Large Scale Manufacture of Granular IMX-104 Melt Pour Explosives

NDIA Insensitive Munitions & Energetic Materials Technology Symposium 2013

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Topics of Discussion

- Insensitive Melt Pour Explosives
- Laboratory Development Work
- Intermediate Scale Up of Baseline Process
- Large Scale Manufacture
- Conclusions and Future Work

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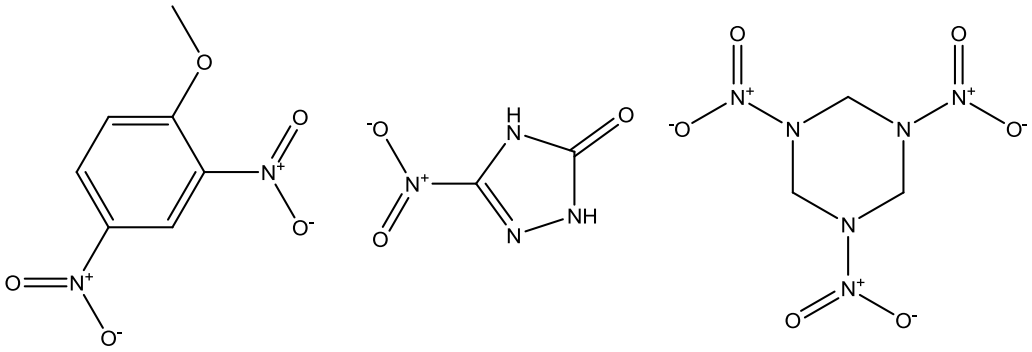
Insensitive Melt Pour Explosives

- Provide Insensitive replacements for TNT based explosives with similar performance
  - IMX-101 – Insensitive replacement with comparable performance to TNT
  - IMX-104 – Insensitive replacement with comparable performance to Composition B
  - Both currently qualified for use as main fill explosives
- Contain non-traditional ingredients



DNAN NTO RDX

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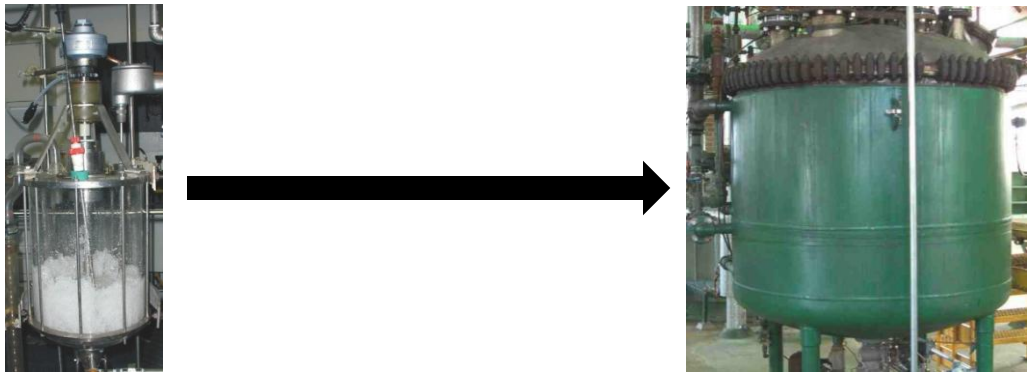
Laboratory Development Work – Overview

- Established process developed using Alternate Fluid
  - Alternate Fluid - A fluorinated hydrocarbon which has similar properties to water and can be used in a place of water in multiple applications
  - Successfully used in the manufacture of aluminized PBX's at HSAAP
  - Utilized laboratory coating still and standard slurry coating techniques
  - Varied agitation rate to observe changes in particle size distribution
    - Ranged from 37.5% of maximum to 100% of maximum
- Analysis of resulting batches is promising
  - Composition, and thermal properties unchanged; bulk density is high



10 Liter Lab Vessel **500 Gallon Reactor**

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Laboratory Development Work – Analysis

Batch ID		Trial 7	Trial 8	Trial 9	Trial 10	Trial 11	Trial 12
Agitation Rate (% of Maximum)		37.5	50	62.5	75	87.5	100
Yield (%)		59.78	61.02	68.30	67.58	75.02	70.38
DNAN		Nominal	Nominal	Nominal	Nominal	Nominal	Nominal
RDX		Nominal	Nominal	Nominal	Nominal	Nominal	Nominal
NTO		Nominal	Nominal	Nominal	Nominal	Nominal	Nominal
Melting Point (ºC)		95.5	96.4	96.6	94.9	92.0	91.7
Exothermic Onset (ºC)		203	207	210	219	204	220
Bulk Density (g/cc)		0.926	0.885	0.962	0.926	0.962	0.961
Screens (% Pass)	4	92.5	98.2	98.8	99.0	100	98.5
	8	24.5	49.0	58.5	69.0	83.0	76.5
	12	7.0	15.3	24.2	37.5	57.5	51.1
	40	0.1	0.7	1.6	2.3	3.2	2.0
	80	0.0	0.5	1.4	1.6	1.9	1.1
	100	0.0	0.4	1.2	1.4	1.3	1.1
	200	0.0	0.1	0.4	0.3	0.4	0.6
	325	0.0	0.0	0.0	0.0	0.0	0.3

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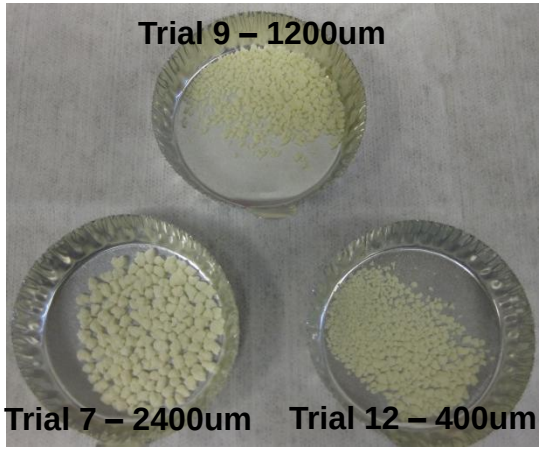
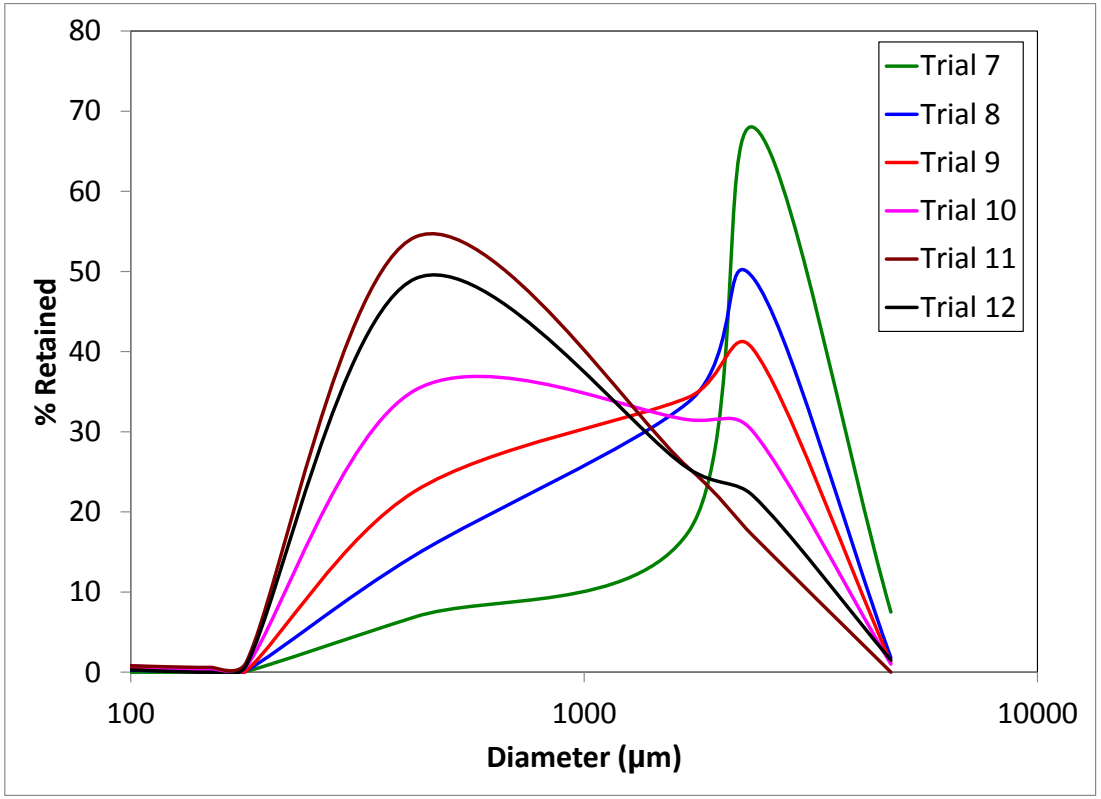
Laboratory Development Work – Granulation

- Effect on granulation observed with changes in agitation
- Slower agitation rates result in larger particle sizes
  - Trial 7 (Slow) – 2400µm
  - Trial 9 (Medium) – 1200µm
  - Trial 12 (Fast) – 400µm
- Further work is required to optimize granulation





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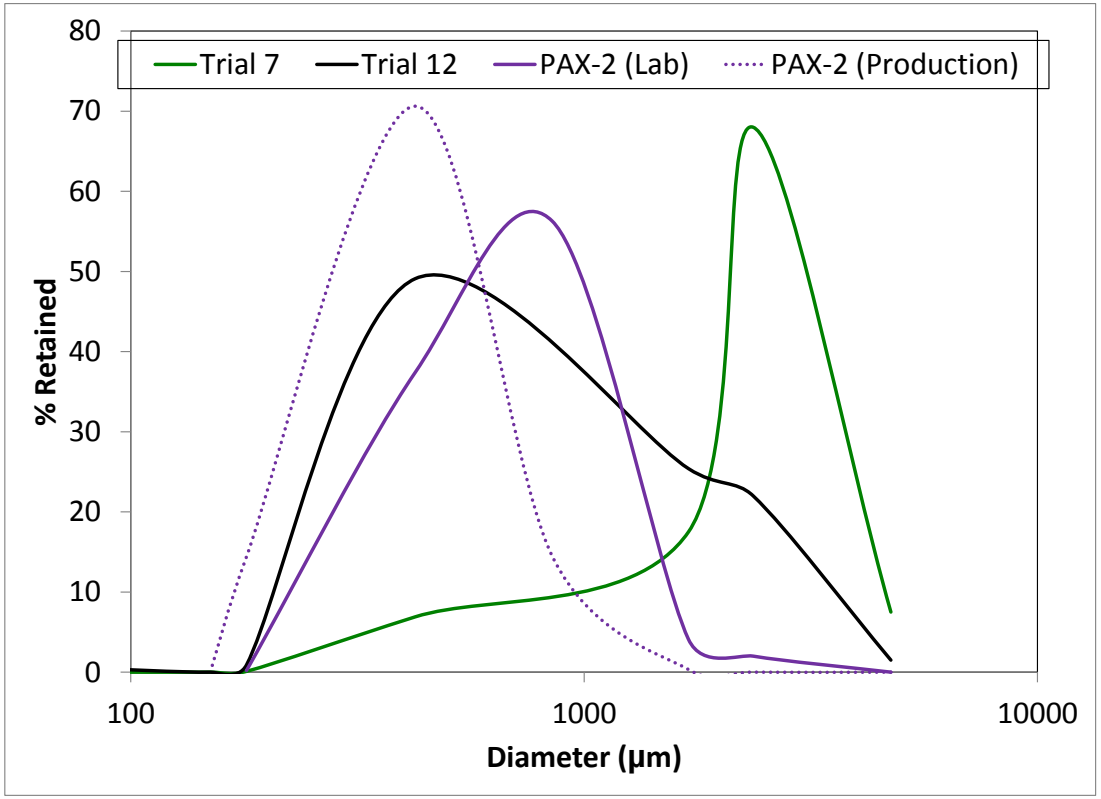
Laboratory Development Work – Granulation Comparison

- Comparison of Granular IMX-104 to typical granulated product at HSAAP
- Largest and Smallest distributions compared to PAX-2 (Laboratory and Production)
  - 37.5% – larger than PAX-2
  - 100% – similar to PAX-2
- Promising result
  - Can make granular melt pour at similar particle sizes to other granular explosives
- Intermediate Scale Conditions Selected from these results



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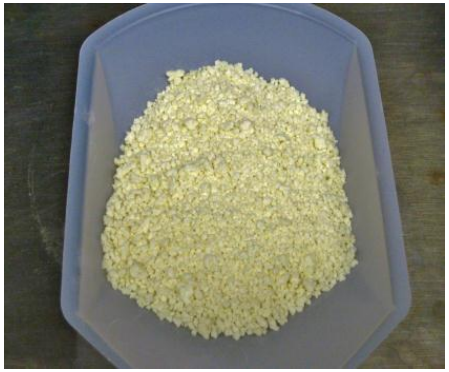
Intermediate Scale Up of Baseline Process – Overview

- Baseline process from trials was selected and scaled to a 50 pound scale
  - Tested for composition, thermal properties, bulk density, and granulation
  - Also tested for shock sensitivity via Large Scale Gap Test (LSGT)
- Analysis yielded promising results
  - Met specification for composition and thermal properties
  - Bulk density is high (greater than 0.9 g/cc)
  - Variation in granulation from small scale is negligible
  - Approximately 98% yield of product



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Intermediate Scale Up of Baseline Process – Analysis

Batch ID		IMX-104 Specification		Trial 12	1105-110B
		Minimum	Maximum		
Yield (%)		70	100	70.38	98.41
DNAN		Nominal	Nominal	Nominal	Nominal
RDX		Nominal	Nominal	Nominal	Nominal
NTO		Nominal	Nominal	Nominal	Nominal
Melting Point (ºC)		86	96	91.7	92.2
Exothermic Onset (ºC)		193	217	217	200
Bulk Density (g/cc)		0.865		0.961	0.926
Impact (cm)		120			>200
Friction (N)		Exceed RDX CL5			231.7
Flowdex		10	20		16
Moisture (%)			0.2		0.0699
VTS (ml/g)			2		0.0846
Screens (% Pass)	4			98.5	95.6
	8			76.5	55.3
	12			51.1	30.3
	40			2.0	2.1
	80			1.1	1.9
	100			1.1	1.7
	200			0.6	1.2
	325			0.3	0.7

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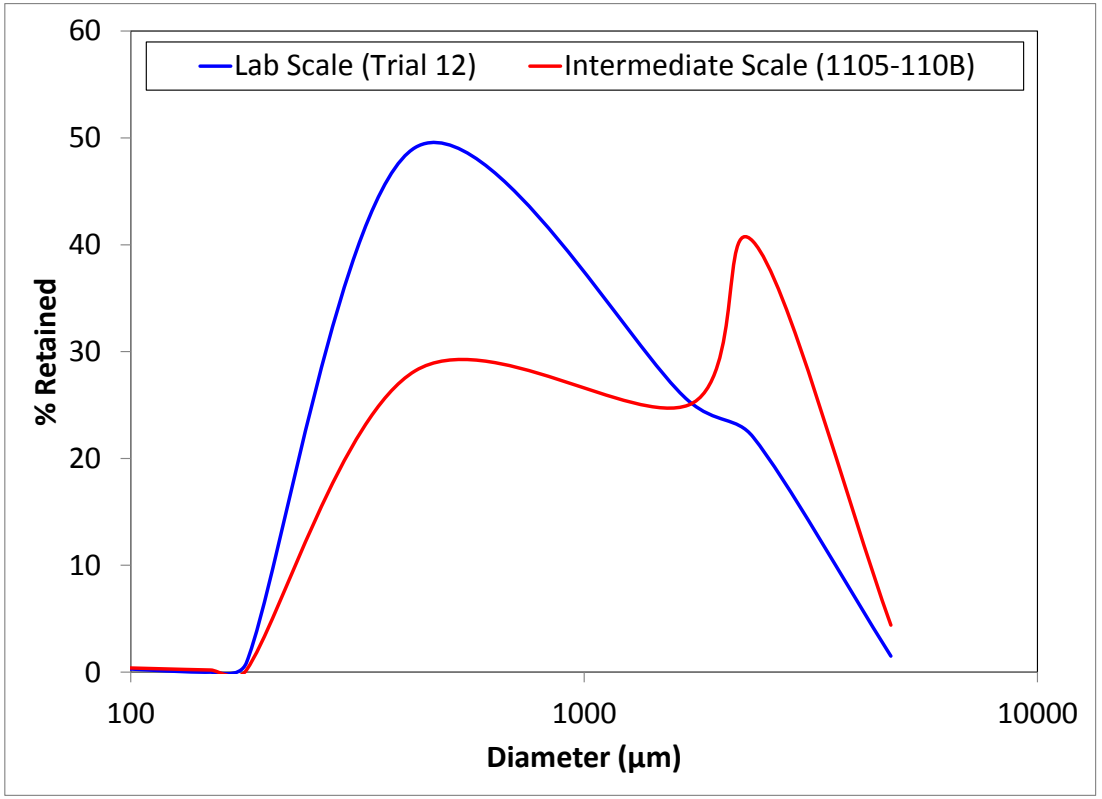
Intermediate Scale Up of Baseline Process – Granulation

- Semi Bi-Modal distribution for larger scale batch
  - Still broad distribution and similar to baseline lab scale batch
- Still usable and processed well
  - Average particle size is ~1100µm



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Intermediate Scale Up of Baseline Process – LSGT

- Material from scale up trials tested in LSGT configuration against poured charges of standard IMX-104

Sample ID	IMX-104 (Flake)	IMX-104 (Granular)		
Manufacture Process	Large Scale (Melt cast)	Intermediate Scale		Lab Scale Baseline
Charge Density (%TMD)	98	98	95	95
50% Point (card gap)	125	126	158	156
Pressure (kbar)	48.8	48.5	35.4	36.3

- No difference in sensitivity observed between melt cast and granular charges
- No difference in sensitivity observed between intermediate scale and lab scale material
- Composition B (201 – 220 cards; 16.9 – 20.5 kbar at 99%TMD)

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Large Scale Manufacture – Overview

- Process scaled to a 500 pound scale
  - Tested for multiple properties
  - Final product to be delivered to customer
- Required Properties
  - Composition, thermal properties, and moisture
- Informational Properties
  - Impact, friction, flowdex, VTS, granulation, and bulk density

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Large Scale Manufacture – Initial Run

Batch ID		IMX-104 Specification		IMX1042-1	IMX1042-2
		Minimum	Maximum		
DNAN		Nominal	Nominal	High	High
RDX		Nominal	Nominal	Low	Nominal
NTO		Nominal	Nominal	Low	Low
Melting Point (ºC)		86	96	90.3	90.2
Exothermic Onset (ºC)		193	217	198	196
Bulk Density (g/cc)		0.865		0.99	1.00
Impact (cm)		120		>200	>200
Friction (N)		Exceed RDX CL5		156.3	242.2
		RDX CL5		182.8	182.8
Flowdex		10	20	32	18
Moisture (%)			0.2	0.019	0.006
VTS (ml/g)			2	0.08	0.04
Screens (% Pass)	4			97.7	94.2
	8			76.9	21.3
	12			57.5	6.3
	40			30.0	2.8
	80			11.7	2.6
	100			6.2	2.4
	200			2.7	1.3
	325			0.4	0.3

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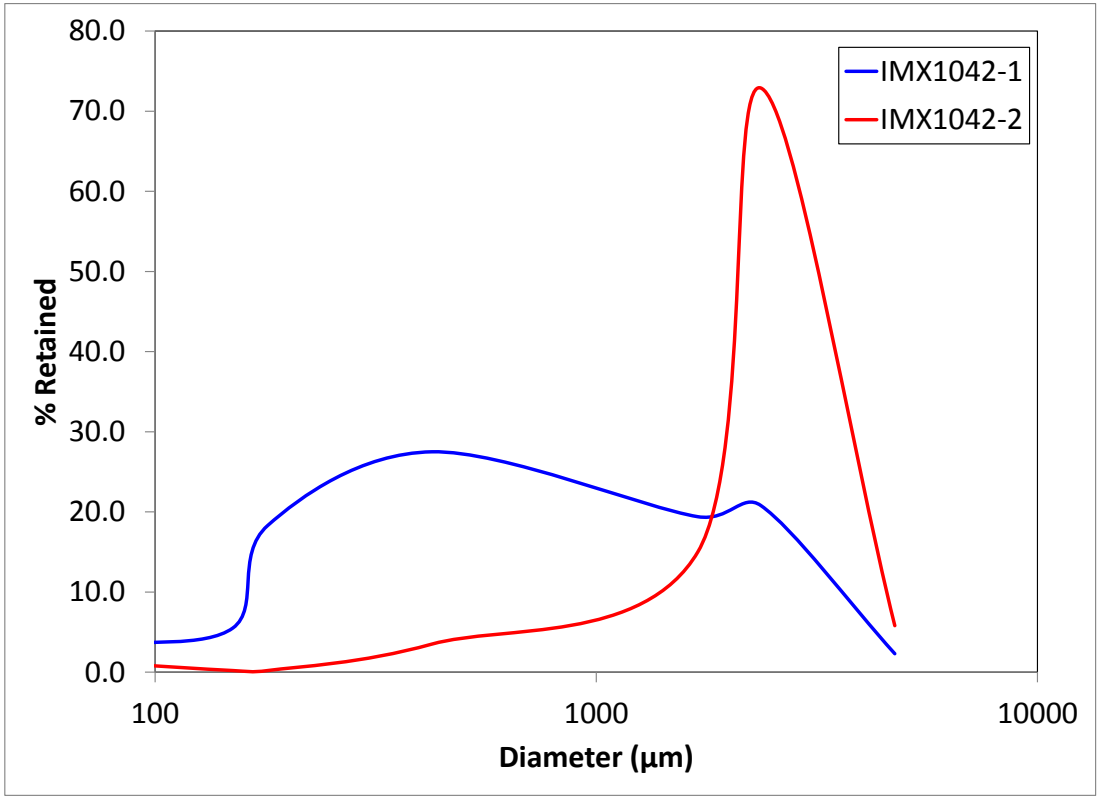
Large Scale Manufacture – Initial Run Granulation

- IMX1042-1
  - Very fine and powder like
  - Conditions adjusted for second batch to make material coarser
  - Analysis of powder resulted in high NTO values
- IMX1042-2
  - Better granulation with narrow distribution
  - Coarser than intermediate batch
  - However still did not meet composition
- Water present in DNAN (~15%)
  - NTO lost in water as it is removed
  - High ratio of fluid to water during removal step (~10:1)



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Large Scale Manufacture – Rework

Batch ID		IMX-104 Specification		IMX1042-1A2	IMX1042-2A
		Minimum	Maximum		
DNAN		Nominal	Nominal	Nominal	Nominal
RDX		Nominal	Nominal	Nominal	Nominal
NTO		Nominal	Nominal	Nominal	Nominal
Melting Point (ºC)		86	96	90.4	90.5
Exothermic Onset (ºC)		193	217	206	204
Bulk Density (g/cc)		0.865		1.02	1.02
Impact (cm)		120		>200	>200
Friction (N)		Exceed RDX CL5		254.6	209.1
		RDX CL5		164.5	164.5
Flowdex		10	20	18	20
Moisture (%)			0.2	0.03	0.04
VTS (ml/g)			2	0.07	0.09
Screens (% Pass)	4			94.6	93.0
	8			38.6	32.7
	12			17.6	11.5
	40			0.4	0.2
	80			0.2	0.1
	100			0.1	0.0
	200			0.0	0.0
	325			0.0	0.0

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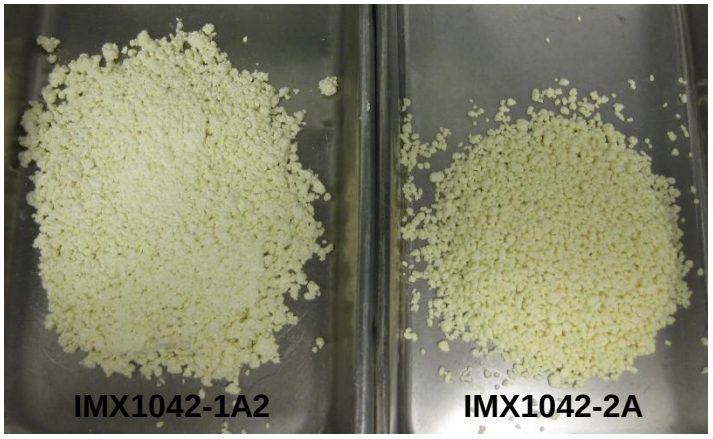
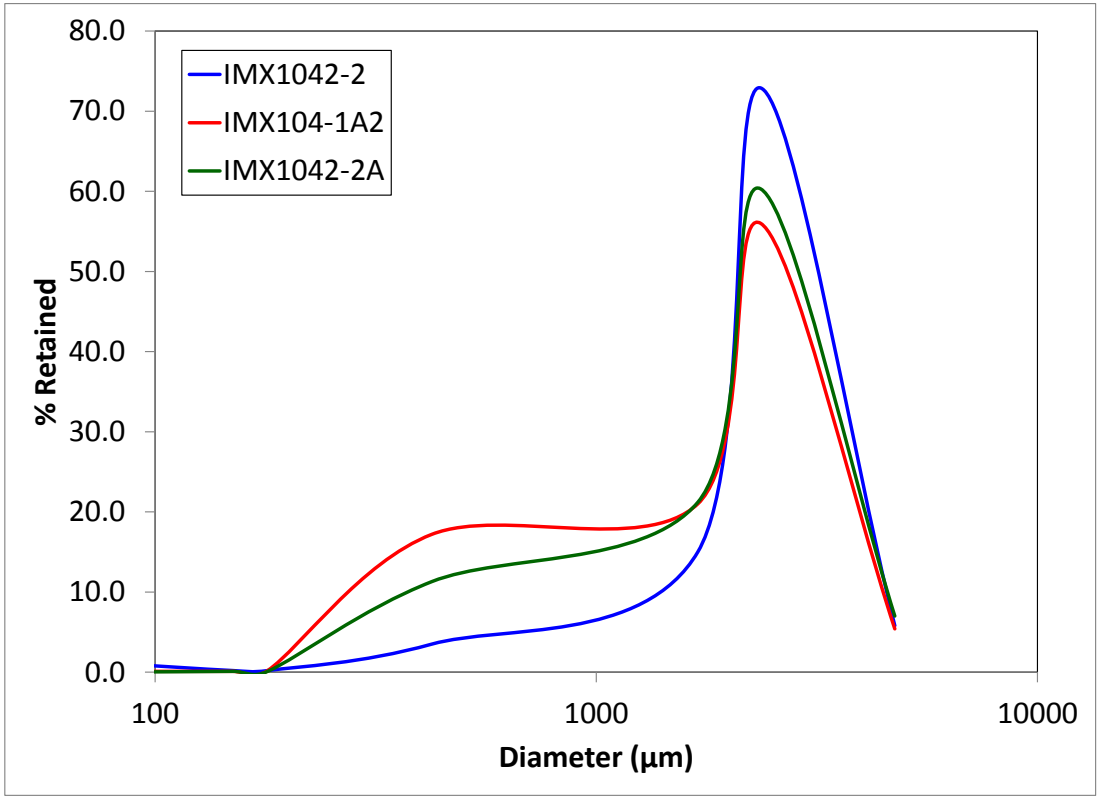
Large Scale Manufacture – Rework Granulation

- IMX1042-1A2
  - Now similar to IMX1042-2
  - Meets composition requirement
- IMX1042-2A
  - No major change to granulation
  - Meets composition requirement
- Material delivered for further evaluation and testing





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Conclusions and Future Work

- Process using alternate fluid has been successful in manufacturing granular versions of IMX-104
  - Laboratory process successfully scaled to 50 pound increment
    - Meet specification for composition with no change in thermal properties
    - Granulation can be controlled to obtain useable material
    - LSGT value not significantly effected by granulation process
  - Process further scaled to 500 pound batch size
    - Meets specification for composition with no change in thermal properties
    - Evidence that granulation can be controlled but requires additional work to optimize
    - Utilizes existing manufacturing infrastructure at HSAAP
    - Additional work is required to determine best method for removing water and minimizing NTO loss

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Acknowledgements

- Mr. Matt Hathaway
- Dr. Jeremy Headrick
- Ms. Kelly Guntrum
- Ms. Robyn Wilmoth
- Mr. Chris Long

- Mr. Phillip Samuels
- Mr. Keyur Patel
- Mr. Omar Abbassi

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Questions?





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