



Development and Production of a New Class of NTO

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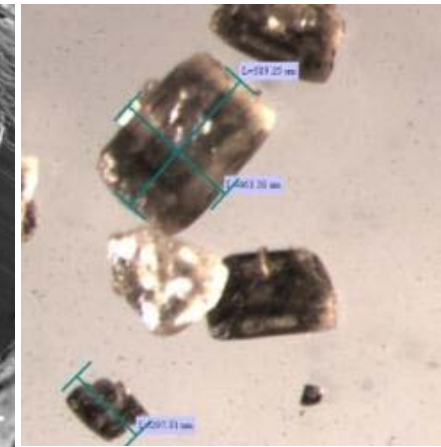
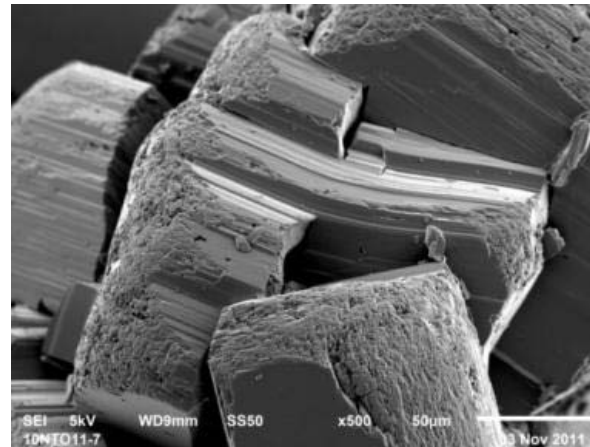
BAE Systems Ordnance Systems
Holston Army Ammunition Plant
October 2013

Abstract #16200



NTO (3-nitro-1,2,4-triazol-5-one)

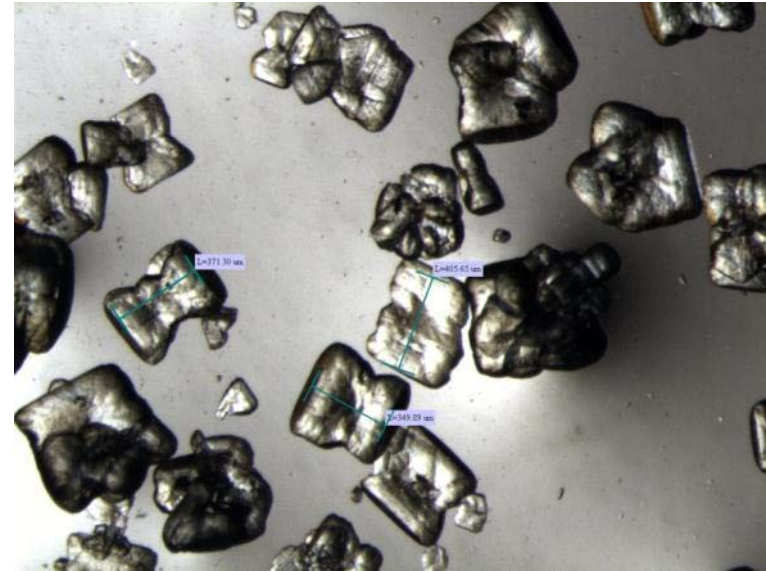
- NTO is not new (discovered over a century ago)
- However, NTO has only recently found significant usage
 - Mostly because NTO is now produced on large scale, affordably, by BAE Systems AND because of the current push for insensitive munitions.
- NTO is extremely insensitive to unplanned stimuli
 - Being used in IMX-101 (TNT replacement) and IMX-104 (Comp B replacement)



Over 350,000 lbs of NTO produced at HSAAP!

NTO & FEM NTO characteristics

- Two grades currently manufactured at HSAAP
 - Regular (Coarse) and Fluid Energy Milled (FEM)
- Typical particle size
 - $d_{50} \sim 300\text{-}400\mu\text{m}$ (coarse)
 - $d_{50} < 10\mu\text{m}$ (FEM)
- Acidity $< 0.01\%$
- Exotherm Onset $\sim 273^{\circ}\text{C}$
- Purity $> 99\%$
- Availability:
 - Production quantity available (~ 3000 lb. batch)



New NTO Crystallization Development

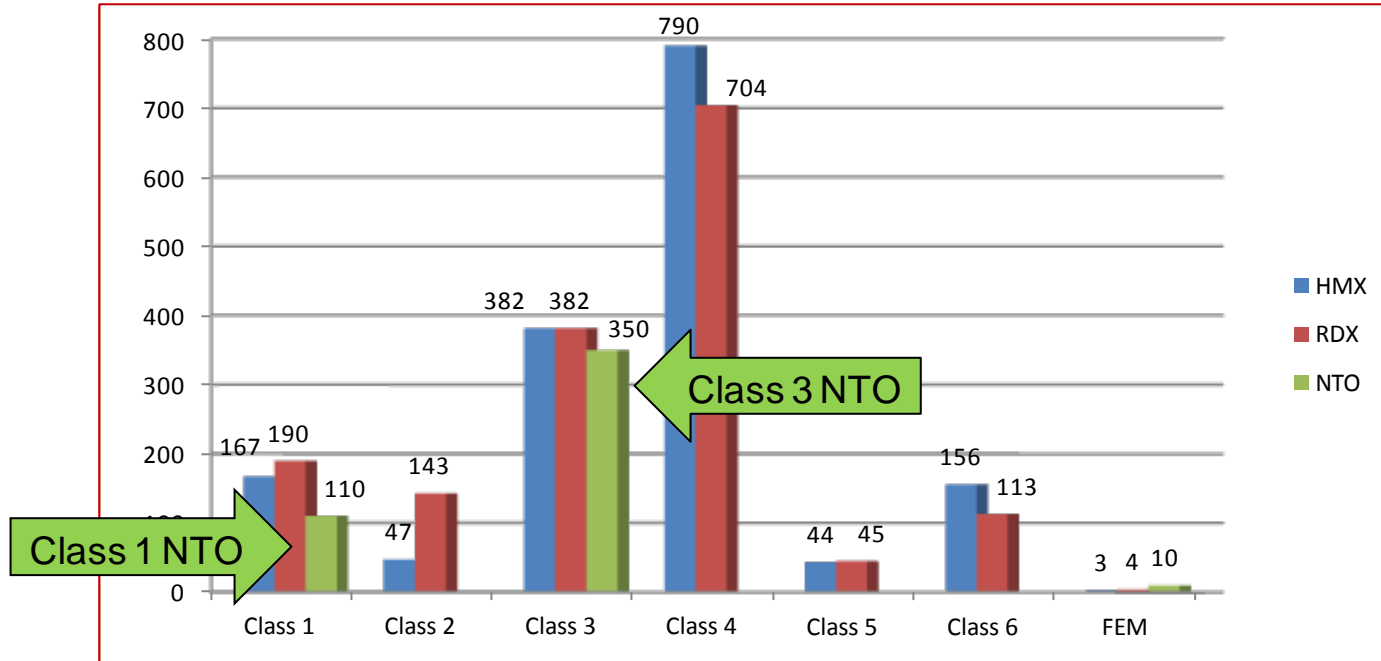
- As with other crystalline energetic ingredients, there is a need for various particle size distributions of NTO to aid in maximizing and optimizing energetic formulations.
- BAE has developed a process to make another grade, or “class”, of NTO, meeting that need.



	Lab Batches of New NTO						
	10NTO12-1	1106-45	1106-49	1106-51	1106-53	1106-55	1106-57
Counts	305	308	310	301	334	305	338
Avg. (µm)	294.69	116.01	159.81	114.28	113.87	110.22	119.48

Simple. Robust. Affordable.

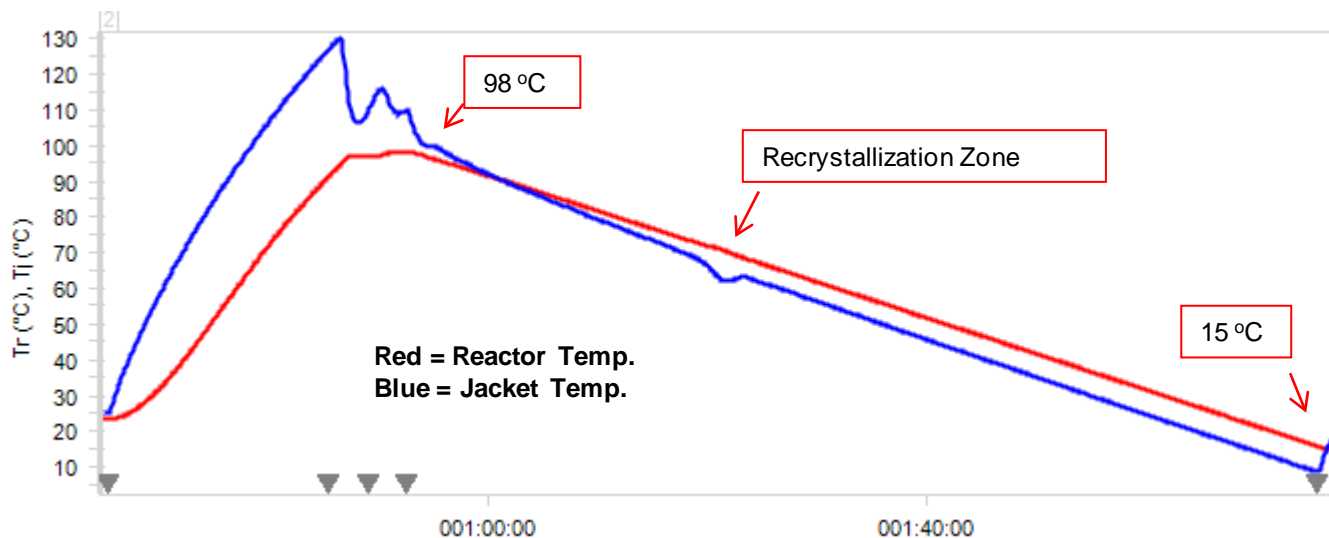
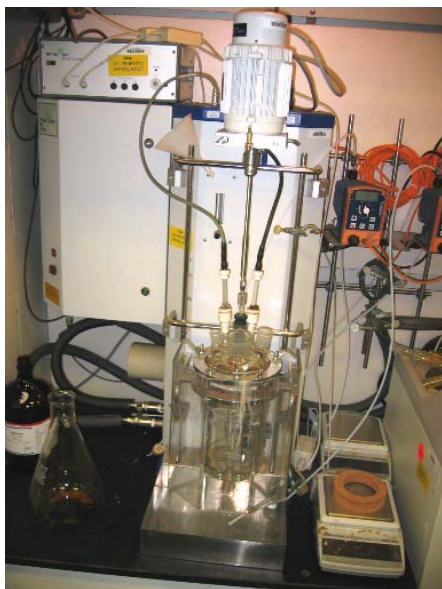
Nomenclature



- Classes of RDX and HMX follow similar trends in particle size distribution (nominal average particle size)
- “Coarse” NTO most closely matches Class 3 RDX and HMX
- BAE Systems’ new NTO most closely matches Class 1 RDX and HMX

NTO-Recrystallization Calorimetry

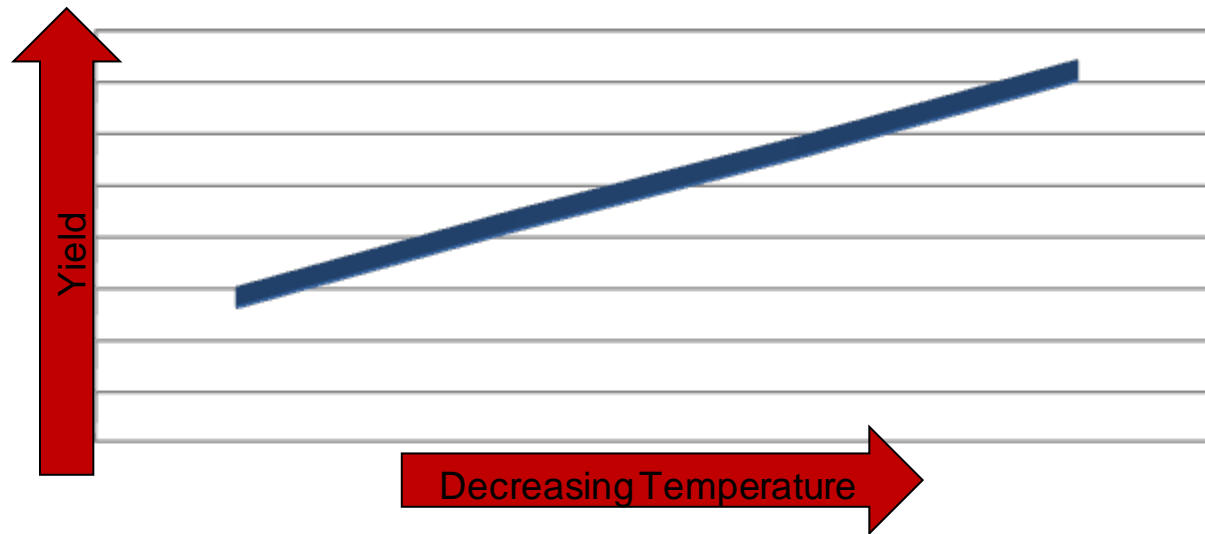
- Reaction calorimetry (RC1) performed to quantify exotherms and assess scale-up safety
- Exothermicity of process is mild (almost non-existent)
- Reaction deemed safe for scale-up



	Q_r (kJ/mol)	$\Delta T_{(ad)}$ (°C)
Recrystallization	19.6	3.66

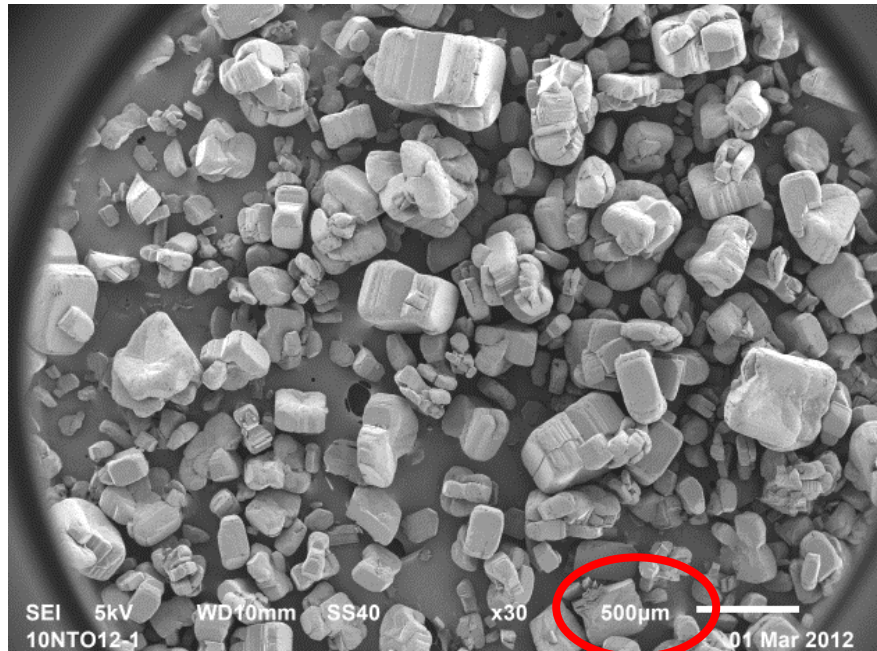
Mild, straight-forward, easily-controlled recrystallization

Increasing Throughput

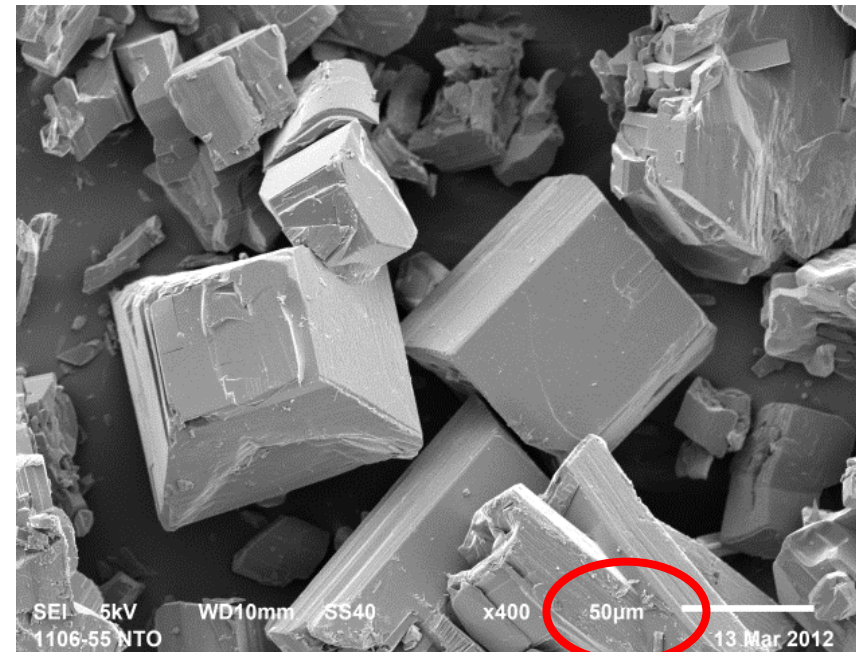


- Because solubility decreases with decreasing temperature, the yield of NTO from the recrystallization process can be enhanced by cooling the final mixture to sub-ambient temperatures

NTO SEM Analysis



Production Grade Class 3 NTO



Lab Produced Class 1 NTO

- Crystal shape of both classes of NTO are cubical
- Lab produced material has sharper edges
 - This is artifact of lab-produced material
 - Class 1 NTO will have rounded edges in full-scale production

NTO Formulations

- Class 1 NTO was evaluated in IMX-104
- The Class 3 NTO (coarse) was replaced with Class 1 NTO
- Compared against standard lab batch of IMX-104 and Production made IMX-104

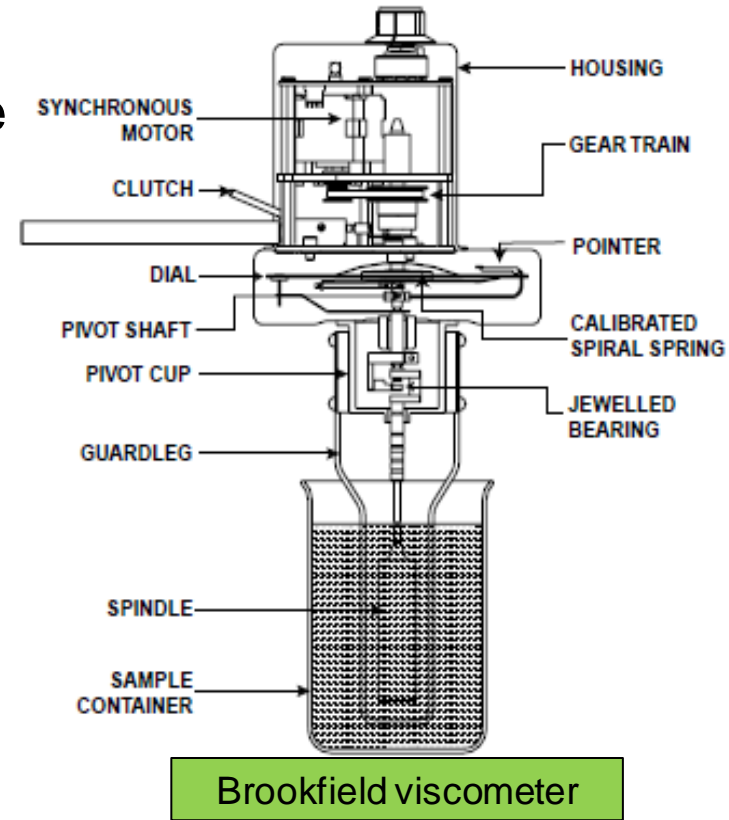
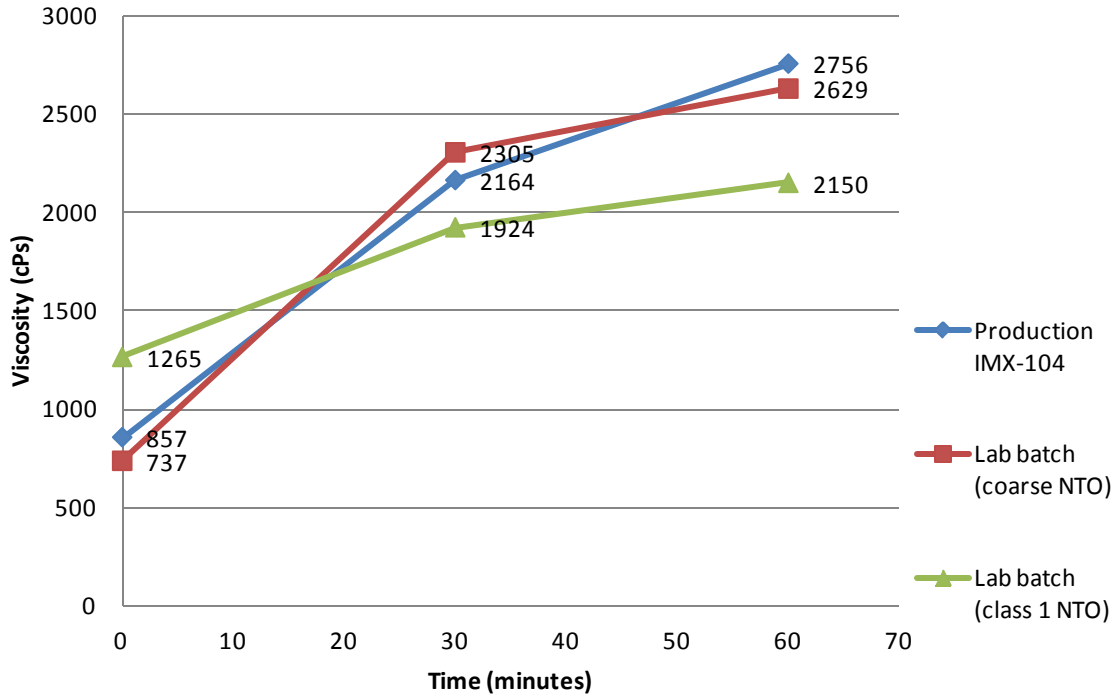


	Batch ID	Efflux Viscosity (sec)	Initial Viscosity (cP)
Production	IMX104-56	6.50	857
Lab batch (coarse NTO)	1105-70	5.53	737
Lab batch (class 1 NTO)	1105-74	13.84	1265

- Incorporation of Class 1 NTO gave higher viscosity as measured by:
 - Efflux
 - Brookfield viscometer

NTO Formulations

- IMX-104 made with Class 1 NTO in lieu of Class 3 NTO:
 - Has higher initial viscosity, but...
 - Exhibits lower viscosity increase over time



Less settling of solids with Class 1 NTO

Class 1 NTO-Phase II

- Currently commissioning a Pilot Scale R&D Facility
 - 50, 100, & 200 Gallon Reactors
 - Better transition from lab scale to Agile Facilities (particularly for ingredient synthesis)
 - Commissioning to be completed by Q4 2013
 - Several ingredient scale-up programs already lined up (DoD, DoE, commercial)
- Class 1 NTO will be produced in our pilot plant in 2013
 - Nominal 100 lb batch size



Path Forward

- Transition to full scale manufacturing of Class 1 NTO
 - 3000 lb batch size (nominal)
- Further evaluate Class 1 NTO in IMX-101 and IMX-104
 - Including looking for changes in shock sensitivity
- Develop new melt-pour formulations to maximize amount of NTO and solids loading through use of Class 1, Class 3 and FEM NTO
- Evaluate Class 1 NTO in other applications such as:
 - Propellants
 - Pressable explosive formulations
 - Cast-cure explosive formulations
- Develop other classes of NTO such as:
 - Class 5 NTO



Conclusions

- A new NTO product has been developed by BAE Systems at HSAAP
- This product, with a nominal particle size of 150 microns, has been designated as Class 1 NTO
- Class 1 NTO (in conjunction with Class 3 and FEM) offers:
 - A way to maximize solids loading in melt-cast, pressable and cast-cure formulations





Acknowledgements



- Kelly Guntrum
- Robyn Wilmoth
- Dr. Jeremy Headrick
- Denise Painter
- Mary Rush
- Matt Hathaway
- Ed LeClaire

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