Development of IM Grenade Submunitions

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Outline

- Six Sigma
- 105mm M915 Projectile
- PAX-2A
- Six Sigma Black Belt Problem Statement/Impact/Goal
- Design of Experiments/Results
- Confirmation Testing
- Summary

Six Sigma

- **Started by Motorola in mid-80's**
  - **Methodology to add robustness to processes**
  - **Focused toward 3.4 defects per-million or less quality level**
  - **Has evolved to a program of improvement across all avenues, providing phenomenal Return On Investment**
- **A *Structured Approach* to achieve a Continuous Measurable Improvement**
  - **Eliminates the "quick fix of the day" or "don't change anything" mentality**
  - **Employs proven tools like Quality Function Deployment (QFD), Process Maps, DOE, Failure Modes & Effects Analysis (FMEA), etc. in a Management-friendly manner**
  - **Enables Management control rather than hindering it**
- **Process Improvement Strategies proven Critical to Commercial Success**

Six Sigma

- **Army Leadership Embraces Commercial Best Practices**
  - **Secretary of Army: Six Sigma**
  - **AMC CG: Lean**
  - **TACOM CG: DFSS/Six Sigma/Lean**
  - **AMC Quality Federation deploying across AMC**
- **Integrated Lean Six Sigma (L6s) training from VSE Corp provides a Recognized, Proven Business Solution that is**
  - **Agile workforce capable of efficiently and effectively addressing problems during changing technologies and shrinking budgets**
  - **Implement culture of "Fact Based Decisions"**
  - **Focused on Payback**

Integrated Lean Six Sigma (L6s)

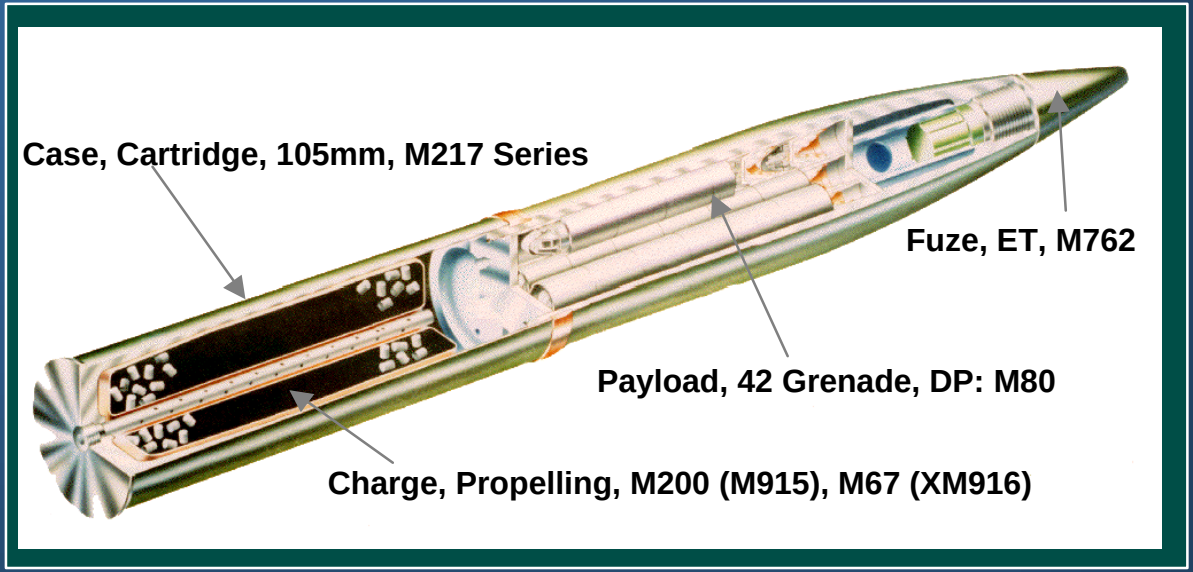
Design for Six Sigma

Lean Design ä

Lean Manufacture

Six Sigma

The 105mm M915 DPICM System



105MM Light Towed Howitzer System M119A1

Grenade, DP: M80

Fuze, Self Destruct: M234

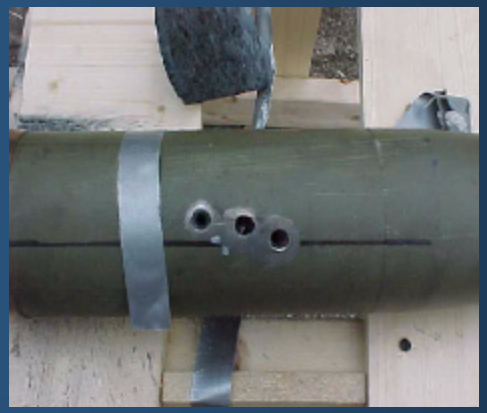
OBJECTIVE: To provide increased lethality for the Light Forces

PERFORMANCE:

- Max. Range
  - 14.2 km (M915 with M119 howitzer)
- Effectiveness/Lethality:
  - Personnel - 2x M444 APICM
  - Material - 63.5 mm into RHA

Picatinny Arsenal Explosive - 2A (PAX-2A)

- **PAX-2A**
  - 85% HMX (Class 5)
  - 9% BDNPA/F
  - 6% CAB
- **Comp A5**
  - 98.5% RDX (Type II)
  - 1.5% Stearic Acid
- **PAX-2A is the Leading IM Replacement for Comp A5 in Army Ordnance**
  - Dramatic improvement in Bullet Impact (BI) and Sympathetic Detonation (SD) shown in M915
- **Performance equivalent to better than Comp-A5**



PAX-2A BI Results

Comp A5 BI Results

PAX-2A SD Results

Comp A5 SD Results

6s Black Belt Project Problem Statements

- **Production-level manufactured PAX-2A explosive not acceptable for sustained high-speed loading**
  - **Safety Concerns**
    - **Excess spillage on the DZI rotary press**
    - **Smearing or flashing of pressed explosive on tooling**
  - **Loading process suspended after producing less than 300 grenades due to safety concerns.**
- **Thiokol PAX-2A manufacturing yield in USSS #20-80 mesh particle size produced lower than expected yield**
  - **Approximately 17% as compared to R&D mixes of 40-50%**

Impact

- Cannot load grenades at normal 50,000 unit schedule between maintenance cycles (2-10 hour shifts)
- Smearing/flashing of PAX-2A explosive precludes high volume grenade loading
  - Culminate in “lock up of press”
  - Nests have to be cleaned mechanically in off-line labor intensive operation
- M915 DPICM would not be able to Materiel Release with PAX-2A IM explosive
- Future of PAX-2A for high speed loading applications in jeopardy
  - Cost prohibitive to produce at 17% yield

Black Belt Project Goals

- Increase yield and lower cost of Thiokol PAX-2A manufacturing process
- Develop a robust loading process that will yield 50,000 or greater grenades between scheduled maintenance cycles

Sequential DOE Approach

- **DOE #1 – Establish baseline data and identify areas to increase yield**
- **DOE #2 – Evaluate particle size and flow additives for best value**
- **DOE #3 – Demonstrate robust process (50,000 units/cleaning cycle) for optimized manufacturing/loading**

DOE # 1

Objective:

- Baseline Explosive Samples through DZI Rotary Press
  - Comp A5
  - USSS #20-80 R&D PAX-2A from 50 gal mixer
  - USSS #6-30 & 12-30 Particle size distributions from ATK/Thiokol 600 Gal production mixer

Results:

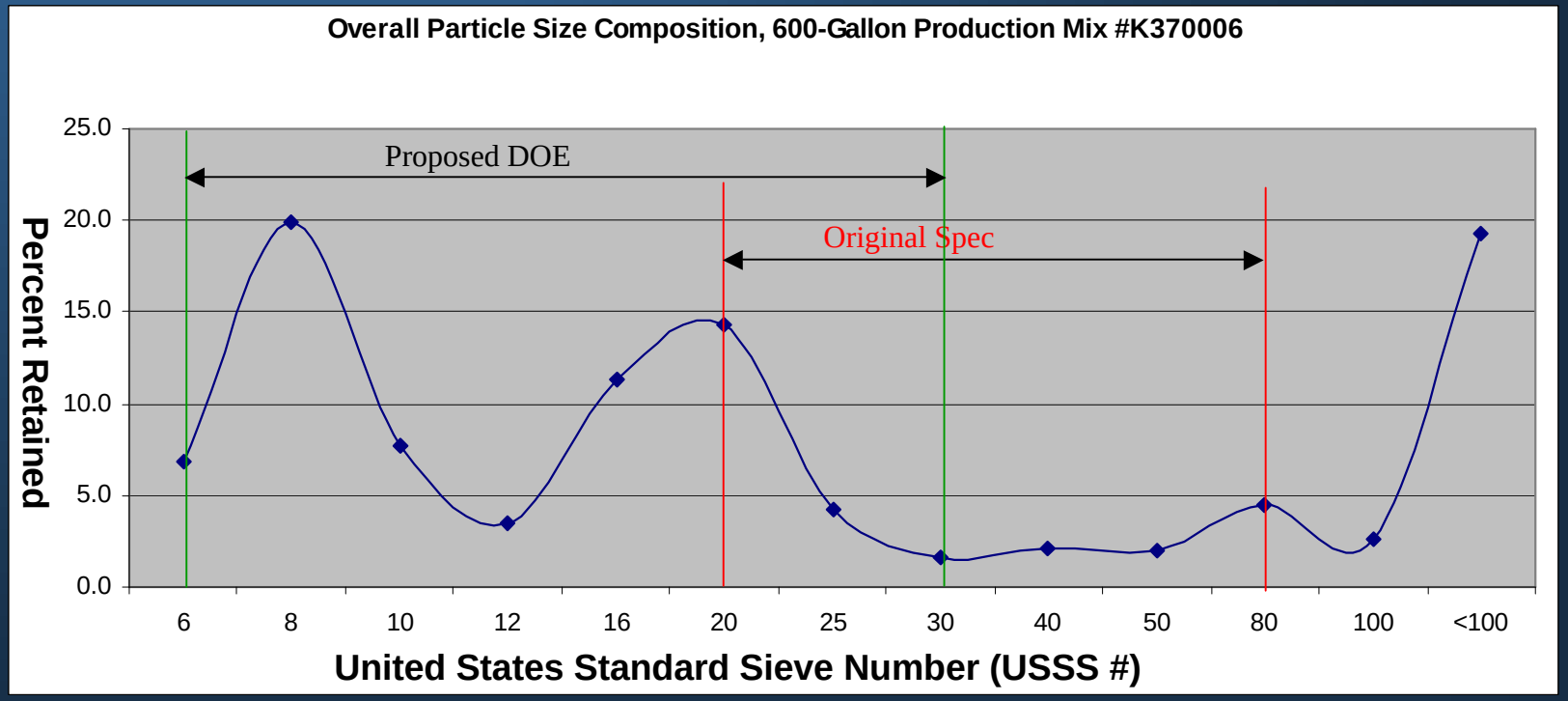
- Comp A5 runs with minimal explosive residue on press (i.e Steady State)
- USSS #6-30 & 12-30 PAX-2A has much higher yield potential and showed an improvement over USSS #20-80; however, spillage still occurring– Safety Issue
  - Excessive PAX-2A residue on punches and nests - labor intensive operation to clean
  - Particle Segregations Occurring

Recommended Solutions:

- Research of various additives to improve flow & reduce press contamination

Yield from ATK/Thiokol Production Mixer

Overall Particle Size Distribution



Yield potential increased from 17% to 62%

DOE #2

Objective: Evaluate Flow Additives & Mesh Size

- Ran 50 lbs of USSS #8-30 mesh and 25 lbs of USSS #6-30 mesh PAX-2A with 0.5% flow additive
- Conducted “mini-DOE” on loading parameters and effect on process SPC, TDP requirements and lethality performance

Results:

- USSS #6-30 mesh particle size is “best value”
- Additive successful in addressing smearing/flashing of explosive
- Established Loading parameters for PAX-2A in M-80 Grenade
- Repeatable Grenade LAP process
- Meet or exceed TDP requirements
  - Achieve greater than 3.0 inches penetration into Armor Plate

Recommended Solutions:

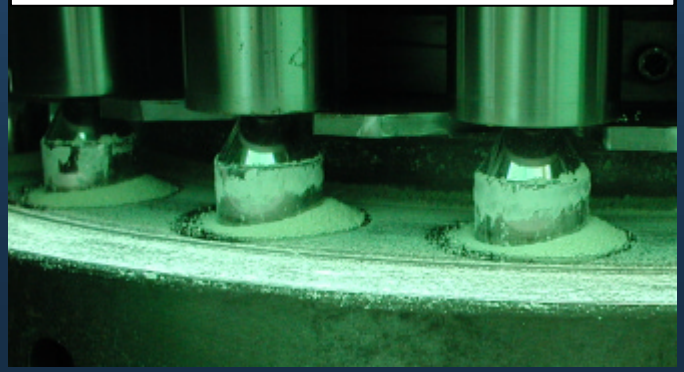
- Fabricate Hopper screen to 0.25 x 0.4 inch for larger 6 mesh particles (original 0.25 x 0.25 inch retained large particles)
- Verify if Additive will permit loading of fines without spillage

DOE #2 Results

PAX-2A- No Additive

Additive Successfully Reduces Flashing

Smearing on Tooling



Minimal Smearing on Punches

DOE #3

Objective:

- Larger Confirmatory Run USSS #6-30 & #8-30 with Additive
- Evaluate Hopper Larger Screen Size
- Evaluate fines with Additive

Results:

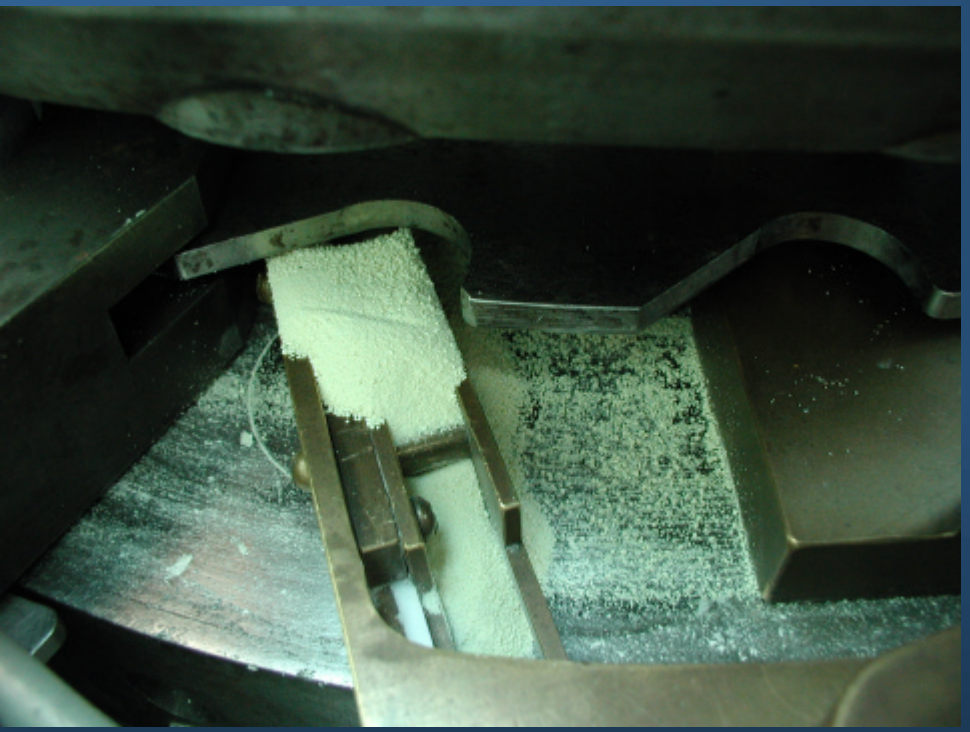
- Larger 6 mesh particles flow easily through new hopper screen
- Identified areas for further improvements in yield

Recommendations:

- Make confirmatory production run of USSS #6-30 mesh PAX-2A with Additive
- Pursue hopper & feed shoe redesign to reduce segregation and allow LAP of larger particle range to maximize available yield from ATK/Thiokol manufacturing process

DOE #3

Before Six-Sigma



USSS #20-80, No Additive

3 Minute Run Time

After DOE #3

USSS #6-30 with Additive

1200 Minute Run Time

400:1 Improvement

Milestone Achievements

- **25 Jan 02 Six Sigma Team Conducted 1st Confirmation Production Run of 3,000 lbs. USSS# 6-30 PAX-2A with additive**
  - Successfully loaded 69,125 M80 grenades at rate with no safety concerns
  - Performed 60 Day Predictive Surveillance Test to confirm no anomalies
- **10 June 02 - Conducted 2nd Confirmation Run**
  - Successfully loaded 65,280 M80 grenades for delivery to M915 program
    - Permits M915 program to field PAX-2A in M80
    - Way forward on other PAX-2A insertion programs for grenade submunitions
- **14 October 02 - Completed 3rd Production Run 69,120 Grenades**

$C_{pk} = 3.2$

M80 Penetration Test Results (Inches)

Minimum Requirement	1st Production Maximum	1st Production Minimum	Mean	Standard Deviation	Mean-3s
2.50	3.30	3.0	3.17	0.07	2.96

M915 Predictive Surveillance Test

- **Issue**
  - Confirm no degradation of grenade penetration performance due to:
    - Contraction/Expansion induced from thermal effects
    - Chemical Exudation leading to incompatibility with explosive train
- **Plan of Action**
  - Conduct JAN Cycle Environmental Conditioning of M80 Grenades loaded with PAX-2A and Composition A5 (-60ºF to 160ºF)
    - End Item M915 Projectiles
    - Bare M80 Grenades
- **Testing**
  - Withdraw sample grenades from test chamber (bare & downloaded from projectiles) @ 15 day intervals and penetration test into Armor Plate
- **Results**
  - All grenades fired (312) exceeded 2.5 inch penetration requirement (>3.0 inches)
  - No degradation in performance
  - No exudation or incompatibilities observed

Accelerated Aging/Cold Temp Test

Accelerated Aging:

- Objective: Investigate aging properties of PAX-2A treated with 0.5% flow additive.
- 60°C (140°F) at 30% Relative Humidity for 8 months.
- Aging Study initiated June 21, 2002
  - Thermal analyses, Safety Tests (ABL impact & friction, ESD, SBAT, etc), Cube Cracking, Mechanical Properties, Composition Analysis, Shock Sensitivity (LSGT), Critical Temperature

Cold Temp Test:

- Objective: Confirm no degradation of grenade penetration performance at system cold temperature requirement of -50°F
- All PAX-2A loaded grenades fired 3.0 inches or greater penetration into Armor Plate at -50°F
- No significant degradation from ambient

Six Sigma Tools used to Accomplish Program Goals

- Completed “Walk The Line Effort”
  - ATK/Thiokol- Explosive manufacturing, packing and shipping
  - DZI/Lone Star - Powder delivery system and M80 Grenade loading
- Generated Process Maps identifying potential improvement points & Re-Walked The Line
- Back to Basics - Brainstorming approach to address original customer requirements
  - Lethality Performance
  - Insensitive Munitions (IM)
  - Low Cost
- Developed Failure Mode Effects Analysis (FMEA) for processes
- Sequential Design of Experiments (DOE’s)
- Confirmation Runs and Testing

Summary

- **Met Objective**
  - Successfully demonstrated loading M80 Grenades with PAX-2A at an acceptable rate of greater than 50,000 grenades between maintenance intervals
  - 400:1 Improvement in continuous run time
- **Further Reduce the cost to the Customer / Warfighter to implement IM technology by applying Lean principles**
  - Reduce drying cycle times
  - Optimize mixer yields
  - Complete hopper/feed shoe mods for wider range of particles
  - Implement upstream segregation improvements
  - Eliminate non-value added processes
- **Lean Six Sigma techniques and integrated team approach provide the Best Buy for Government**
  - Balance between manufacturing PAX-2A and grenade loading
  - Continually reduce cost while improving end item quality

Contributors

- **Norm Frigon - VSE Corp.**
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- **Dave Humes – Alliant Techsystems (ATK)**
  - Lean Six Sigma Implementation
- **David Taylor - ATK-Thiokol**
  - PAX-2A Manufacture Program Management
- **Jeffrey Widener - ATK-Thiokol**
  - PAX Explosives Development
- **Dillard Baker – Day & Zimmerman Inc (DZI)-Lone Star AAP**
  - Grenade Manufacture Load Line Engineering
- **Robert Ho – TACOM-ARDEC AMMOLOG**
  - Independent Test Funding