Copy 16
RM SL51L13

[redacted]

copy 2

Unavailable Removed
EO 12958 dtd 4-17-95
Ann 3/98

RESEARCH MEMORANDUM

for the

Office of Chief of Ordnance, U. S. Army

WIND-TUNNEL INVESTIGATION OF THE DESCENT CHARACTERISTICS OF BODIES OF REVOLUTION SIMULATING ANTI-PERSONNEL BOMBS

By Stanley H. Scher

Langley Aeronautical Laboratory
Langley Field, Va.

1.N. 6404

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
WASHINGTON

[redacted]

NACA RM SL51L13

[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

for the

Office of Chief of Ordnance, U. S. Army

WIND-TUNNEL INVESTIGATION OF THE DESCENT CHARACTERISTICS OF BODIES OF REVOLUTION SIMULATING ANTI-PERSONNEL BOMBS

By Stanley H. Scher

SUMMARY

An investigation has been conducted in the Langley 20-foot free-spinning tunnel to study the relative behavior in descent of a number of homogeneous balsa bodies of revolution simulating anti-personnel bombs with a small cylindrical exploding device suspended approximately 10 feet below the bomb. The bodies of revolution included hemispherical, near-hemispherical, and near-paraboloid shapes. The ordinates of one near-paraboloid shape were specified by the Office of the Chief of Ordnance, U. S. Army. The behavior of the various bodies without the cylinder was also investigated.

The results of the investigation indicated that several of the bodies descended vertically with their longitudinal axis, suspension line, and small cylinder in a vertical attitude. However, the body, the ordinates of which had been specified by the Office of the Chief of Ordnance, U. S. Army, oscillated considerably from a vertical attitude while descending and therefore appeared unsuitable for its intended use. The behavior of this body became satisfactory when its center of gravity was moved well forward from its original position. In general, the results indicated that the descent characteristics of the bodies of revolution become more favorable as their shapes approached that of a hemisphere.

INTRODUCTION

The Army and Navy are currently engaged in an attempt to develop anti-personnel bombs of hemispherical, near-paraboloid, or other possible

[redacted]

shapes, having an exploding device connected to the bomb by means of an electrical-conductor string approximately 10 feet long. It is desired that the exploding device strike the ground first and cause the bomb to explode when it is about 10 feet above the ground. For maximum shrapnel-dispersing effectiveness of the bomb, it is also desired that its longitudinal axis of symmetry be in a vertical attitude at the time it explodes. Because of the importance of obtaining some information as to the effect of various possible bomb shapes on the descent characteristics of the bomb and exploding-device configurations, the Office of the Chief of Ordnance, U. S. Army, requested that an investigation be conducted in the Langley 20-foot free-spinning tunnel to study the relative behavior in descent of various solid balsa bodies of revolution, each with a small cylindrical lead weight suspended from the body by means of a string.

One of the bodies of revolution investigated was made with ordinates specified by the Office of the Chief of Ordnance, U. S. Army, and appeared as a near-paraboloid. Another of the bodies was a hemisphere, and four other intermediate bodies were selected as possible alternate bomb configurations. The small cylindrical weight used in the wind-tunnel investigation represented a bomb-exploding device. As a matter of general interest, the behavior of the various bodies of revolution without the cylinder attached was also investigated. The behavior in descent of each body with and without the attached cylinder is reported herein, and the general effects of body-of-revolution shape are discussed.

APPARATUS

Wind Tunnel

The wind-tunnel tests of this investigation were made in the Langley 20-foot free-spinning tunnel. This tunnel was used because it has a vertically rising air stream in the testing area and, therefore, was a convenient apparatus to use in investigating experimentally the behavior in descent of the body-of-revolution configurations. The tunnel has an airspeed range up to about 95 feet per second.

Bodies of Revolution

The profile views and over-all dimensions of the six bodies of revolution used in the investigation are indicated in the sketches of figure 1. The ordinates of the bodies are presented in detail in table I. Each body was symmetrical about its longitudinal axis. The ordinates of body F (fig. 1) were specified by the Office of the Chief of Ordnance, U. S. Army. Another of the bodies used was a hemisphere. The ordinates for the four intermediate bodies of revolution were selected as indicated in figure 1. The bodies were made homogeneously at Langley of solid balsa segments and had lacquered surfaces. The weight of each body is listed in figure 1. The bodies did not represent any specific proposed bomb in weight but were made so as to allow convenient testing in the tunnel.

Cylindrical Weight

The small cylindrical weight used in the investigation was a right circular cylinder and was made at Langley with a length of 0.75 inch and a diameter of 0.25 inch according to specifications of the Office of the Chief of Ordnance, U. S. Army. The cylinder was made of lead and weighed 6.5 grams (0.0144 lb).

METHODS AND TESTS

For the wind-tunnel tests of the simulated bomb and bomb-exploding device, the axis of symmetry of the body of revolution at the rounded surface was connected to one end of the longitudinal axis of the cylinder by means of a string. Brief preliminary tests were made in which suspension strings of various lengths were used, including a 10-foot string to represent the actual length being considered by the Office of the Chief of Ordnance, U. S. Army. The results indicated little effect of suspension-string length, and a 5-foot string was arbitrarily used for the remainder of the investigation as a matter of testing convenience. A typical body-cylinder arrangement is illustrated in the sketch in figure 2. Each configuration was held with the longitudinal axis of the body of revolution and the cylinder alined with the fully extended 5-foot connection string and was released into the tunnel alternately in a vertical and a horizontal attitude. Some tests were also made in which the string was wrapped around the body of revolution and the launching made with rotation applied about various body axes. Some tests were made of the bodies of revolution alone and for those tests launching techniques similar to the aforementioned simple-release and applied-rotation methods were used.

Motion pictures were made and visually obtained observations were recorded as to the behavior of each configuration after launching and during descent. Descent velocities were recorded as the airspeed necessary to hold the configuration being tested at a given level in the tunnel. The results were analyzed to determine general effects of design variables on the behavior of the bodies in descent.

The Reynolds numbers of the tests ranged from about 25,000 to 100,000, based on lengths of the longitudinal axes of symmetry of the bodies of revolution.

RESULTS AND DISCUSSION

The results of the tests in which each body of revolution with the cylindrical weight at the end of the fully extended 5-foot string was released into the vertical air stream are tabulated in table II. When the body and cylinder were released in any attitude, the cylinder dropped below the body of revolution and assumed a stable attitude with its longitudinal axis and the suspension string in line with the air stream. The hemispherical and near-hemispherical bodies of revolution, bodies A and B, respectively, in figure 1, trimmed in a nose-down vertical attitude with little or no horizontal travel in the tunnel. Bodies C, D, and E (fig. 1) trimmed generally in a nose-down vertical attitude. However, there was some slight horizontal travel of bodies D and E in the tunnel, and for bodies C and E, there were occasional oscillations of the order of $\pm 5^{\circ}$ from the vertical. For the three latter bodies of revolution, the behavior in descent appeared in general to become less favorable as the body shape became less like that of a hemisphere. Body F, which appeared as a near-paraboloid, made continuous side-to-side oscillations of approximately $\pm 35^{\circ}$ to $\pm 45^{\circ}$ from the vertical at a rate of about 0.5 second per cycle without appreciable horizontal travel in the tunnel. The oscillatory motion of body F appeared to be approximately about the string attachment point, with some slight occasional side-to-side motion of the upper few inches of the string being evident. Brief tests were made in which a relatively much larger cylindrical weight (32.5 grams) was suspended below body F. The results indicated increases in the rate of descent of the body and decreases in the period and in the amplitude of the oscillation (table II). In an attempt to prevent the oscillations of body F, various multiple-bridle-line arrangements were used in attaching the suspension string to several points on the body. The results of these tests are not presented in tabular form, but indicated that the multiple bridles had little effect on the natural tendency of body F to oscillate while descending with the suspended cylinder.

When each body of revolution and cylinder was launched with the string wrapped around the body, the string unwrapped within a few seconds while the body made irregular gyrations. Once the unwrapping was complete, each body-cylinder configuration descended as described in the previous discussion.

When the bodies of revolution without the cylinder attached were released into the wind stream in a nose-down or near nose-down attitude without any applied launching rotation or with rotation applied only about the longitudinal body axis, the resulting behavior of all except bodies E and F was similar to their behavior when the weights were attached. Body F made erratic falling-leaf motions and eventually went into a continuous end-over-end tumbling motion about a lateral body axis while traveling horizontally in the tunnel. Body E trimmed in a nose-down vertical attitude part of the time, but also tended to make erratic motions which led to an end-over-end tumbling motion like that of body F. For any of the bodies, when launched with any other launching technique, a rotation ensued which continued with no appreciable subsequent reduction in rotation rate and at the same time the body traveled horizontally in the tunnel; it appeared that the rotary motion would gradually evolve to an end-over-end tumbling motion similar to that described for body F. Rate of nose-down vertical descent, and rates of tumbling descent and rotation obtained during these tests are presented in table III.

A few additional tests were made with body F without the attached cylinder in which small lead weights were mounted on the rounded surface end of the longitudinal axis of symmetry in order to ascertain the effect of moving the center of gravity forward from its original position at approximately 64 percent of the length back from the rounded-surface end. The results of these tests indicated that with its center of gravity moved forward to or beyond a position at 50 percent of its length, body F was inherently stable and damped any applied rotation in the tunnel and descended in a stable nose-down attitude without any horizontal travel in the tunnel. The results also indicated that an intermediate position of the center of gravity at 54 percent of its length was not far enough forward to provide nose-down stability. Brief tests with balsa blocks to replace the lead weights indicated that the improved stability was due to the forward shift in center-of-gravity position and not due to any aerodynamic effects.

The results of the investigation indicate that use of the proposed suspended exploding device, which of course has the primary purpose of exploding the bomb, has the additional beneficial effect of preventing or of eventually halting any end-over-end tumbling rotation of the bomb which may occur when the bomb is released into an air stream. The suspended exploding device should also cause the bomb to attain a near nose-down attitude at which the inherent stability characteristics of the bomb will determine whether or not it will seek and attain the desired stable descent with its longitudinal axis of symmetry in a vertical attitude. As indicated by the results obtained with body F, it appears impracticable to depend upon the restoring moment of the suspended exploding device to stabilize completely an inherently unstable bomb, inasmuch as an uneconomically heavy weight for the exploding device would be required if indeed it were possible at all. Rather, it appears that it may be more practicable to simply use a bomb whose inherent stability characteristics are such that it would tend to remain in or attain the desired vertical attitude once in or near it. In general, the results indicated that the descent characteristics of the bodies of revolution became more favorable as the shapes of the bodies approached that of a hemisphere. It should be noted that the six bodies of revolution investigated are sketched in figure 1 in order of their decreasing stability (A to F).

As indicated by the results of the investigation, it appears that a bomb similar to body F, which has ordinates suggested by the Office of the Chief of Ordnance, U. S. Army, may not be suitable unless its center of gravity is well forward, and that one of the other bodies described herein may therefore be useful as a compromise design. The relative drag of any bomb and exploding device selected should, of course, be such that the terminal velocity of the exploding device alone is greater than that of the bomb alone. In order to achieve such a condition, the effects of Reynolds number on the respective drags of each body may have to be considered. Possible changes in the nature of the air flow associated with Reynolds number may also have some effect on the inherent stability of any actual bomb used, and may have to be considered. The importance of proper relative drag for the bomb and exploding device was noted during the tunnel tests when a brief investigation of the effect of using a light-weight aluminum cylinder instead of the lead cylinder with body F resulted in the cylinder floating above the body.

CONCLUDING REMARKS

An investigation has been conducted in the Langley 20-foot free-spinning tunnel to study the relative behavior in descent of a number of homogeneous balsa bodies of revolution simulating possible anti-personnel bombs. The bodies were tested with and without a small cylindrical weight suspended below the body to simulate an exploding device. Several of the bodies had desirable descent characteristics in that they descended vertically with their longitudinal axis, suspension line, and small cylinder in a vertical attitude. However, one body, the ordinates of which were specified by the Office of the Chief of Ordnance, U. S. Army, oscillated considerably from a vertical attitude while descending and therefore appeared unsuitable for its intended purpose. The behavior of this body became satisfactory when its center of gravity was moved well forward from its original position. In general, the results indicated that the descent characteristics of the bodies of revolution became more favorable as their shapes approached that of a hemisphere.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

Stanley H. Scher

Stanley H. Scher
Aeronautical Research Scientist

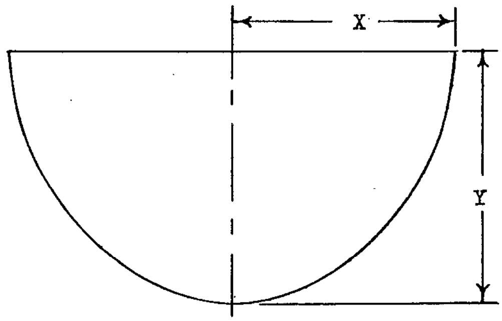
Approved: Thomas A. Harris

Thomas A. Harris
Chief of Stability Research Division

cig

TABLE I.- ORDINATES FOR BODIES OF REVOLUTION TESTED IN THE LANGLEY 20-FOOT FREE-SPINNING TUNNEL

[Values for X and Y in inches]



Body A

Hemisphere radius, 125 inches

Body B	
X	Y
0	0
.426	.084
.588	.169
.845	.338
.974	.507
1.123	.676
1.238	.845
1.326	1.014
1.373	1.184
1.427	1.353
1.461	1.522
1.475	1.691
1.488	1.772

Body C	
X	Y
0	0
.342	.097
.519	.195
.740	.389
.900	.584
1.030	.778
1.130	1.000
1.218	1.168
1.280	1.362
1.360	1.560
1.430	1.750
1.490	1.945
1.515	2.040

Body D	
X	Y
0	0
.373	.097
.521	.194
.746	.388
.886	.583
1.003	.777
1.112	.972
1.197	1.166
1.244	1.360
1.298	1.555
1.345	1.749
1.368	1.944
1.384	2.037

Body E	
X	Y
0	0
.322	.108
.488	.216
.695	.433
.840	.650
.965	.865
1.060	1.070
1.142	1.299
1.205	1.515
1.277	1.730
1.340	1.950
1.400	2.160
1.422	2.270

Body F	
X	Y
0	0
.310	.125
.470	.250
.670	.500
.810	.750
.930	1.000
1.000	1.250
1.100	1.500
1.160	1.750
1.230	2.000
1.280	2.250
1.350	2.500
1.370	2.620

[redacted]

TABLE II.- BEHAVIOR IN DESCENT OF VARIOUS BALSA BODIES OF REVOLUTION WITH SUSPENDED LEAD CYLINDER AS OBTAINED FROM LANGLEY 20-FOOT FREE-SPINNING-TUNNEL TESTS

Body (see fig. 1)	Behavior of body in descent	Descent velocity (fps)
A	Trimmed in nose vertically down attitude; no horizontal travel in tunnel	41.0
B	----------do----------	51.0
C	Trimmed generally in nose vertically down attitude; made occasional oscillations of $\pm 5^\circ$	51.0
D	Trimmed generally in nose vertically down attitude; traveled horizontally in tunnel very slowly	56.4
E	Trimmed generally in nose vertically down attitude; made occasional oscillations of $\pm 5^\circ$ and traveled horizontally in tunnel very slowly	56.4
F	[a]Oscillated $\pm 35^\circ$ to $\pm 45^\circ$ from nose vertically down attitude; rate of oscillation was 0.54 second per cycle	44.7

[a]When the suspension weight was increased to 32.5 grams, oscillation was $\pm 17^\circ$ to 20°; rate was 0.30 second per cycle and rate of descent was 68.8 feet per second.

TABLE III.- RATES OR DESCENT AND OF ROTATION OF VARIOUS

BALSA BODIES OF REVOLUTION WITHOUT SUSPENDED LEAD

CYLINDER AS OBTAINED FROM LANGLEY 20-FOOT

FREE-SPINNING-TUNNEL TESTS

Body (see fig. 1)	Rate of descent when in nose vertically down attitude (fps)	Rate of descent when tumbling (fps)	Approximate rate of tumbling rotation (rps) (a)
A	39.8	(b)	(b)
B	46.5	35	6.00
C	49.0	37	5.00
D	51.0	35	3.25
E	53.0	38	6.5
F	(c)	38	3.2

[a]Difficult to determine equilibrium tumbling rate because of lateral travel of bodies in limited tunnel test area.

[b]Data film not clear.

[c]Body F did not descend in nose-down attitude.

[redacted]

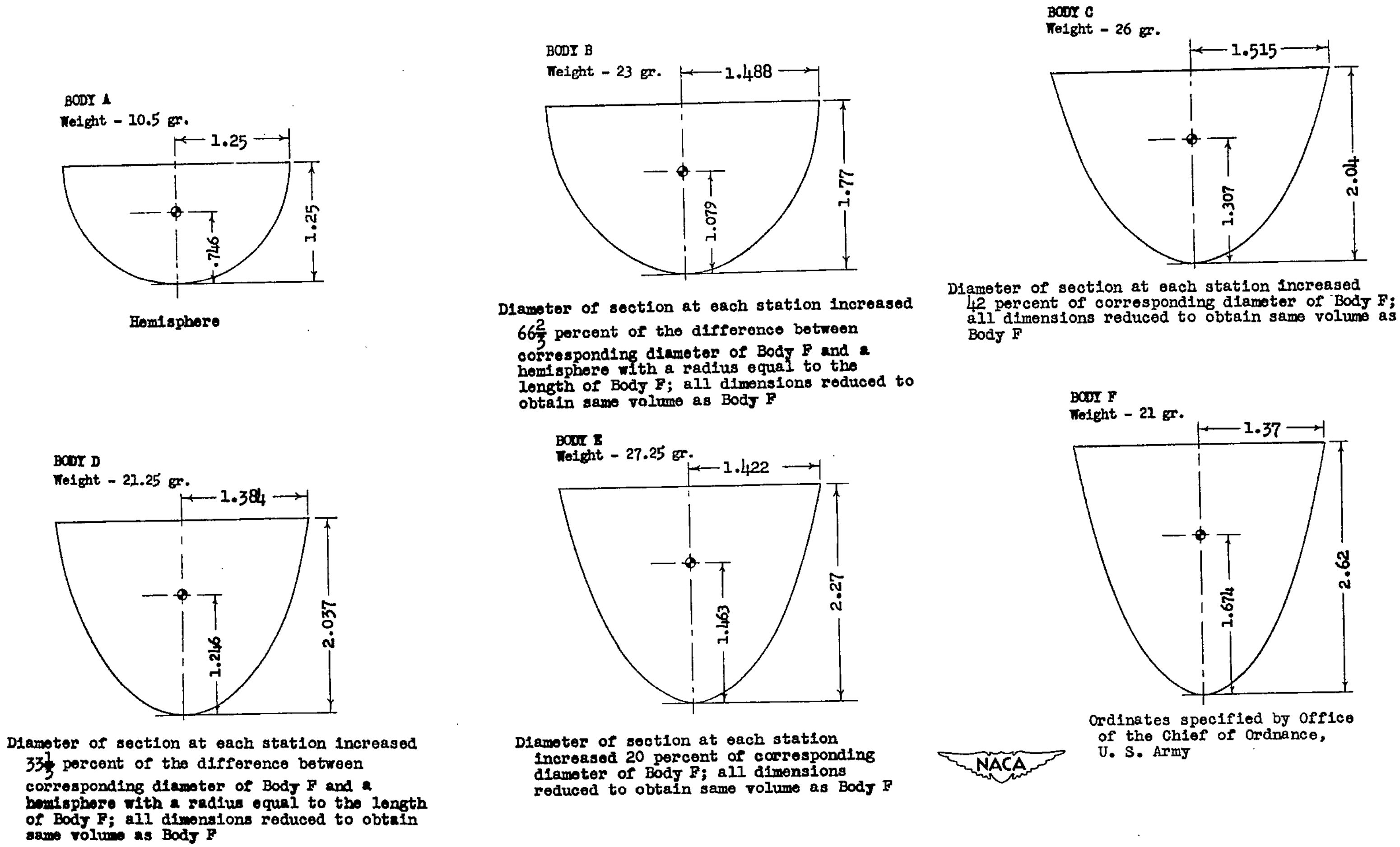


Figure 1.- Sketches of bodies of revolution tested in the Langley 20-foot free-spinning tunnel. Dimensions given in inches.

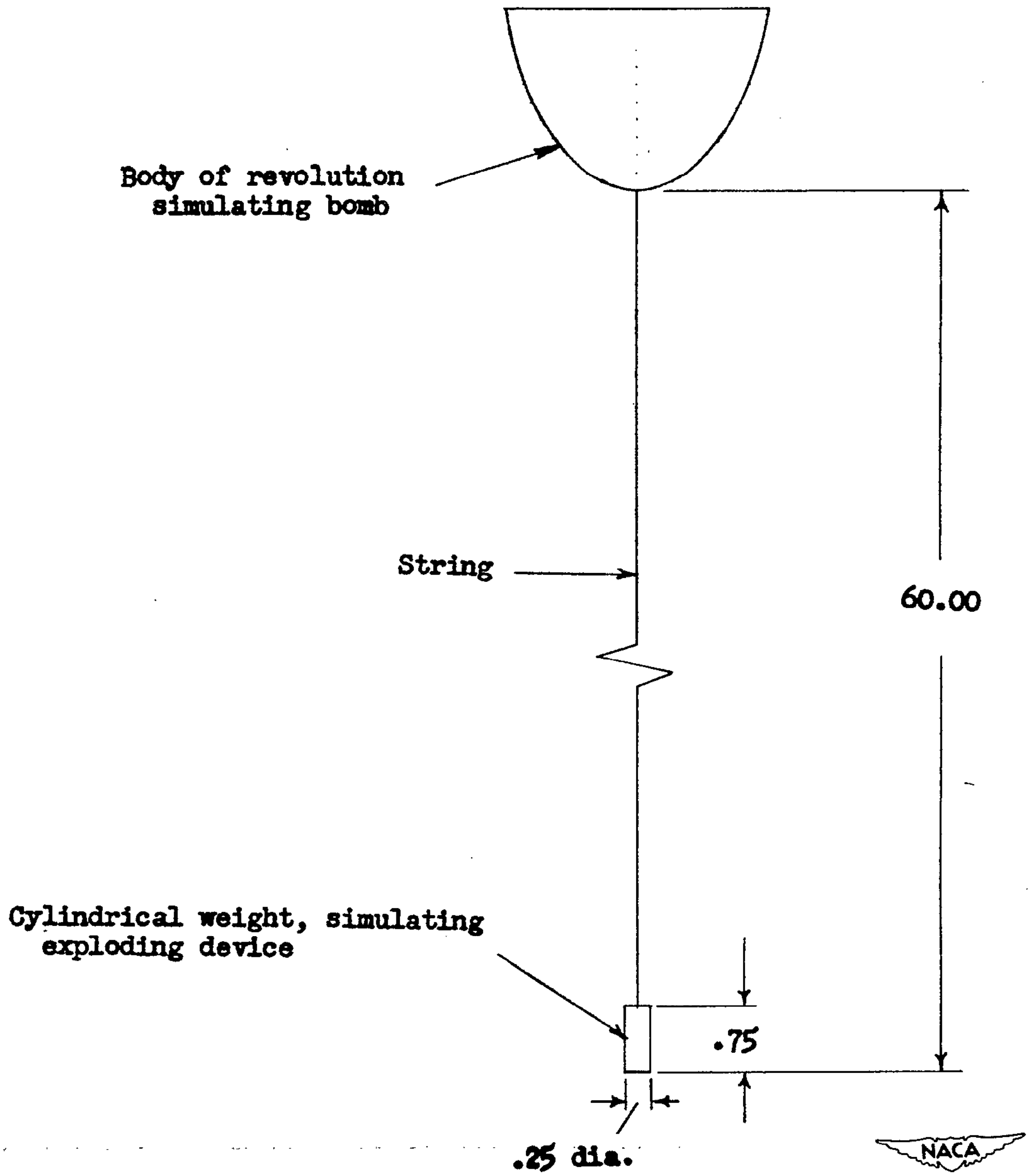


Figure 2.- Sketch illustrating configurations tested, simulating bomb and exploding device.

INDEX

Subject	Number
Bodies - Shape Variables	1.3.2

ABSTRACT

Presented herein are the results of Langley 20-foot free-spinning-tunnel tests made to determine the behavior in descent of a number of bodies of revolution simulating bombs, with and without a small cylindrical weight suspended below the body to simulate an exploding device. Body shapes tested included hemispheres, near-hemispheres, and near-paraboloids.