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A "UNIVERSAL" COOKOFF MODEL FOR EXPLOSIVES

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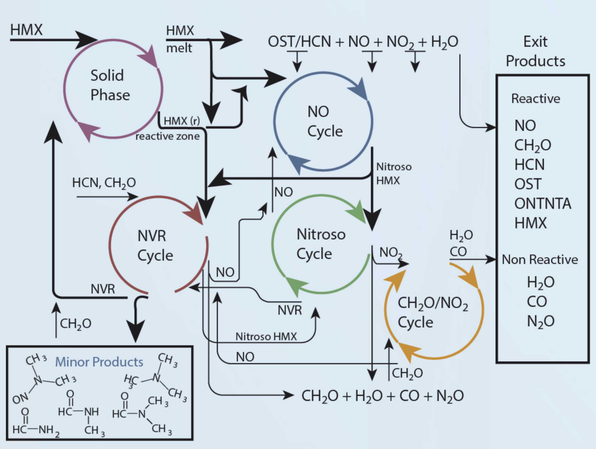
MOTIVATION: UNDERSTANDING EXPLOSIVE RESPONSE TO FIRE

Carrier	Deaths	Injured	Cost
Oriskany, 1966	44	156	$63.6M
Forestal, 1967	134	162	$758M
Enterprise, 1969	28	343	$554M
Nimitz, 1981	14	48	$150M
	220	**709**	**$1525M**

Universal cookoff model simplifies cookoff modeling and scales.

COMPLEX MODELS CAN BE SIMPLIFIED

Complex process



Universal Mechanism

4 reactions

$S \xrightarrow{1} S_g$ Moisture

$E \xrightarrow{2} \alpha G_E + \beta C_E$ Explosive, r ≠ f(P)

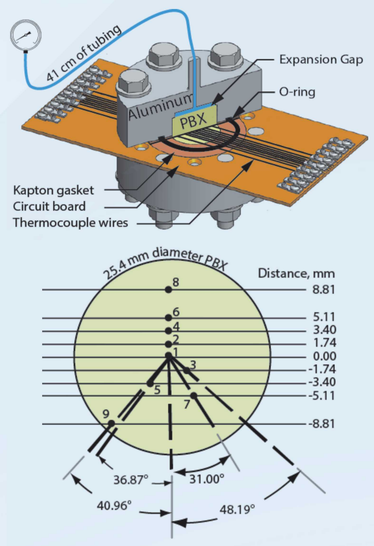
$E \xrightarrow{3} \alpha G_E + \beta C_E$ Explosive, r = f(P)

$B \xrightarrow{4} \gamma G_B + \delta C_B$ Binder

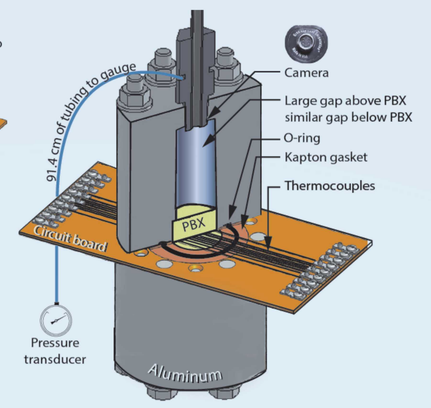
Prior models had different mechanisms for each explosive. The mechanism in the current work is the same for each explosive with parameters specific to each explosive. Calculations are 2-10 times faster. The only limitation is the availability of calibration data.

PARAMETERIZATION AND VALIDATION

SITI-small gap*

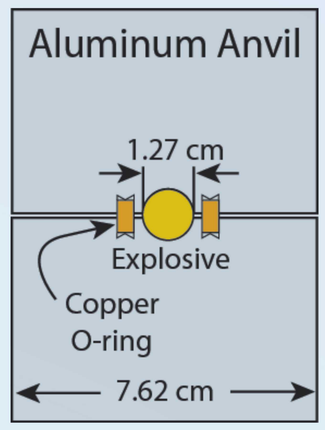


SITI-small gap*



Parameterization (SNL)

ODTX†



Validation (LLNL)

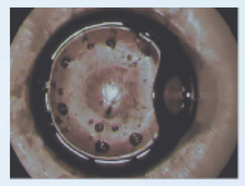
*Sandia Instrumented Thermal Ignition

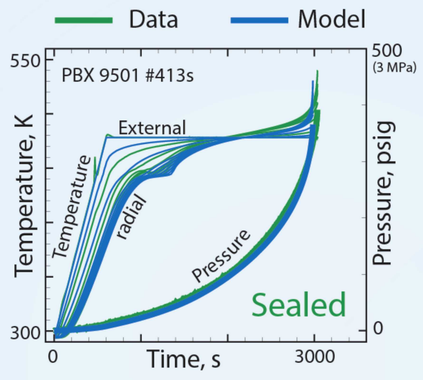
†One Dimensional Time-to-eXplosion

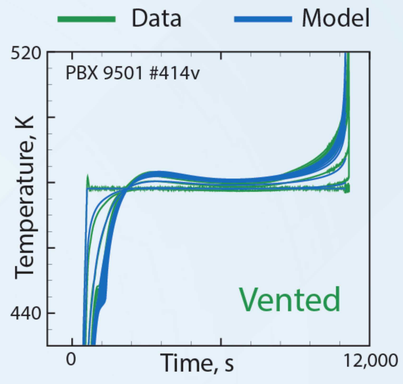
We work with other DOE (LANL, LLNL, SRNL, etc.), DoD (Army, Navy, Air Force), and University (BYU, Purdue, etc.) labs.

KEY TO ACCURACY AND INCREASED AGILITY

$$rate = A\lambda T^m \left(\frac{P}{P_o}\right)^n \exp\left(\frac{-\mathrm{E} + \xi\sigma}{RT}\right) [\mathrm{HMX}]$$

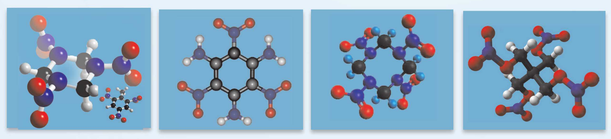




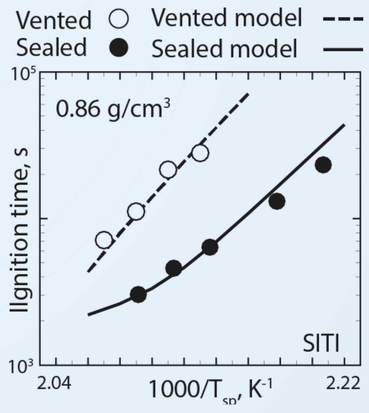


The reaction mechanism is universal with rates specific for each explosive.

RDX (Comp-B) *TATB (PBX 9502)* *HMX (PBX 9501)* *PETN*



Example is PBX 9501, the most studied explosive in the world.



IMPACT

- The model works for diverse explosives
- The model is fast and provides agile implementation/application
- Model is being evaluated by other laboratories (e.g. US Army)
- Recent publications
  - Hobbs ML, Kaneshige MJ, Erikson WW, 'A "UNIVERSAL" Cookoff Model for Explosives," 50th International Annual Conference of the Fraunhofer ICT, Karlsruhe, Germany (June 25-28, 2019).
  - Hobbs ML, Kaneshige MJ, "Small-scale cook-off experiments and models of ammonium nitrate," Journal of Energetic Materials, 37 (1), 29-43 (2019).
  - Hobbs ML, Kaneshige MJ, Yarrington CD, "Large deformation and gas retention during cookoff of a plastic bonded explosive (PBX 9407)," Combust. Flame, 198, 278-289 (2018).
  - Hobbs ML, Kaneshige MJ, Erikson WW, Miers KR, "Gas retention in an HMX-based explosive (LX-14)," Sci. Tech. Energetic Materials, 79(2), 35-42 (2018).

We have fit the model to other explosives with great results

Sandia National Laboratories

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