TO:
Approved for public release; distribution is unlimited.

FROM:
Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; JAN 1955. Other requests shall be referred to Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD 21005.

AUTHORITY
brl d/a ltr 22 apr 1981
The Effect Of Nose Truncation
On The Aerodynamic Properties
Of 9-Caliber Long Army-Navy
Spinner Rocket Models
Near Sonic Velocity

E. J. ROSCHKE
Destroy when no longer needed. DO NOT RETURN
THE EFFECT OF NOSE TRUNCATION ON THE AERODYNAMIC PROPERTIES OF 9-CALIBER LONG ARMY-NAVY SPINNER ROCKET MODELS NEAR SONIC VELOCITY

E. J. Roschke

Department of the Army Project No. 503-05-011
Ordnance Research and Development Project No. TB3-0240

ABERDEEN PROVING GROUND, MARYLAND
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>3</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>5</td>
</tr>
<tr>
<td>TREATMENT OF DATA</td>
<td>5</td>
</tr>
<tr>
<td>RESULTS</td>
<td>6</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>7</td>
</tr>
<tr>
<td>TABLES</td>
<td>7</td>
</tr>
<tr>
<td>FIGURES</td>
<td>10</td>
</tr>
<tr>
<td>1 - Photograph of Modified Model</td>
<td>10</td>
</tr>
<tr>
<td>2 - $K_D$ vs $M$</td>
<td>11</td>
</tr>
<tr>
<td>3 - $K_N$ vs $M$</td>
<td>12</td>
</tr>
<tr>
<td>4 - $K_M$ vs $M$</td>
<td>13</td>
</tr>
<tr>
<td>5 - $K_A$ vs $M$</td>
<td>14</td>
</tr>
<tr>
<td>6 - $K_T$ vs $M$</td>
<td>15</td>
</tr>
<tr>
<td>7 - $[K_H]$ vs $M$</td>
<td>16</td>
</tr>
<tr>
<td>8 - Models in Subsonic Flight</td>
<td>17</td>
</tr>
<tr>
<td>9 - Models in Supersonic Flight</td>
<td>18</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>19</td>
</tr>
<tr>
<td>DISTRIBUTION</td>
<td>20</td>
</tr>
</tbody>
</table>
THE EFFECT OF NOSE TRUNCATION ON THE AERODYNAMIC PROPERTIES
OF 9-CALIBER LONG ARMY-NAVY SPINNER ROCKET MODELS NEAR SONIC VELOCITY

ABSTRACT

The results of a limited program to determine the effect of nose truncation on the aerodynamic properties of the 9-caliber long Army-Navy spinner rocket shape near sonic velocities are given.
INTRODUCTION

In order to study the motions of spinner rockets in launchers and the effects of various launching characteristics on subsequent flight it was necessary to modify the noses of the rockets. This nose modification consisted of a truncation for the purpose of attaching a flat, circular mirror. These experiments were conducted by Dr. J. W. Cell and his associates of North Carolina State University; firings were done at Redstone Arsenal.

The question then arose whether truncation of the nose appreciably affected the aerodynamics of the configuration, especially near sonic velocity. Past experience indicated that in this region of velocities the aerodynamics could be quite sensitive to even relatively small modifications of shape.

To test this a limited program was fired in the Aerodynamics Spark Range utilizing six surplus 20mm diameter, 9-caliber long AN rocket models from a previous program [1]. Four of these were modified as described above (Fig. 1). Table 1 gives the physical properties of the six models.

TREATMENT OF DATA

Due to the limited number of models fired data from other sources had to be relied upon to interpret the results properly. Those aerodynamic coefficients affected by center of gravity position were corrected to a common center of gravity to facilitate data comparison with unmodified shape.

Curves of the various aerodynamic coefficients versus Mach number were plotted in order to compare results of the two types of models. No transonic data for unmodified 9-caliber long rocket models was available. It became necessary to determine curves for unmodified models with just three points, the two determined in this program and one extrapolated from 9-caliber supersonic data [1] at M = 1.2. To deal with this difficulty the three points were faired as well as possible with trends similar to that of existing 7-caliber transonic data [2]. While this method assumes that the curve trends of the 7 and 9-caliber models are similar in the transonic region, it is probably justifiable as a rough approximation. Points for unmodified rounds were plotted in a second series of curves and the two sets were then compared.

It should be noted that the curves for the unmodified models were drawn intuitively considering errors of individual points. The data were insufficient to accomplish more than to establish trends. Coefficients for all model rounds came from sufficient swerve with the exception of round 3241, an unmodified model. Values of coefficients obtained from the swerve reduction of this round were inconsistent with the other data.

1 A normal head-length of 2 calibers for unmodified models was reduced by 0.65 caliber for the modified models.
RESULTS

Results are presented in Tables 2 and 3 and the accompanying curves Figs. 2-7. Table 2 gives a tabulation of basic data. Table 3 indicates the percentage differences due to modification at two Mach Nos. Results are not corrected for yaw.

Drag

This parameter was the best determined and probably the most significant. Deviation of the curves becomes greater with increasing Mach No.; drag coefficients were 8% to 15% greater for modified models.

Normal Force

Although individual points were fairly well determined the overall curves were not, particularly for modified models. The actual trends of the curves may be different than shown. Normal force coefficients were approximately 3% greater for modified models.

Overturning Moment

These coefficients were corrected to a common center of gravity. The effect of decreasing physical length was to decrease the overturning moment coefficient. The coefficients were less for modified models, the decrease being from 9% to 15% over the velocity range fired. The center of pressure of the modified models moved rearward, as compared to unmodified models, by an amount of one-half to one caliber.

Spin Deceleration

The absence of spin data for the high Mach No. modified model made it difficult to predict what occurred in that region. The high end of the modified curve is thus poorly determined. Spin deceleration coefficients were 9% to 11% greater for the modified models.

Magnus Moment

These coefficients were corrected to a common center of gravity. At a Mach No. of 0.95 Magnus moment coefficients were about 9% greater for modified models. The value of $K_T$ for modified models was twice that for unmodified models but of opposite sign at a Mach No. of 1.18. The center of pressure of the Magnus force was poorly determined. It is estimated to have moved slightly forward, perhaps one-quarter or one-third of a caliber, due to modification.

Damping Moment

It was found to be impossible to correct this quantity exactly for center of gravity due to lack of knowledge of the corresponding force. No attempt was made to fair in between the extremities of the curves; they would seem to cross. Modified models produced the lower coefficients
(about 17%) for the subsonic case, while the converse was true for the supersonic case.

CONCLUSIONS

On the whole, truncating the nose of the 9-caliber long AN Spinner rocket model to a méplat diameter of 0.45 caliber produced changes in such aerodynamic coefficients as $K_D$ and $K_M$ of a nature to be expected. In addition, the magnus moment coefficient, $K_M$, also experienced a marked change. Other coefficients, in view of the uncertainty of the data, were not appreciably affected; at least there was no evidence of drastic change. Figs. 8 and 9 are shadow graphs of models in subsonic and supersonic flight respectively.

E. J. Roschke

E. J. ROSCHKE

TABLE 1

Physical Characteristics

<table>
<thead>
<tr>
<th>Round</th>
<th>Wt.-gms.</th>
<th>$A$ (gm.-in.$^2$)</th>
<th>$B$ (gm.-in.$^2$)</th>
<th>c.g. (cal. from base)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3238</td>
<td>194.6</td>
<td>16.22</td>
<td>458.0</td>
<td>3.929</td>
</tr>
<tr>
<td>3239</td>
<td>194.9</td>
<td>16.23</td>
<td>460.2</td>
<td>3.931</td>
</tr>
<tr>
<td>3243</td>
<td>301.0</td>
<td>22.67</td>
<td>737.1</td>
<td>3.094</td>
</tr>
<tr>
<td>3240</td>
<td>301.3</td>
<td>22.67</td>
<td>745.7</td>
<td>3.101</td>
</tr>
<tr>
<td>3242*</td>
<td>195.8</td>
<td>16.24</td>
<td>470.7</td>
<td>3.943</td>
</tr>
<tr>
<td>3241*</td>
<td>195.5</td>
<td>16.24</td>
<td>470.7</td>
<td>3.943</td>
</tr>
</tbody>
</table>

* Unmodified Models
### TABLE 2

#### a) Table of Data

<table>
<thead>
<tr>
<th>Round</th>
<th>M</th>
<th>$K_D$</th>
<th>$K_N$</th>
<th>$K_T$</th>
<th>$K_A$</th>
<th>$K_M$</th>
<th>$K_H$</th>
<th>$\overline{\delta^2}$ (square deg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3238</td>
<td>.948</td>
<td>.1536</td>
<td>1.02</td>
<td>0.18</td>
<td>.0127</td>
<td>2.61</td>
<td>10.7</td>
<td>6.43</td>
</tr>
<tr>
<td>3239</td>
<td>.956</td>
<td>.1591</td>
<td>1.04</td>
<td>0.11</td>
<td>.0124</td>
<td>2.56</td>
<td>10.5</td>
<td>7.66</td>
</tr>
<tr>
<td>3243</td>
<td>1.043</td>
<td>.2083</td>
<td>1.12</td>
<td>0.43</td>
<td>.0121</td>
<td>3.53</td>
<td>10.6</td>
<td>3.87</td>
</tr>
<tr>
<td>3240</td>
<td>1.184</td>
<td>.2190</td>
<td>1.01</td>
<td>0.40</td>
<td>-</td>
<td>3.57</td>
<td>19.9</td>
<td>1.39</td>
</tr>
<tr>
<td>3242*</td>
<td>.924</td>
<td>.1287</td>
<td>1.00</td>
<td>0.11</td>
<td>.0118</td>
<td>2.75</td>
<td>12.5</td>
<td>5.93</td>
</tr>
<tr>
<td>3241*</td>
<td>.966</td>
<td>.1475</td>
<td>1.00</td>
<td>0.32</td>
<td>.0115</td>
<td>2.92</td>
<td>17.3</td>
<td>0.31</td>
</tr>
</tbody>
</table>

#### b) Aerodynamic coefficients corrected to a center of gravity 5.05 calibers from the theoretical nose.

<table>
<thead>
<tr>
<th>Round</th>
<th>M</th>
<th>$K_T$</th>
<th>$K_M$</th>
<th>$[K_H]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3238</td>
<td>.948</td>
<td>0.18</td>
<td>2.60</td>
<td>10.6</td>
</tr>
<tr>
<td>3239</td>
<td>.956</td>
<td>0.11</td>
<td>2.54</td>
<td>10.4</td>
</tr>
<tr>
<td>3243</td>
<td>1.043</td>
<td>0.20</td>
<td>2.52</td>
<td>7.6</td>
</tr>
<tr>
<td>3240</td>
<td>1.184</td>
<td>0.21</td>
<td>2.71</td>
<td>16.8</td>
</tr>
<tr>
<td>3242*</td>
<td>.924</td>
<td>0.11</td>
<td>2.75</td>
<td>12.5</td>
</tr>
<tr>
<td>3241*</td>
<td>.966</td>
<td>0.32</td>
<td>2.92</td>
<td>17.3</td>
</tr>
</tbody>
</table>

* Unmodified Models
<table>
<thead>
<tr>
<th></th>
<th>M = 0.95</th>
<th>M = 1.18</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_D$</td>
<td>+ 8%</td>
<td>+ 15%</td>
</tr>
<tr>
<td>$K_N$</td>
<td>+ 3</td>
<td>+ 3</td>
</tr>
<tr>
<td>$K_M$</td>
<td>- 9</td>
<td>- 15</td>
</tr>
<tr>
<td>$K_A$</td>
<td>+ 9</td>
<td>+ 11</td>
</tr>
<tr>
<td>$K_T$</td>
<td>+ 9</td>
<td></td>
</tr>
<tr>
<td>$[K_H]$</td>
<td>- 17</td>
<td>+ 14</td>
</tr>
</tbody>
</table>

(see curve discussion)
FIG. 1. Truncated Spinner Rocket Models
DRAG COEFFICIENT
VS.
MACH NUMBER
9 CAL. AN ROCKET

\[ K_D \]

\[ M \]

- UNMODIFIED MODEL
- MODIFIED MODEL
- EXTRAPOLATED FROM SUPersonic DATA

FIGURE 2
NORMAL FORCE COEFFICIENT

VS.

MACH NUMBER

9 CAL. AN ROCKET

\[ K_N \]

\[ M \]

FIGURE 3
OVERTURNING MOMENT VS. MACH NUMBER

(AT c.g. 5.05 CAL. FROM NOSE)

9 CAL. AN ROCKET

FIGURE 4
SPIN DECELERATION MOMENT COEFFICIENT
VS.
MACH NUMBER

9 CAL. AN ROCKET

\[ K_A \]

\[ M \]

\( \times \) UNMODIFIED MODEL
\( \circ \) MODIFIED MODEL
\( \bigcirc \) EXTRAPOLATED
FROM SUPersonic DATA

FIGURE 5
MAGNUS MOMENT COEFFICIENT
VS.
MACH NUMBER

(AT c.g. 5.05 CAL. FROM NOSE)
9 CAL. AN ROCKET

\[ K_T \]

\[ M \]

FIGURE 6
MODIFIED DAMPING MOMENT COEFFICIENT
VS.
MACH NUMBER

(AT c.g. 5.05 cal. from nose)
9 CAL. AN. ROCKET

[Diagram]

Figure 7
FIG. 8. Models in Subsonic Flight

A. Unmodified Model, $M=.97$

B. Modified Model, $M=.95$
REFERENCES


<table>
<thead>
<tr>
<th>No. of Copies</th>
<th>Organization</th>
<th>No. of Copies</th>
<th>Organization</th>
</tr>
</thead>
</table>
| 3             | Chief of Ordnance  
Department of the Army  
Washington 25, D. C.  
Attn: ORDTB - Bal Sec  
ORDTX - AR (1 cy)  
ORDTU (1 cy) | 4 | Commander  
Air Research and Dev. Command  
P. O. Box 1395  
Baltimore 3, Maryland  
Attn: Deputy for Dev. |
| 10            | British - ORDGU-SE, Foreign Relations Section for distribution | 1 | Commander  
Arnold Engineering Div. Center  
Tullahoma, Tennessee  
Attn: Deputy Chief of Staff, Operations |
| 4             | Canadian Joint Staff - ORDGU-SE, Foreign Relations Section for distribution | 5 | Director  
Armed Services Technical Information Agency  
Documents Service Center  
Knott Building  
Dayton 2, Ohio  
Attn: DSC - SA |
| 4             | Chief, Bureau of Ordnance  
Department of the Navy  
Washington 25, D. C.  
Attn: Re3 | 4 | ASTIA Reference Center  
Technical Information Division  
Library of Congress  
Washington 25, D. C. |
| 2             | Commander  
Naval Proving Ground  
Dahlgren, Virginia | 3 | Director  
National Advisory Committee for Aeronautics  
1512 H Street, N. W.  
Washington 25, D. C. |
| 2             | Commander  
Naval Ordnance Laboratory  
White Oak  
Silver Spring, Maryland  
Attn: Mr. Nestingen  
Mr. May | 2 | Director  
National Advisory Committee for Aeronautics  
Ames Laboratory  
Moffett Field, California  
Attn: Dr. A. C. Charters  
Mr. H. J. Allen |
| 1             | Superintendent  
Naval Postgraduate School  
Monterey, California | 1 | Commanding General  
Redstone Arsenal  
Huntsville, Alabama  
Attn: Technical Library |
| 2             | Commander  
Naval Air Missile Test Center  
Point Mugu, California | | |
| 2             | Commander  
Naval Ordnance Test Station  
Inyokern  
P. O. China Lake, California  
Attn: Technical Library  
W. R. Haseltine | | |
## DISTRIBUTION LIST

<table>
<thead>
<tr>
<th>No. of Copies</th>
<th>Organization</th>
</tr>
</thead>
</table>
| 3             | Commanding General  
                 Picatinny Arsenal  
                 Dover, New Jersey  
                 Attn: Technical Division |
| 1             | Commanding Officer  
                 Frankford Arsenal  
                 Philadelphia 37, Pennsylvania |
| 1             | Commanding Officer  
                 Diamond Ordnance Fuze Laboratories  
                 Connecticut Avenue and Van Ness St., N. W.  
                 Washington 25, D. C.  
                 Attn: Ordnance Library |
| 2             | Armour Research Foundation  
                 35 West 33rd Street  
                 Chicago 16, Illinois  
                 Attn: Mr. W. Casier  
                 Dr. A. Wundheiler |
| 1             | California Institute of Technology  
                 Norman Bridge Laboratory of Physics  
                 Pasadena, California  
                 Attn: Dr. Leverett Davis, Jr. |
| 1             | University of Southern California  
                 Engineering Center  
                 Los Angeles 7, California  
                 Attn: Mr. H. R. Saffell, Director |
| 1             | Dr. L. H. Thomas  
                 Watson Scientific Computing Laboratory  
                 612 West 116th Street  
                 New York 27, New York |
| 2             | Prof. J. W. Cell  
                 North Carolina State College  
                 Raleigh, North Carolina |