ELIMINATING PROPELLANT BAG DETERIORATION

38TH ANNUAL GUN, AMMUNITION, AND MISSILES SYMPOSIUM & EXHIBITION
24-27 MARCH 2003

Presented by

Adriana Eng
U.S. Army Armament Research, Development and Engineering Center
Picatinnny Arsenal, New Jersey  07806-5000
OBJECTIVES

- Eliminate rapid deterioration of propellant bag
- Improve safety and reliability
- Extend service life
- Reduce life cycle cost
ITEM DESCRIPTION

105mm M1 Cartridge with M67 Propelling Charge
BACKGROUND

➢ Over three million 105mm rounds in unserviceable conditions due to propellant bag deterioration

➢ Rayon propellant bag deterioration
  • Observed in as little as 3 to 4 years
  • Bags no longer hold propellant safely
  • Require expensive rework ($114/round)
Early studies determined

- Cloth deterioration caused by propellant outgas and moisture
  - Nitrogen dioxide + H₂O → Nitric Acid
- Acrylic cloth is significantly more resistant to nitric acid than rayon cloth
TECHNICAL APPROACH

- Assure chemical compatibility between acrylic and M1 propellant
- Maintain proper test controls
  - Manufacture two sets of M67 charges:
    - “Test charges” with acrylic propellant bags
    - “Control charges” with rayon propellant bags
- Establish Evaluation Criteria, comparison of cloths based on:
  - Ballistic performance
  - Residue evaluation
  - Simulated rough handling and transportation
  - Shelf Life
RESULTS
COMPATIBILITY TEST

Requirement:
(MIXTURE GAS) – (ACRYLIC GAS + M1 PROPELLANT GAS) < 3 ml

Result:
6.38 ml – (5.55 ml + 0.35 ml) = 0.48 ml
PASS
RESULTS (CON’T)
BALLISTIC PERFORMANCE AT +70°F

Zones 3 and 7 Pressure Range at 70 deg F

Zone 3 Velocity Standard Deviation at +70 deg F

Zone 7 Velocity Standard Deviation at +70 deg F

04/15/2003
RESULTS (CON’T)

BALLISTIC PERFORMANCE AT -50°F & +145°F

Zone 7 Average Pressure + 4 Sigma at +145 deg F (Propellant Uniformity Series)

Zone 7 Average Pressure + 4 Sigma at -50 deg F (Sequential Environmental)

SPEC (PIMP)  ACRYLIC  RAYON

Zone 7 Average Pressure + 4 Sigma at +145 deg F

Zone 7 Average Pressure + 4 Sigma at -50 deg F

SPEC (PIMP)  ACRYLIC  RAYON

04/15/2003
RESULTS (CON’T)

CLOTH RESIDUE EVALUATION

- ACRYLIC - NO RECOVERABLE RESIDUE
- RAYON RESIDUE:
RESULTS (CON’T)
SEQUENTIAL ENVIRONMENTAL TESTS

% DAMAGED M67 CHARGES AFTER LOGISTIC VIBRATIONS

- 50 deg F
+ 145 deg F

NUMBER OF BAG DAMAGES AFTER LOOSE CARGO VIBRATION

- 50 deg F
+ 145 deg F
RESULTS (CON’T)

PROPELLANT BAG SHELF LIFE STUDY

EXPERIMENTAL METHOD

- **DURATION:** UP TO 48 WEEKS
- **CONDITIONING:** 65°C, 75°C, 85°C, 95°C AT 75% RH
- **SAMPLING:** WEEKLY (RAYON) & MONTHLY (ACRYLIC)

0 week

Rayon bag
12 weeks

Rayon bag
16 weeks

04/15/2003
RESULTS (CON’T)

% REMAINING TENSILE STRENGTH AFTER 12 WEEKS

65 deg C

Left bars = Rayon cloth
Right bars = Acrylic cloth

75 deg C

85 deg C
RESULTS (CON’T)

PREDICTED TENSILE STRENGTH LOSS

ARRHENIUS DEGRADATION MODEL:\(^2\):
\[ \log(S) = a + t \beta \exp(-\frac{?}{T}) \]

Figure 1. Predicted Fraction Loss in Tensile Strength at 25 deg C & 75% RH

Figure 2. Predicted Fraction Loss in Tensile Strength at 35.38 deg C & 75% RH

PREDICTED SHELF LIFE BASED ON 10% LOSS IN TENSILE STRENGTH\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>ACRYLIC CLOTH</th>
<th>RAYON CLOTH</th>
<th>ACRYLIC BETTER THAN RAYON BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>25°C &amp; 75% RH</td>
<td>143 years</td>
<td>16 years</td>
<td>9 TIMES</td>
</tr>
<tr>
<td>35.38°C &amp; 75% RH</td>
<td>37 years</td>
<td>3.4 years</td>
<td>11 TIMES</td>
</tr>
</tbody>
</table>

Note: Based on data collected over 32 weeks.
SUMMARY

- Acrylic propellant bags have been successfully qualified as a replacement for rayon bags based on
  - High resistance to bag deterioration
  - Met shelf life requirements
  - Comparable ballistic performances
  - Less cloth residue
  - More durable for rough-handling and transportation

- Eliminate rework of propellant bags