - Necessarily assumptions:
    - Burn rate temperature sensitivity would remain linear up to autoignition
    - Burning rate equation was valid to low pressures.
- Calculations based on the ambient grain configuration, with the assumption that all grain surfaces were ignited simultaneously.

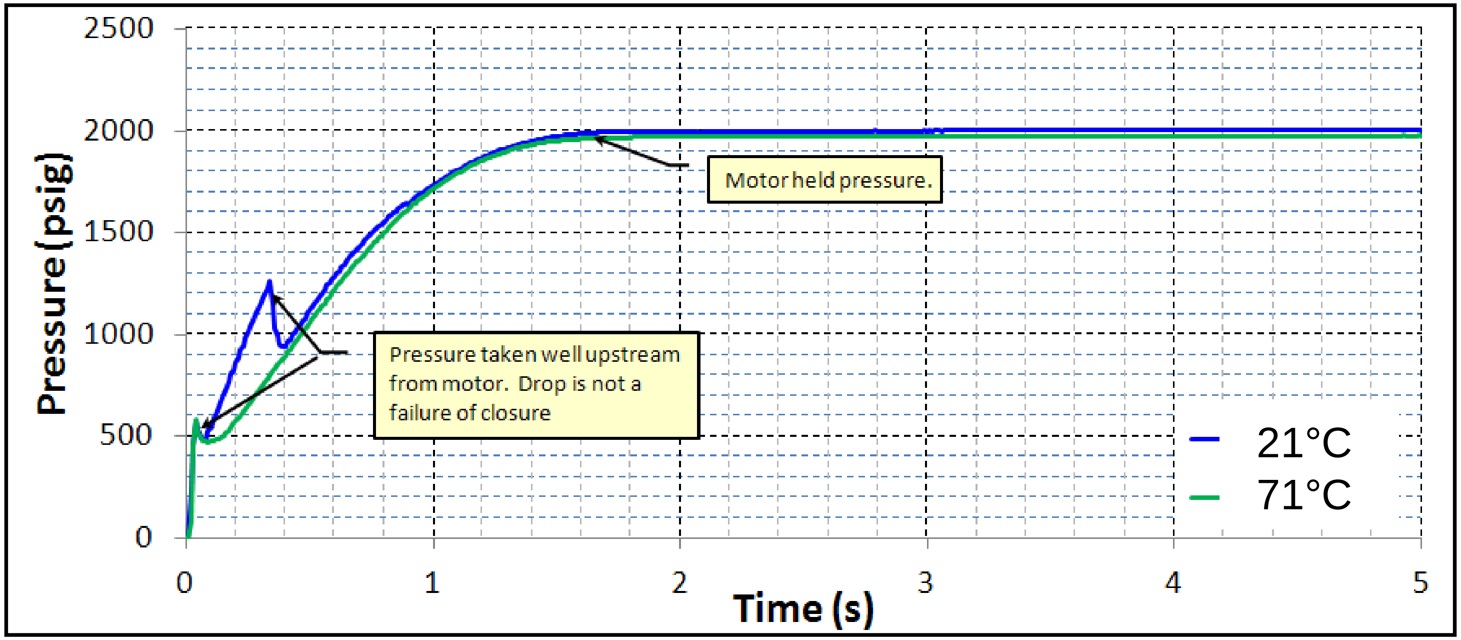
A Shape Memory Alloy Venting Solution

- **Compact ring**
  - **Less than 9g for a 5.08cm (2-inch) diameter test motor**
  - **Providing 11.4cm² (1.76-inch²) vent area**
- **Ring can be implemented in the tactical motor with only minor modifications to parts that would already exist.**



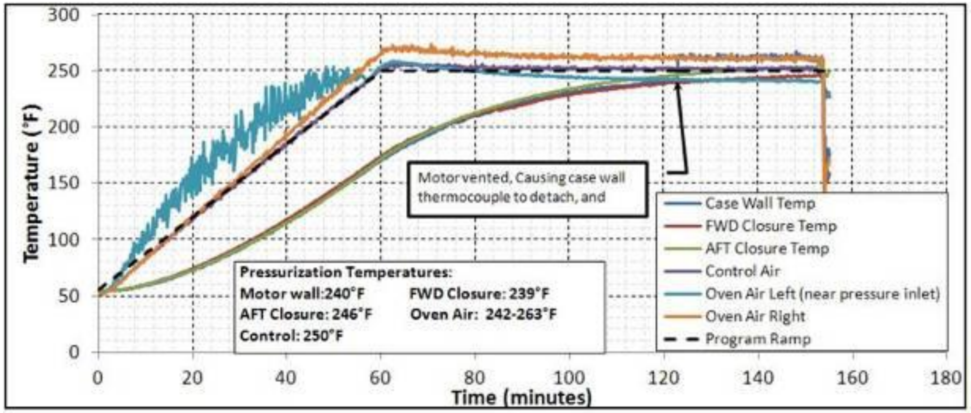
Vent Design Inert Demonstration Testing

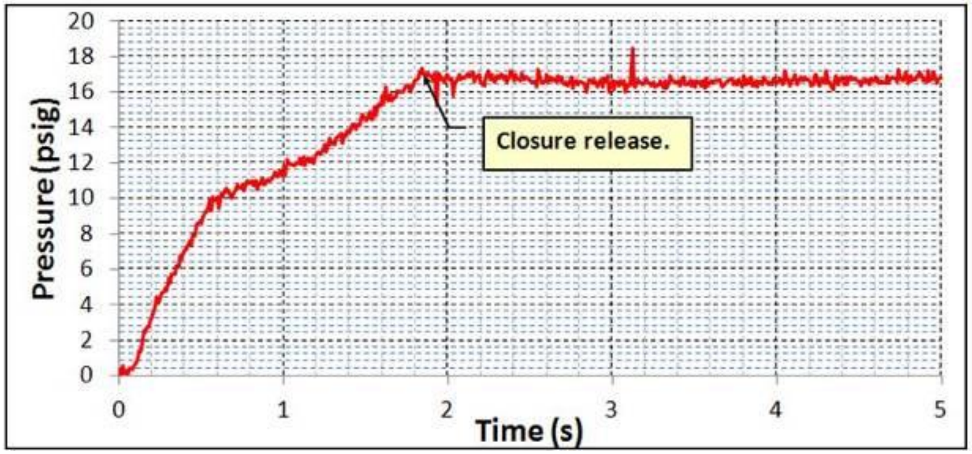
- **Inert motor in oven hooked to supply pressure:**
  - **Rapidly pressurized @ 21°C & 71°C (70°F-160°F).**
    - ***Vent held 13.8 MPa (2000 psi) pressure.***



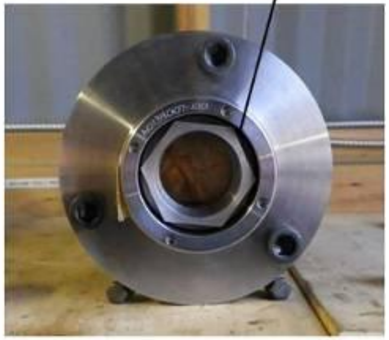
Vent Design Inert Demonstration Testing

- **Conditioned at 250°F and gradually pressurized.**
  - ***Vent opened @17 psi.***

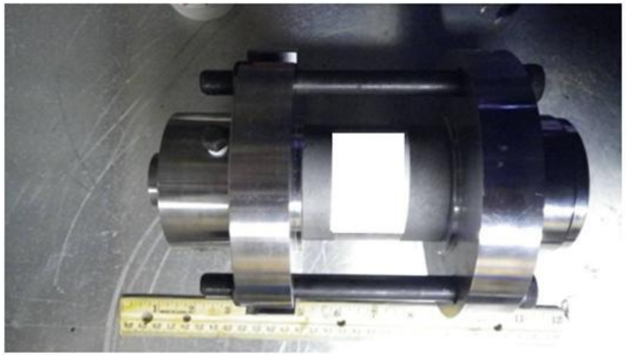


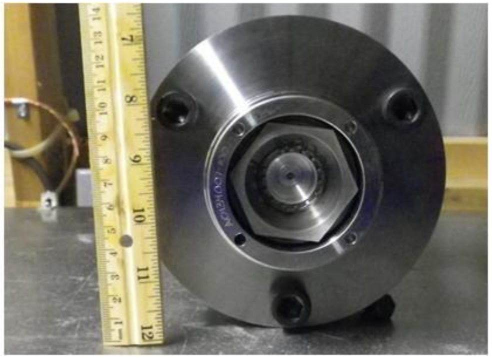


Released Closure at 250°F, 17 psi

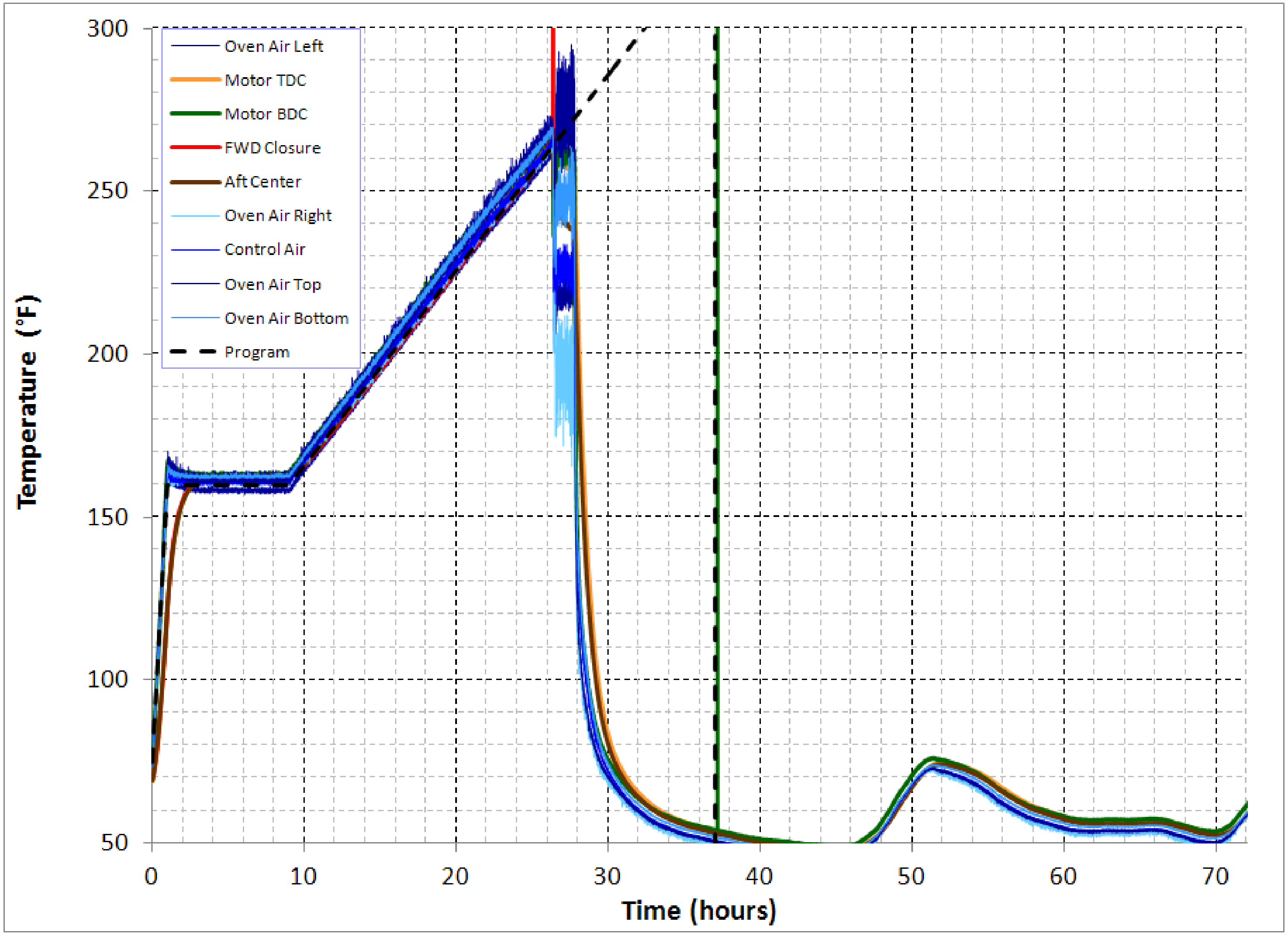


Vent Design SCO Testing





Vent Design SCO Testing



Vent Design SCO Testing

- **Closure vented on propellant ignition @260°F.**
  - **Propellant extinguished (dP/dt)**
- **Continue heating resulted in mild burn.**

Summary & Conclusions

- **Insensitive Munitions design requires system solutions.**
  - **Often times replacing the propellant is not viable.**
- **Aerojet characterized the high-temperature behavior of a high-performance minimum-signature propellant.**
- **Aerojet successfully demonstrated this venting device in inert gas testing and in slow heating testing with a loaded test motor.**
  - **This testing marks a leap forward for passive venting in small systems due to the low weight and simplicity of the mechanism.**
  - **The entire feature replaces material already in use in the motor case construction, with the exception of the critical components.**

Acknowledgements

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