Novel Plasticizer for IM Compliant Solid Propellants

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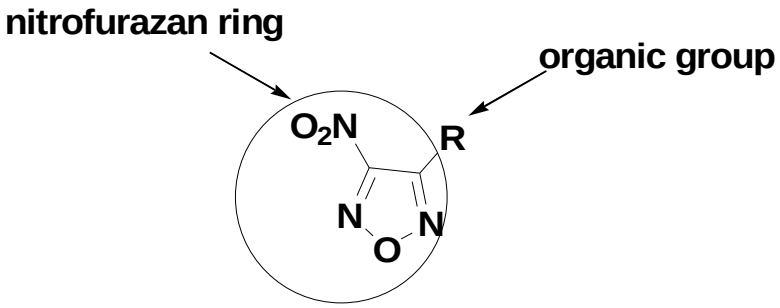
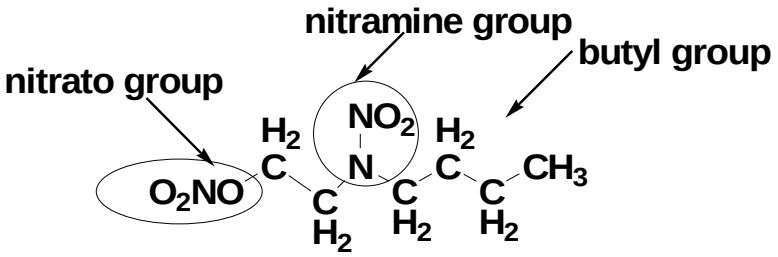
- **36 year-old company of 180 talented scientists, and engineers**
- **We work in headquarters in Andover, MA, with five satellite locations in the United States**
- **Acoustics**
- **Electro-magnetics**
- **Fluid physics**
- **Life sciences**
- **Chemical sciences**
- **Energetic Materials**
- **Optical sciences**
- **Plasma physics**
- **Space physics**

Nitrofurazan Plasticizers (NF)

- **Nitrofurazan family offers promise as high energy, good thermal behavior, high density and low sensitivity plasticizers**



NF plasticizers



Butyl NENA plasticizer

- **NF core: heterocyclic ring with high thermal stability, good density**
- **Organic Group R: capability to functionalize the nitrofurazanic core**
- **R group variation may generate various categories of NF plasticizers**

Background: NF1

- **PSI synthesized and characterized NF1 from low cost precursors (30% yield)**
- **Aerojet performed the energetic and thermal properties testing: promising plasticizer with good energy and good density**

	Density Gm/cc	Decomposition Temperature, °C	ΔHf, Kcal/mol
NF1 theor	**1.620**	**180**	**69.5**
NF1 exp.	**1.467**	**180**	**58.8**
Butyl NENA	1.211	165	-45.55
TMETN	1.488	158	-105.8
BTTN	1.520	154	-92.6

Background: NF1 Cont'd

- **NF1 properties**
  - Low viscosity fluid
  - Moderate volatility
- **Measurements show it is insensitive**
  - Category "Green" [normal]

Hazard	NF1	RDX
Impact, kg-cm	145	49
Friction, psi @ drop angle, ^{o}	1800 @ 90^{o}	1200@90^{o}
ESD, J @ 5kv	6.0	0.38

Background: NF1 Cont'd

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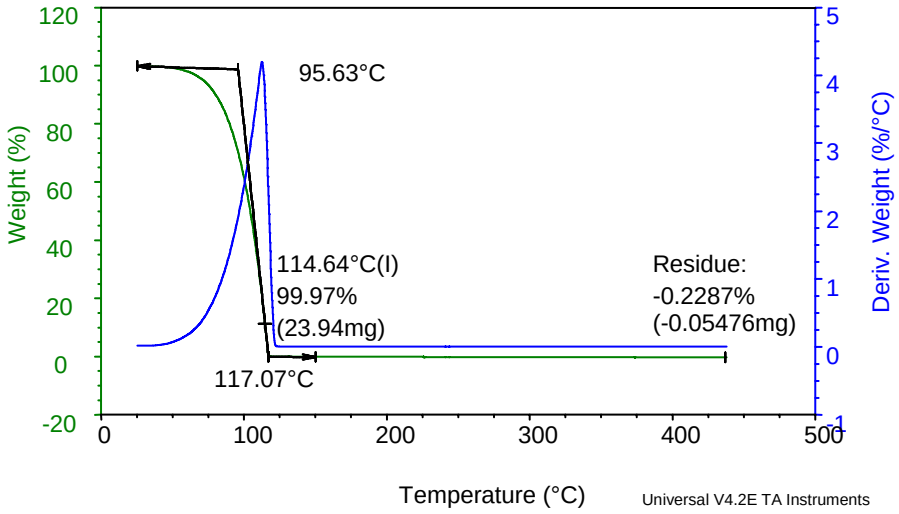
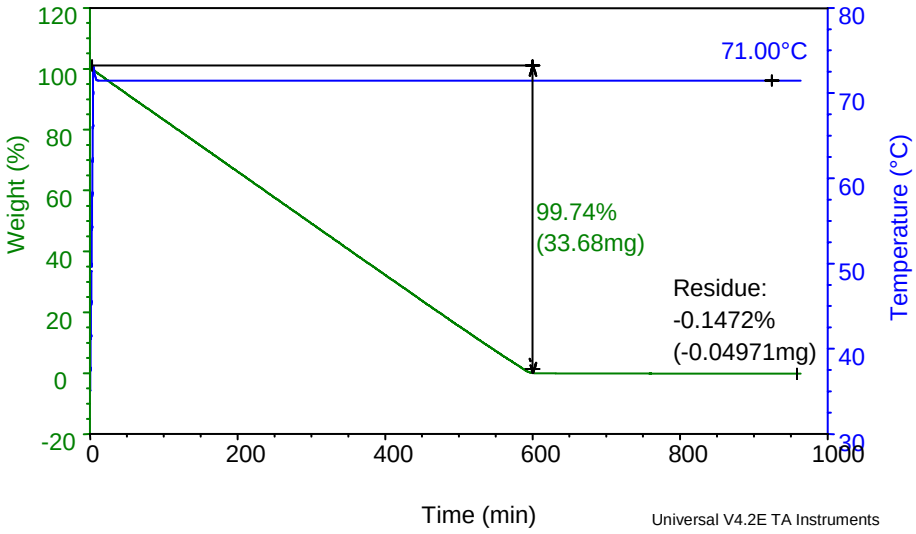


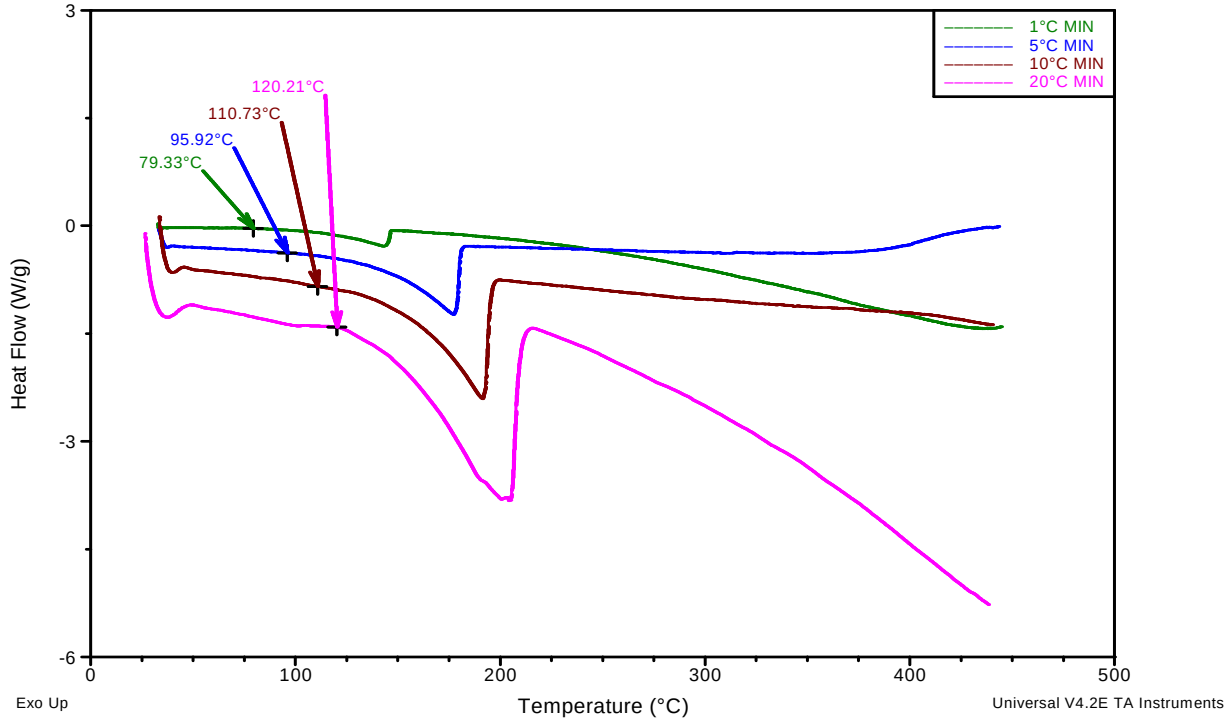


Onset of weight loss in TGA occurs at a low temperature

Isothermal TGA shows material evaporates after 10 hr at 70°C

Chemical modification to NF1 was required to eliminate volatility

NF1: Background Cont'd



In Differential Scanning Calorimetry (DSC)
only endotherms noted due to vaporization – no exotherms

Novel Nitrofurazan Plasticizer: NF2

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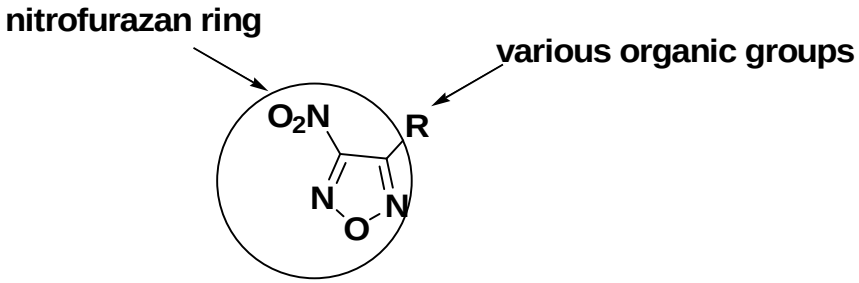
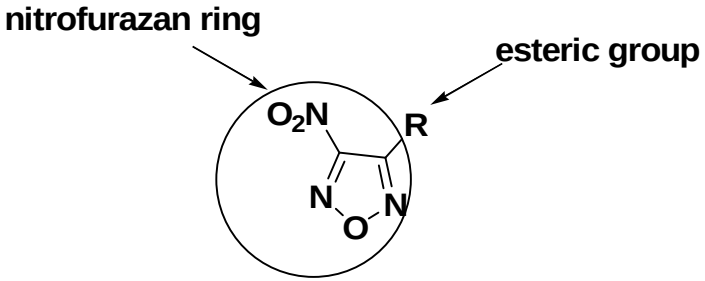
- **Variation of the R group generated various NF classes of nitrofurazanic plasticizers**
- **R = esteric group: Esteric NF Plasticizers Candidates**
- **NF2 showed good energy, good density and acceptable volatility**



NF plasticizers



NF2 plasticizer

Novel Nitrofurazan Plasticizer: NF2 Cont'd

	Density G/cm^3	Decomposition Temperature, ^{o}C	ΔHf, Kcal/mol
NF2 exp.	**1.264**	**176.4**	**-62**
NF1 exp.	**1.467**	**180**	**58.8**
Butyl NENA	1.211	165	-45.55
TMETN	1.488	158	-105.8
BTTN	1.520	154	-92.6

NF2 has good sensitivity and good thermal properties

Hazard	NF2	RDX
Impact, kg-cm	**300**	**49**
Friction, psi @ drop angle, ^{o}	**1800 @ 90^o**	**1200@90^o**
ESD, J @ 5kv	**6.0**	**0.38**

Novel Nitrofurazan Plasticizer: NF2 Cont'd

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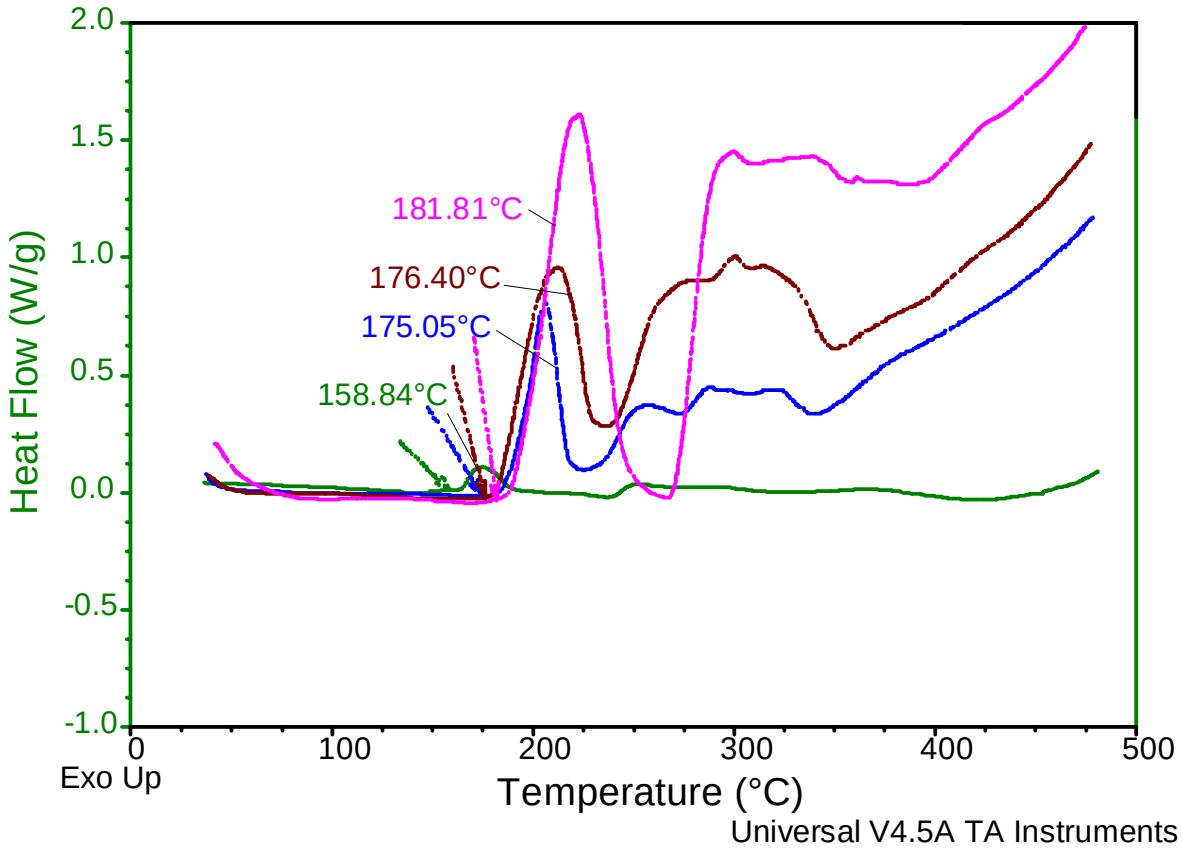
DSC Overlay: 1 °C/min., 5 °C/min., 10 °C/min., 20 °C/min.



In Differential Scanning Calorimetry (DSC) only exotherms were noted: low volatility of NF2

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Novel Nitrofurazan Plasticizer: NF2 Cont'd

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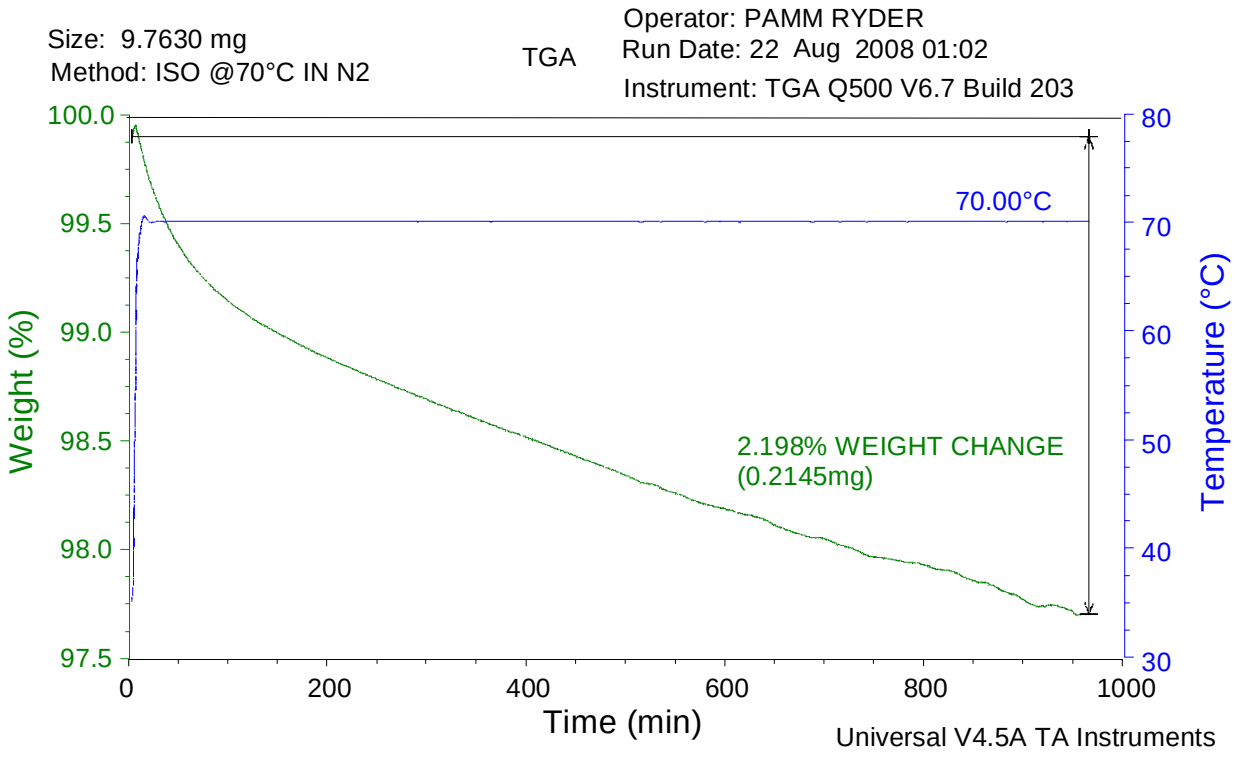
TGA ISO @ 70°C FOR 16 HRS



NF2 has low volatility: 2% loss in weight at 70 °C for 16 hrs

Novel Nitrofurazan Plasticizer: NF2 Cont'd

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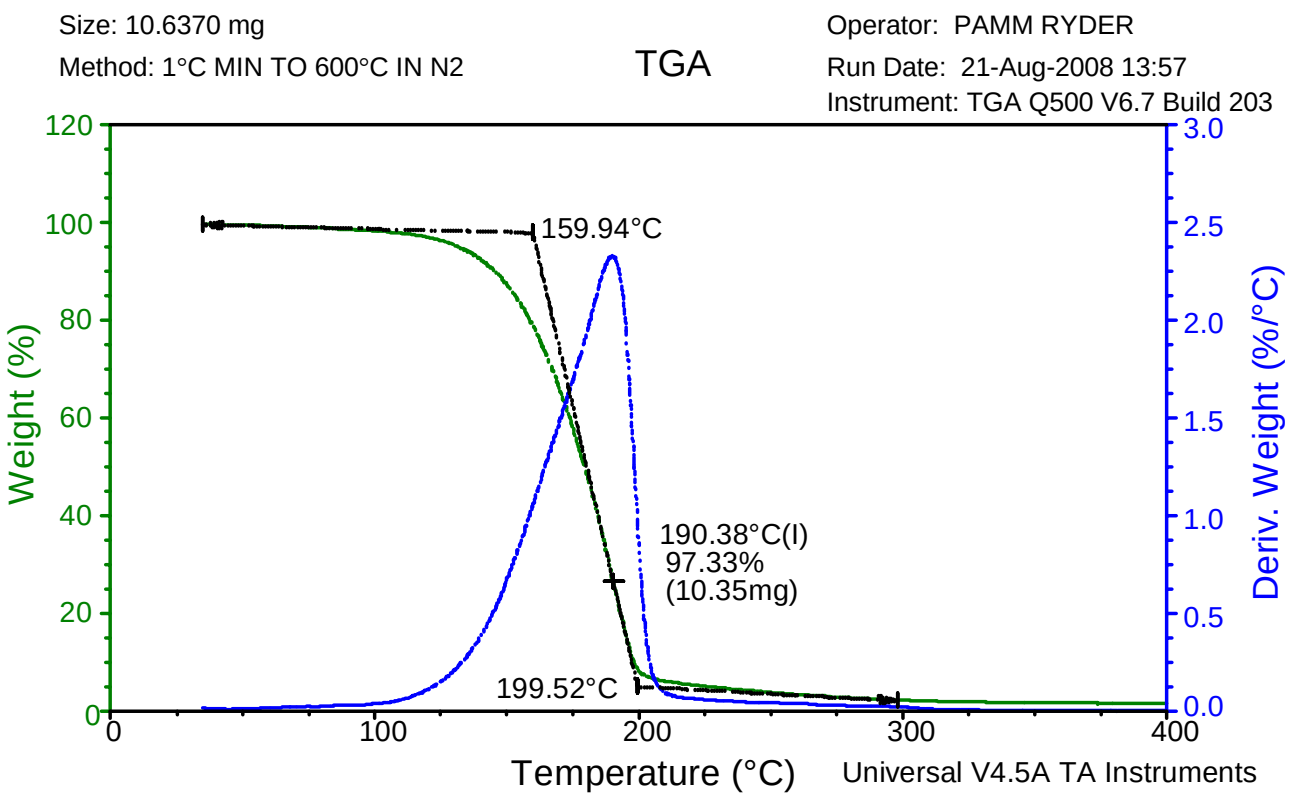
Thermal Gravimetric Analysis 1°C MIN



Onset in the weight loss for NF2 starts above 100 °C

Conclusions

- **NF2 has been successfully synthesized and characterized in a 40% overall yield**
- **NF2 synthesis used low cost precursors and was produced in high purity (>98%)**
- **NF2 Testing Results: insensitive (“green” category material)**
- **NF2 showed good thermal properties: it has good decomposition temperature and low volatility**
- **Additional work will be conducted - NF2 will be incorporated in propellant samples (work in progress at Aerojet)**

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