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High Rate Thermal Analysis of Propellant Based Cook-Off Mitigants

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Intent of Experiment

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- **A part of ongoing work to address improving Insensitive Munitions Cook Off Response**
- **This effort focused on cost-effective propellant based mitigation of Fast Cook Off**
- **Fast cook off phenomenology is difficult for several reasons**
- Very high flux rates
- Very chaotic conditions
- High thermal gradients
- **Use of propellants helps reduce risks from incompatibility, availability and manufacturability**
- **Intent was to examine a potential "off the shelf" solution**

NTS Camden Operations

Redstone Technical Test Center

Propellants

- **11 propellants from 5 types (single, double, triple, lova and high-temp)**
- **46 valid runs – many had to be rejected because the sample cups exploded**
- **The majority of propellants are NC based (this represents the state of the industry)**
- **Covers a wide range of ingredients, system applications, and manufacturing methods**
- **Samples included what were believed to have a high thermal resistance and a low thermal resistance (driven by high NG level) to serve as controls on the experiment**

TYPE OF PROPELLANT	# OF PROPELLANTS	COMPOSITION
SINGLE BASE	4	NITROCELLULOSE (NC)
DOUBLE BASE	4	NC & NITRATE ESTER (NG)
TRIPLE BASE	1	NC, NG & NITRAMINE (NQ)
LOW VULNERABILITY (LOVA)	1	COMPLEX COMPOSITION
HIGH-TEMPERATURE PROPELLANT	1	NITRAMINE W/ POLYMER BINDER

Methodology

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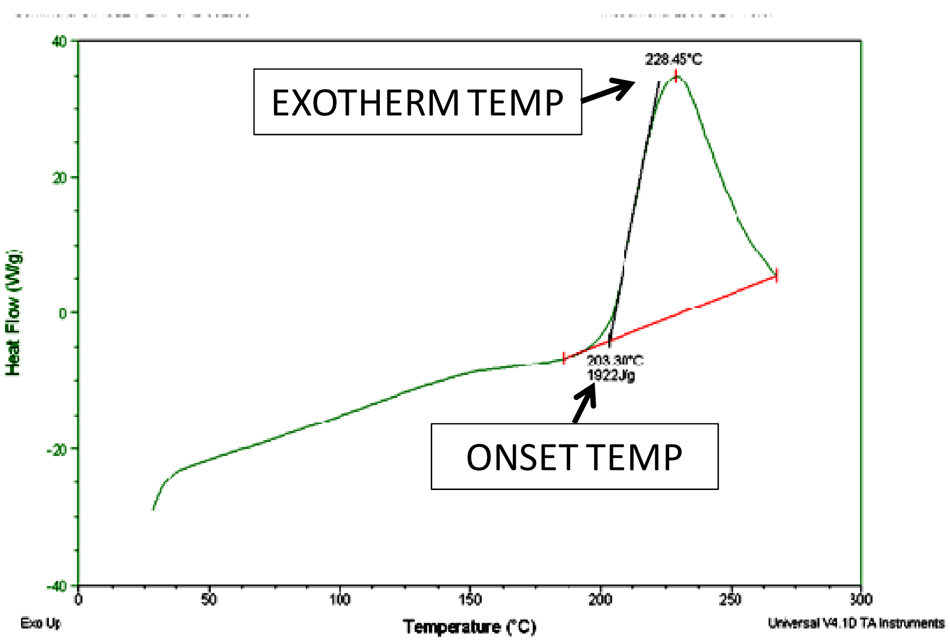
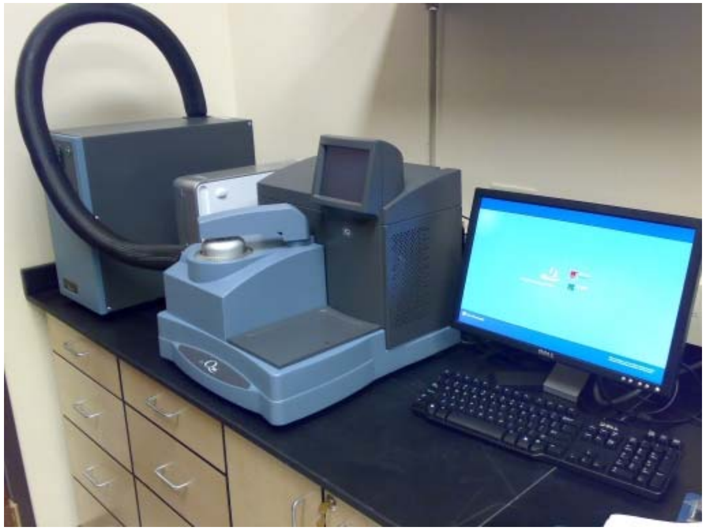
- This project focused on using Differential Scanning Calorimetry to evaluate runaway thermal behavior
- Heating rates needed to be very high in order to simulate fast cook off heating rates
- Thermo-Analytical methods on energetic materials require the use of very small samples (milligram scale)
- DSC on small samples allow rapid low cost screening of multiple candidates





Results

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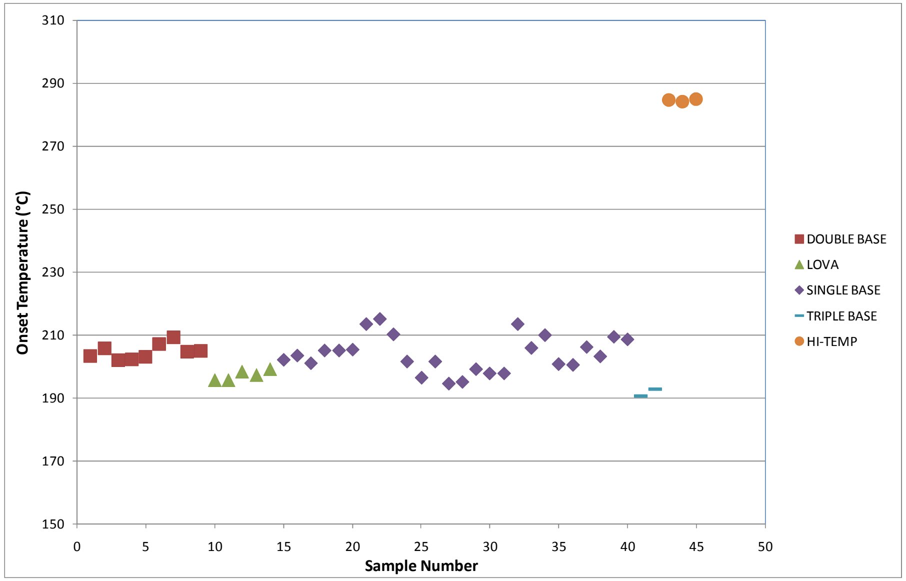
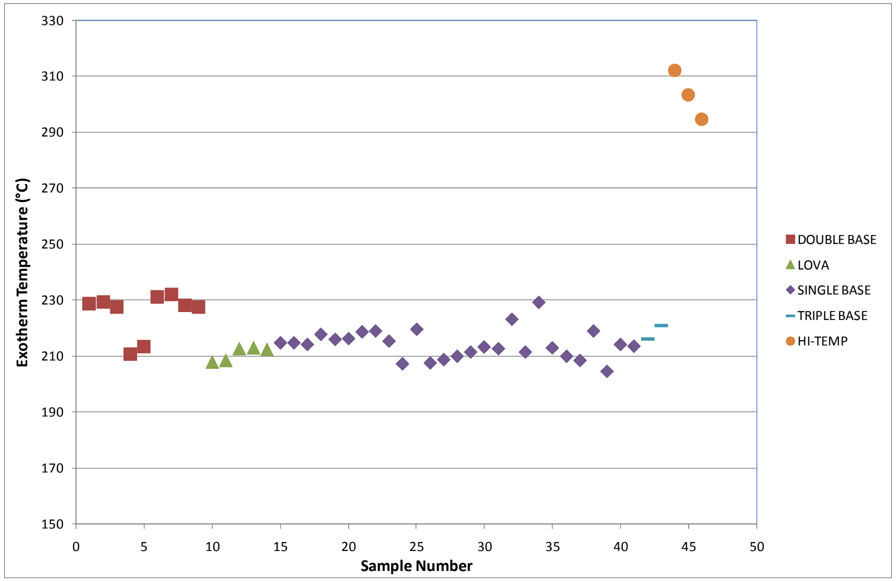
- **Evaluation of Onset Temperature showed some good candidates**
  - Triple base had good separation from double and most single
  - LOVA also had good separation from double base





- **Evaluation of Exotherm Temperature highlighted conflicting data**
  - Triple base lost its positive separation and is a poor candidate based on exotherm
  - LOVA was still low but lost its separation from double and single base propellants

Results Continued

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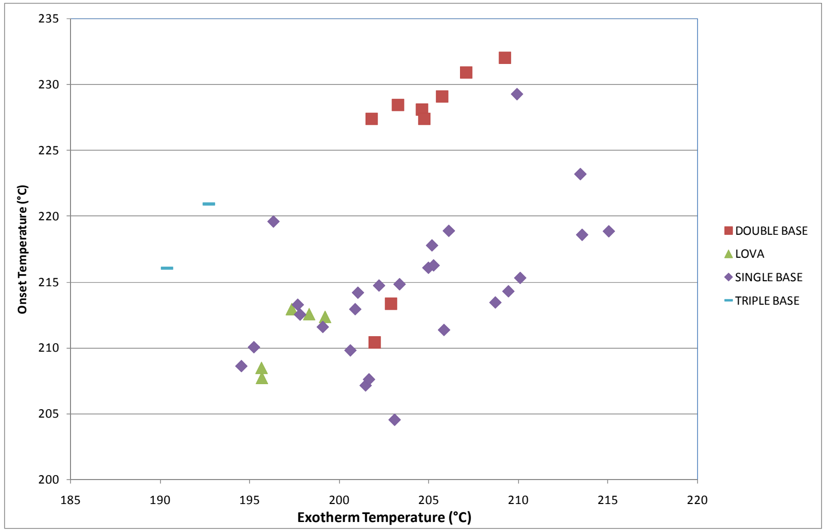

	ONSET (°C)		EXOTHERM (°C)	
	AVERAGE	SD	AVERAGE	SD
A	204	2.0	228	0.9
B	202	0.6	212	2.1
C	208	1.5	231	0.8
D	205	0.1	228	0.5
E	197	1.6	211	2.5
F	207	5.0	216	1.7
G	200	3.0	211	7.1
H	202	7.1	215	7.3
I	205	3.9	212	4.6
J	192	1.6	218	3.4
K	284	0.4	303	8.7

- **The relationship between Onset and Exotherm was presumed to be linear**
- **While true generally the data is quite messy and the different materials have different slopes**
- **The only clear result is that in all cases the NC based propellants are more sensitive to cook off then high temperature propellants**

Conclusions

- The primary conclusion is that according to DSC analysis, NC based propellants show little difference in cook off behavior

- The low thermal resistance propellant turned out to have similar behavior to the other NC based propellants

- For materials that are very thermally stable NC based propellants could be effective cook off mitigants

- More work has to be done, the “off the shelf” method didn’t work out, but some simple modifications may pay high dividends

Future Work

- **Examine the effect of doping NC based propellants with energetics that have a low thermal sensitivity**

- **These energetics do not necessarily need to be novel or expensive materials. There are several promising candidates that are energetics that have been previously used by the defense community but never made it to common use**

- **Upgrading the evaluation method to one that uses larger samples would be a positive change – Several improved methods exist**

  – Open burning (DOT method with improved instrumentation)

  – Simulated Bulk Autoignition Testing (Probably the ideal candidate but requires special equipment)

  – Small Scale Cook Off tests (several are available, each lab has a favorite, no one has really caught on yet)