Comparison Of Aerodynamic Characteristics
Of 20MM, HEI, T282E1 Shell With Fuze M505 And 20MM, HEI, T282E1 Shell
With Fuze T321

EUGENE D. BOYER

DEPARTMENT OF THE ARMY PROJECT No. 5B03-07-002
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT No. TB3-0426 (AIR)
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND
Destroy when no longer needed. DO NOT RETURN
COMPARISON OF AERODYNAMIC CHARACTERISTICS OF 20MM, HEI, T282E1 SHELL WITH FUZE M505 AND 20MM, HEI, T282E1 SHELL WITH FUZE T321

Eugene D. Boyer

Department of the Army Project No. 5B03-07-002
Ordnance Research and Development Project No. TB3-0426 Air

ABERDEEN PROVING GROUND, MARYLAND
COMPARISON OF AERODYNAMIC CHARACTERISTICS OF 20MM, HEI, T282El SHELL WITH FUZE M505 AND 20MM, HEI, T282El SHELL WITH FUZE T321

ABSTRACT

Comparison of the aerodynamic characteristics of the 20mm HEI, T282El shell with a standard M505 fuze and with a T321 fuze showed no significant difference at velocities where the presence of the arming ball rotor in the M505 fuze does not influence the dynamics. Above $M = 1.6$, the T282El shell with the T321 fuze behaves the same as with the M505 fuze with the rotor removed.
### TABLE OF SYMBOLS AND COEFFICIENTS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Axial moment of inertia (gram - in^2)</td>
</tr>
<tr>
<td>B</td>
<td>Transverse moment of inertia (gram - in^2)</td>
</tr>
<tr>
<td>d</td>
<td>Diameter in inches</td>
</tr>
<tr>
<td>K_D</td>
<td>Drag coefficient</td>
</tr>
<tr>
<td>K_H</td>
<td>Damping moment coefficient</td>
</tr>
<tr>
<td>K_N</td>
<td>Normal force coefficient</td>
</tr>
<tr>
<td>K_T</td>
<td>Magnus moment coefficient</td>
</tr>
<tr>
<td>K_M</td>
<td>Overturning moment coefficient</td>
</tr>
<tr>
<td>CP_N</td>
<td>Normal force center of pressure</td>
</tr>
<tr>
<td>M</td>
<td>Mach number</td>
</tr>
<tr>
<td>N</td>
<td>Number of yaw stations</td>
</tr>
<tr>
<td>N_T</td>
<td>Number of timing stations</td>
</tr>
<tr>
<td>m</td>
<td>Weight in grams</td>
</tr>
<tr>
<td>c.m.</td>
<td>Center of mass in calibers from base</td>
</tr>
<tr>
<td>L</td>
<td>Overall length in calibers</td>
</tr>
<tr>
<td>( \lambda_{1,2} )</td>
<td>Yaw damping rates</td>
</tr>
<tr>
<td>( \bar{s}^2 )</td>
<td>Mean squared yaw (Degrees^2)</td>
</tr>
<tr>
<td>K_D 0^2</td>
<td>Yaw drag coefficient</td>
</tr>
<tr>
<td>K_D0</td>
<td>Zero yaw drag coefficient</td>
</tr>
<tr>
<td>K_{1,2}</td>
<td>Magnitude of epicyclic yaw arms</td>
</tr>
<tr>
<td>S_L</td>
<td>Swerve associated with the lift force</td>
</tr>
<tr>
<td>s</td>
<td>Gyroscopic stability factor</td>
</tr>
<tr>
<td>( \bar{s} )</td>
<td>Dynamic stability factor</td>
</tr>
<tr>
<td>( \epsilon_Y )</td>
<td>Error in yaw fit</td>
</tr>
<tr>
<td>( \epsilon_S )</td>
<td>Error in swerve fit</td>
</tr>
</tbody>
</table>
INTRODUCTION

Preparation of firing tables for a bullet fired from high speed aircraft and involving conditions of large yaws is a complicated matter. Therefore, it is very desirable, if possible, to spot check firing table entries by actual observations. This is difficult but could be done by accurately instrumented aircraft recording the initial conditions of the bullet's trajectory and exploding the bullet at a predetermined time so that both the aircraft and the explosion could be photographed from the ground. For the 20mm HEI, T282E1, shell this procedure required the development of a special time fuze. This has been done by the Bulova Watch Company and the fuze is designated as T321.

Our job was to compare the aerodynamic characteristics of the T282 shell with the T321 fuze relative to those of the same shell equipped with the standard M505 fuze. This note contains the results of such a comparison.

Ten rounds of shell with the T321 fuze were fired in the Aerodynamics Range at Mach numbers from 0.78 to 3.2. The characteristics of the T282E1 shell with M505 fuze are contained in Reference 1.

TREATMENT OF DATA

The aerodynamic coefficients are extracted from attitude, position, and time measurements of the shell by employing standard linearized reduction techniques. Table I gives the physical measurements for the shell with both fuzes. Table II lists the aerodynamic data for each round with the T321 fuze. The aerodynamic data for the shell with the M505 fuze can be found in Tables II and III of Reference 1.

Figures 1 through 8 compare the aerodynamic coefficients of the shell with the T321 fuze, with the M505 fuze, and with the modified M505 fuze. The solid line represents the M505 fuze; the broken line, the modified M505 fuze. Since the modified fuze differed from the M505 fuze only in $K_H$ and $\lambda_1$, only Figures 6 and 7 have a broken line. The data for the T321 fuze are plotted as circled points.

* The arming ball rotor was removed from the fuze.
RESULTS

As was expected, the aerodynamic coefficients, other than $K_H$, of the shell do not change significantly by substituting the T321 fuze for the M505 fuze. Consequently, the sole purpose of Figures 1 through 5 (which plot $K_{D0}$, $K_M$, $K_N$, $C_{F_N}$, and $K_T$, respectively, vs. Mach number) is to depict the aerodynamic similarity of both fuzes. For Figure 1, $K_D$ was reduced to $K_{D0}$ by the equation: $K_D = K_{D0} + K_{D0} \frac{M^2}{2}$. For the comparison of $K_M$ values in Figure 2, it was necessary to compute the moment with the T321 fuze about the c.m. position of the M505 fuzed shell.

Figure 6 shows the difference in observed $K_H$ values between the two fuze types for varying Mach number. Above $M = 1.6$, $K_H$ for the shell with the T321 fuze coincides with $K_H$ with the modified M505 fuze, the unmodified M505 fuzed shell having smaller $K_H$ values.

Figures 7 and 8 show $\lambda_1$ and $\lambda_2$, the yaw damping rates plotted vs. Mach number. The observed differences in $K_H$ are naturally reflected in $\lambda_1$; these differences in $K_H$ do not materially affect $\lambda_2$.

Plate 1 is a photograph of the shell with both fuze types. Plate 2 is a shadowgraph of the T321 fuzed shell in flight.

EUGENE D. BOYER

EUGENE D. BOYER
TABLE I

Physical Measurements of 20mm, HEI, T282El Shell

<table>
<thead>
<tr>
<th>Units</th>
<th>With M505 Fuze</th>
<th>With T321 Fuze</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>98.163</td>
<td>97.861</td>
</tr>
<tr>
<td>c.m.</td>
<td>1.566</td>
<td>1.536</td>
</tr>
<tr>
<td>A</td>
<td>8.305</td>
<td>8.313</td>
</tr>
<tr>
<td>B</td>
<td>62.56</td>
<td>59.43</td>
</tr>
<tr>
<td>e</td>
<td>3.819</td>
<td>3.799</td>
</tr>
<tr>
<td>d</td>
<td>.784</td>
<td>.784</td>
</tr>
<tr>
<td>Rd No</td>
<td>$M$</td>
<td>$b^2$</td>
</tr>
<tr>
<td>-------</td>
<td>-----</td>
<td>-------</td>
</tr>
<tr>
<td>3906*</td>
<td>0.788</td>
<td>9.16</td>
</tr>
<tr>
<td>3907**</td>
<td>0.794</td>
<td>10.46</td>
</tr>
<tr>
<td>3908</td>
<td>1.404</td>
<td>8.43</td>
</tr>
<tr>
<td>3909</td>
<td>1.460</td>
<td>2.94</td>
</tr>
<tr>
<td>3910</td>
<td>1.818</td>
<td>13.71</td>
</tr>
<tr>
<td>3911</td>
<td>2.146</td>
<td>4.71</td>
</tr>
<tr>
<td>3912</td>
<td>2.904</td>
<td>4.23</td>
</tr>
<tr>
<td>3913</td>
<td>2.924</td>
<td>8.23</td>
</tr>
<tr>
<td>3914</td>
<td>3.087</td>
<td>5.10</td>
</tr>
<tr>
<td>3915</td>
<td>3.257</td>
<td>3.31</td>
</tr>
</tbody>
</table>

* Nutational yaw arm too small for reduction.

** Since no satisfactory swerve reduction was obtained, $K_H$, $K_T$, and $\bar{s}$ were computed by using $K_N$ from Reference 1.
REFERENCES


ZERO YAW DRAG COEFFICIENT

vs.

MACH NUMBER

WITH M-505 FUZE

O

WITH T-321 FUZE

FIG. 1
NORMAL FORCE COEFFICIENT
VS
MACH NUMBER

\[ K_N \]

\[ 0 \quad 0.4 \quad 0.8 \quad 1.2 \quad 1.6 \quad 2.0 \quad 2.4 \quad 2.8 \quad 3.2 \quad 3.6 \]

- WITH M-505 FUZE
- WITH T-321 FUZE

FIG. 3
NORMAL FORCE CENTER OF PRESSURE
VS
MACH NUMBER

CPN (CAL.)

0
1
2
3

0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6

M

WITH M-505 FUZE
O WITH T-321 FUZE

FIG. 4
MAGNUS MOMENT COEFFICIENT

VS
MACH NUMBER

WITH M-505 FUZE

○ WITH T-321 FUZE

FIG. 5
FIG 6

DAMPING COEFFICIENT

\( K_h \)

VS

MACH NUMBER

\( \delta^2 = 20 \)

\( \delta^2 = 10 \)

\( \delta^2 = 5 \)

WITH M-505 FUZE

WITH T-321 FUZE

WITH MODIFIED M-505 FUZE

SUBSONIC BEHAVIOR

WITH M-505 FUZE

0

0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6

M
NUTATIONAL YAW DAMPING RATE

vs

MACH NUMBER

$\lambda_1 \times 10^3 \text{ FT}^{-1}$

$M$

WITH M-505 FUZE

WITH T-321 FUZE

WITH MODIFIED M-505 FUZE

SUBSONIC BEHAVIOR

WITH M-505 FUZE

FIG. 7
Precessional Yaw Damping Rate vs Mach Number

\[ \lambda_e \times 10^3 \text{ FT}^{-1} \]

\[ \delta^2 = 20 \]

\[ \delta^2 = 10 \]

\[ \delta^2 = 5 \]

WITH M-505 FUZE

WITH T-321 FUZE

-- SUBSONIC BEHAVIOR

WITH M-505 FUZE

0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6

M

FIG 8
PLATE 1. Photograph of Shell
Left: M505 Fuze
Right: T321 Fuze
PLATE 2. Round 3914
T282E1 Shell with T321 Fuze
Mach Number = 3.087
<table>
<thead>
<tr>
<th>No. of Copies</th>
<th>Organization</th>
<th>No. of Copies</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Commander</td>
<td>Commander</td>
</tr>
<tr>
<td>15</td>
<td>Air Force Armament Center</td>
<td>Air Munitions Development Laboratory</td>
</tr>
<tr>
<td>10</td>
<td>British Joint Services Mission</td>
<td>Wright Air Development Center</td>
</tr>
<tr>
<td>10</td>
<td>Chief, Bureau of Ordnance</td>
<td>Wright-Patterson Air Force Base, Ohio</td>
</tr>
<tr>
<td>5</td>
<td>Commander</td>
<td>Commander</td>
</tr>
<tr>
<td>5</td>
<td>Air Force Armament Center</td>
<td>Wright-Patterson Air Force Base, Ohio</td>
</tr>
<tr>
<td>4</td>
<td>Chief of Ordnance</td>
<td>Commander</td>
</tr>
<tr>
<td>4</td>
<td>Department of the Army</td>
<td>Arnold Engineering Development Center</td>
</tr>
<tr>
<td>3</td>
<td>British Joint Services Mission</td>
<td>Tullahoma, Tennessee</td>
</tr>
<tr>
<td>3</td>
<td>Chief, Bureau of Ordnance</td>
<td>USAF Fighter Weapons School</td>
</tr>
<tr>
<td>2</td>
<td>Commander</td>
<td>Commander</td>
</tr>
<tr>
<td>2</td>
<td>Naval Proving Ground Dahlgren, Virginia</td>
<td>Arnold Engineering Development Center</td>
</tr>
<tr>
<td>2</td>
<td>Commander</td>
<td>Commander</td>
</tr>
<tr>
<td>2</td>
<td>Naval Ordnance Lab. White Oak</td>
<td>USAF Fighter Weapons School</td>
</tr>
<tr>
<td>1</td>
<td>Commander</td>
<td>Commander</td>
</tr>
<tr>
<td>1</td>
<td>Naval Air Development Center Johnsville, Pennsylvania</td>
<td>USAF Fighter Weapons School</td>
</tr>
<tr>
<td>1</td>
<td>Commander</td>
<td>Commander</td>
</tr>
<tr>
<td>1</td>
<td>Naval Ordnance Test Station China Lake, California</td>
<td>National Advisory Committee for Aeronautics</td>
</tr>
<tr>
<td>1</td>
<td>Commander</td>
<td>Director</td>
</tr>
<tr>
<td>1</td>
<td>Naval Ordnance Test Station China Lake, California</td>
<td>Director</td>
</tr>
<tr>
<td></td>
<td>Canadian Army Staff 2450 Massachusetts Ave. Washington 8, D. C.</td>
<td>National Advisory Committee for Aeronautics</td>
</tr>
<tr>
<td></td>
<td>Commander</td>
<td>Director</td>
</tr>
<tr>
<td></td>
<td>Chief, Bureau of Ordnance</td>
<td>National Advisory Committee for Aeronautics</td>
</tr>
<tr>
<td></td>
<td>Department of the Army</td>
<td>National Advisory Committee for Aeronautics</td>
</tr>
<tr>
<td></td>
<td>Attn: ORDTB - Bal Sec</td>
<td>National Advisory Committee for Aeronautics</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. John Izzard, Reports Officer</td>
<td>National Advisory Committee for Aeronautics</td>
</tr>
<tr>
<td></td>
<td>Attn: Re3</td>
<td>National Advisory Committee for Aeronautics</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Nestingen Dr. May</td>
<td>National Advisory Committee for Aeronautics</td>
</tr>
<tr>
<td></td>
<td>Attn: Technical Library</td>
<td>National Advisory Committee for Aeronautics</td>
</tr>
<tr>
<td>No. of Copies</td>
<td>Organization</td>
<td>No. of Copies</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>1</td>
<td>National Advisory Committee for Aeronautics</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Lewis Flight Propulsion Laboratory</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cleveland Airport</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cleveland, Ohio</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attn: F. K. Moore</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>National Advisory Committee for Aeronautics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Langley Memorial Aeronautical Laboratory</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Langley Field, Virginia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. J. Bird</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mr. C. E. Brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dr. Adolf Busemann</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Commanding General</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Frankford Arsenal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Philadelphia 37, Pennsylvania</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Commanding General</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Picatinny Arsenal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dover, New Jersey</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attn: Samuel Feltman</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ammunition Labs.</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Commanding General</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Redstone Arsenal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Huntsville, Alabama</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attn: Technical Library</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Armour Research Foundation</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Illinois Institute of Technology</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technology Center</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Chicago 16, Illinois</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. W. Casier</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dr. A. Wundheiler</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Applied Physics Laboratory</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Silver Spring, Maryland</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. George L. Seielstad</td>
<td></td>
</tr>
</tbody>
</table>

22
## DISTRIBUTION LIST

<table>
<thead>
<tr>
<th>No. of Copies</th>
<th>Organization</th>
<th>No. of Copies</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General Electric Company</td>
<td>1</td>
<td>Sperry Gyroscope Co.</td>
</tr>
<tr>
<td></td>
<td>1 River Road</td>
<td></td>
<td>Division of the Sperry Corp.</td>
</tr>
<tr>
<td></td>
<td>Schenectady, New York</td>
<td></td>
<td>Great Neck, L. I.</td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. J. C. Hoffman</td>
<td></td>
<td>New York</td>
</tr>
<tr>
<td>1</td>
<td>Glenn L. Martin Co.</td>
<td>1</td>
<td>United Shoe Machinery Corp.</td>
</tr>
<tr>
<td></td>
<td>Baltimore, Maryland</td>
<td></td>
<td>Balch Street</td>
</tr>
<tr>
<td></td>
<td>Attn: Mrs. Mary Ezzo, Librarian</td>
<td></td>
<td>Beverly, Massachusetts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Attn: Mr. R. S. Parker</td>
</tr>
<tr>
<td>1</td>
<td>General Mills, Inc.</td>
<td>1</td>
<td>United Aircraft Corp.</td>
</tr>
<tr>
<td></td>
<td>1620 Central Avenue</td>
<td></td>
<td>Research Department</td>
</tr>
<tr>
<td></td>
<td>Minneapolis 13, Minnesota</td>
<td></td>
<td>East Hartford 8, Connecticut</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Attn: Mr. C. H. King</td>
</tr>
<tr>
<td>1</td>
<td>Lockheed Aircraft Corp.</td>
<td>1</td>
<td>University of Michigan</td>
</tr>
<tr>
<td></td>
<td>Factory &quot;A&quot;</td>
<td></td>
<td>Willow Run Research Center</td>
</tr>
<tr>
<td></td>
<td>Burbank, California</td>
<td></td>
<td>Willow Run Airport</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ypsilanti, Michigan</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Attn: Mr. J. E. Corey</td>
</tr>
<tr>
<td>1</td>
<td>McDonnell Aircraft Corp.</td>
<td>2</td>
<td>University of Texas</td>
</tr>
<tr>
<td></td>
<td>P. O. Box 516</td>
<td></td>
<td>Box 8036, University Station</td>
</tr>
<tr>
<td></td>
<td>Municipal Airport</td>
<td></td>
<td>Austin 12, Texas</td>
</tr>
<tr>
<td></td>
<td>St. Louis 1, Missouri</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>M. W. Kellogg Company</td>
<td>1</td>
<td>Wright Aeronautical Corp.</td>
</tr>
<tr>
<td></td>
<td>Foot of Danforth Avenue</td>
<td></td>
<td>Wood-Ridge, New Jersey</td>
</tr>
<tr>
<td></td>
<td>Jersey City 3, New Jersey</td>
<td></td>
<td>Attn: Sales Department (Government)</td>
</tr>
<tr>
<td></td>
<td>Attn: Miss E. M. Hedley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Massachusetts Institute of Technology</td>
<td></td>
<td>Westinghouse Air Arm Division</td>
</tr>
<tr>
<td></td>
<td>68 Albany Street</td>
<td></td>
<td>Friendship International Airport</td>
</tr>
<tr>
<td></td>
<td>Cambridge 39, Massachusetts</td>
<td></td>
<td>Baltimore, Maryland</td>
</tr>
<tr>
<td></td>
<td>Attn: Lt. Col. C. N. DeGennora</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Northrop Aircraft, Inc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Department 3483</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hawthorne, California</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. D. C. Olmore</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>North American Aviation, Inc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12214 Lakewood Boulevard</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Downing, California</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attn: Mr. Jim Elms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>