Caseless Ammunition & Advances in the Characterization of High Ignition Temperature Propellant

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• Objective
  – To re-establish, develop, and demonstrate a capability to manufacture Caseless Ammunition prototypes and characterize the High Ignition Temperature Propellant
  – In support of the Lightweight Machine Gun and Ammunition Science & Technology Objective, deliver Caseless Ammunition for a ballistic demonstration
  – Transfer technology to industry
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• Why Caseless Ammunition?
  – Lightweight
  – Force Multiplier
  – Decreased Logistics Burden
  – High Ignition Temperature Propellant (HITP) Provides Improved Propellant Characteristics & Energetic Behavior
  – The State of the Art
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Overall Program Requirements

Threshold requirements (“must haves”)
- 35% Decrease in ammunition weight
- Same lethality as the 5.56mm M855 cartridge
- Environmentally friendly ammunition and process
- Low life-cycle costs

Extra requirements (“nice to haves”)
- 40% decrease in ammunition weight
- Increased lethality over the 5.56mm M855 cartridge
- Same cost/round as current 5.56mm M855 ammunition
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Why Use an HITP?

• Brass is a heat sink that is discharged with each round fired and provides structural strength

• Caseless ammo will not have a heat sink through mass discharge
  – HITP will need to provide significantly more insulation and thermal stability than typical ball powders
  – HITP will also need high degree of structural stability and maintain tolerances over operational temperature ranges

• Integration of this technology requires a system approach to be successful
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• Background
  – Previous work performed under the Advanced Combat Rifle (ACR) Program
  – Technology Development funded by US (ARDEC) and Germany to Heckler & Koch(H&K)/Dynamit Nobel(DNAG)
  – Successful Demonstration of a Caseless Ammunition Rifle System
  – Technology Licensed & Transferred to the US at ARDEC
G11 Open Source Data

<table>
<thead>
<tr>
<th>Caseless ammunition</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>33 mm/1.29 in.</td>
</tr>
<tr>
<td>Cross-section</td>
<td>8 x 8 mm/0.32 in.</td>
</tr>
<tr>
<td>Total weight</td>
<td>5.20 g/0.18 oz.</td>
</tr>
<tr>
<td>Projectile weight</td>
<td>3.25 g/0.12 oz.</td>
</tr>
<tr>
<td>Ignition</td>
<td>Mean gas pressure</td>
</tr>
<tr>
<td></td>
<td>Muzzle velocity $V_0$</td>
</tr>
<tr>
<td>Ignition mechanism</td>
<td>mechanical</td>
</tr>
<tr>
<td>Ignition pressure</td>
<td>3850 bar</td>
</tr>
<tr>
<td>Ignition velocity</td>
<td>approx. 930 m/sec.</td>
</tr>
<tr>
<td>Ignition velocity</td>
<td>3051 ft./sec.</td>
</tr>
</tbody>
</table>

Components of a 4.73 x 33mm Caseless Round: Plastic Cap, Projectile, Propellant Body, Booster, Primer.
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5.56mm Caseless Prototypes

Original Caseless Ammunition

5.56 mm LMGA Concept
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• Technical Approach
  – Determine Feasibility
    • Identify and address technical challenges/potential risk areas
      – Near term & long term
    • Material needs and source suppliers - availability
    • Assess equipment condition
    • Costs
      – Determined viability → Organizational Commitment
  – Re-establish capability and prototyping process utilizing existing technology
    • Validation of In-house Caseless Ammunition capability in a 5.56mm cartridge configuration in support of the Lightweight Machine Gun and Ammunition STO
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• Characterization of HITP
  – Original Caseless HITP and ARDEC HITP
    • Chemical analysis of original caseless HITP (NMR, HPLC & GPC)
    • Propellant density
    • Thermal stability
    • Heat of Explosion
    • Hazards analysis – friction, impact and ESD

• Demonstrate Producibility
  – Several hundred rounds have been produced from lab-scale propellant mixes

• Deliver Ammunition for testing
  – Conducted three ballistic firings in Mann Barrel @ ATF

• Transfer Technology to Industry
  – CRADA established with AAI
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Caseless Firings

• Test Firing I
  – Five Shots
  – Chamber Pressure (8190-11314 psi)
  – Muzzle Velocity (589-1204 fps)

• Test Firing II (Addition of Booster Charge)
  – 12 Shots
  – Chamber Pressure (14372-62225 psi)
  – Muzzle Velocity (1489-2795 fps)

• Test Firing III
  – 14 Shots
  – Chamber Pressure (15992-24579 psi)
  – Muzzle Velocity (1000-1686 fps)
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• Status of Progress
  – Next Steps
    • Continuing Characterization
    • Continue to manufacture qty of prototypes
      – Implementation of any processing improvements/fixes
    • Continue ballistic testing
    • Deliver prototypes for ballistic demonstration
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- Technical Challenges being addressed as technology is transitioned:
  - Long term availability and identification of source suppliers
  - Material replacements
  - Environmentally friendly alternatives/manufacturing processes for constituents
  - Manufacturing process
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• Summary
  – Three Ballistic Test Firings
  – Validation of the in-house capability proceeding
  – Efforts focused to bring Caseless Ammunition Capability/Technology to a sufficient maturation level for transfer to industry
  – Potential applications in other caliber ammunition as the propulsion charge
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Status of JHU/APL Modeling

• IBHVG2 Model developed
  – HITP burn data
  – Single perf grain
  – ACR/G11 IB sequence recreated

• Reasonable results given limited data
  – Pressure & velocity close
  – Sensitivity analysis generally consistent

• Model will be updated as better data becomes available
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ATK – Phase II Contractor for CL Propellant

- H&K’s propellant used as a foundation
- ATK Thiokol’s energetic thermoplastic elastomer (ETPE) gun propellant experience will provide processing and modeling experience
- Propellant options
  - HITP recreation of DNAG propellant
  - HITP development of new binder and combination of energetic ingredients
  - ETPE with insulating layer
  - LOVA with insulating layer
  - Consolidated ball powder with insulating layer
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Concept Model

• Critical Assumptions:
  – Surface area of consolidated ball powder
  – Burning rate of HITP insulating layer

• The system was modeled as shown here:

![Diagram of Concept Model]

Preliminary IB Modeling

\[ P_{\text{max}} = 55000 \text{ psi} \]

![Graph showing relationship between Muzzle Velocity, Core Prop Grain Dia, and Frac of Outer Layer burned at time of Inner Core Ignition]
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Future Work

• Determine optimum propellant formulation
• Develop process for low-rate production of caseless rounds
• Deliver ammunition for testing and evaluation
• Scale-up process for pilot-scale ammunition production