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Investigation into Penetration Performance of the M789 HEDP Cartridge

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ATK Ammunition Systems Co.

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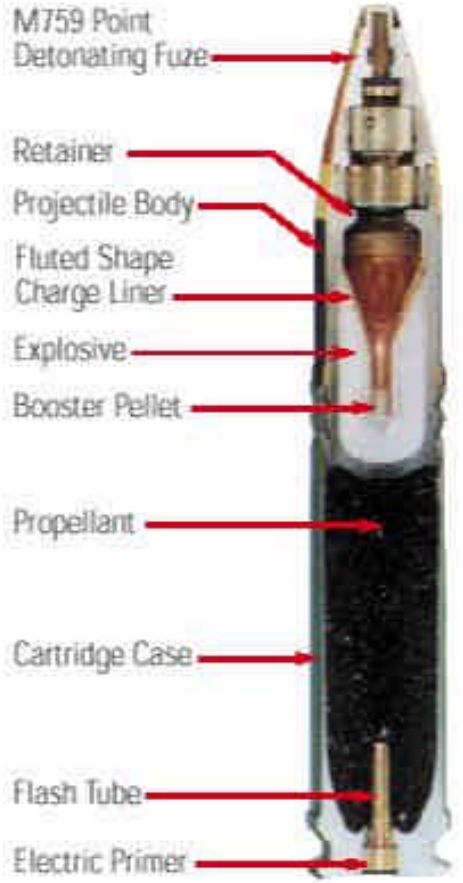
TACOM ARDEC

NDIA 38th Annual Gun, Ammunition, and Missiles Symposium & Exhibition
March 24-27, 2003

What is the M789 HEDP ?

LW30mm M789 HEDP
High Explosive Dual Purpose



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Statement of the Problem

- Multiple occurrences of penetration degradation in the 90's have led to failure investigations
  - » Static Penetration
  - » Dynamic Penetration
- Previous investigations did not identify a primary root cause.
- Penetration results continued to show little margin – leading to unacceptable risk and production shut-down
- Extensive effort over past 2+ years to identify the key characteristics contributing to penetration performance

Objective:Return penetration performance to level that will ensure repeatable success in meeting LAT requirements

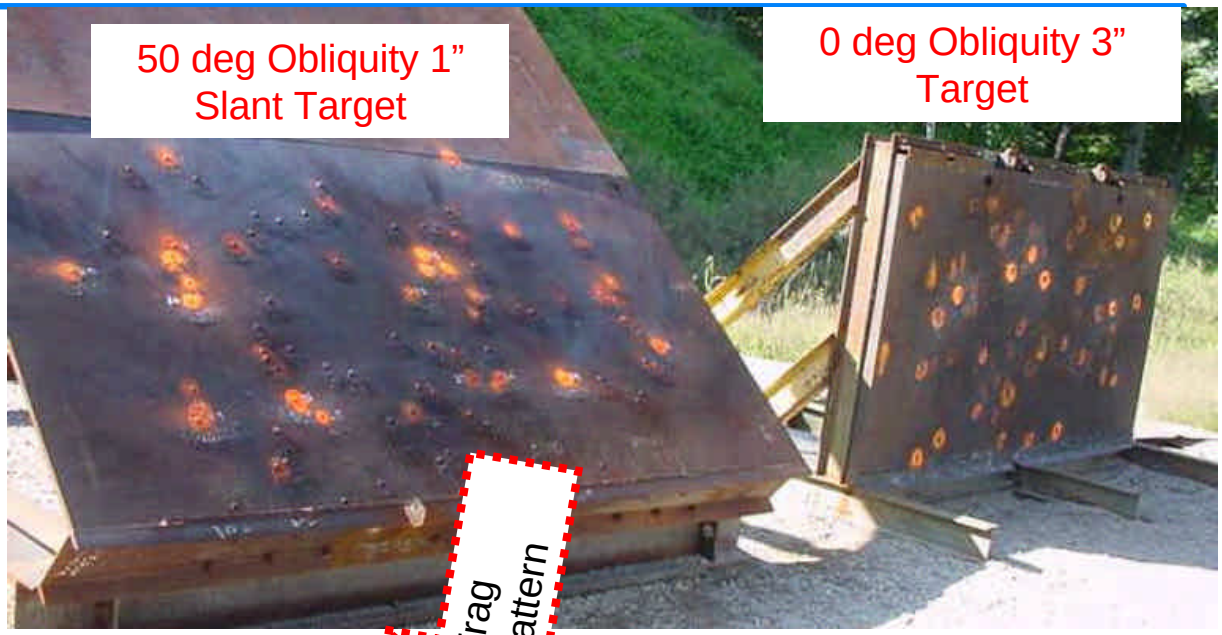
LW30 M789 HEDP Dynamic Penetration Requirement

Cartridge Spec MIL-C-63982A Requirement.

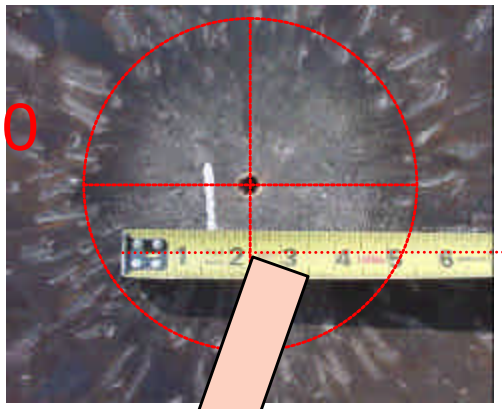
3.14.1 **Dynamic Penetration**. When fired from Barrel, Test: Gun M230 (progressive w/6.5 deg twist) (dwg. 9090748) the cartridge shall **completely penetrate the target** specified in 4.5.14 with the **reliability of 70 %** (complete penetration is evidenced by an exit hole at the rear of the target).

1”RHA @ 50 deg Slant Target & 3” RHA @ 0 deg Target

Mann Barrel



Perforation **Non-Perforation**



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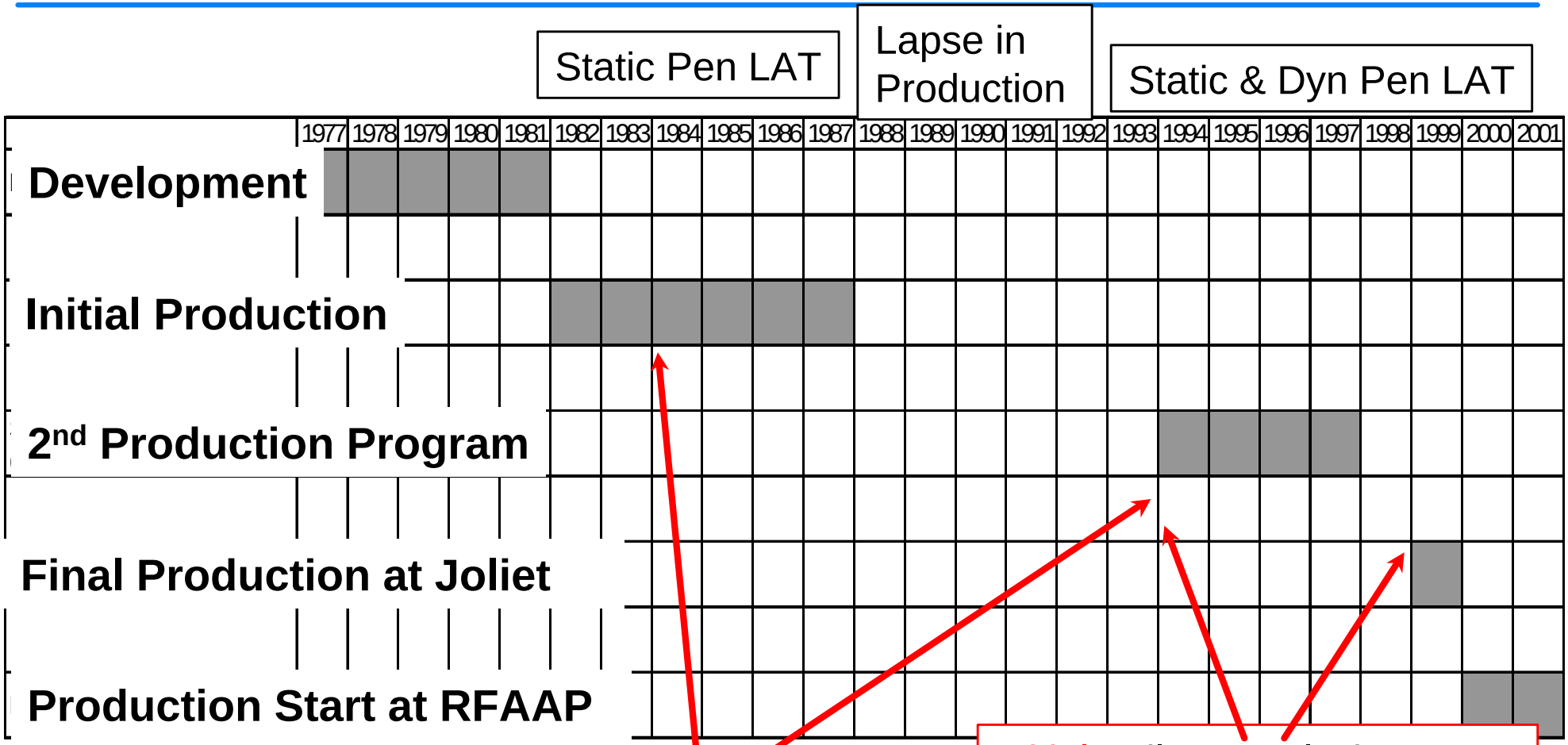
HEDP Development & Production History – Joliet to RFAAP



Recent Failure Analysis focused on "what's changed" since '80's timeframe.

Initial Failure Analysis focused on "what's changed" since '94 when Dyn Pen LAT was conducted

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Approach

- Establish Fault Tree and Perform Root Cause Analysis
  - » Identify supporting and refuting data
- "What's changed" approach
  - » Isolate the component or characteristic contributing to penetration change.
- Joint Effort under contract with JMC / ARDEC
  - » Program Funded by Joint Munitions Command (JMC – Rock Island) & ATK
  - » Worked in conjunction with ARDEC – Picatinny Arsenal

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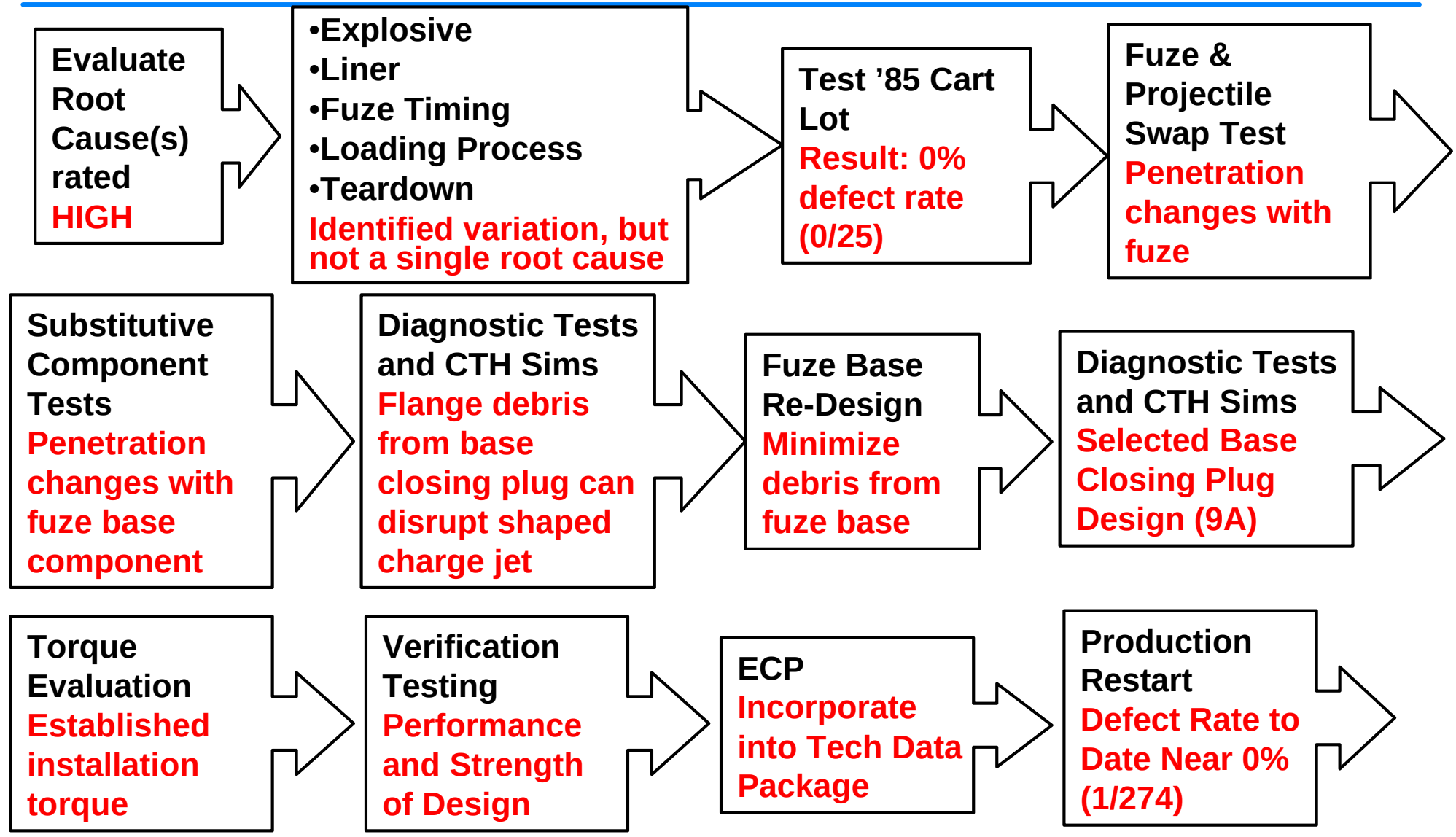
Roadmap of HEDP Penetration Investigation (STS Contract)



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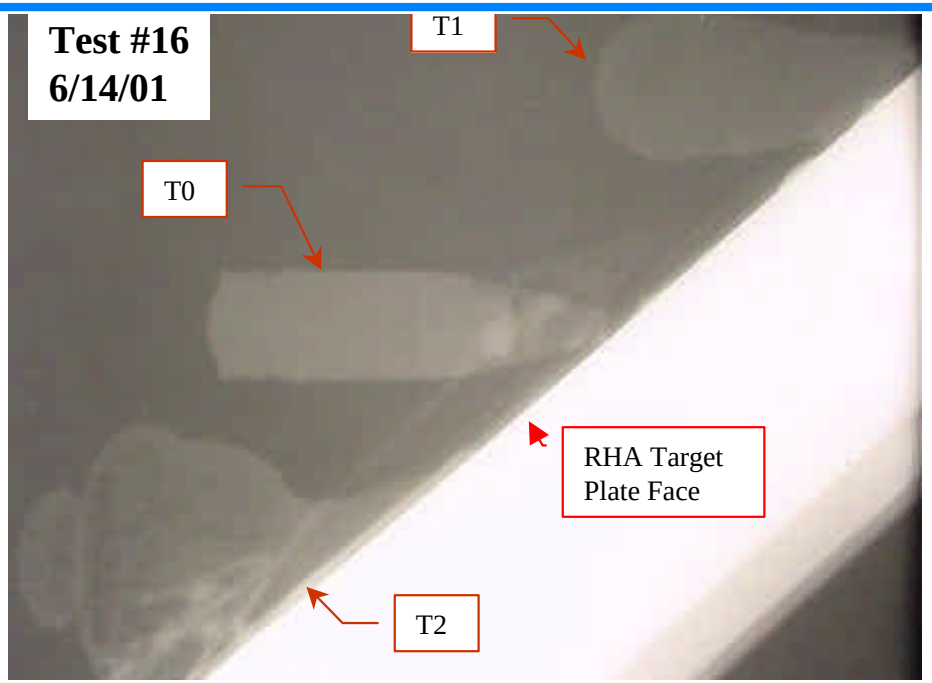
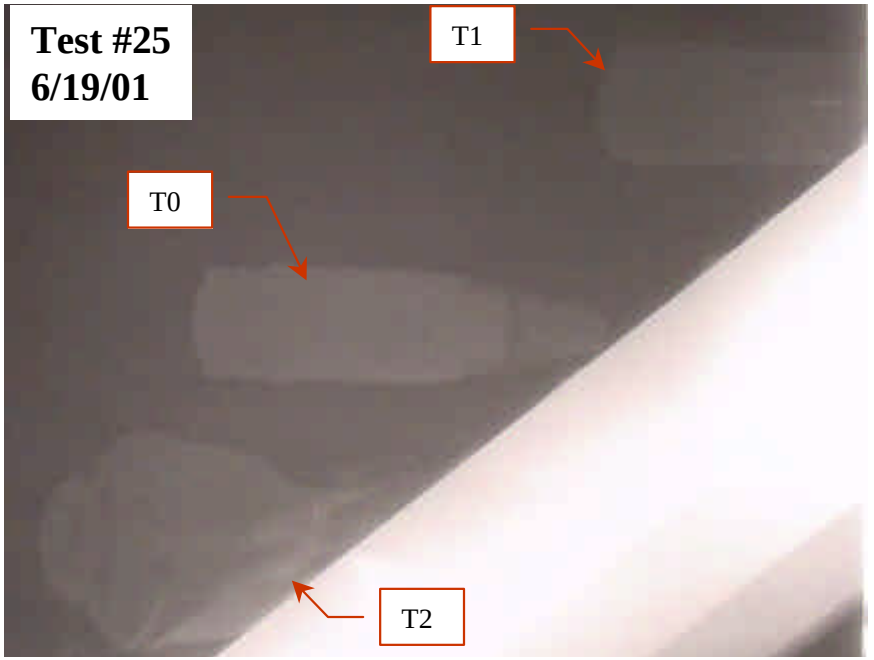
Fuze Timing Investigation – Slant Target

Fuze Function time for ’01 fuze comparable to earlier production

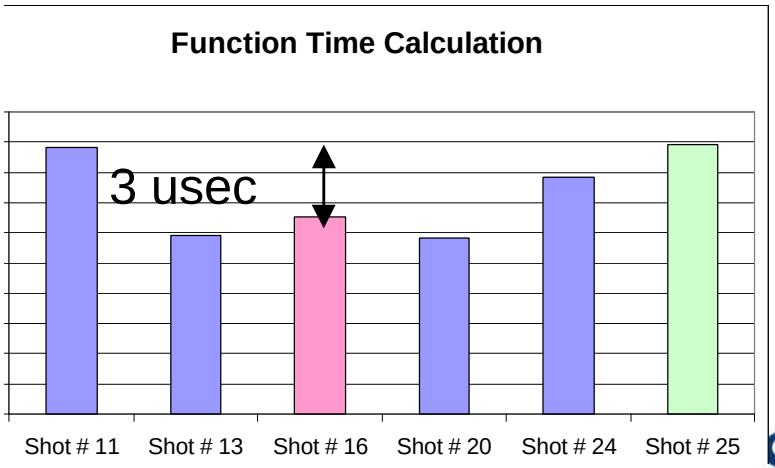


RFAAP Projectile lot with high defect rate



Joliet Projectile lot with low defect rate

Testing Conducted at
Alliant Techsystems Proving Ground
(ATPG)
Elk River, MN



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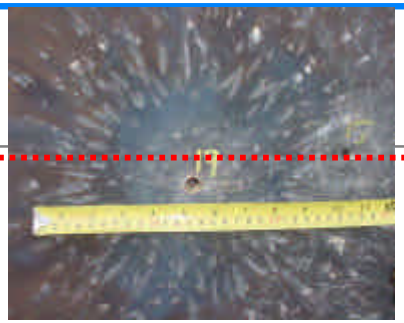
Dynamic Penetration Testing – 3” RHA @ 0 Deg

10-rd Groups



Explosive Evaluation

’85 Cart Lot

’85 round performance >> Explosive variant effects

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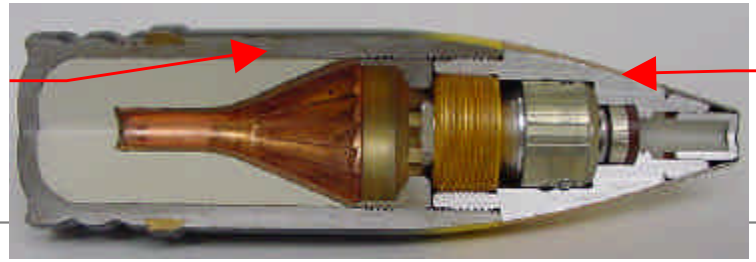
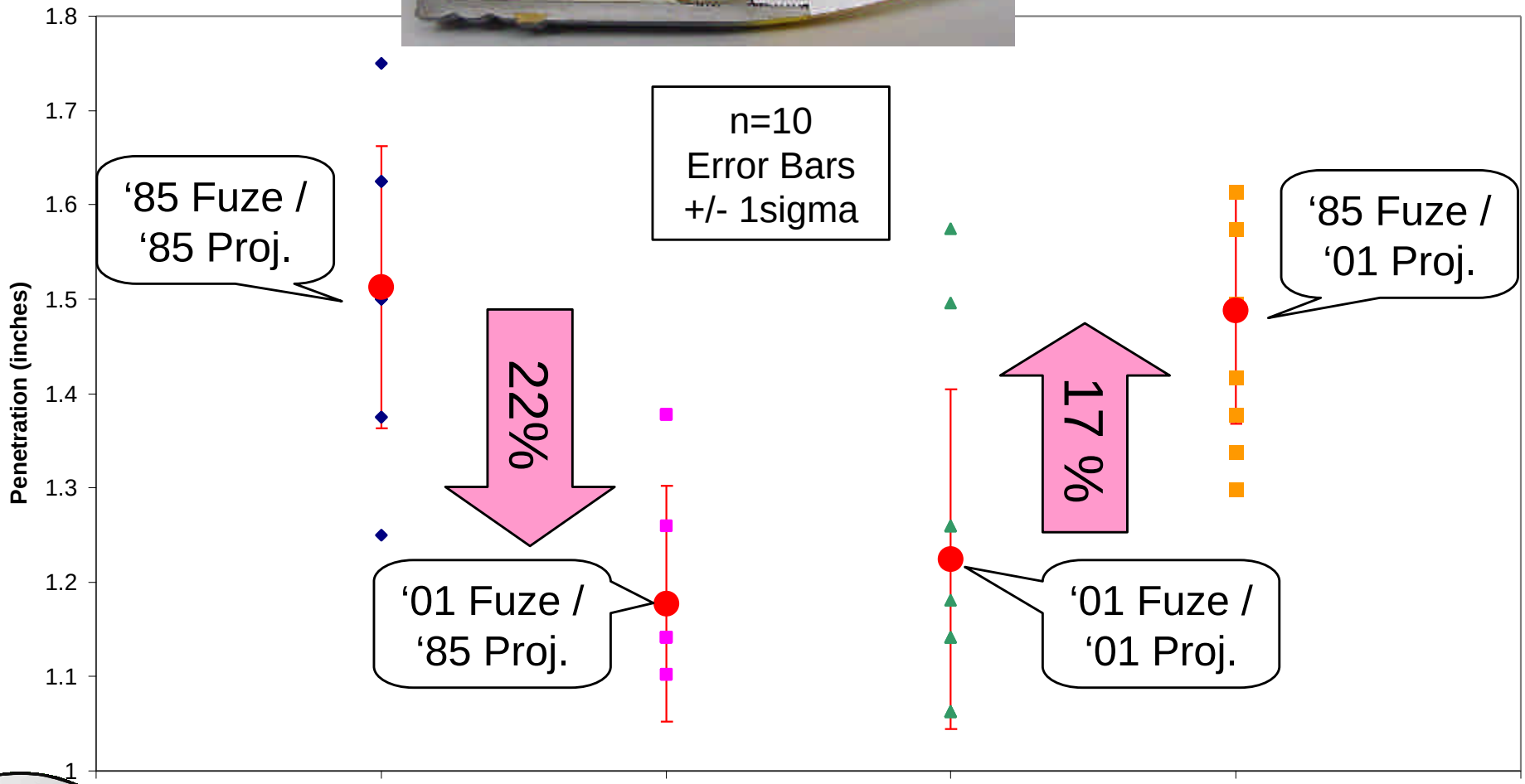
Fuze Swap Tests

[redacted]



Fuze



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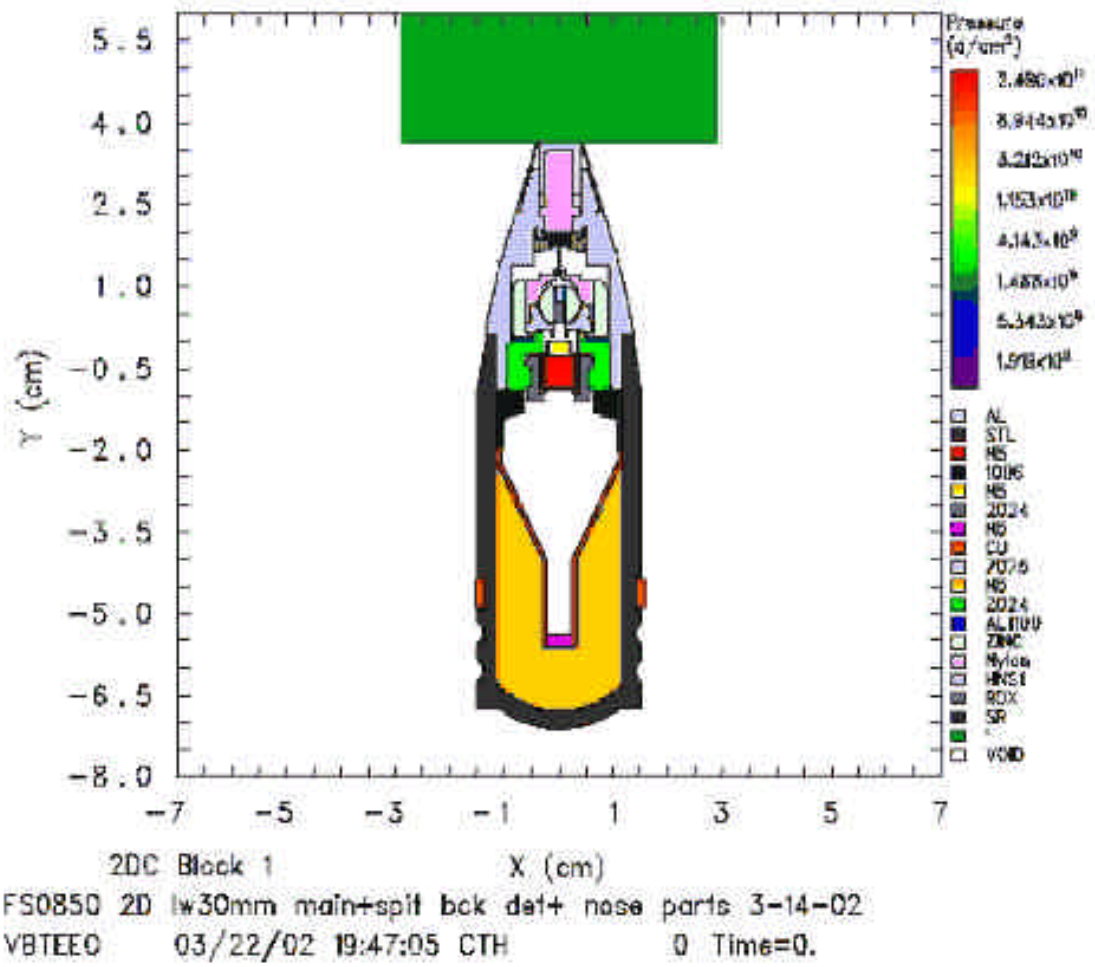
CTH Simulation of Projectile @ 0 deg Impact



CTH Simulations generated by
F. Stecher
ATK Warheads Group

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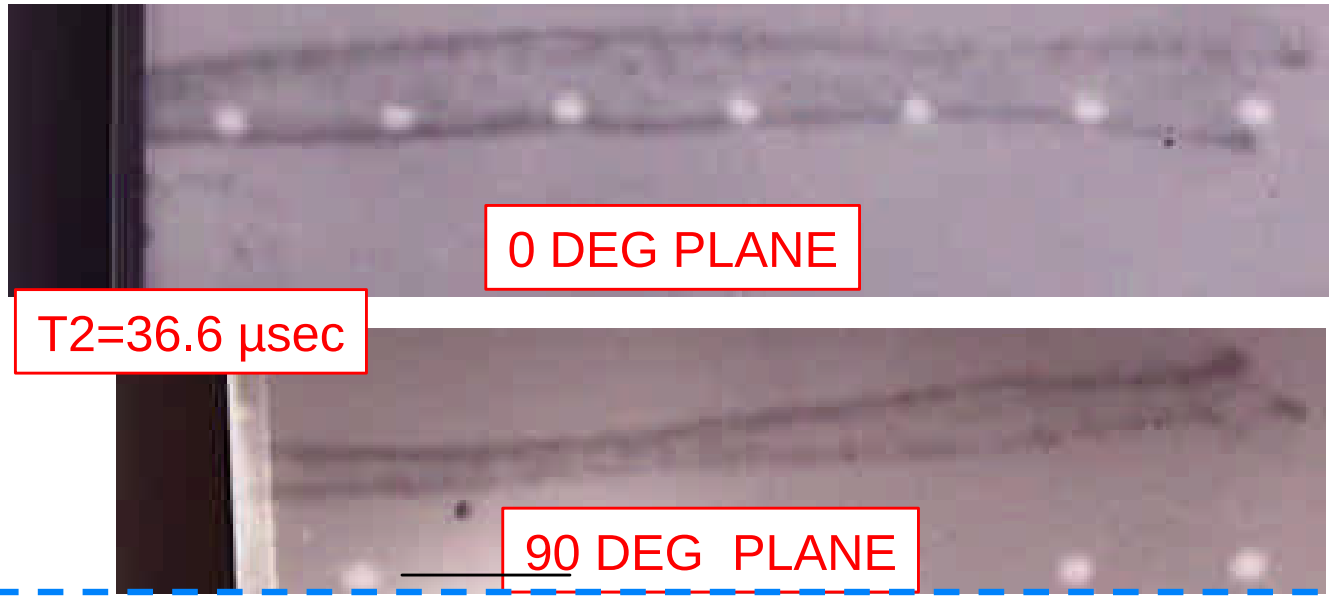
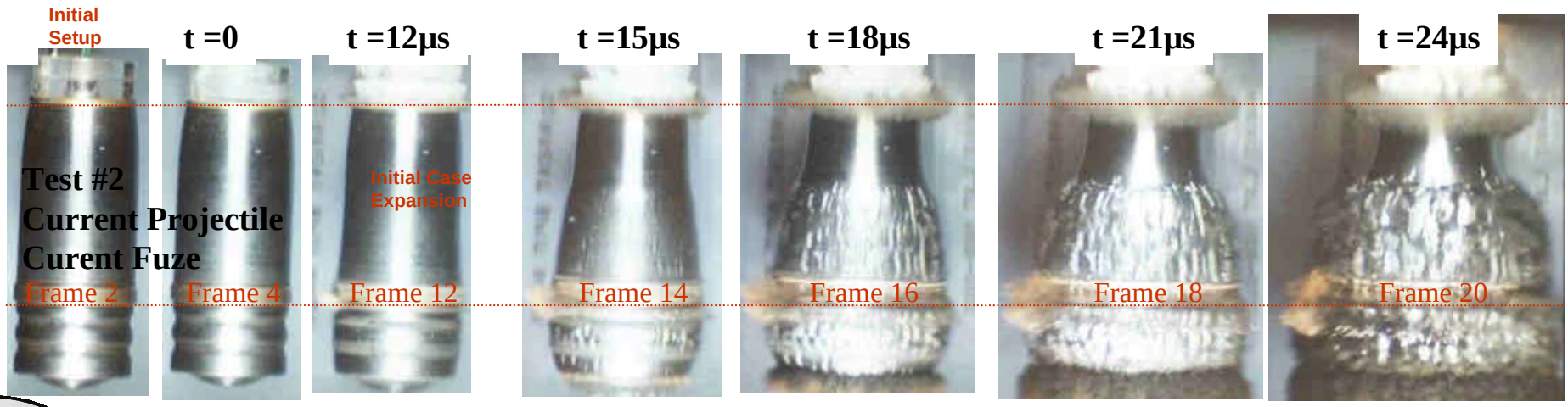
Warhead Diagnostic Testing – X-ray & Cordin Camera

Projectile: NRE01C103-002
Spitback: RSL01A011-004
Base: Current 2-piece
Spin Rate: 848 rps





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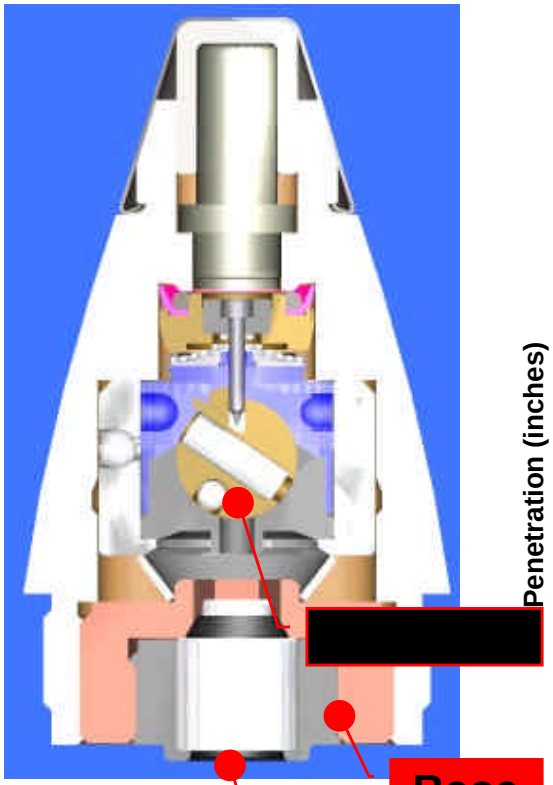
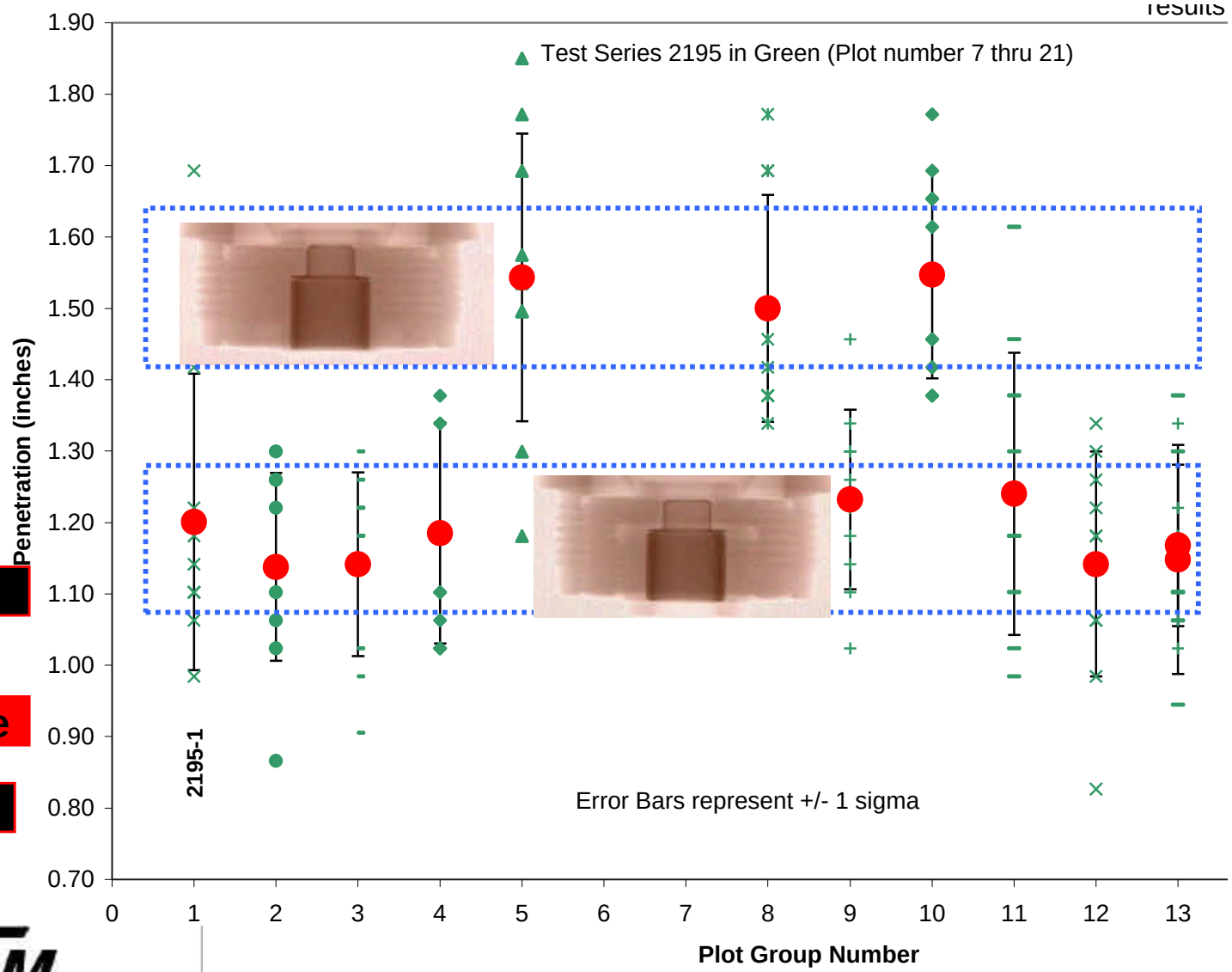
Substitutive Fuze Testing – Test Series 2195 Results

Change in fuze base results in change in penetration





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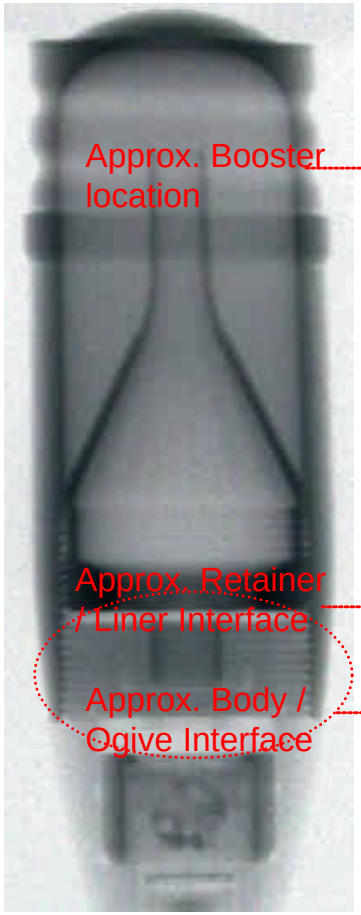
Flash X-ray of Spitback Flyer Plate at High Spin Rate



Approx. Booster location

Approx. Retainer / Liner Interface

Approx. Body / Ogive Interface

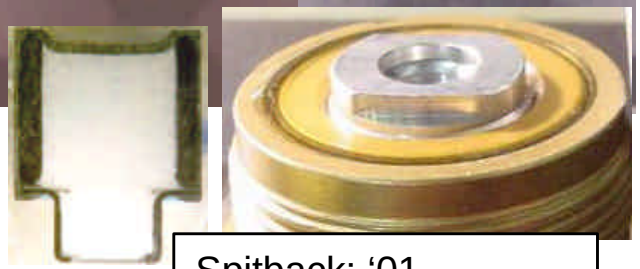
Reference X-ray of Projectile for positions

Witness Block

T=7 µsec

T=13 µsec

Flyer Plate



Spitback: ‘01
Base: Current 2-piece

T=7 µsec

T=13 µsec

Flyer Plate

Spitback: ’85
Base: ’85 1-piece

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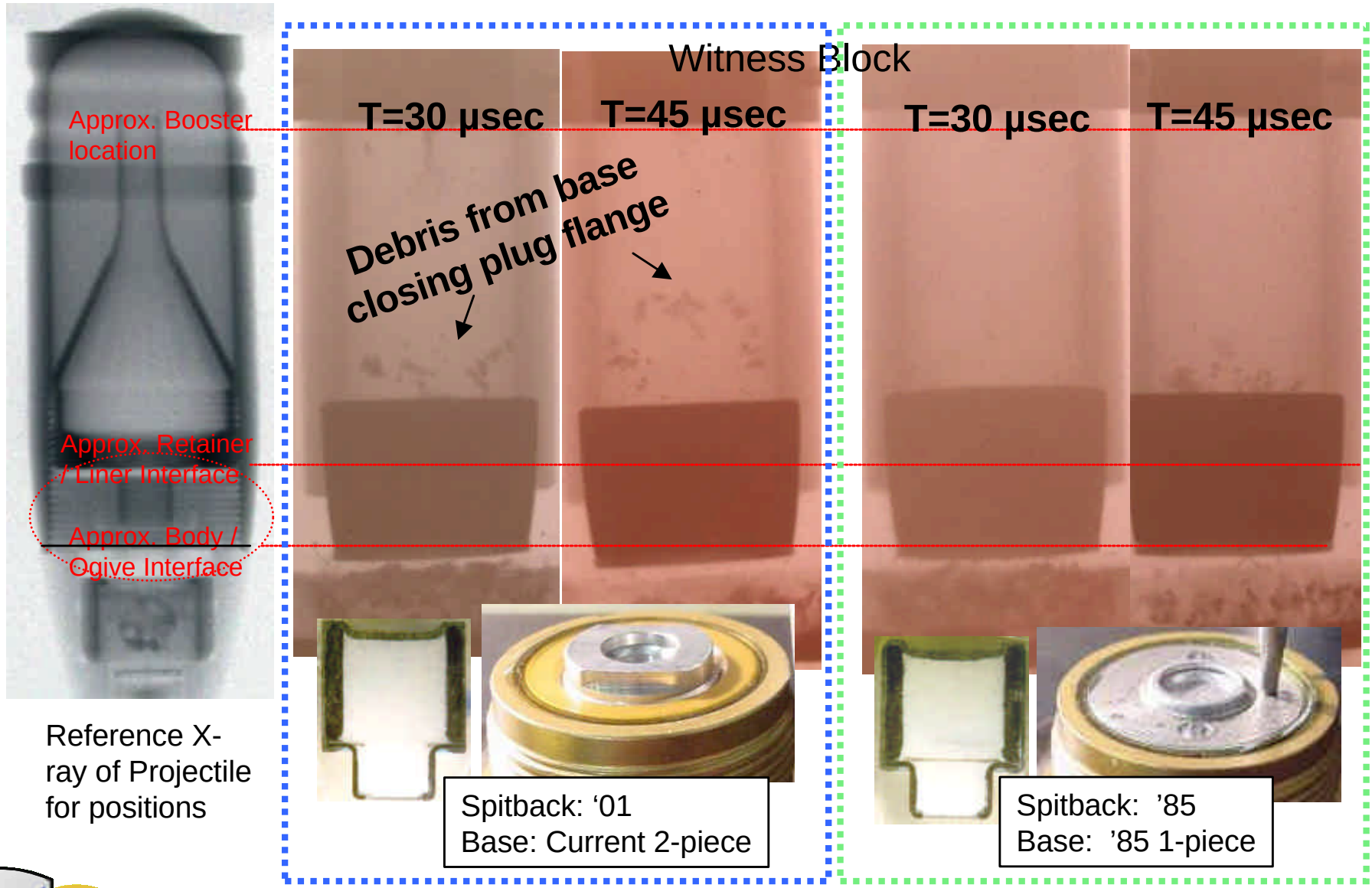
Flash X-ray of Fuze Base Debris at High Spin Rate



Reference X-ray of Projectile for positions

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Fuze Base Redesign

Approach:

- Minimize debris from fuze base
- Design must be producible
  - » For incorporation into fuze assembly process
  - » Cost

Evaluation of Fuze Base Redesign

- CTH Simulations
- Flash X-ray Static Spin Tests
- ANSYS Stress Analysis
- Conduct Dynamic Penetration testing for selected designs

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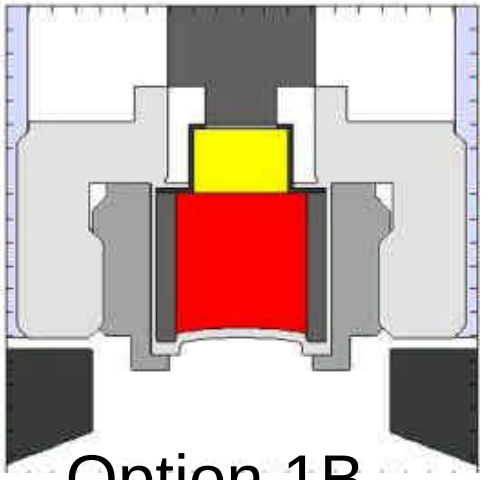
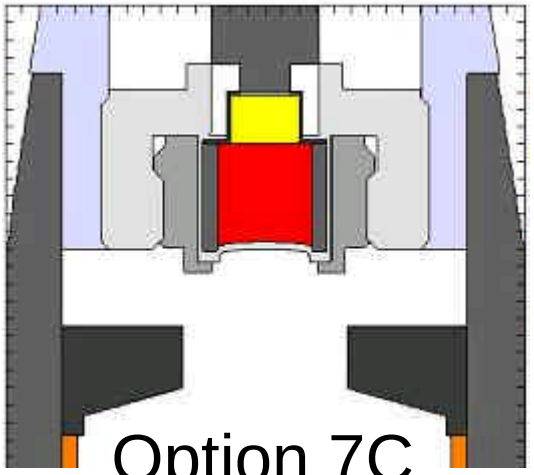
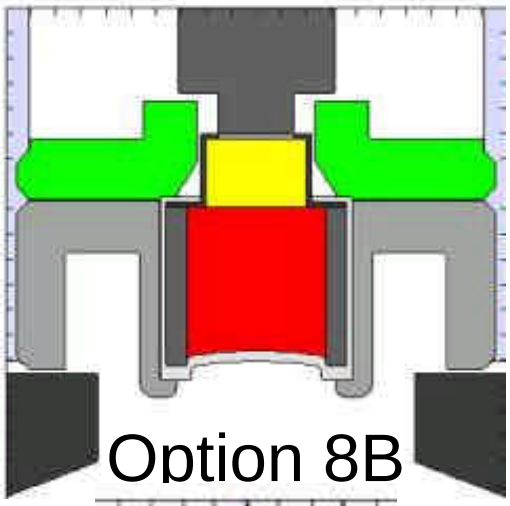
Fuze Base Redesign – CTH Simulation Examples



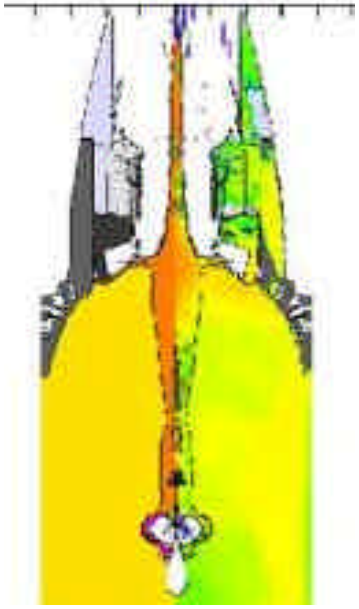
Option 1B

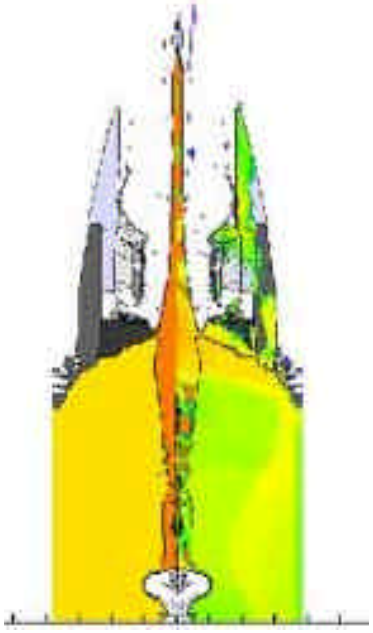


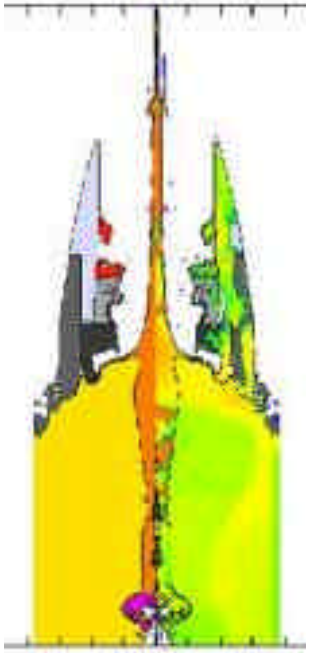
Option 7C



Option 8B







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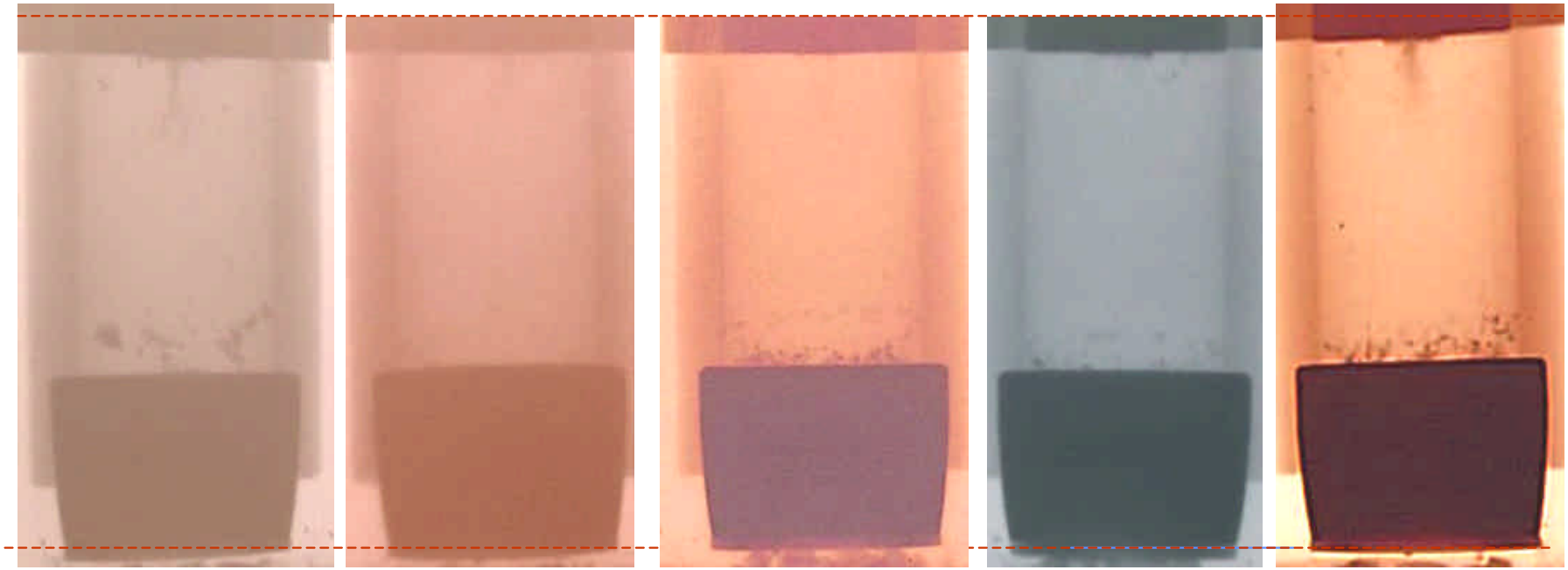
Fuze Debris Comparisons @ Approx. 30 usec



Current Baseline 2-piece w/

’85 1-piece w/ crimp flange & ’85 spitback

Option 1B (spanner slots)

Option 8B

Option 9A (socket

Replicate ’85 flange geometry

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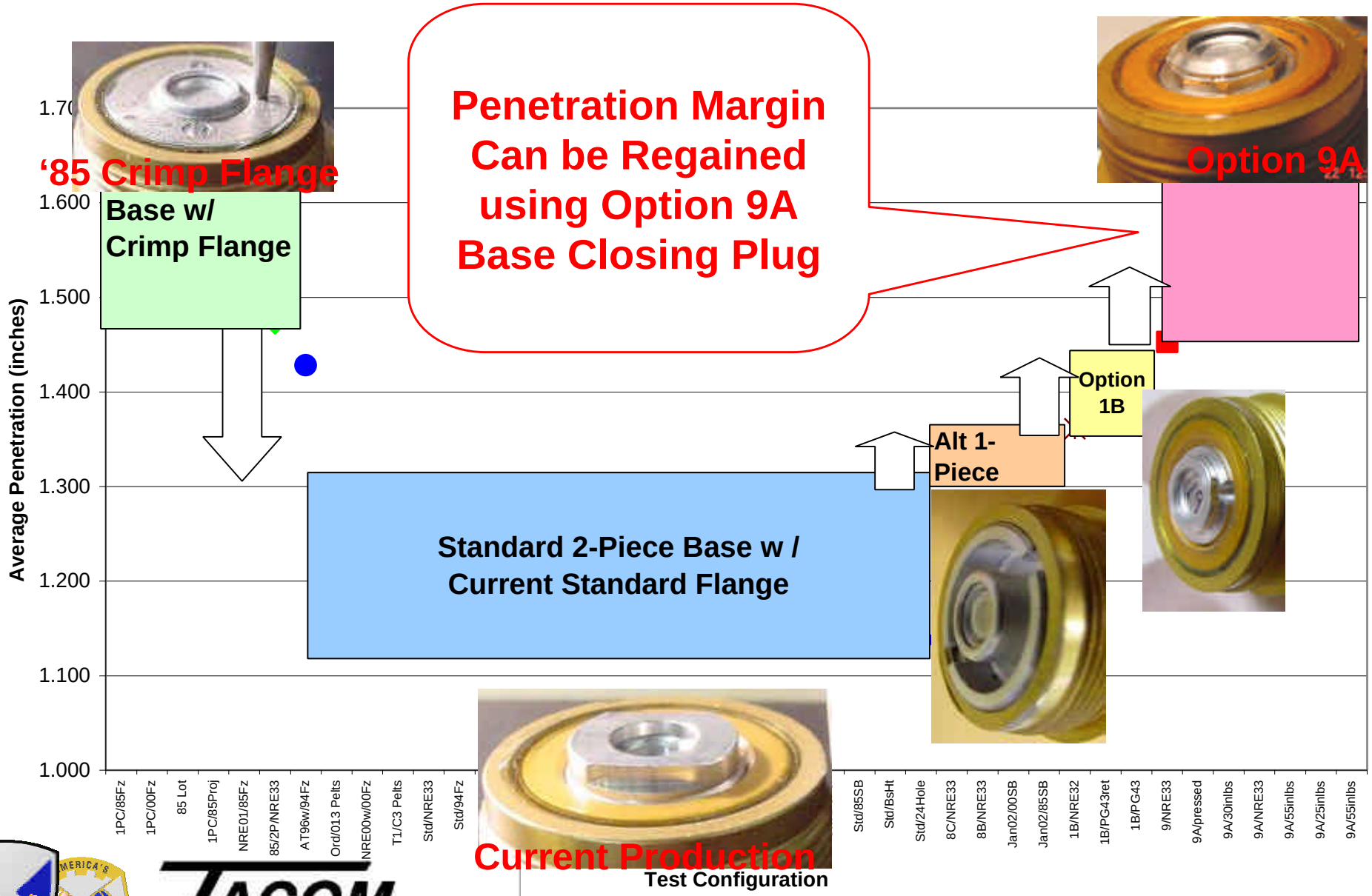
Dynamic Penetration vs. 3” RHA for Flange Configurations



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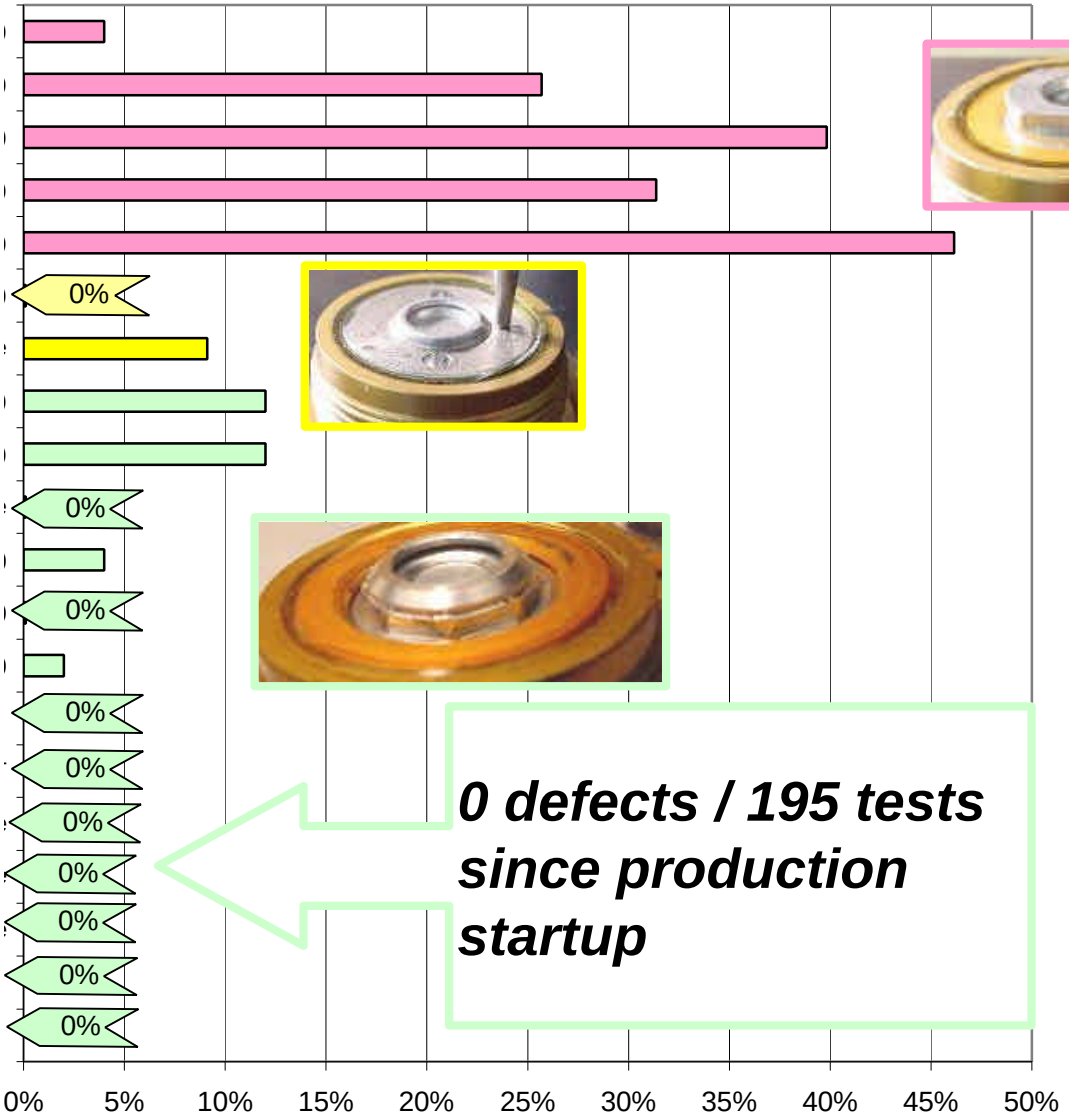
Slant Target Defect Rate Reduced



0 defects / 195 tests since production startup

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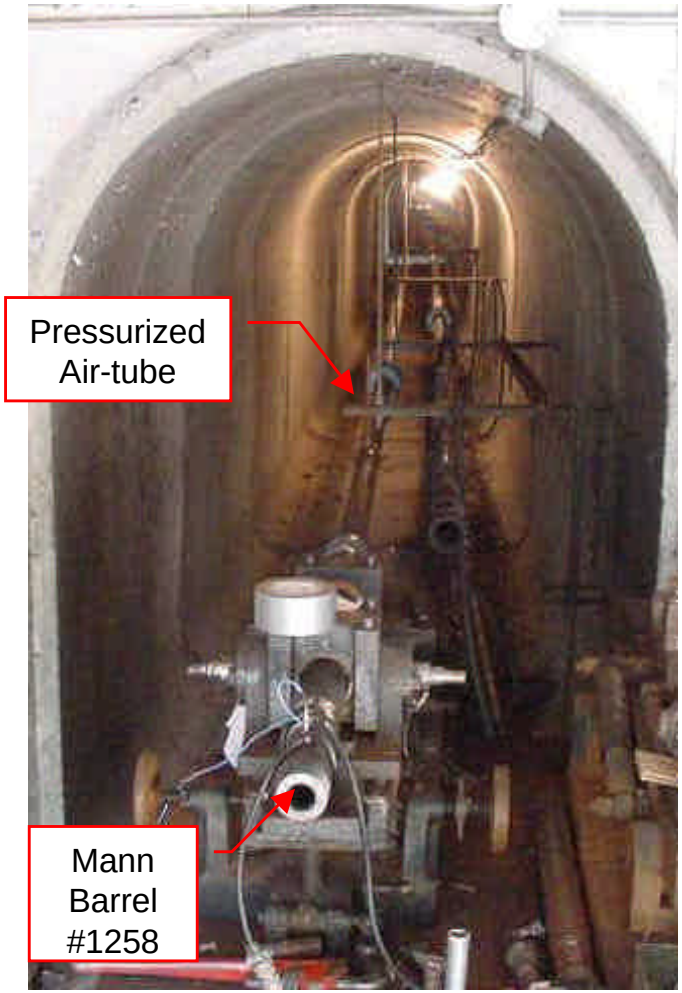
Strength of Design Testing

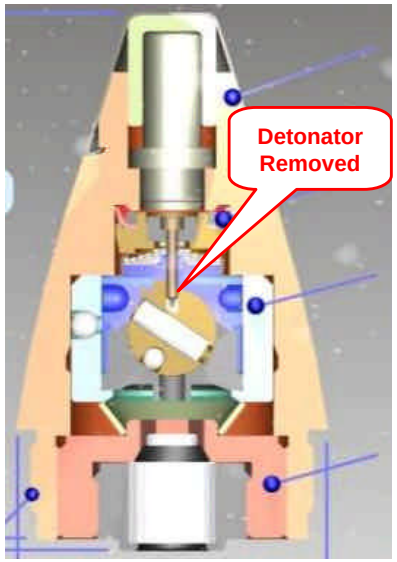
- Defined and conducted testing / analysis required for ECP to incorporate new Base Closing Plug into TDP for M759 Fuze

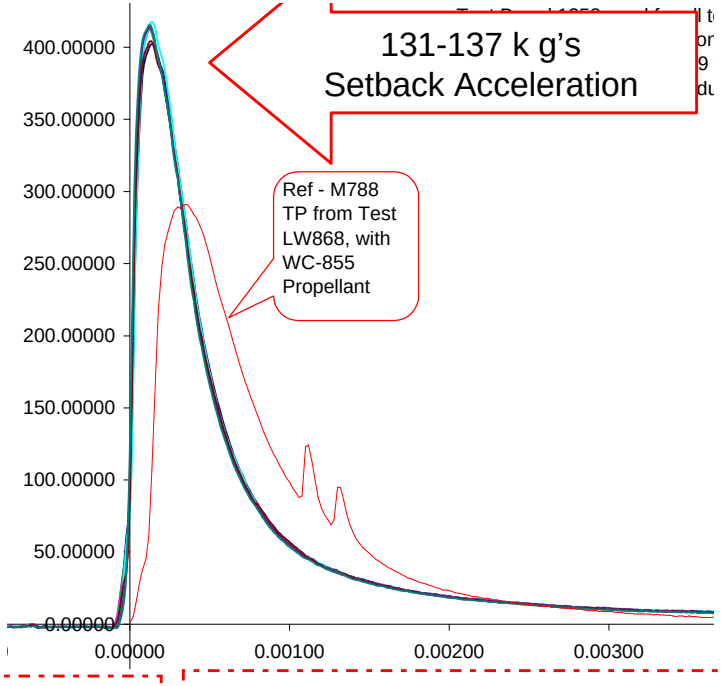
- Objective: Strength of design test to verify that new base closing plug design (Option 9A) is capable of supporting the spitback lead assembly when subjected to max setback acceleration loads.
  - » Soft-Catch Recovery Tests
  - » Push-Out Tests
  - » ANSYS Stress Analysis

M759 Fuze Soft Catch Recovery – Strength of Design

Spitback Lead Assembly Intact After Subjected to Extreme Setback Acceleration Loads







Pre-Test

Post-Test

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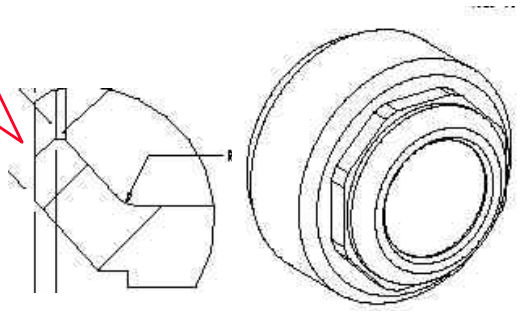
Option 9A Base Closing Plug Flange - Strength of Design

Base Closing Plug is structurally adequate to survive setback loads

Push-Out Tests

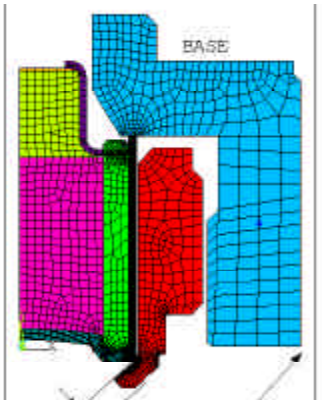
Flange machined to Least Material Condition

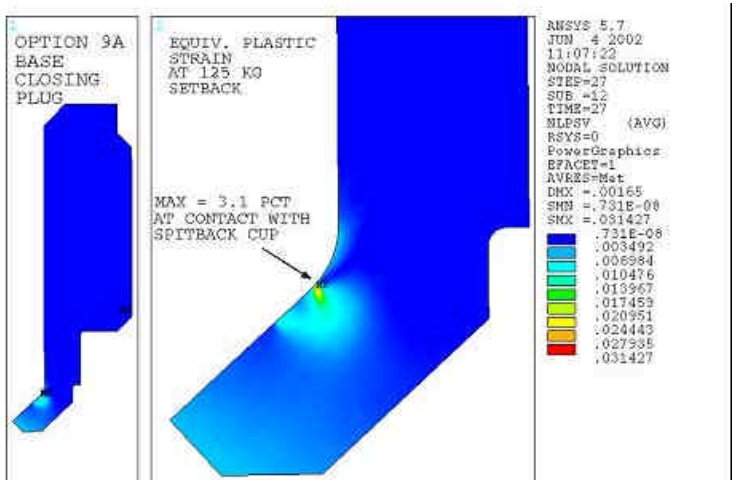


#5 & #6

Safety factor at 125,000 g's, = 1.37

ANSYS Stress Analysis





Equivalent Plastic Strain at 125 KG Setback

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Summary

- Production Shut-down due to penetration performance
- Investigation identified Base Closing Plug flange as a significant contributor to penetration degradation
- Base Closing Plug Re-designed
- Design qualified through test and analysis
- Implemented into production
- Penetration testing of new production to date shows performance well exceeds requirements