Exceptional service in the national interest

SAND2014-18993C

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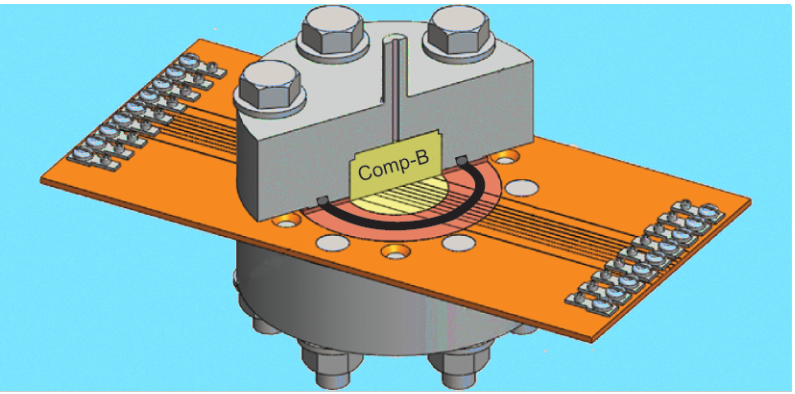
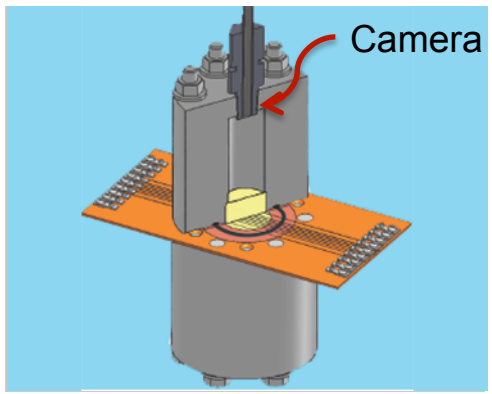
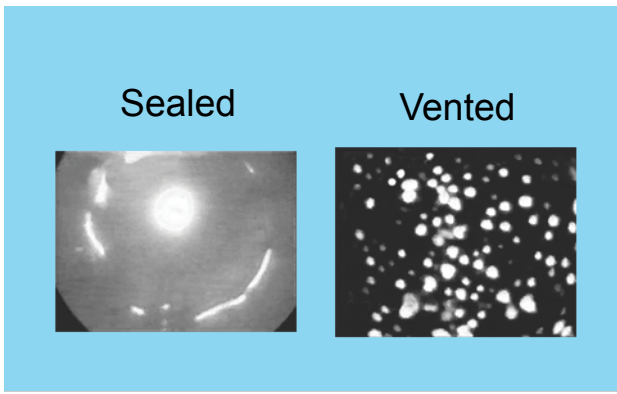
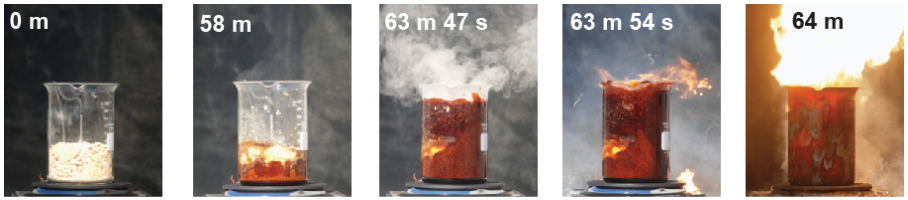






The Effect of Venting on Cookoff of a Melt-Castable Explosive (Comp-B)



M. L. Hobbs and M. J. Kaneshige

Sandia National Laboratory, USA

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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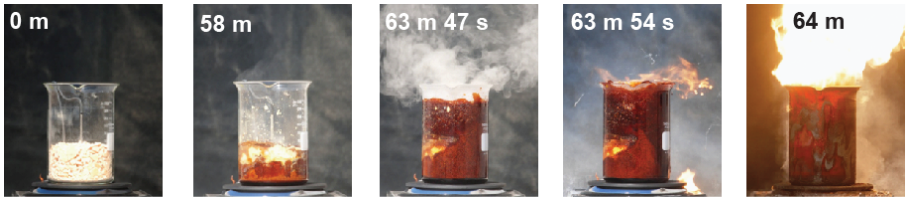
Introduction



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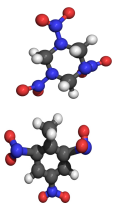
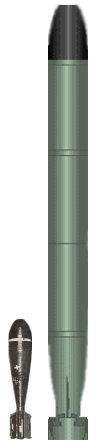
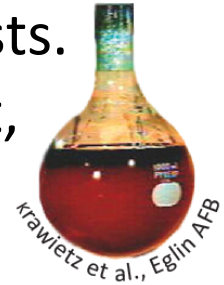


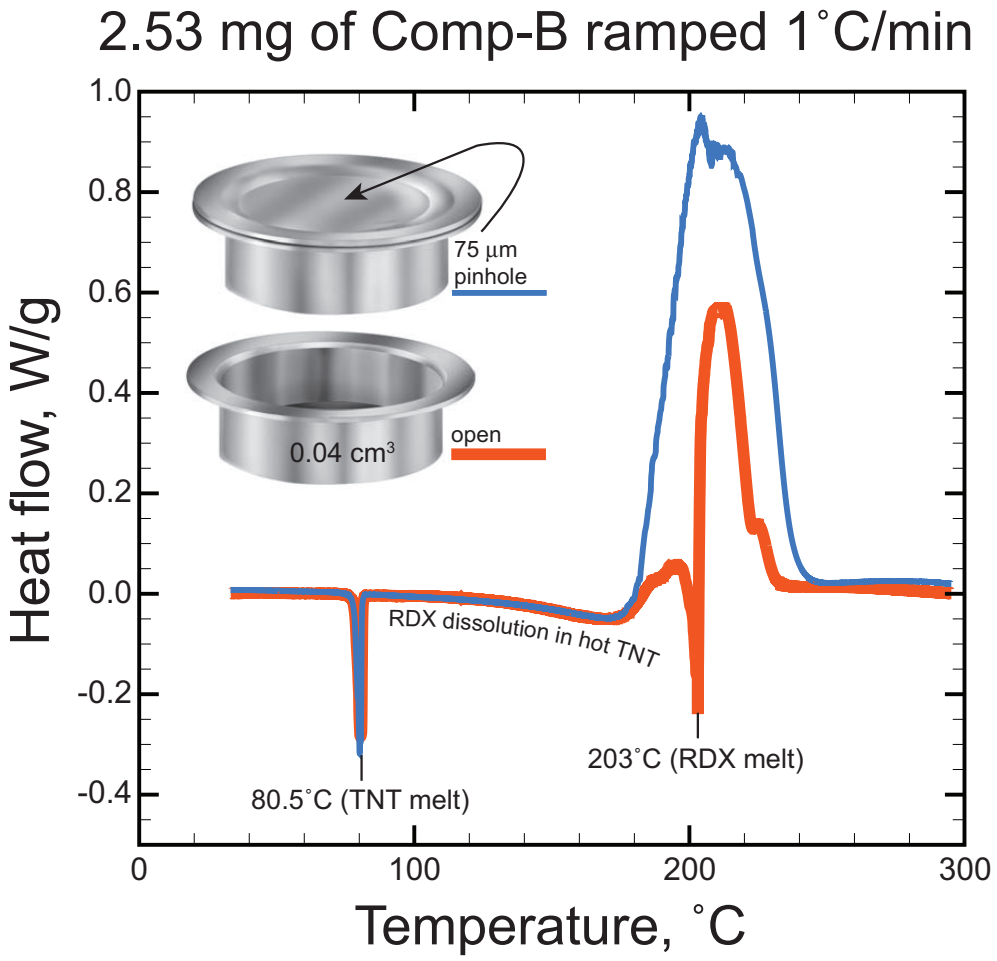
- Composition B (Comp-B) explosives consist of mixtures of RDX and TNT, and a desensitizing wax.
- Developed prior to WWI and used in mortar shells, torpedoes, demolition charges, warheads, shaped charges, and bombs.



- Prepared by melting TNT in a steam-jacketed kettle, adding wet RDX slowly, heating and stirring until the water is evaporated. Comp-B is cast into desired shape and cooled.
- Comp-B is easy to process, has a high detonation pressure, but fails many insensitive munitions (IM) requirements.
- Comp-B does not always pass slow and fast cookoff IM tests. Consequently, the response of Comp-B during an accident, such as a fire, is important for safety analysis.



Differential Scanning Calorimeter



- To our knowledge, this is the first time the RDX melt endotherm has been shown in a DSC of Comp-B.
- Better heat transfer slows the exothermic release in the open DSC.
- RDX melt obscured by exotherm in sealed DSC.
- TNT melt and RDX dissolution are similar in vented vs. sealed DSC.

Sandia's Instrumented Thermal Ignition (SITI)

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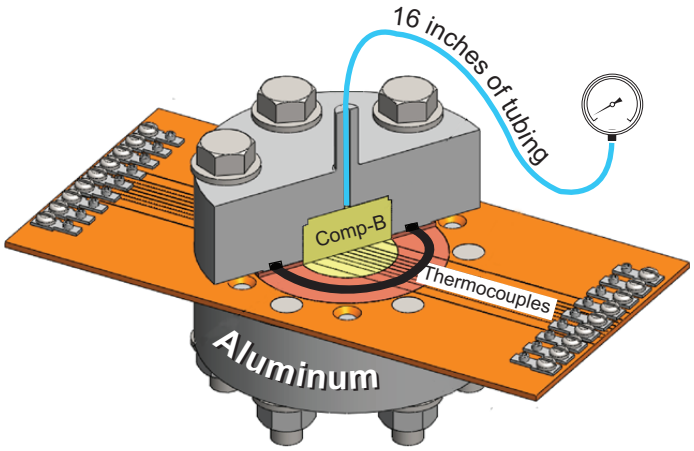
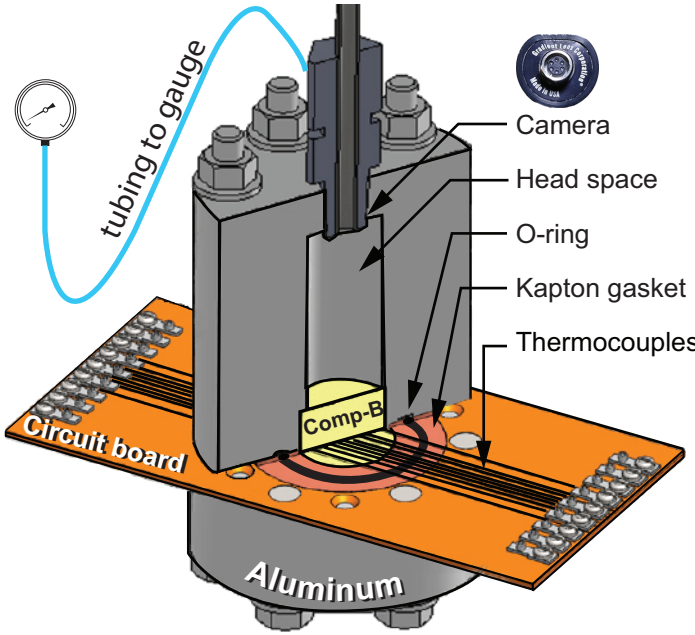
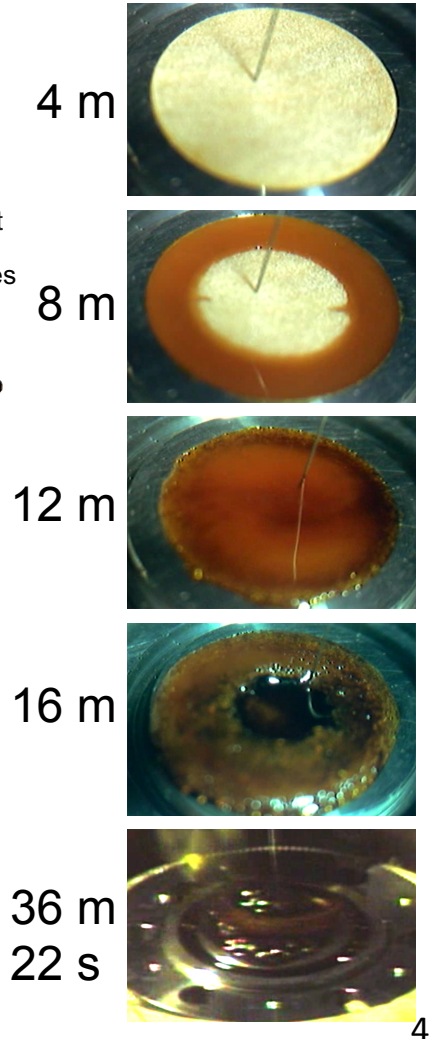
Limited head space



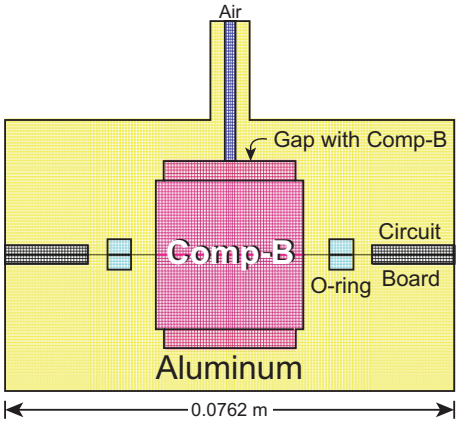
Ample head space



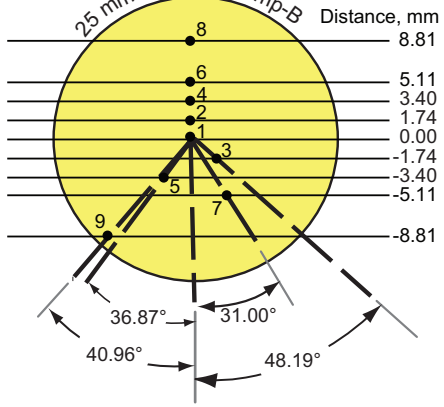
Open half shell



Finite element mesh



Thermocouple locations



Pressure affects mixing/heat transfer

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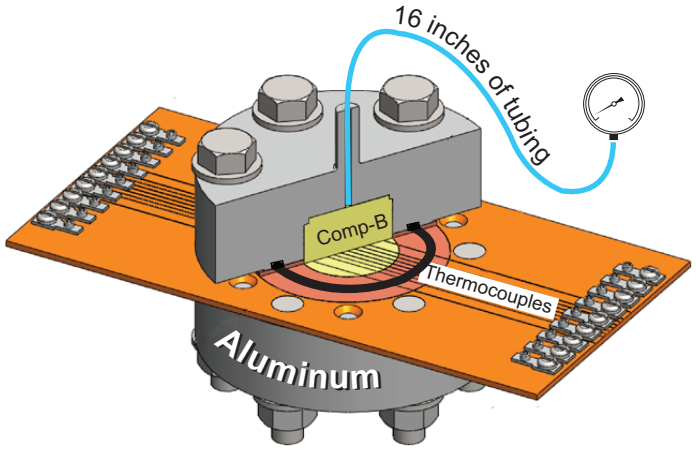
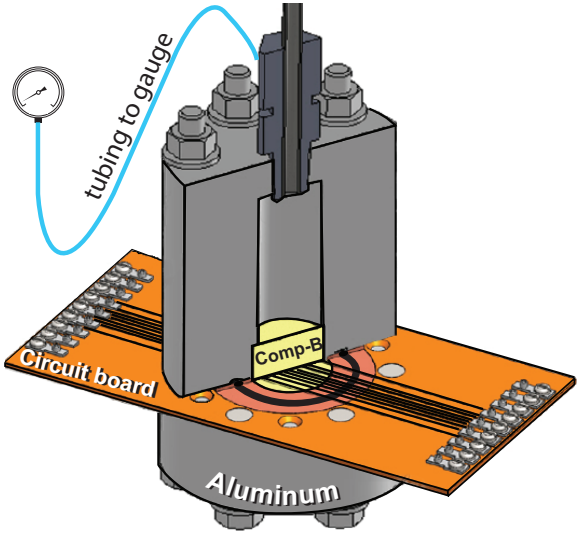
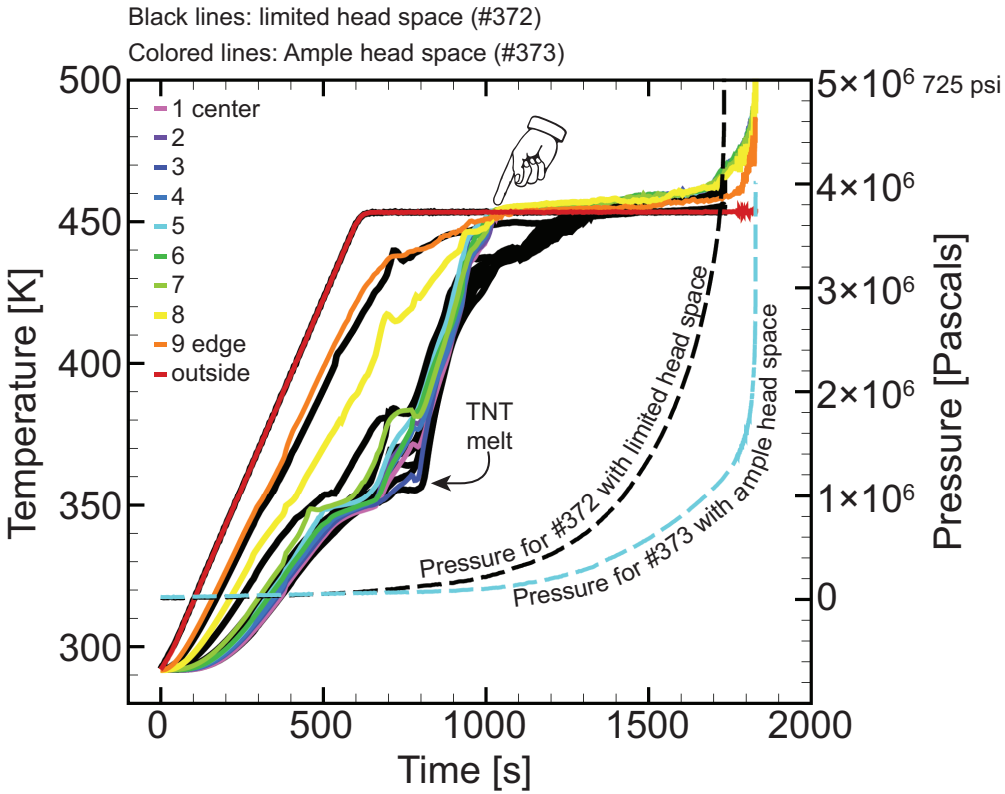
Limited head space, #372



Ample head space, #373



Large head space (colored) shows increased heat transfer



Pressure affects heat transfer more than chemistry since ignition times are similar.

Venting has a *significant* effect

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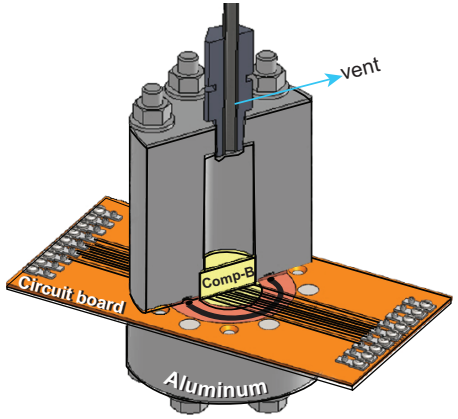
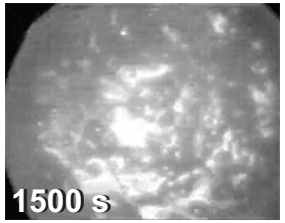
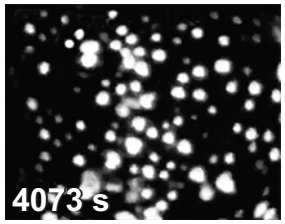
Vented, #370

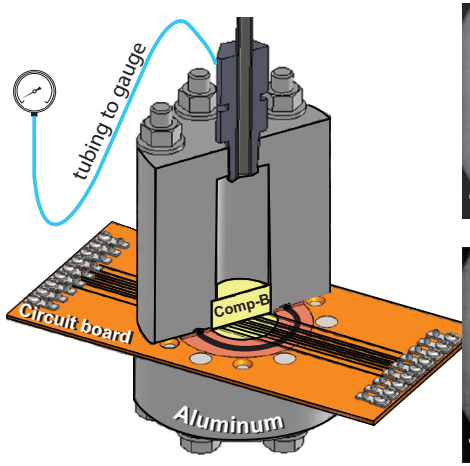


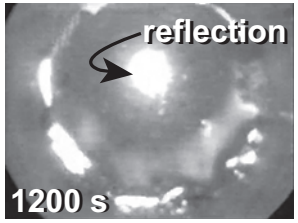


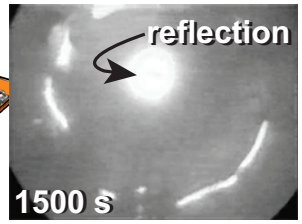


vigorous motion

Sealed, #373

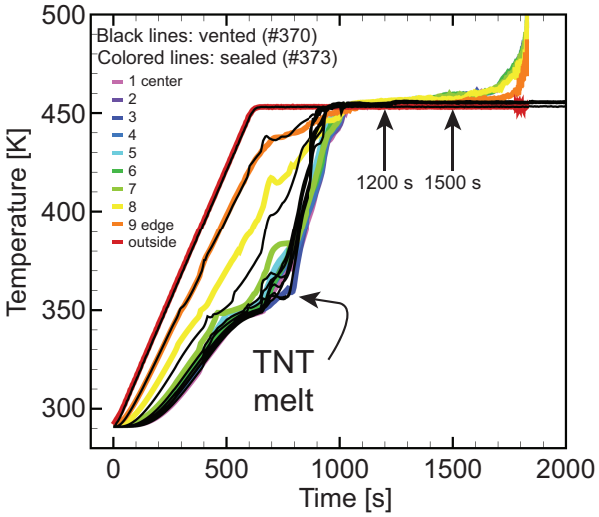


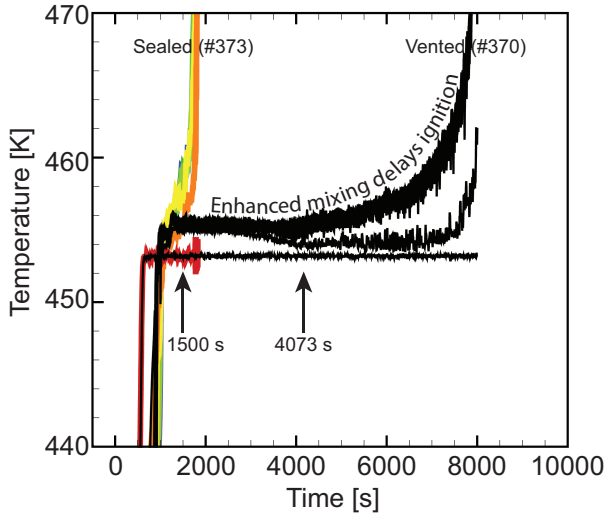




quiescent motion

Temperatures





Observations

- Bubbly two-phase flow increases heat transfer and delays ignition.
- Higher pressure causes large bubbles to escape along the edge of the Comp-B.

One-Dimensional Time-to-eXplosion (ODTX)

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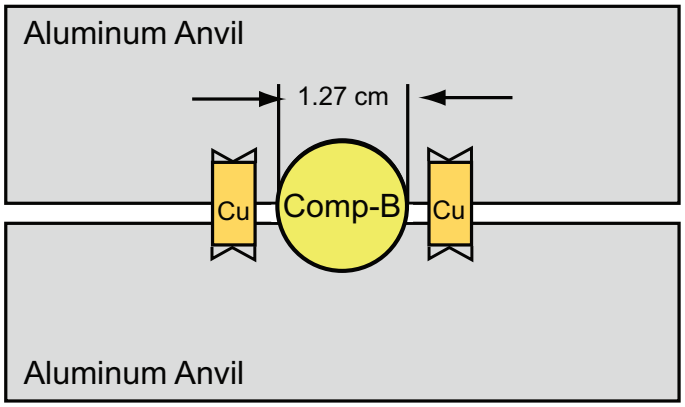
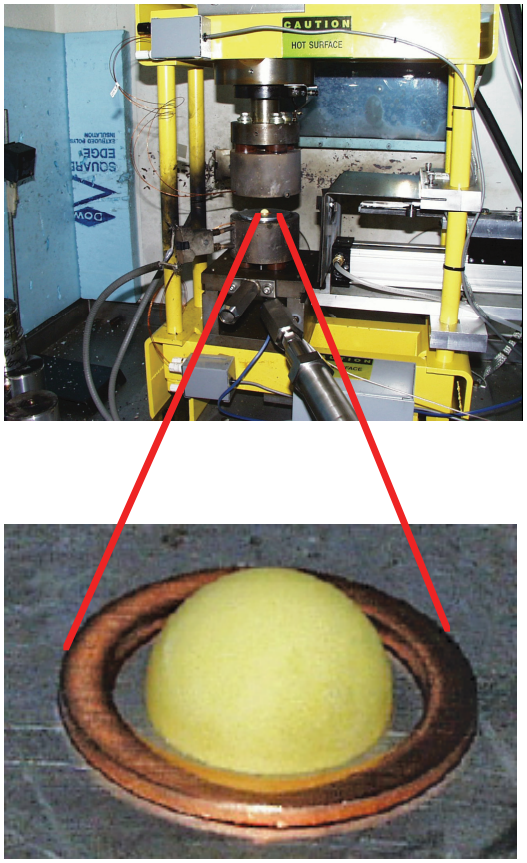
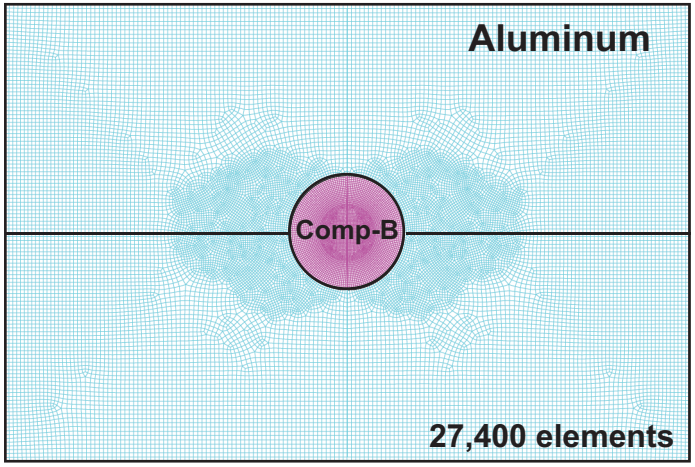
Schematic



Photograph



Finite element mesh



ODTX should behave like a sealed system without vigorous two-phase flow effects.

Model Features

- One-step, first-order mechanism
- Distributed Arrhenius rate
- Product hierarchy from equilibrium calculations
- Liquefaction and dissolution modeled thermodynamically
- Liquid rates are 30 times larger than solid rates
- One energy equation and three continuity equations for Comp-B, Gas, and Carbon.

$C_{2.03}H_{2.64}N_{2.18}O_{2.66} \rightarrow 1.09\ N_2 + 1.08\ H_2O + 0.79\ CO_2 + 0.11\ CH_4 + 0.02\ H_2 + 1.13\ C$

Comp-B $\rightarrow$ 3.09 Gas + 1.13 C + 5.87×10^6 Jkg^{-1}

$$\rho C_p \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + r h_{rxn} M_{w,compb}$$

$$\frac{d}{dt}[\text{compb}] = -r \qquad \frac{d}{dt}[\text{gas}] == +3.09r \qquad \frac{d}{dt}[\text{carbon}] = +1.13r \qquad r = A\lambda \exp\left[-\left(E + \xi\sigma_E\right)/RT\right][\text{compb}]$$

SITI model results

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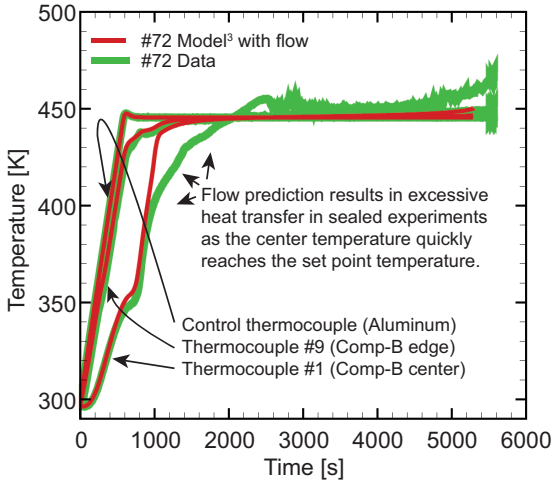
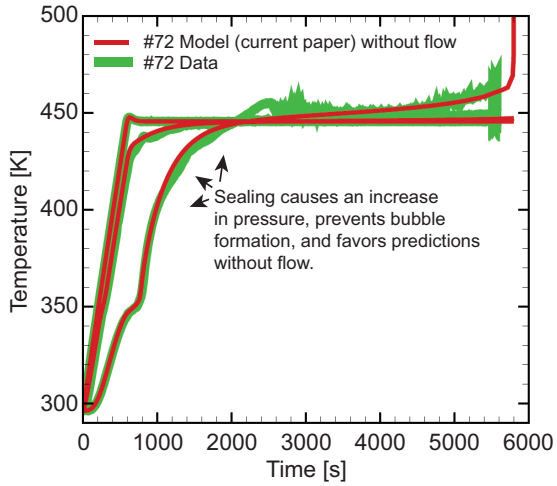
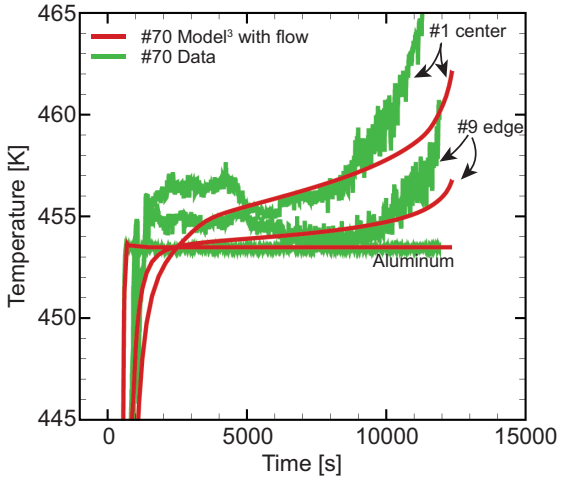
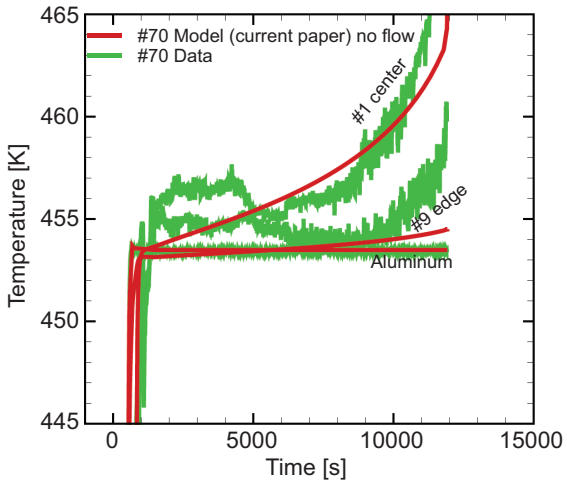
Sealed (short times)



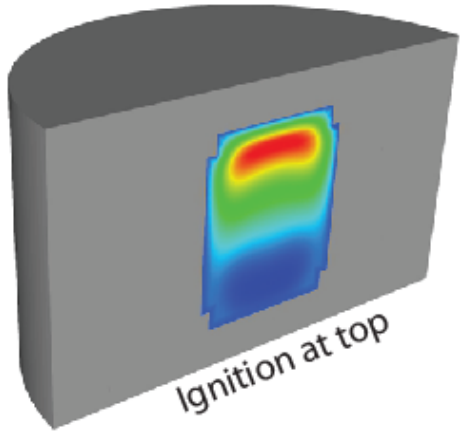


Vented (long times)

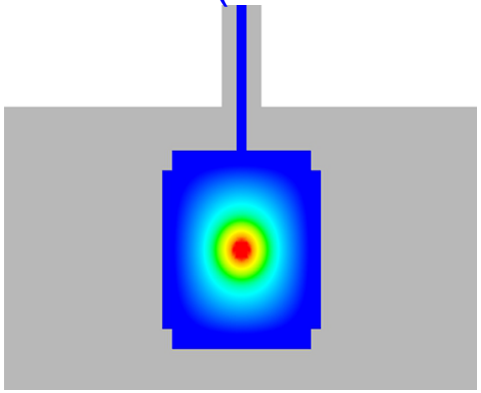




Flow (reference 3)



No flow (current work)

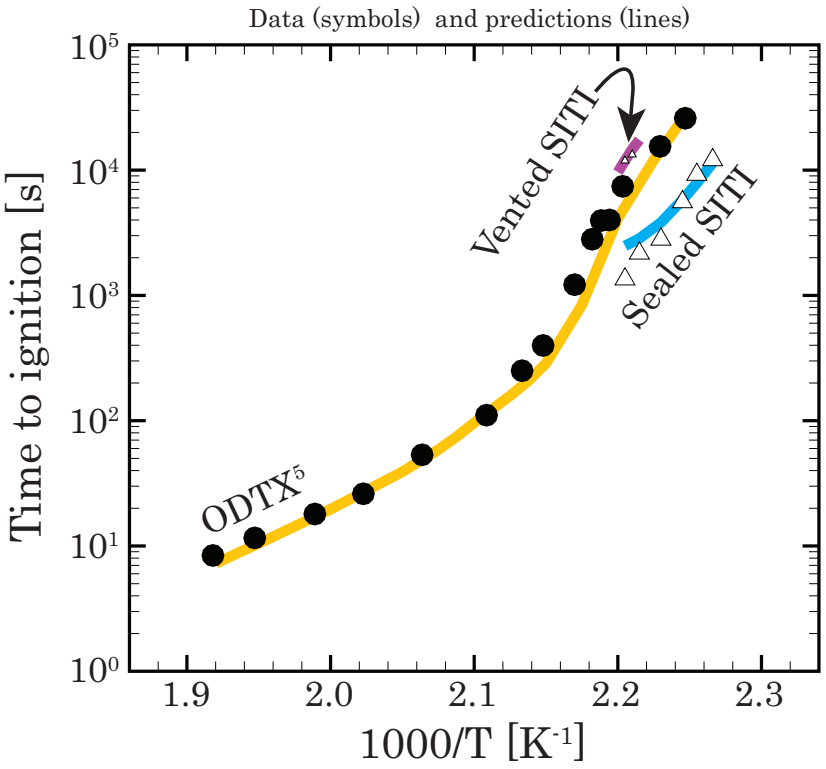


[3]M. L. Hobbs, M. J. Kaneshige, and M. U. Anderson, JANNAF 27th Propulsion Systems Hazards Joint Subcommittee Meeting, Monterey, CA (2012).

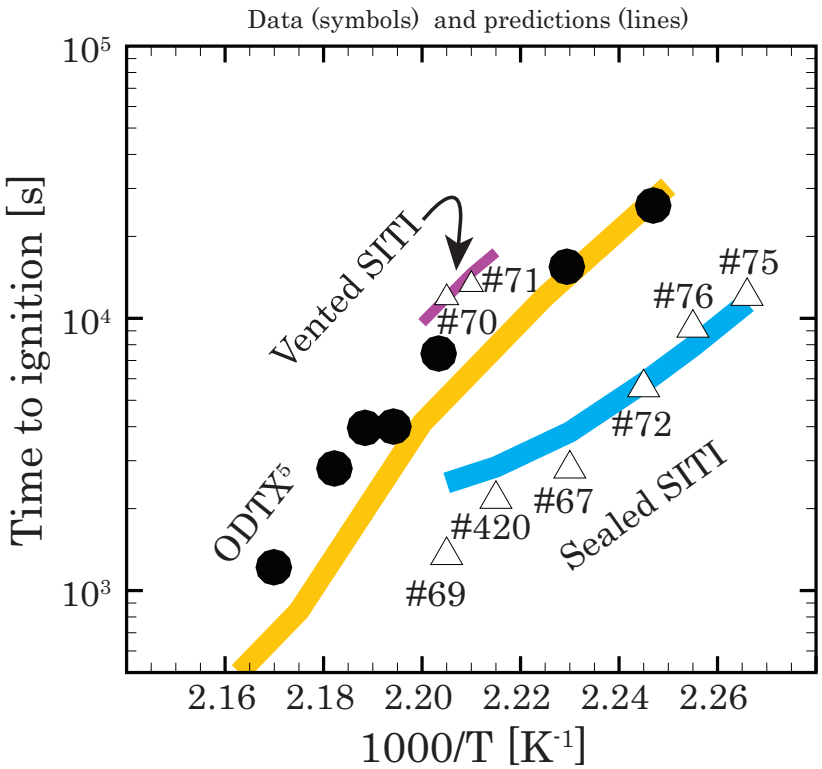
Model with no flow (current work) matches data better for both sealed and vented SITI experiments than model with flow from reference 3.

Ignition plots

ODTX (orange)



SITI (cyan)



[5]R. R. McGuire and C. M. Tarver, Seventh Symposium (International) on Detonation, 56-64, Annapolis, MA (1981).

Need more vented data and data taken in larger geometries.

Conclusions

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- Comp-B decomposes differently as a mixture than the individual components RDX and HMX.
- TNT melts between 77-102°C in Comp-B.
- The RDX suspension in hot TNT dissolves between 147-187°C.
- The dissolution of RDX is not as sharp as a phase change and favors a distributed activation energy model.
- Melting of RDX is obscured by the exotherm in published DSC data. However, melting is observed when heating slowly in an open system.
- More data is needed for both sealed and vented systems.
- More data is needed for large-scale systems.