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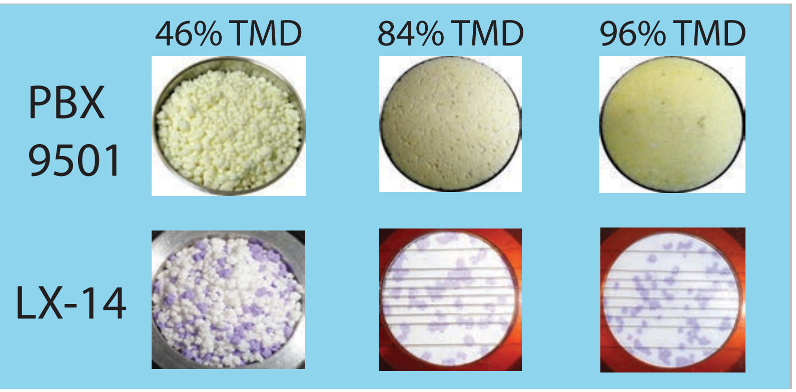
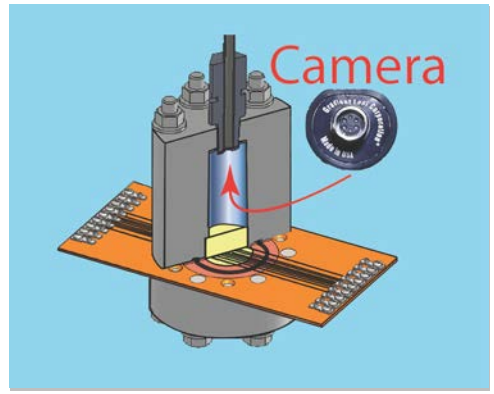
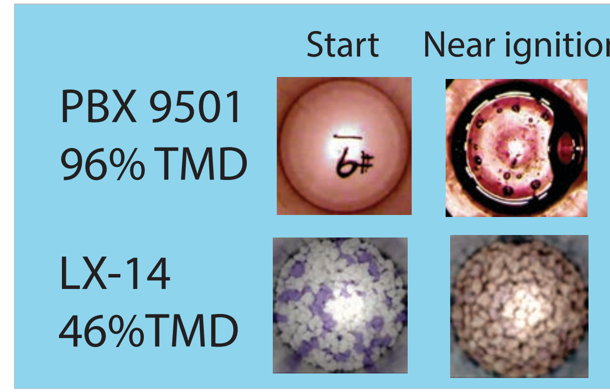
SAND2017-10519C







Gas Retention in a Heated Plastic Bonded Explosive (LX-14)

M. L. Hobbs, M. J. Kaneshige, W. W. Erikson, K. T. Miers

Sandia National Laboratory and US Army, USA

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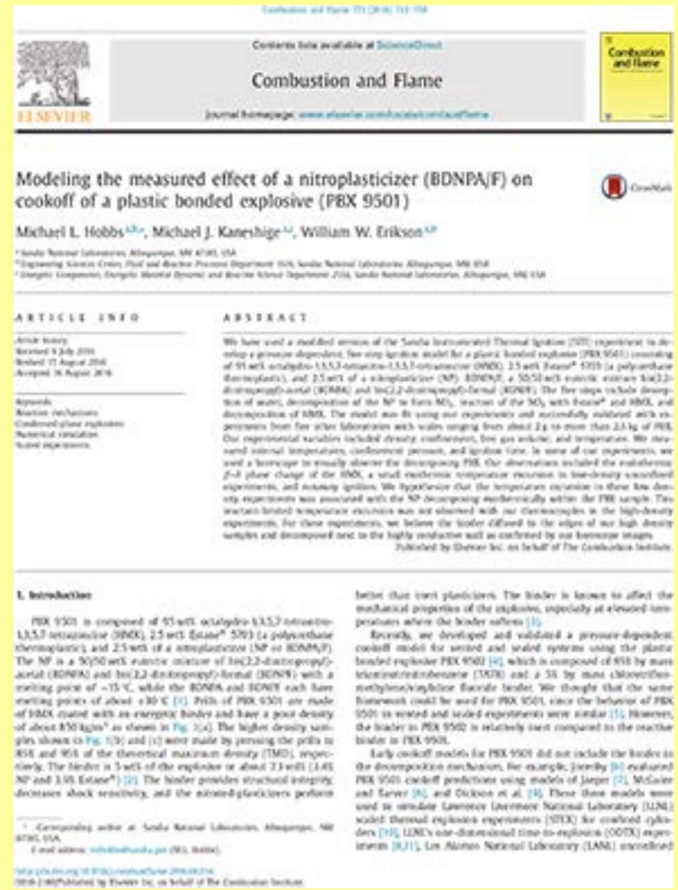
Introduction

- Published observation that the nitroplasticizer (NP) in PBX 9501 played a significant role in cookoff.
- For confirmation, we did several experiments with LX-14, which has nominally the same amount of HMX, has an Estane binder, but has no NP.
- Expected LX-14 to be less reactive than PBX 9501 due to lack of the NP; but LX-14 reacted faster.
- We discovered that gas retention in LX-14 plays a significant role in cookoff.
- Retention of reactive gases in LX-14 may explain observed violence in slow cookoff experiments.
- We present small-scale experiments, a model of LX-14 ignition, and validation using smaller-scale (ODTX) and larger-scale (TOW) cookoff data.


Combustion and Flame

Modeling the measured effect of a nitroplasticizer (BDNPA/F) on cookoff of a plastic bonded explosive (PBX 9501)

Michael L. Hobbs, Michael J. Kaneshige, William W. Erikson

ARTICLE INFO

ABSTRACT

1. Introduction

LX-14 is more reactive and ignites sooner than PBX-9501 in cookoff tests due to retention of reactive decomposition gases.

LX-14 and PBX 9501 differences

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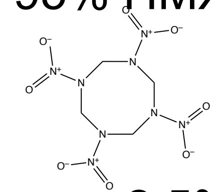
PBX 9501

46% TMD

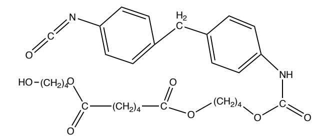
84% TMD

96% TMD

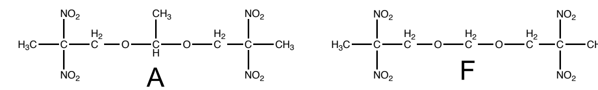
95% HMX



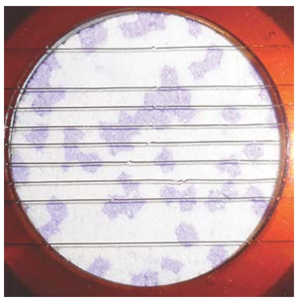
2.5% Estane

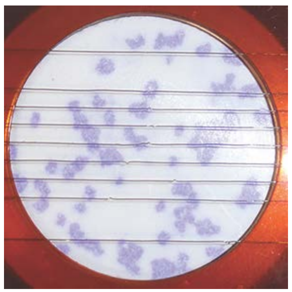


2.5% BDNPA/F

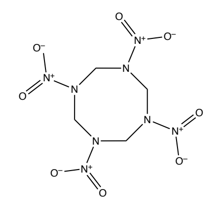


LX-14

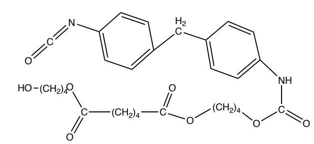




95.5% HMX



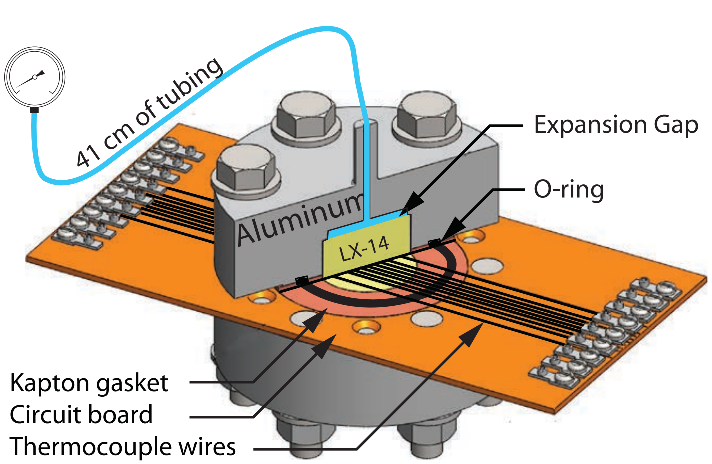
4.5% Estane



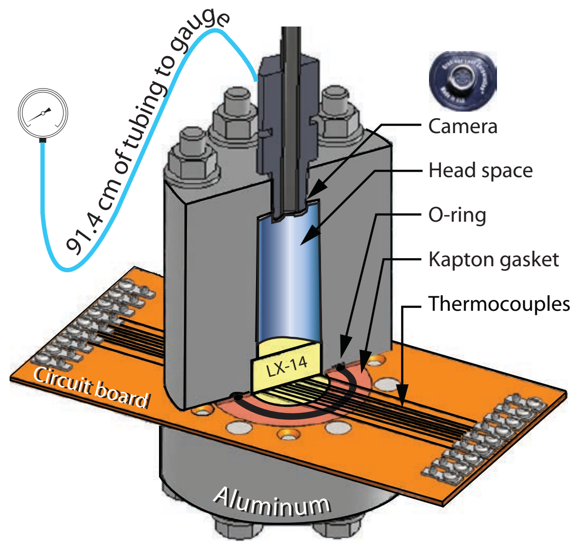
These explosives have nominally the same detonation performance and give the same flame temperatures. However, the LX-14 reacts sooner in cookoff tests and is more violent in blunt impact tests.

Sandia's Instrumented Thermal Ignition (SITI)

Limited head space



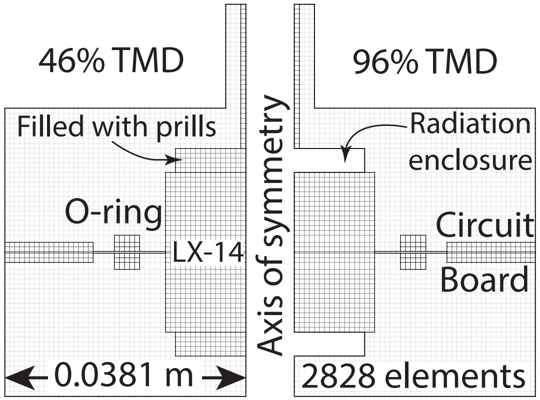
Ample head space



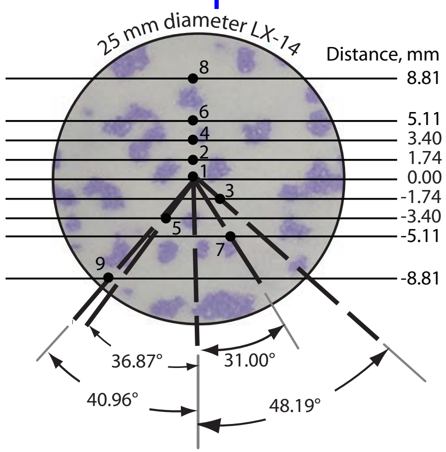
Borescope images

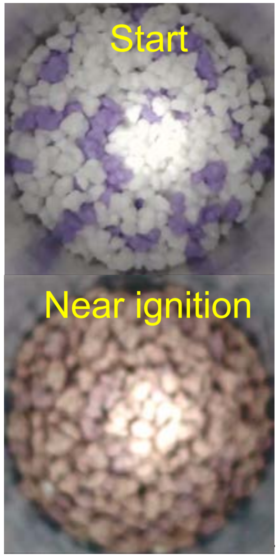
PBX 9501 gases escape

Finite element mesh



Thermocouple locations



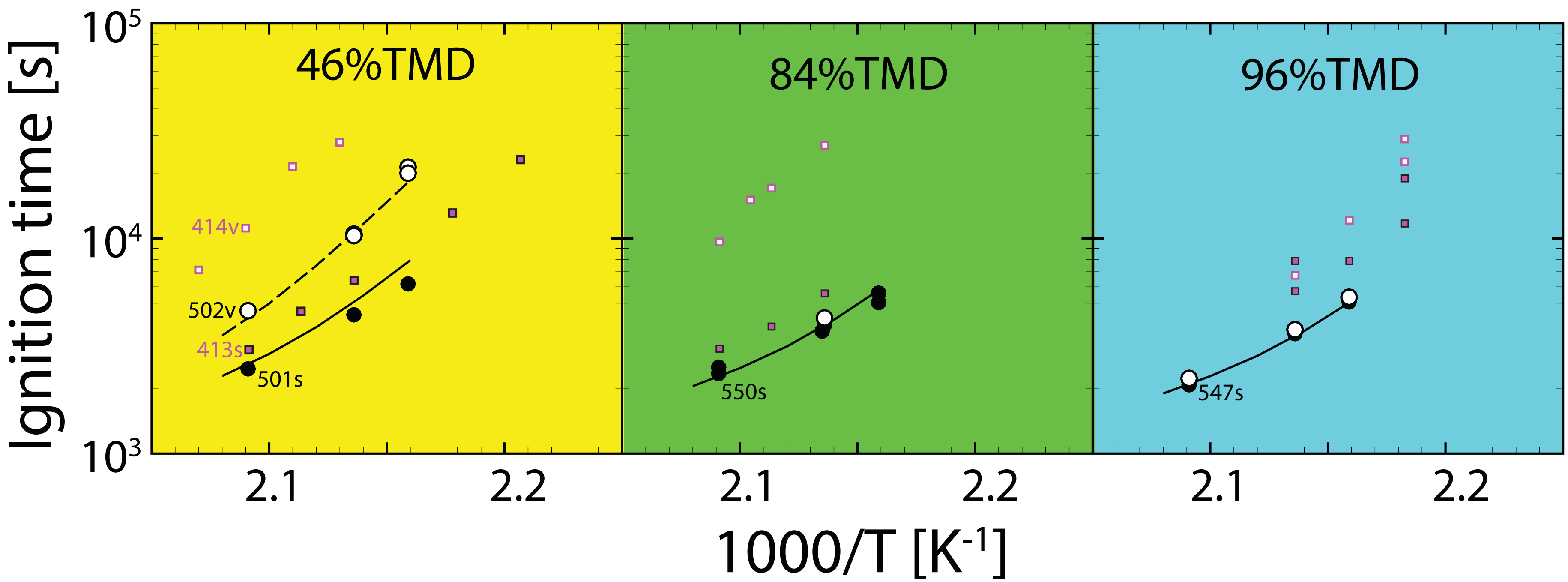


LX-14 gases retained

SITI ignition data at various densities

Data: LX-14 (sealed ● ,vented ○) and PBX 9501 (sealed ▪ , vented ▫)

Model: LX-14 (sealed —— ,vented – –)

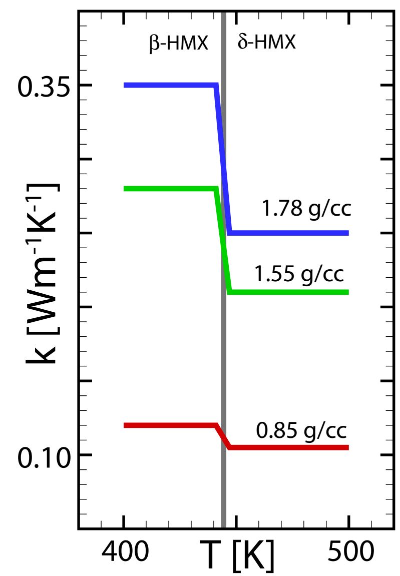


PBX 9501 ignition delay due to venting is significantly greater than for LX-14.
Venting does not affect LX-14 for densities greater than 84% TMD (1.5 g/cc).

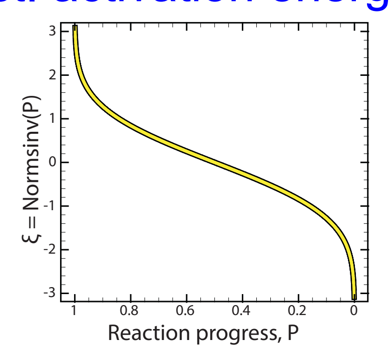
Model

Energy conservation	$\rho_b C_b \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + \sum_{i=1,3} r_i h_{ri} M_{w,i}$
Mechanism	$(H_2O)_a \overset{1}{\rightarrow} H_2O$
	$HMX(C_4H_8N_8O_8) \overset{2}{\rightarrow} 4N_2 + 3.6H_2O + 2.2CO_2 + 0.2CH_4 + 1.6C$ or, $HMX \overset{2}{\rightarrow} 10G + 1.6C$ P dependent, gas-phase dominates.
	$HMX(C_4H_8N_8O_8) \overset{3}{\rightarrow} 4N_2 + 3.6H_2O + 2.2CO_2 + 0.2CH_4 + 1.6C$ or, $HMX \overset{3}{\rightarrow} 10G + 1.6C$ P independent, condensed-phase dominates.
Rates	$r_1 = A_1 exp\left(\frac{-E_1 + \zeta\sigma_1}{RT}\right)[H_2O]$
	$r_2 = A_2\left\{1 + 0.5\left(1 + \tanh\frac{[T - T_m]}{\Delta T_m}\right)\xi\right\}\left(\frac{P}{P_o}\right)^{0.5} T^{-1} exp\left(\frac{-E_2 + \zeta\sigma_2}{RT}\right)[HMX]$
	$r_3 = A_3\left\{1 + 0.5\left(1 + \tanh\frac{[T - T_m]}{\Delta T_m}\right)\xi\right\} T^{-1} exp\left(\frac{-E_3 + \zeta\sigma_3}{RT}\right)[HMX]$
Species conservation	$\frac{d[(H_2O)_a]}{dt} = -r_1;\ \frac{d[H_2O]}{dt} = r_1;\ \frac{d[HMX]}{dt} = -r_1 - r_2;$ $\frac{d[G]}{dt} = 10(r_1 + r_2);\ \frac{d[C]}{dt} = 1.6(r_1 + r_2)$
Reaction progress	$P_1 = \frac{[H_2O]}{\omega_{H_2O_a}\rho_{b,o}/Mw_{H_2O_a}};\ P_2 = P_3 = \frac{[HMX]}{\omega_{HMX}\rho_{b,o}/Mw_{HMX}}$
Pressure	$P = znRT_{ave}/V_g\,;\ z = 1 + Xexp(\beta X);\ X = \frac{nk\sum x_i k_i}{v_g(T_{ave}+\theta)^\alpha};$ $n = \iiint([H_2O] + [G])dV;\ T_{ave} = \frac{\iiint CTdv}{\iiint \rho C dv};\ V_g = \iiint \phi dV;$ $\phi = 1 - S_f\rho_{c.o}(1 - \phi_o)/\rho_c;\ S_f = \frac{([(H_2O)_a]Mw_{H_2O} + [HMX]Mw_{HMX} + [C]Mw_C)}{\rho_{b,o}}$ $\rho_c = \rho_{c,o}[1 - 0.00031(T - T_o)]$, when $T \le T_{\beta\ to\ \delta}$ $\rho_c = \rho_{c,o}\{[1 - 0.00031(T - T_o)] - 0.067\}$, when $T > T_{\beta\ to\ \delta}$

Thermal conductivity



Dist. activation energy

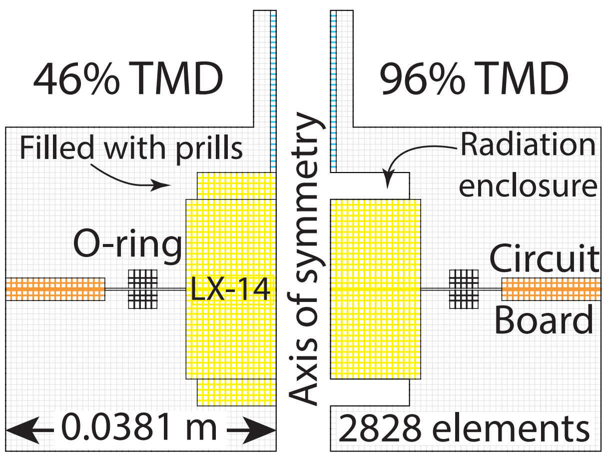


Three-step mechanism includes drying and pressure dependency.

Experiments

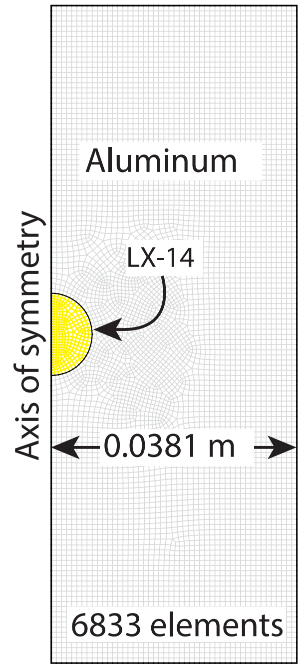
Primary

Sandia Instrumented Thermal Ignition (SITI)

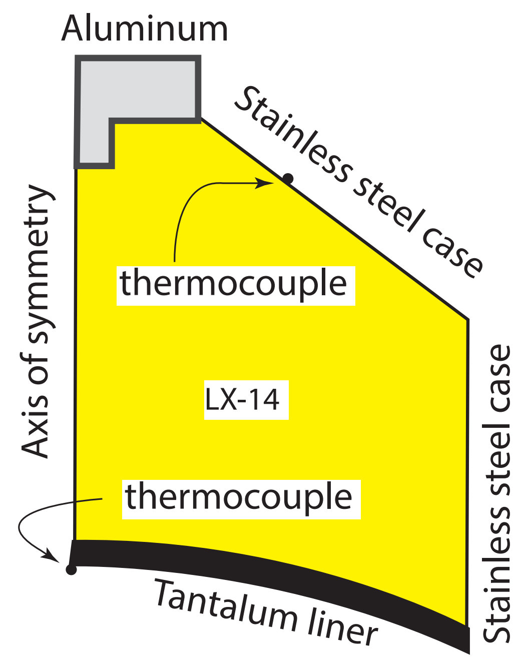


Validation

One-Dimensional Time-to-eXplosion (ODTX)



Tube-launched, Optically-guided, Wire-tracked (TOW)



SITI (21) experiments considered effects of temperature, density, and confinement. ODTX (1) and TOW (3) were used for validation.

SITI Results

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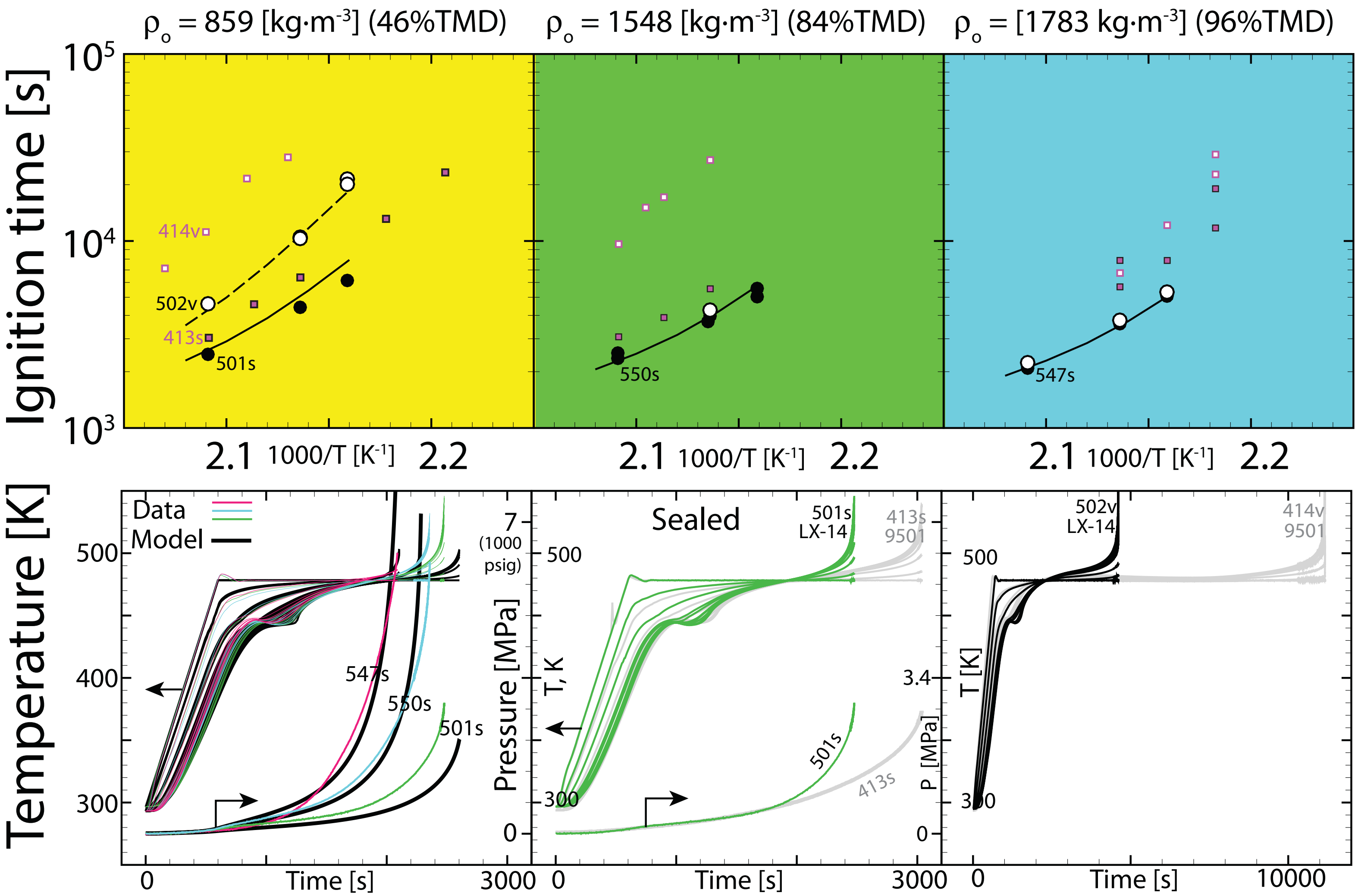
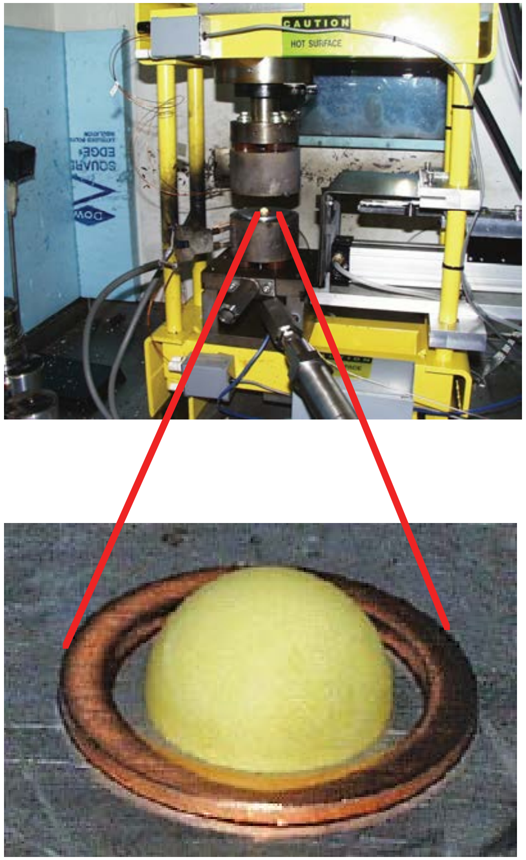


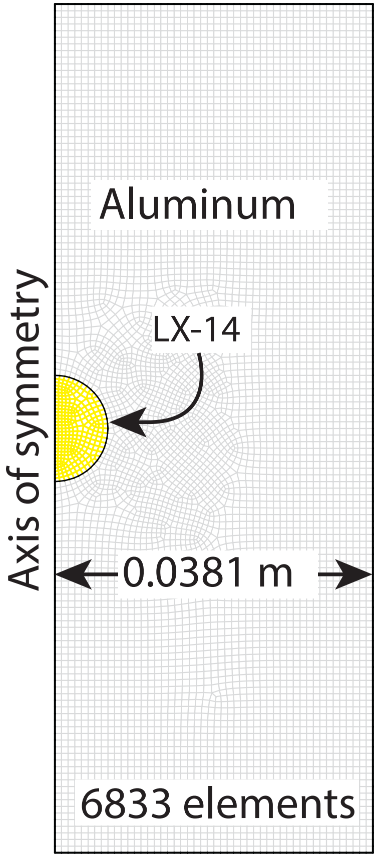
Model matches ignition time, internal temperatures, and pressure. The effect of venting on LX-14 is significantly less than with PBX 9501.

One-Dimensional Time-to-eXplosion

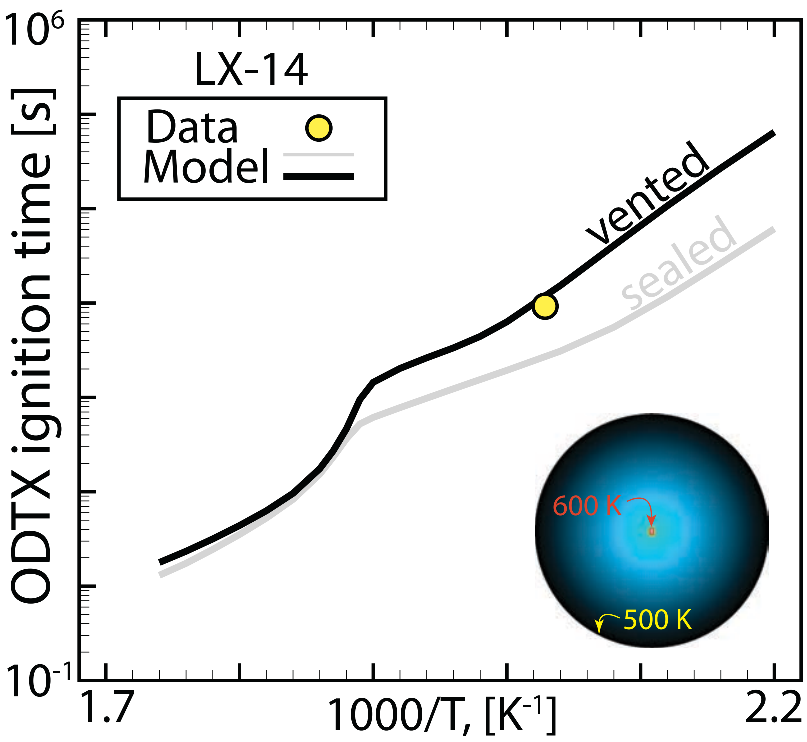
Experiment



Mesh



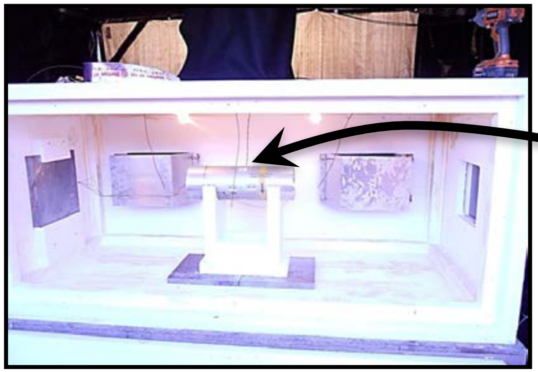
Results

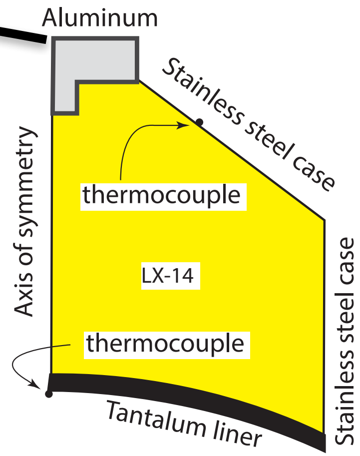


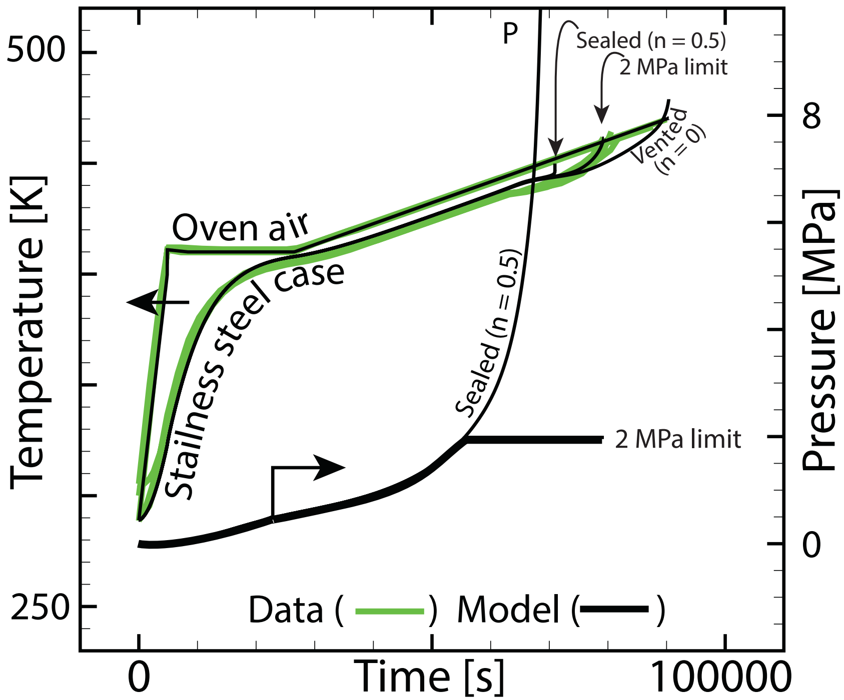
Leak? Limited data with only one temperature. Need more experiments.

Tube-launched, Optically-guided, Wire-tracked (TOW)

Experiment | Schematic | Results







Vented model (n=0) and sealed model (n=0.5) bound data. Setting working pressure of confinement to 2 MPa matches data.

Summary and Conclusions

- Ran experiments with LX-14 to confirm the role of energetic plasticizer during cookoff of PBX 9501.
- LX-14 ignited sooner than PBX 9501 in our experiments despite nominally the same HMX composition and a less energetic binder.
- Venting effects are negligible in LX-14 at 84 %TMD and 96 %TMD.
- Retention of reactive gases within LX-14 leads to faster pressure-dependent reactions.
- Our model matches ignition times, internally measured temperatures, and pressure.