THE EFFECTS OF PROPELLANT POSITION ON SMALL CALIBER BALLISTIC PERFORMANCE

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INTRODUCTION

• **Ullage**: The amount by which a container falls short of being full.
  (http://www.dictionary.com)

• Historical studies have generally shown that when more ullage is present in the cartridge, the position of the propellant during firing has a greater effect on characteristics such as velocity and pressure.

• **Purposes of Testing**
  
  – To characterize the ullage of small caliber ball and tracer cartridges through the use of x-ray analysis
  
  – To analyze the effects of propellant position on the ballistics characteristics of small caliber ball and tracer cartridges

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TEST SAMPLES

5.56mm
M855 Ball (left)
M856 Trace (right)

7.62mm
M80 Ball (left)
M62 Trace (right)

Caliber .50
M33 Ball (left)
M17 Trace (right)
• X-ray analysis was used to estimate the ullage for a subset of each of six cartridge types

• Ballistics analysis consisted of Electronic Pressure, Velocity, Action Time Testing (EPVAT) testing resulting in the following data:
  • Velocity at 78 feet
  • Chamber Pressure
  • Action time
  • Pressure-Time Curves
• To orient the propellant prior to x-ray and ballistics analysis, each round was rotated slowly 360 degrees in a vertical plane, pausing at 180 degrees.

• After one full rotation, the round was tapped lightly on a flat surface to further settle the propellant.

• Care was taken during handling to minimize propellant shift during horizontal loading of the weapon.
• 10 unfired rounds from each cartridge type were x-rayed in 2 orientations: nose up & nose down
  – Propellant and ullage heights were approximated from each image

• One additional unfired round from each cartridge type was also x-rayed in the horizontal position
X-RAY IMAGES – 5.56MM

M855 Ball

M856 Trace

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X-RAY IMAGES – CALIBER .50

M33 Ball

M17 Trace
## Test Method – Ballistics Firing Matrix

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Caliber</th>
<th>Cartridge Type</th>
<th>Total Sample Size Fired</th>
<th>Nose Up Sample Size</th>
<th>Nose Down Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.56mm</td>
<td>M855 Ball</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>5.56mm</td>
<td>M856 Trace</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>7.62mm</td>
<td>M80 Ball</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>7.62mm</td>
<td>M62 Trace</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>Cal .50</td>
<td>M33 Ball</td>
<td>90</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>6</td>
<td>Cal .50</td>
<td>M17 Trace</td>
<td>90</td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>

**Note:** Of the 10 x-rayed rounds from each cartridge type, 5 were fired with the propellant oriented near the primer and the other 5 were fired with the propellant oriented near the projectile.
5.56MM BALLISTICS

<table>
<thead>
<tr>
<th>Cartridge Type</th>
<th>Orientation</th>
<th>Avg. Chamber Pressure (psi)</th>
<th>Avg. Velocity (ft/s)</th>
<th>Avg. Action Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M855</td>
<td>Nose Up</td>
<td>48772.71</td>
<td>2939.33</td>
<td>0.785</td>
</tr>
<tr>
<td></td>
<td>Nose Down</td>
<td>49330.81</td>
<td>2941.36</td>
<td>0.765</td>
</tr>
<tr>
<td>M856</td>
<td>Nose Up</td>
<td>50996.24</td>
<td>2973.94</td>
<td>0.770</td>
</tr>
<tr>
<td></td>
<td>Nose Down</td>
<td>51158.69</td>
<td>2978.69</td>
<td>0.770</td>
</tr>
</tbody>
</table>

**M855 Ball Findings:**
- Chamber Pressure: 558.11 psi (nose down)
- Velocity: 2.03 ft/s (nose down)
- Rise Time: Unaffected by propellant orientation – varies by <1%

**M856 Tracer Findings:**
- Chamber Pressure: 162.45 psi (nose down)
- Velocity: 4.75 ft/s (nose down)
- Rise Time: Unaffected by propellant orientation – varies by <1%
## 7.62mm Ballistics

<table>
<thead>
<tr>
<th>Cartridge Type</th>
<th>Orientation</th>
<th>Avg. Chamber Pressure (psi)</th>
<th>Avg. Velocity (ft/s)</th>
<th>Avg. Action Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M80</td>
<td>Nose Up</td>
<td>50363.04</td>
<td>2733.98</td>
<td>1.293</td>
</tr>
<tr>
<td></td>
<td>Nose Down</td>
<td>51652.10</td>
<td>2772.21</td>
<td>1.240</td>
</tr>
<tr>
<td>M62</td>
<td>Nose Up</td>
<td>52981.93</td>
<td>2691.12</td>
<td>1.088</td>
</tr>
<tr>
<td></td>
<td>Nose Down</td>
<td>52158.94</td>
<td>2685.54</td>
<td>1.058</td>
</tr>
</tbody>
</table>

### M80 Ball Findings:
- Δ Chamber Pressure: 1289.06 psi (nose down)
- Δ Velocity: 38.23 ft/s (nose down)
- Rise Time: Unaffected by propellant orientation – varies by <1%

### M62 Tracer Findings:
- Δ Chamber Pressure: 823.00 psi (nose up)
- Δ Velocity: 5.59 ft/s (nose up)
- Rise Time: Unaffected by propellant orientation – varies by <1%
## Caliber .50 Ballistics

<table>
<thead>
<tr>
<th>Cartridge Type</th>
<th>Orientation</th>
<th>Avg. Chamber Pressure (psi)</th>
<th>Avg. Velocity (ft/s)</th>
<th>Avg. Action Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M33</td>
<td>Nose Up</td>
<td>59,675.56</td>
<td>2911.84</td>
<td>1.830</td>
</tr>
<tr>
<td></td>
<td>Nose Down</td>
<td>48,033.31</td>
<td>2790.66</td>
<td>1.915</td>
</tr>
<tr>
<td>M17</td>
<td>Nose Up</td>
<td>49,080.13</td>
<td>2873.89</td>
<td>2.017</td>
</tr>
<tr>
<td></td>
<td>Nose Down</td>
<td>50,908.47</td>
<td>2896.24</td>
<td>1.975</td>
</tr>
</tbody>
</table>

**M33 Ball Findings:**
- Δ Chamber Pressure: 11,642.25 psi (nose up)
- Δ Velocity: 121.18 ft/s (nose up)
- Rise Time: Unaffected by propellant orientation – varies by <1%

**M17 Tracer Findings:**
- Δ Chamber Pressure: 1828.34 psi (nose down)
- Δ Velocity: 22.35 ft/s (nose down)
- Rise Time: Unaffected by propellant orientation – varies by <1%
### SUMMARY OF RESULTS

<table>
<thead>
<tr>
<th>Cartridge Type</th>
<th>Approx. % Ullage</th>
<th>∆ Avg. Chamber Pressure (psi)</th>
<th>∆ Avg. Velocity (ft/s)</th>
<th>∆ Avg. Action Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M855</td>
<td>3.90%</td>
<td>-558.11</td>
<td>-2.03</td>
<td>0.0194</td>
</tr>
<tr>
<td>M856</td>
<td>1.04%</td>
<td>-162.45</td>
<td>-4.75</td>
<td>-0.001</td>
</tr>
<tr>
<td>M80</td>
<td>9.53%</td>
<td>-1289.06</td>
<td>-38.23</td>
<td>0.053</td>
</tr>
<tr>
<td>M62</td>
<td>4.19%</td>
<td>823.00</td>
<td>5.59</td>
<td>0.030</td>
</tr>
<tr>
<td>M33</td>
<td>12.05%</td>
<td>11,642.25</td>
<td>121.18</td>
<td>-0.084</td>
</tr>
<tr>
<td>M17</td>
<td>15.17%</td>
<td>-1828.34</td>
<td>-22.35</td>
<td>0.042</td>
</tr>
</tbody>
</table>

**Note:** Negative values indicate that the particular characteristic in nose down orientation is greater than in nose up orientation.
• **M855**: The propellant orientation does not have a significant effect on the ballistic results due to very little ullage within the cartridge

• **M856**: The propellant orientation does not have a significant effect on the ballistic results due to very little ullage within the cartridge
7.62mm Conclusions

- **M80**: The effects of ullage in nose-down orientation appear to be overcome by a flashover effect resulting from the exposure of more propellant surface area along the diagonal to the flash hole.

- **M62**: The propellant orientation does not have a significant effect on the ballistic results due to very little ullage within the cartridge.
• **M33**: The relatively large percentage of ullage manifests itself as drastic variations in chamber pressure and velocity due to dissipation of energy in the space between the primer and propellant in nose-down orientation.

• **M17**: In nose-down orientation, effects of the relatively large percentage of ullage appears to be overcome by back pressure originating from the igniter mix which initiates the tracer.
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