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WIND-TUNNEL INVESTIGATION OF VARIOUS CONFIGURATIONAL MODIFICATIONS OF THE LOW-DRAG BOMB (U)

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U.S. NAVAL ORDNANCE LABORATORY
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Aeroballistic Research Report 403

WIND-TUNNEL INVESTIGATION OF VARIOUS CONFIGURATIONAL MODIFICATIONS OF THE LOW-DRAG BOMB

Prepared by:
Fred J. DeMerlitte
Harry Gauzza

ABSTRACT: This report presents the results of an investigation in the NOL 40 x 47 cm aeroballistics tunnel No. 1 to study the static stability and drag of the low-drag bomb at subsonic and supersonic speeds. The following tests were made:

(a) Study of configurational changes designed to reduce the yaw of the bomb,

(b) Drag of the 250-lb. bomb with supporting lugs (Mk-31 bomb),

(c) Stability of an 8-fin bomb with reduced fin span to improve the ground clearance problem.

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND
This investigation was performed at the request of the Bureau of Ordnance (reference (a)) under Task Number A3d-493-1-50. The report covers recent wind-tunnel tests in the NOL 40 x 40 cm Aeroballistics Tunnel No. 1. Additional work has been done in the NOL firing ranges, the National Bureau of Standards wind-tunnel, and the Cornell transonic wind-tunnel under the direction of the NOL staff.

Previous NOL reports on the aerodynamics of the low-drag series can be found in references (b) through (f).

MELL A. PETERSON  
Captain, USN  
Commander  

R. KENNETH LOBB  
By direction
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WIND TUNNEL INVESTIGATION OF VARIOUS CONFIGURATIONAL MODIFICATIONS OF THE LOW-DRAG BOMB

INTRODUCTION

1. This report describes investigations carried out in a series of low-drag bombs of the U. S. Navy, in the wind tunnels at the Naval Ordnance Laboratory. These bombs have a shape developed by Douglas Aircraft. The four low-drag bombs of this series are the 250 pound bomb, Mk 81; the 500 pound bomb, Mk 82; the 1000 pound bomb, Mk 83; and the 2000 pound bomb, Mk 84.

2. The tests made involved:
   a. An investigation of the configurational changes to reduce the induced yawing moment and rolling moment of the bomb and improve the dynamic characteristics.
   b. Drag of the 250 pound bomb with suspension lugs.
   c. Investigation of the stability of configuration with fin span equal to the maximum body diameter.

3. The low-drag bomb with two-degree fin cant is believed to be one of the best bombs developed. The erratic flight mentioned in this report applies to only a small percentage of the bombs dropped.

Symbols

\[
\begin{align*}
A & : \text{area (maximum) of the body (sq. in.)} \\
C.G. & : \text{center of gravity (42.5 per cent length from the nose)} \\
C_{D0} & : \text{drag coefficient at zero angle of attack (C_D)} \\
C_D & : \text{drag coefficient (C_D)} \\
C_N & : \text{normal force coefficient (C_N)} \\
C_y & : \text{side force coefficient (C_y)} \\
C_R & : \text{rolling moment coefficient (C_R)} \\
C_t & : \text{yawing moment coefficient (C_t)} \\
\end{align*}
\]
Discussion

4. The study of configurational changes of the low-drag bomb was a result of recurring indications of instability of the bomb during drops.

5. Early in the drop tests of the bombs it became obvious that the bomb was yawing badly. It appeared probable that the pitch frequency and the roll frequency were becoming equal at about the cycle per second and that the bomb was locking into resonance. Initially the fin cant was zero degree with a manufacturing tolerance of ±0.5 degree. Calculation showed that accidental fin cant within this tolerance could produce sufficient roll to cause resonance. Hence it was decided to cant the fin two degrees and thus produce a roll which would be too large to result in resonance. This change appeared to cure the trouble with the low-drag bombs.

6. Several years later, however, during dive-bombing tests, large yaw reappeared in a few of the drops. Figures 2a and 2b present the yaw history of a drop made at Chincoteague, Virginia. The figures show the bomb beginning to damp then undamp and later damp again. The key to the problem appears to be the roll-lock-in. The roll history shows that the roll rate of the bomb increases from zero to about one cycle per second, then "locks in," and the bomb continues to roll uniformly. While rolling at this rate the bomb is in a resonance condition. The yaw increases until a large angle is reached. Wind-tunnel tests at the National Bureau of Standards show that large rolling moments are present at large angles of attack. These large
moments cause increase in roll rate, breaking out of resonance, and an approach to a steady state rolling frequency of 7 to 10 cycles per second. While the roll rate is increasing the yaw decreases rapidly and the bomb falls satisfactorily.

7. The condition for roll-lock-in is

$$L + L_p + L = 0$$

where:

- $L$: Rolling moment due to fin cant
- $L_p$: Roll damping moment
- $L$: Induced rolling moment

Wind-tunnel tests show that the induced rolling moment causes the roll-lock-in. Possible cures for roll-lock-in appear to be:

- a. reduce the induced rolling moment
- b. increase the fin span

When roll-lock-in occurs, the low drag bomb experiences what is known as "Catastrophic Growth of Yaw" at resonance due to yawing moment. To cure this:

- a. reduce yawing moment
- b. increase fin span
- c. increase damping moment
- d. reduce rotation arm

When it was first learned that the bomb was yawing badly, studies were made to determine if the trouble was resonance or Magnus instability. Calculation of the damping rate of the precessional and nutational arms showed that the present bomb was probably not experiencing Magnus instability but if the steady state rolling velocity was increased by more fin cant, Magnus instability could occur. Therefore, increasing fin cant in hopes of preventing "lock-in" did not appear feasible. Since the bomb experiences difficulty at large angles of attack, two methods appeared promising in preventing the erratic flight. One method was to increase the fin span and chord to increase the pitch damping and the other method was to investigate fin shapes which have low induced rolling moments and low yawing moments.
Induced Roll Program and Large Fin Program

c. The following configurations were reported in this test program. These configurations are reported in references e and f.

(a) basic low-drag bomb (no fin cart)  Figures 1, 24
(b) .5 degree fin cart  Figure 2
(c) 1.00 d-span tail  Figure 4
(d) 2.05 d-span tail  Figures 5, 6
(e) large nose vanes  Figures 7, 9
(f) small nose vanes  Figures 8, 9
(g) 1.00 d d-span (tail moved rearward  Figures 3, 4
    0.233 inches)
(h) end plate  Figures 13, 17
(i) box shroud  Figures 15, 17
(j) 1/2 box shroud  Figures 16, 17
(k) porous box shroud  Figures 14, 17
(l) o fin model  Figures 12, 17
(m) long chord (1.4 d span and chord  Figures 10, 11
    of 2.05 d span model)
(n) body alone  Figure 18

9. The configurations were all tested at a Mach number of 0.91 or 0.95 at a fin roll orientation of 22.5 degrees. In addition some configurations were tested at a fin orientations of zero degree and 45 degrees and at Mach numbers of 0.85 and 1.57 or 1.58. Figures 61, 62, and 63 show, in barograph form, a comparison of the various configurations. It should be pointed out that the nose vanes were placed in such a position, due to model construction, that a loss of stability resulted. If the vanes had been placed on the center of gravity or aft of the center of gravity this would not have occurred. The porous box shroud was selected as a configuration because it was believed that the solid box shroud would be unstable at transonic and supersonic Mach numbers. However, the solid box shroud configuration was stable at the Mach numbers tested. Photographs and sketches of all the models are shown in Figures 1 through 18. Figures 26 through 35 are plots of normal force, pitching moment, rolling moment, side force and yawing moment versus angle of attack.

10. The effects of the induced rolling moment were investigated by free-spin tests at the National Bureau of Standards on a number of modifications to the fins such as twist, tangent, sweep and at the Naval Ordnance Laboratory using configurations which are altered more radically (ref. f).
Reduced Fin Span Program

11. There has been some interest in reducing the fin span of the 250 pound bomb. This would aid the ground and airplane clearance problems. Tests were made (reference (d)) of an eight-fin bomb with a fin span of one diameter. The configuration was unstable. Later an attempt was made to stabilize the configuration using one-half and one-diameter chord shrouds. Photographs and sketches of the configurations are shown in Figures 56 through 59. The shrouds stabilized the bomb at the supersonic speeds but at the transonic speeds the bomb was still unstable. Figures 56 and 57 show the data obtained for these configurations.

Effect of Lugs Program

12. Tests were made of the Mk 81 (250 pound bomb) with mounting lugs. The stability data for the lug configuration are shown in Figures 58 and 59. Note that this lug seems to cause a very slight change in trim as would be expected. The drag coefficient was greatly increased as can be seen in Figure 50. The drag coefficient with lugs compared favorably with free-flight drop data obtained informally from the Bureau of Ordnance. Photographs and sketches of this configuration are shown in Figures 23 and 24.

Models, Balances, and Data Reduction

13. All the models and balances were designed and manufactured by the Naval Ordnance Laboratory. The models were manufactured of steel and are shown in photographs and sketches in Figures 1 through 24. The data were obtained using a six-component strain-gage balance (5-16) (see reference (g)).

14. The data were recorded using the automatic data recording system explained in reference (h). The raw data are recorded into IBM cards and the data are then reduced to coefficient form by IBM machines using the data reduction equations given in reference (i).

15. Test conditions are given in Table 1. All angles of attack were corrected for the static deflection of the balance sting due to the aerodynamic loads. An index of the plotted data is presented in Table 2. The NOL sign convention is shown in Figure 25.
Conclusions

16. Figures 61, 67, and 63 show the effect of configuration changes on the pitching moment, yawing moment, and induced rolling moment at a Mach number of approximately 0.49 and Froude number 1.5. The configurations with large increases in lift moment or large decreases in the induced rolling moment and yawing moment are configurations which should perform more reliably than the basic low drag bomb.

17. This report is intended as a progress report on the work done on the low-drag bomb in the NOL wind tunnels. Work is continuing in the NOL wind tunnel on the induced rolling moment problem and tests are being made by NOL personnel at the National Bureau of Standards to study the induced rolling moment, and at Cornell Aeronautical Laboratory to determine the transonic aerodynamics of the existing bomb, and firings are being made in the NOL firing range to obtain more information on the low-drag bomb.
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References

(a) Griffin, T. A., "Wind-Tunnel Request" (WTR 260) (Conf.) 1955
(b) Gauzza, H. J., "Aeroballistic Investigation of the EX-10 Bomb at Subsonic Speeds," NAVORD Report 2614 (Conf.) 1953
(c) Long, J. E., "Free Flight Investigation of the Stability and Drag of the EX-10 General Purpose Bomb," NAVORD Report 2610 (Conf.) 1953
(d) Long, J. E., "Low Yaw Data on the Low Drag Bomb (EX-10) at Transonic Speeds (0.3 M. to 1.4)," NAVORD Report 4227 (Conf.) 1955
(e) Piper, W. D., "Static Stability Characteristics of the EX-10 Low Drag Bomb," NAVORD Report 4503 (Conf.) 1957
(g) Nicolaides, J. D., "On the Flight of Ballistic Missiles," BuOrd Ballistic Technical Note Number 1, 1950 (Conf.)
(i) Nicolaides, J. D., "First Primer of Bomb Ballistics," BuOrd Technical Note 20 (Unclass.) 1955
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FIG. 2 BASIC MODEL (2-DEGREE FIN CANT)
FIG. 3 1.667d FIN SPAN (REAR-POSITION) MODEL
FIG. 4 1000 LBS LOW DRAG BOMB
(4 FIN - 1.667 D SPAN)
FIG. 8 SMALL NOSE VANES MODEL
FIG. 9 1000 LB LOW DRAG BOMB
NOSE VANES ATTACHED
(4 FIN -1.40 D SPAN)
FIG. 10 1.40d FIN SPAN AND CHORD OF 2.05d
FIG. 13 END PLATE MODEL
FIG. 14 POROUS BOX MODEL
FIG. 16  HALF TIP CHORD SOLID BOX SHROUD MODEL
FIG. 17 PARTS TESTED ON LOW DRAG BOMBS

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FIG. 22 1000 LB LOW DRAG BOMB
(8 FIN - 1.00 D SPAN)
FIG. 23 250-POUND LOW-DRAG BOMB MODEL WITH LUGS
NOTE:

VAN IS PROPPED IN STANDARD REFERENCE
ORIENTATION IS CLOCKWISE FROM VERTICAL (0°)
ORIGIN OF COORDINATES IS THE VELOCITY VECTOR

TIME BETWEEN POINTS = 0.12 SECONDS
TANGENTS AT EACH POINT & POINTS TO AID IN FOLLOWING FLIGHT HISTORY

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Figure 26
NOTE:

BURR APS PLATON ON DEGREES IN READONE
ORIENTATION IS RELATIVE FROM VERTICAL (VE)
ORIGIN OF COORDINATES IS THE VELOCITY VECTOR.

TIME BETWEEN POINTS = 0.16 SECONDS

These are measured every 0.5 POINTS TO HELP IN FOLLOWING RIGHT HISTORY.

Figure 27

CONFIDENTIAL

(Continuation of Fig. 26)
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BSCONFIGURATION - BASIC LOW-DRAG BOMB

M = 0.9

\( \alpha = 2\degree \)

BASE CONFIGURATION - BASIC LOW-DRAG BOMB

Fig. 61
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LOW DRAG BOMB
\[ M = 1.57 \]
\[ \alpha = 24^\circ \]
BASE CONFIGURATION - BASIC LOW-DRAG BOMB

![Graphs showing pitching, yawing, and induced rolling moments](image)

Basis: 2.0 Greg
1.0670
Fuel Tank
Small Valve
Large Valve
Box Fairing
Porous Box

Fig. 62
NAVORD Report 4053
LOW DRAG BOMB
BASE CONFIGURATION - BASIC
LOW-DRAG BOMB

\[ C_{D_0} (\text{kg}) \]

\[ C_{D_0} (\text{kg}) \]

\[ M=0.9 \]
\[ \alpha=0^\circ \]

\[ M=1.57 \]
\[ \alpha=0^\circ \]

- Basic
- 2° Canard
- 1.667\%
- 1.657\%
- Large Canard
- Rad Plate
- Small Valve
- Large Valve
- Air-Brake
- Porous Box

\[ 6.71 \text{ in} \]
\[ 1000 \text{ lb. Bpritch, Large } \]
\[ 250 \text{ lb. Both} \]