



**RDECOM**



# Irreversible Growth of DNAN Based Formulations



***TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.***

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- DNAN based Explosives have been shown to have greatly improved IM characteristics, while still being able to meet performance requirements
- Army Qualified DNAN formulations are used in
  - PAX-21 (60mm M720A1/M768 Mortars)
  - PAX-41 (Spider Grenade)
  - PAX-48 (120mm HE-T)
  - IMX-101 (155mm M795 IM Artillery)
  - IMX-104 (60/81/120mm Mortar)

- AOP-7 suggests it is preferred that explosives have no more than 1% irreversible growth during extreme thermal cycling.
- New IM explosives and traditional melt cast explosives like TNT and Comp-B exhibit growth in excess of 1%.
- The recent development and performance characterization of insensitive explosives based on 2,4-Dinitroanisole (DNAN) has lead to determining the effects of irreversible growth in end items using these explosives.

Formulation	Average % Volume Change
DNAN	15.01%
PAX-41	12.12%
<b>Comp B</b>	<b>8.46%</b>
<b>IMX-101</b>	<b>8.00%</b>
PAX-21	6.77%
IMX-104	5.26%
PAX-48	3.97%
Recovered TNT	3.52%
TNT	3.10%

- PAX-21: DNAN, RDX, AP
- PAX-41: DNAN, RDX
- PAX-48: DNAN, HMX, NTO
- IMX-101: DNAN, NTO, NQ
- IMX-104: DNAN, NTO, RDX

1" x 1" bare pellets subjected to 30 cycles -54°C to +71°C (AOP 7)



- AOP-7 states the advisory criteria is that the amount of growth be no more than 1%.

Exudation and Growth: No advisory criterion but data from tests performed per U.S. 202.01.010 (Exudation) and U.S. 202.01.011 (Growth) are required for TNT based explosives. Tests performed per U.S. 202.01.010 are required for explosives containing energetic plasticizers.

- Significant growth was noted for all of the materials tested; IMX-101, IMX-104, TNT, and Comp B.
- The IMX formulations formed a powdery, chalky coat on the pellet surfaces after about forty cycles.
- Although TNT had the smallest volume increase, the pellets were the most physically damaged.
- IMX-104, TNT, and Comp B all had approximately linear growth through the 98 cycle test.
- The Comp B samples, with the largest percent volume growth, cracked on the top and bottom surfaces.
- IMX-101 appeared to show a decrease in the rate of growth near the end of the test.

Formulation	Percent Growth
Comp B	20.29%
TNT	7.46%
IMX-101	14.66%
IMX-104	12.72%

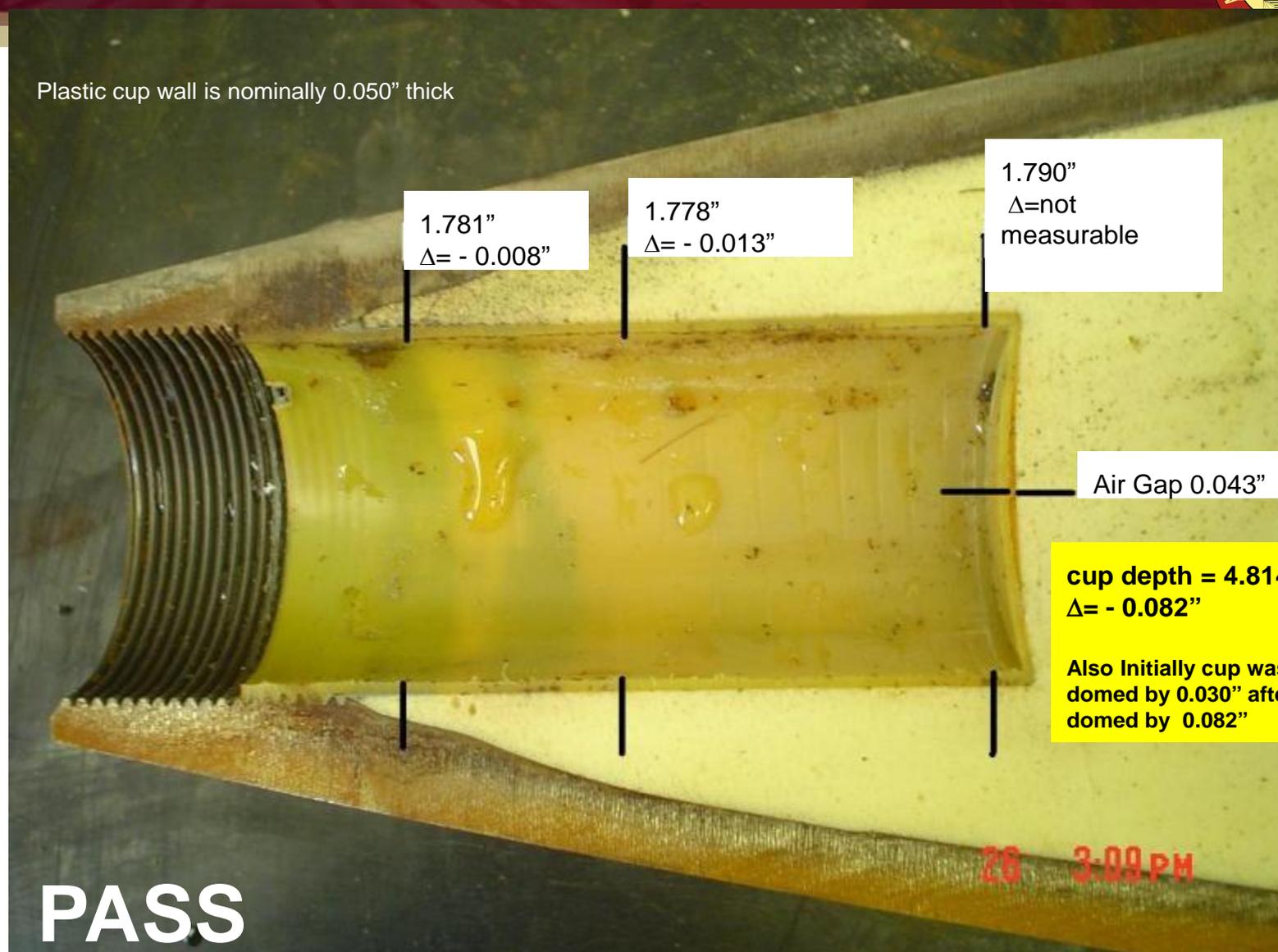


## Comparison of Temperature Conditioning Among Tests

<b>M795 Life Cycle Temperature Extremes</b>	<b>Irreversible Growth Test</b>	<b>ITOP Sequential Environment Test</b>
<b>Operation</b> -45.6 to 62.7 °C <b>Transportation</b> -46.1 to 71.1 °C <b>Storage</b> -51.1 to 71.1 °C no more 4 hours/day, less 3 days	<b>3 Rounds</b> 30 cycles between -54 to 71°C	<b>60 Rounds each</b> 28 Day Hot Cycle: 33 °C @ 80% RH to 71 °C. 14 Day Cold Cycle: -51 °C
	<b>Dimensional measurements</b>	<b>Gun Firing, All pass</b>

- Purpose – Following AOP-7 guidance, the effect of IMX-101 explosive growth on the fuze well cavity and explosive cast quality was studied
- Test Description – Subject three (3) M795 projectiles to 30 cycles of temperature conditioning between 71.1°C and -53.9°C
  - Test is normally done on explosive unconfined
- Test Items
  - Sample 1 – M795 with 40% fiber reinforced fuze well liner with PBXN-9 supplementary charge and plastic lift plug
  - Sample 2 – M795 with 40% fiber fuze well liner and plastic lift plug
  - Sample 3 – M795 with drilled fuze well cavity (no liner) and plastic lift plug
- Result
  - No observable issues identified
  - No significant dimensional change

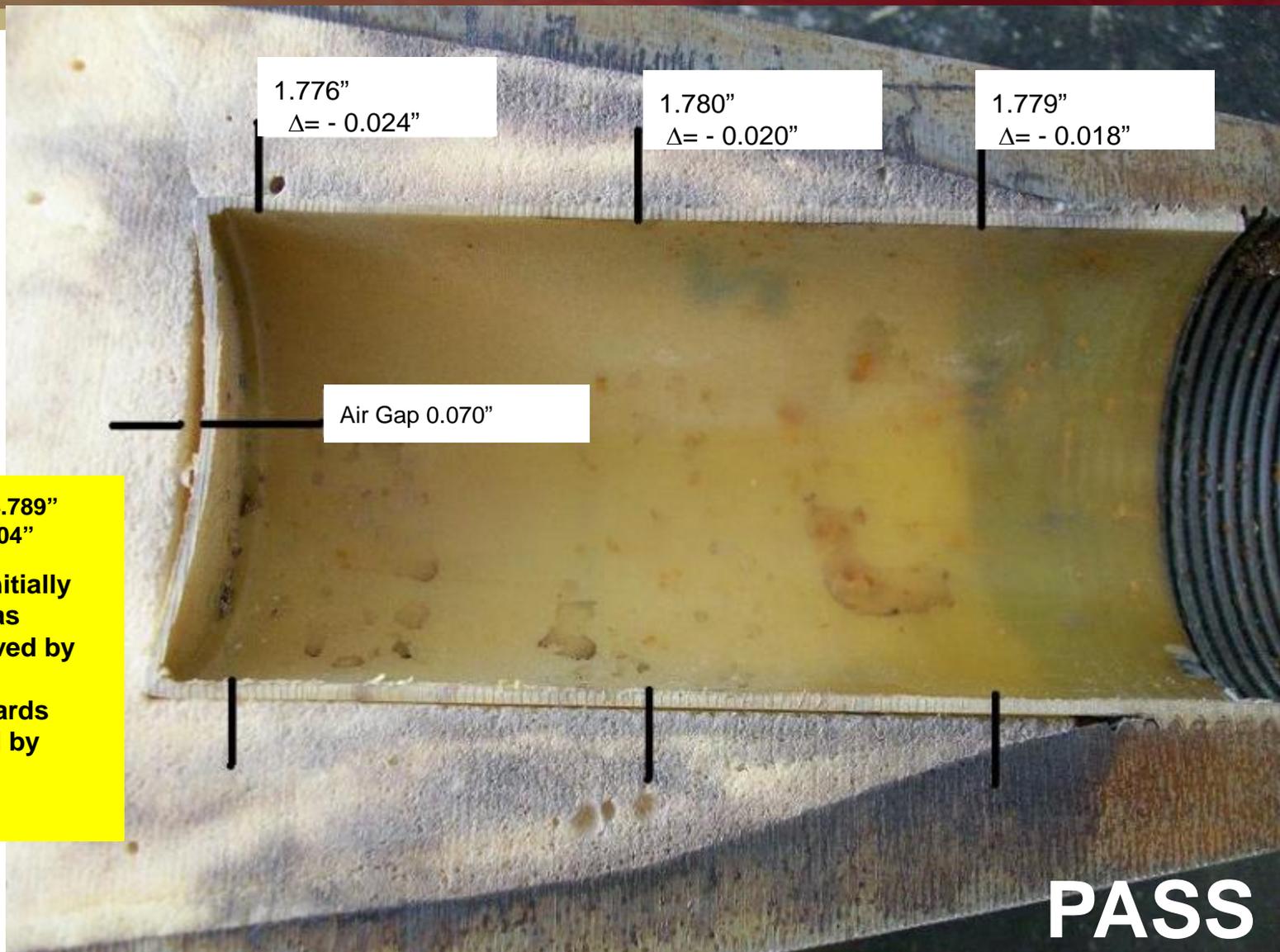
Plastic cup wall is nominally 0.050" thick



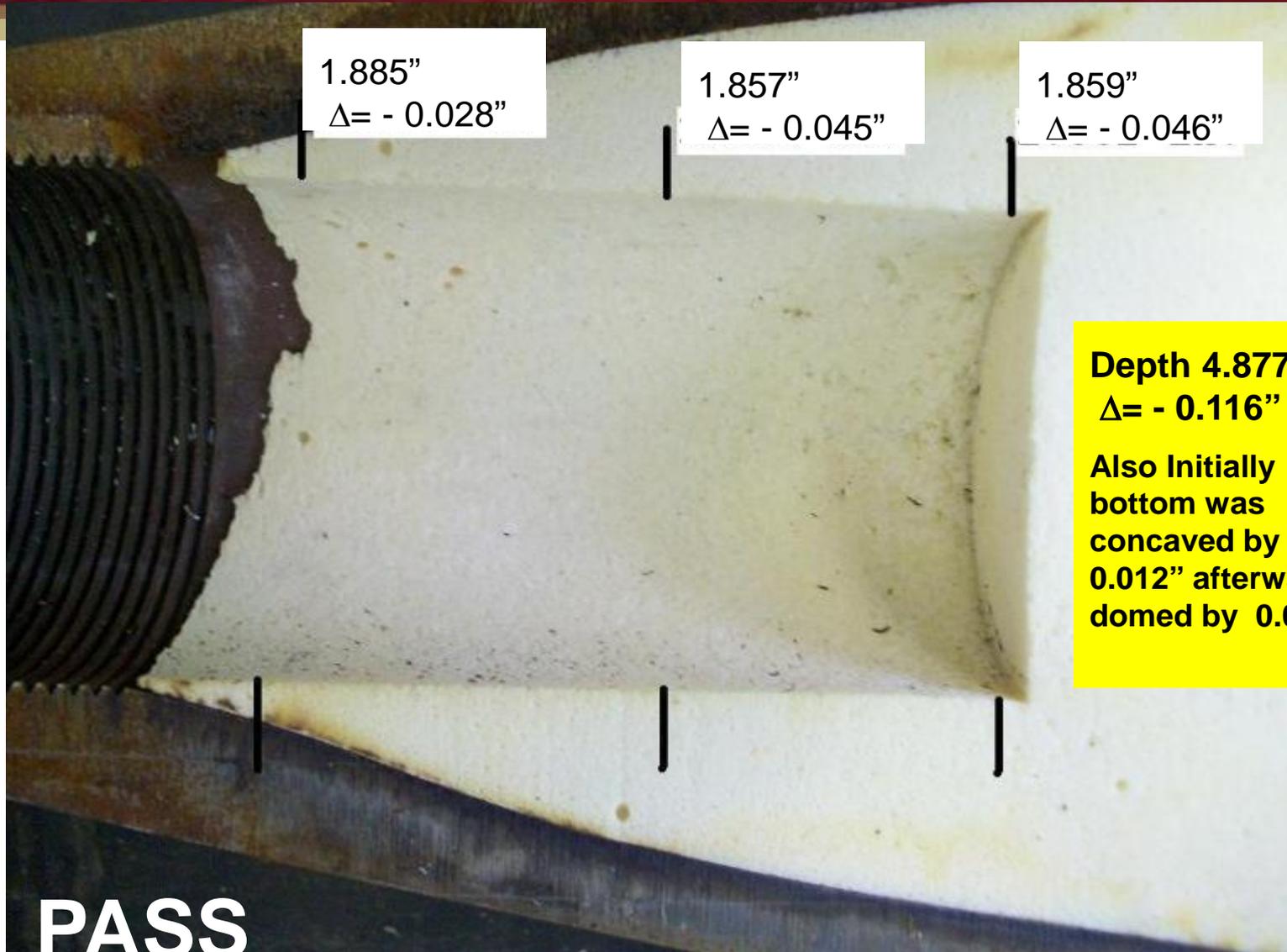
# PASS

Sample 1 - Liner with sup charge

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Sample 2 – Liner without sup charge



Sample 3 - No liner

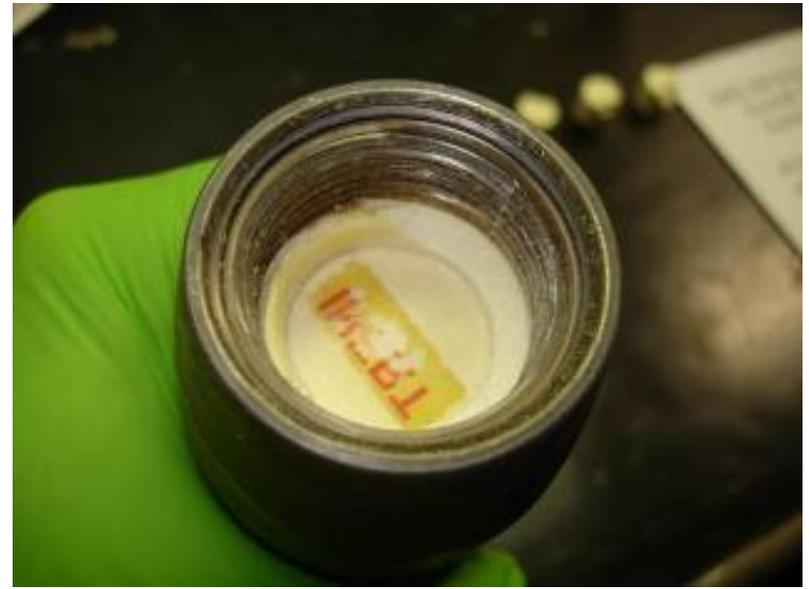
- Observations from the three loaded M795 subjected to growth protocol:
  - Minimal change to inside diameter of fuze well cavity
    - Least change observed on projectile with liner and supplementary charge (0.008” vs 0.028”)
  - Minimal change to gap between HE and fuze well cavity
    - Gap increase when liner/sup chg were not present: 0.116”
  - No adverse impact on removing the supplementary charge after growth cycling
  - Explosive expansion into the fuze threads not observed
    - Cup is sealed into the projectile threads with RTV
  - Supplementary charge has 3/8” felt pad at bottom to make up for fuze/projectile tolerance

- 30 Cycles between  $-65^{\circ}$  F and  $160^{\circ}$  F (cycle time for each mortar based on time needed for internal temperature to reach mark, 6 hrs)
- All rounds sealed with inert fuzes and DP-8010
- No aux charge was included in this test
- Measurements taken for fuze well cavity depth and fuze well cavity diameter as well as on the formion fuze well adapter

## Pre-Test



## Post-Test



60mm growth testing shows a change of 1.35% in the fuze well cavity

- 30 Cycles between  $-65^{\circ}$  F and  $160^{\circ}$  F (cycle time for each mortar based on time needed for internal temperature to reach mark, 6 hrs)
- System level 81mm mortars
- All rounds sealed with inert fuzes and DP-8010
- Measurements taken for fuze well cavity depth and fuze well cavity diameter as well as on the formion fuze well adapter

## 81mm mortar with an auxiliary charge

- Measurements show a displacement of 2.8%
- System inhibits growth of the explosive
  - Based on X-rays, no pinching or crushing of the aux charge takes place

### Pre-Test

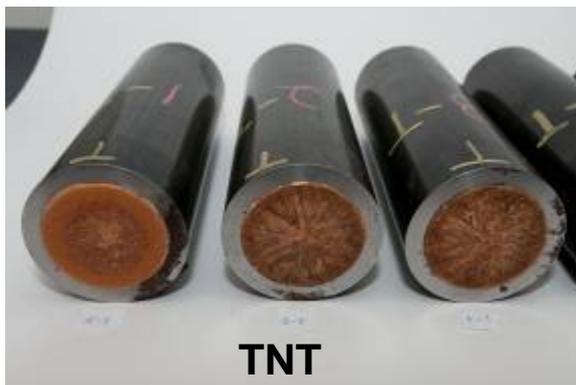


### Post-Test

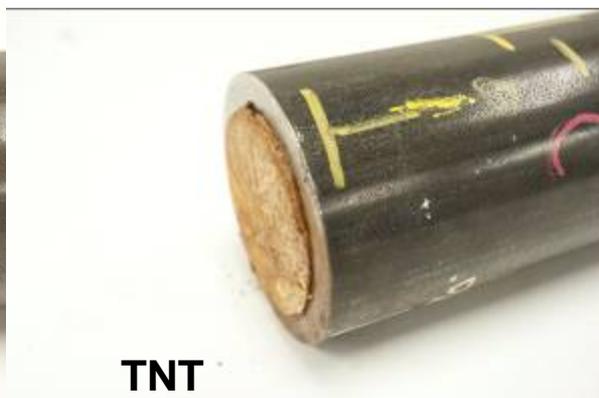


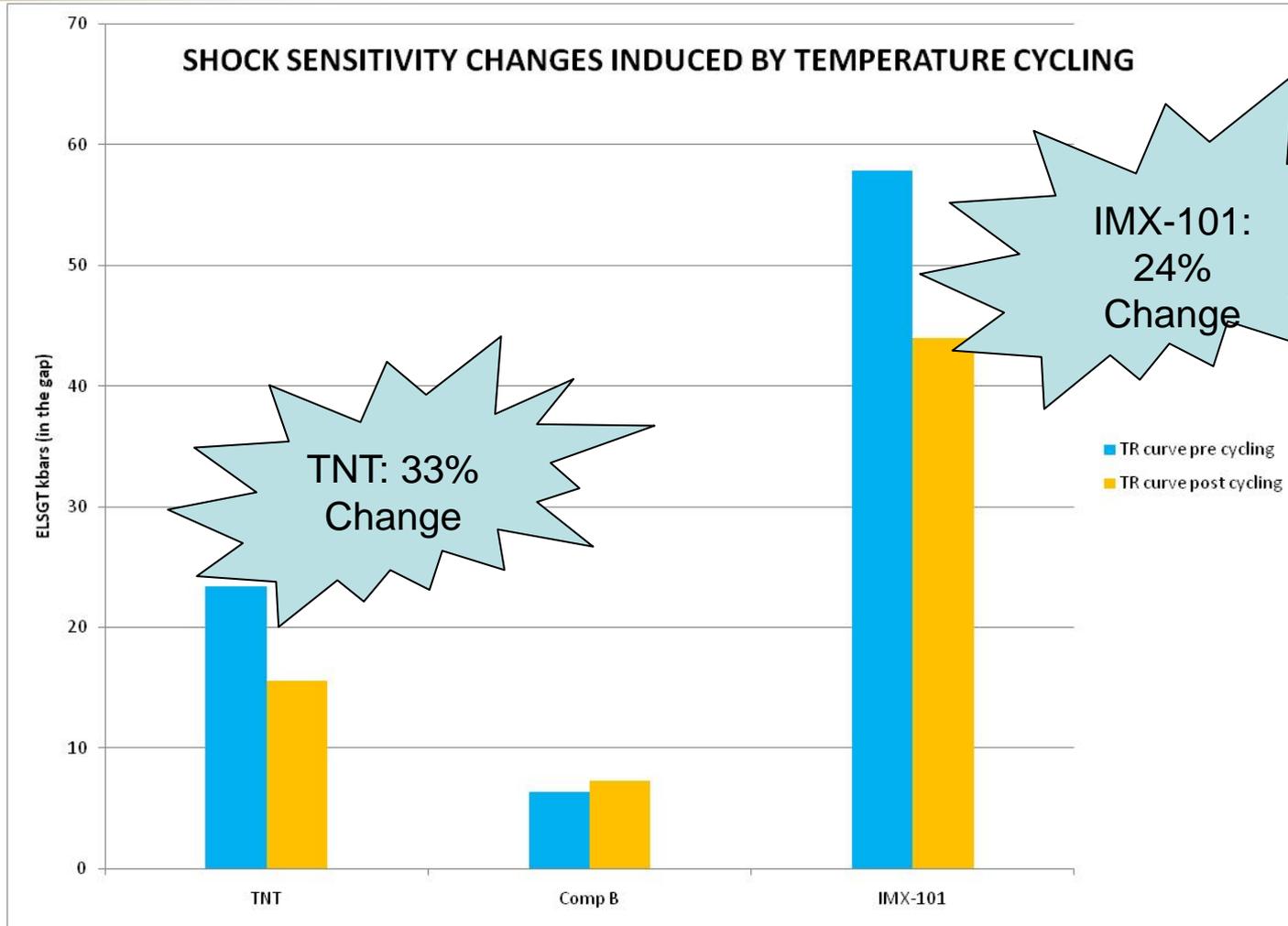
- Loaded 6 ELSGT tubes 0.050" above flush
- ELSGT tubes were x-rayed
- ELSGT tubes were thermal cycle (IAW AOP-7 Growth Test Cycle) to allow the explosive to grow within the tubes at ATC, Aberdeen, MD
- Growth was measured at the end of 30 cycles
- ELSGT tubes were re x-rayed
- Machine off 0.050" above flush surface before performing ELSGT testing
- TNT and Comp B subjected to the growth cycle and tested as above
- A control sample (un-cycled IMX-101, TNT and/or Comp B) was also tested

## Pre-Conditioned



## Post-Conditioned





IMX-101 maintains its superior shock insensitivity

- Tested IAW ITOP 4-2-504(1)
  - Life cycle profile
    - -51.1°C (severe cold)
    - +62.8°C (extreme hot)
  - Temperature cycle tests
    - No issues fuzing projectiles
    - No reliability failures after gun launch
  - Safety Confirmation from Independent evaluator (DTC)
  - Assigned HC 1.2.1

	FCO	SCO	BI	FI	SD	SCJI
IM Test:						
Passing Criteria	V	V	V	V	III	III
M795 Baseline (TNT)	III	III	IV	IV	I	I
IMX-101	V	V	IV	IV	P	P

- IMX-101 has undergone and passed all testing necessary for an Engineering Change Program which includes ITOP testing and supplementary tests
- Testing of irreversible growth on Artillery and Mortars does not show any adverse effect on Form, Fit or Function
- IMX-101 maintains its superior shock insensitivity over the others even after the irreversible growth
- Minimal amount of irreversible growth was seen in system level (Artillery and Mortars) irreversible growth tests while all ITOP conditioning tests were satisfactory
- All rounds that were fired after thermal conditioning functioned as designed
- Each DNAN based explosive will be evaluated for irreversible growth in new end items on a case by case basis

# QUESTIONS?

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