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RESEARCH MEMORANDUM

EXPERIMENTAL TECHNIQUES FOR PREDICTING STORE MOTIONS DURING RELEASE OR EJECTION

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
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EXPERIMENTAL TECHNIQUES FOR PREDICTING STORE MOTIONS DURING RELEASE OR EJECTION

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SUMMARY

A discussion is presented of experimental methods for determining store-release trajectories at supersonic speeds from measured force data on scale models and from dynamic-model tests. The dynamic-similarity laws which are significant when conducting either free-fall or ejected dynamic-model tests are presented and discussed. Results from force tests and dynamic-model tests were used in an effort to evaluate the ability of both techniques to predict full-scale-release trajectories.

INTRODUCTION

With the development of supersonic bombers, the problems of bomb release have become increasingly important. The extremely turbulent and random flow within the open bomb bay, as well as the nonuniform flow field surrounding the airplane, can cause bomb-release motions that endanger the airplane and seriously affect bombing accuracy.

In view of the danger to airplane and crew, it is necessary that the nature of the release be studied before full-scale tests are attempted. This paper presents a discussion of methods for determining store-release trajectories from measured force data on scale models and from dynamic-model tests.

The trajectory of the store following release may be calculated by a step-by-step process, provided that sufficient knowledge of the flow disturbances from the mother ship within the region of possible store trajectories is known. These disturbances have been measured in terms of aerodynamic forces and moments in the Langley 4- by 4-foot supersonic pressure tunnel for a number of store shapes. The results from tests such as these may be used for determining trajectories for any desired set of release conditions, such as angle of attack, altitude, and ejection method.

Store-release trajectories may also be determined from dynamic-model tests. Investigations of this type using ejected stores have been conducted in the preflight jet of the Langley Pilotless Aircraft Research

Station at Wallops Island, Va. Although such tests may be used only for the particular altitude and release conditions simulated, the data, which are given by a Strobolight photograph of the store model's motion, are available for interpretation almost immediately following the tests. Thus, various fixes may be intelligently developed during the test period.

SYMBOLS

$V_{z,0}$	initial vertical ejection velocity, positive downward
z	vertical distance traveled
x	horizontal distance traveled
t	time
l	bomb length
θ	bomb attitude angle to horizontal
M	Mach number
F	fineness ratio of bomb
C_m	pitching-moment coefficient
$C_{m_\alpha} = \dfrac{\partial C_m}{\partial \alpha_{bomb}}$	
α	angle of attack of both bomb and airplane
Δt	increment of time
$C_{m_q} = \dfrac{\partial C_m}{\partial \frac{ql}{2V}}$ per degree	

RESULTS AND DISCUSSION

The setup for the force test is shown in figure 1. Both the wing-body configuration, used as a mother ship, and the store were mounted on six-component balances. During the test period, the wing-body configuration was traversed vertically at several horizontal locations with respect to the store. These traverses were made with the wing-body configuration at angles of attack of 0°, 4°, and 8° and with the store at various attitude angles ranging from -15° to 15° in 5° increments. The force tests were made at $M = 1.6$.

Also shown in figure 1 is a series of store shapes on which data have been obtained. The fineness ratio of these shapes varied from 2.5 to 10. Data on several bluff stores were also obtained.

Typical results obtained from the force tests are shown in figure 2 which is a contour plot of C_m about the 50-percent station for the fineness-ratio-4 store at zero attitude angle. The value assigned to a particular contour line is the moment coefficient experienced when the store midpoint lies on that line. Plots similar to this one are also obtained for C_D and C_L. A complete set of plots for each store attitude angle is required in order that trajectory computations may be carried out. Some idea of the flow angularity in the vicinity of the bomb bay may be obtained from consideration of the fact that $C_{m_{\alpha}} = -0.02$ for this store. Thus, for the $C_m = 0.12$ contour line, the angularity is equivalent to 6°.

Figure 3 illustrates several factors which might affect the accuracy of trajectories obtained by step-by-step calculations. This is shown by plots of bomb attitude angle against time for the period immediately following release. The first time-history plot shown compares results obtained when a uniform-flow field is used rather than the interference flow existing in the vicinity of the airplane as obtained with the force-measurement technique. From this comparison it is obvious that a knowledge of the interference forces and moments acting on the bomb is necessary in order that accurate predictions of its trajectory may be made. In the second plot, the effect of time increment used in the step-by-step calculation is shown and indicates that small time increments are required for obtaining a suitable accuracy. Experience indicates that angular changes between successive steps should be kept to less than 1°. Only static aerodynamic coefficients are obtained in the force technique. In the third plot, the effect of damping is shown to play a rather minor part in the motion immediately following release. Here, the motion determined by consideration of static forces only is compared with the motion obtained when a damping term is included. The value $C_{m_q} = 0.12$ was obtained analytically by the method outlined in reference 1.

The setup used for making dynamic-model tests is illustrated in figure 4. The photograph shows the wing-fuselage configuration, from which the store was released, mounted in the stream of the blowdown jet. A store is shown mounted in a semisubmerged position from which some of the stores were ejected. Also shown are the camera which took pictures of the model's motion and the bank of Strobolight bulbs which was used for illumination. The test was run as follows: First the tunnel was started and stabilized at operating pressure; then the shutter of the camera was opened. Simultaneously, the store was ejected and the Strobolights were fired in sequence at accurately timed intervals by an electronic timer. Dynamic-model tests were made at $M = 0.8$, 1.4, 1.6, and 2.0.

A typical photograph taken by the camera is shown in figure 5. This figure shows the ejection of a store at $M = 1.4$ with an initial velocity of 30 fps. The images of the store in the photograph are for 2-millisecond time intervals and, as can be seen, the motion of the store is graphically recorded. Data are obtained from the photograph by measuring the vertical and horizontal distances traveled as well as the store attitude angle for each image.

The following discussion lists the requirements to be met for dynamic similarity. First, the model must have the proper center-of-gravity location in order that the aerodynamic forces act about the correct axis and thereby provide correct aerodynamic moment coefficients. In order that the undamped rotary motion of the model be coordinated with the translational motion produced by aerodynamic forces, the model's moment of inertia must be properly related to its mass. This is accomplished by keeping the radius of gyration proportional to the model size. In other words, the mass distribution of the model must be similar to that of the full-scale store. In determining the density of the model, the engineer is faced with conflicting requirements. Proper simulation of damping requires that the ratio of store density to dynamic pressure be kept the same, regardless of scale; whereas, if the gravitational forces are to be kept in proportion to aerodynamic forces, it is required that the ratio of store density to dynamic pressure be inversely proportional to the scale. It should be noted that, for a 1/20-scale test, the model which properly simulates gravity is twenty times as heavy as one in which the damping is properly simulated.

Previous tests, such as those presented in references 2 and 3, have used heavy models which properly simulated the effect of gravity. Since aerodynamic damping was not simulated, the results from tests such as these may be considered conservative provided the moment of inertia is properly scaled. It should be noted, however, that it is not always possible to simulate gravity properly, since the store model may not always be made as heavy as required. This is most apt to be the case when a small scale is used, when the full-scale conditions are at a high altitude, and when a high-density tunnel is used. The heaviest model which can be made is, of course, a solid one. Such a model will invariably have a higher moment of inertia than proper similitude would call for. Tests run with models of this type may be misleading in that the model will be slow to respond to pitching disturbances, and, thereby, not truly represent the severity of these disturbances.

In the dynamic-model tests discussed in this paper, the models were ejected from the bomb bay with a high initial velocity. With this condition, the effect of gravity on the vertical motion of the model is negligible for a short period of time after release. Since it was not considered necessary to simulate gravity, light models were used which properly simulated damping.

The effect of not properly simulating gravity is shown in figure 6. The trajectories shown in this figure were obtained by using the force data to predict the motion of a full-scale store and a 1/20-scale model for three different initial release conditions. The first case is for a free drop with no ejection. It can be seen that the motion of the model falls far short of simulating the motion of the full-scale article. In the next case, a 15-fps ejection velocity is used. It can be seen that the model test agrees fairly well with the actual full-scale case. In the last store position shown, the full-scale store is 17 percent farther down from the release position than would be predicted by the model test. With the initial velocity increased to 30 fps, the dynamic-model tests give a very good picture of the full-scale case. The error in vertical position is about one-half of that shown for the 15-fps ejection.

Figure 7 shows the comparison obtained with dynamic-model tests and calculations for the conditions of this test using force data. The model was ejected at 30 fps at $M = 1.61$ from the wing-body configuration at 4° angle of attack. The calculated time histories of vertical position, horizontal position, and store-attitude angle are shown as solid lines. The data from the dynamic-model tests are shown by circular symbols. The calculations satisfactorily predicted the vertical and horizontal motion of the store, but failed to predict the pitching motion of the store. This is accounted for by the fact that the force balance tests were conducted without the store support which was used to eject the stores in the dynamic-model tests. It is apparent that this support caused an interference large enough to reduce the initial pitching-down moment which was measured in the force tests. Thus, in the dynamic-model tests, the store was not as greatly disturbed as was predicted. These results indicate that details in the bomb bay may have a strong influence on the motion of the stores; and, therefore, as far as is possible, model tests should include all the pertinent details of the full-scale bomb bay.

The experiments conducted with the force tests and the dynamic-model tests include a wide variety of store shapes for many conditions.

Accordingly, before closing, it should be pointed out that large changes in bomb motion may result when configuration changes are made. Figures 5 and 8 are photographs taken of two dynamic-model tests using stores that differed in frontal area and fineness ratio. Both stores are closely similar in length, weight, moment of inertia, and stability. Both were ejected at 30 fps at $M = 1.4$. It can be seen that the fineness-ratio-8.5 store made a very good separation; whereas the low-fineness-ratio, less dense store pitched up, reversed its initial vertical direction, and almost hit the rear of the fuselage. Results such as those make it apparent that separation of stores at supersonic speeds should not be attempted without first obtaining conclusive information from which the path of the stores may be predicted. At present, model tests such as those just described are a requirement for such a prediction. Considerable effort is currently being expended, however, to obtain a more general understanding of the problem.

CONCLUDING REMARKS

Various methods of conducting dynamic-model tests as well as a calculation procedure utilizing measured force data have been outlined and discussed. It was shown that the light-model technique (when damping is simulated) is a valid test procedure for reasonably low ejection velocities but not for bombs released without ejection. A comparison of data from an actual model bomb drop with a calculated drop for similar conditions indicated but did not prove the validity of the calculative procedure. The importance of duplicating as far as is possible all details of the bomb and bomb bay was emphasized in the previously mentioned comparison and in a comparison of the dynamic-model release of a fineness-ratio-6 and a fineness-ratio-8.5 bomb.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 3, 1955.

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2. O'Hara, J. C.: Wind Tunnel Similitude of Full-Scale Bomb Trajectories. Rep. No. BF-490-D-14, Cornell Aero. Lab., Inc., May 1952.

3. Rainey, Robert W.: A Wind-Tunnel Investigation of Bomb Release at a Mach Number of 1.62. NACA RM L53L29, 1954.

MODELS USED IN FORCE TESTS

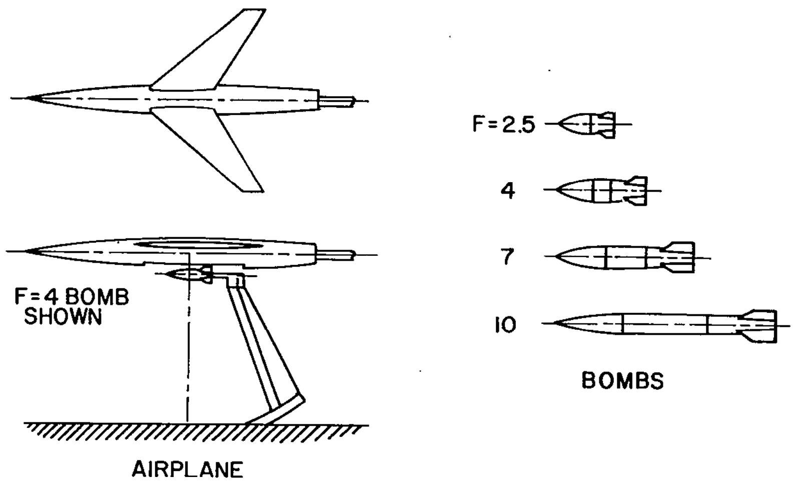


Figure 1

SAMPLE CONTOUR PLOT OF FORCE-TEST DATA
α (AIRPLANE) = 4°; θ (BOMB) = 0°

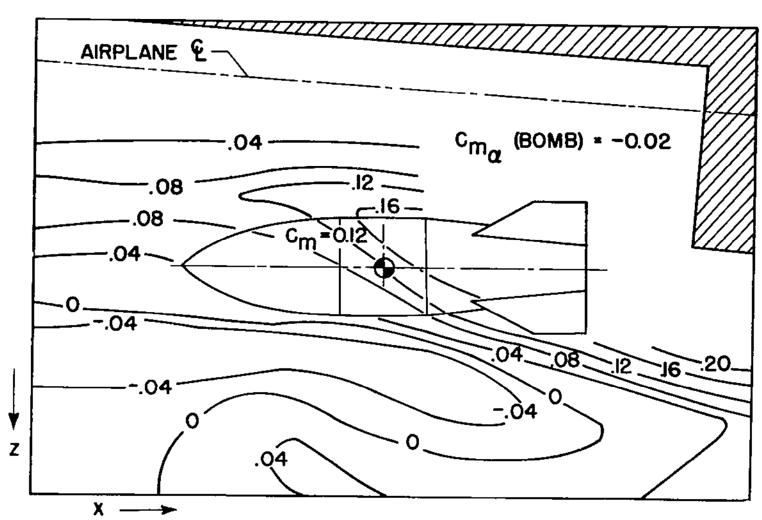


Figure 2

FACTORS INFLUENCING ACCURACY OF CALCULATED RELEASE

INTERFERENCE AND DAMPING INCLUDED; $\Delta t = 0.005$ UNLESS OTHERWISE NOTED

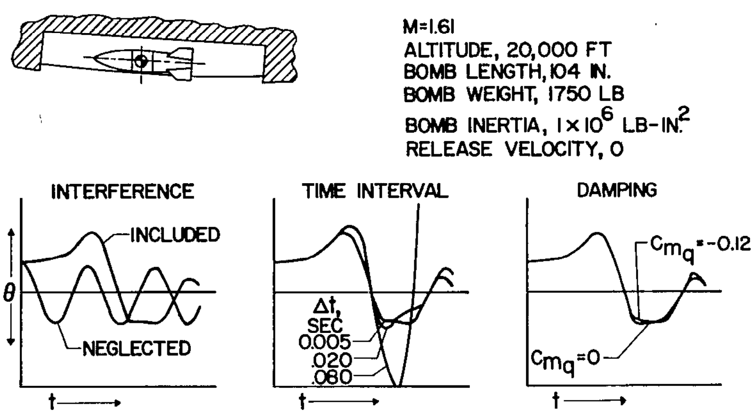
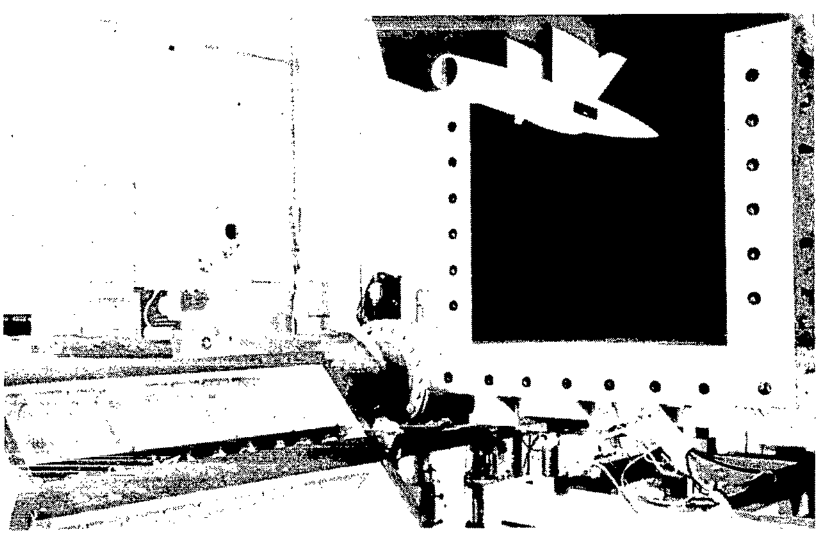


Figure 3

TEST SETUP USED IN DYNAMIC-MODEL TESTS



L-91200

Figure 4

DYNAMIC RELEASE OF STORE OF FINENESS RATIO 8.5

L-91133

Figure 5

CALCULATED EFFECT OF EJECTION VELOCITY
ON SIMULATION

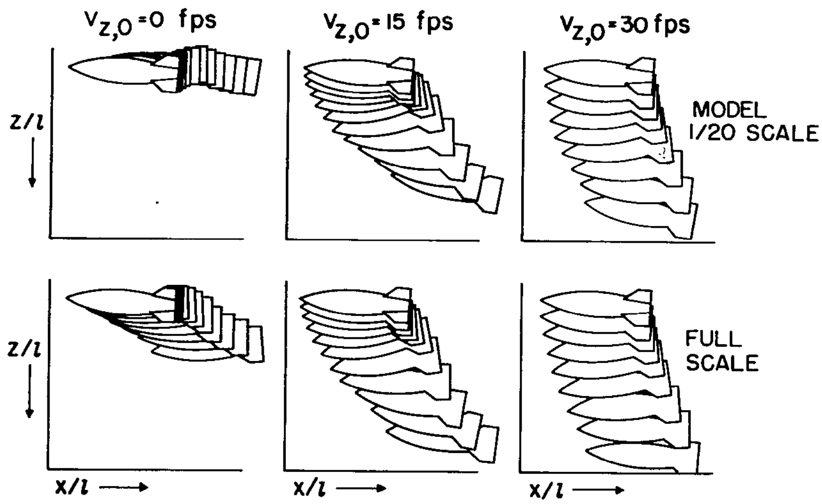


Figure 6

CALCULATED RELEASE COMPARED WITH ACTUAL MODEL DROP

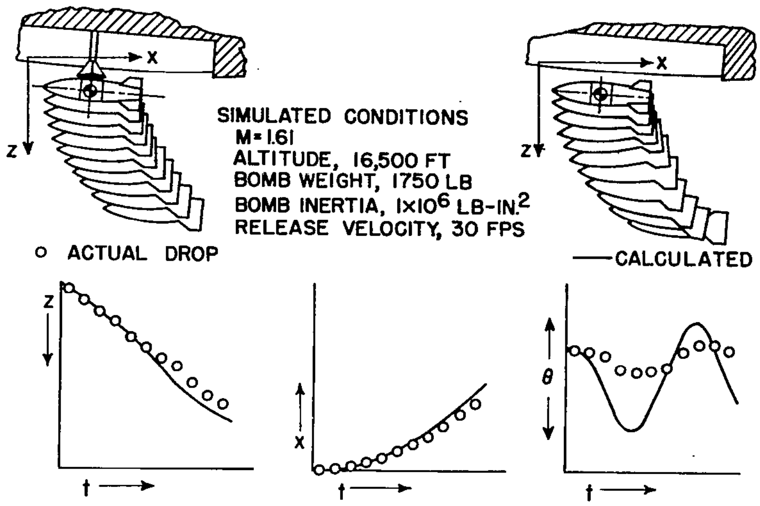


Figure 7

DYNAMIC RELEASE OF STORE OF FINENESS RATIO 6

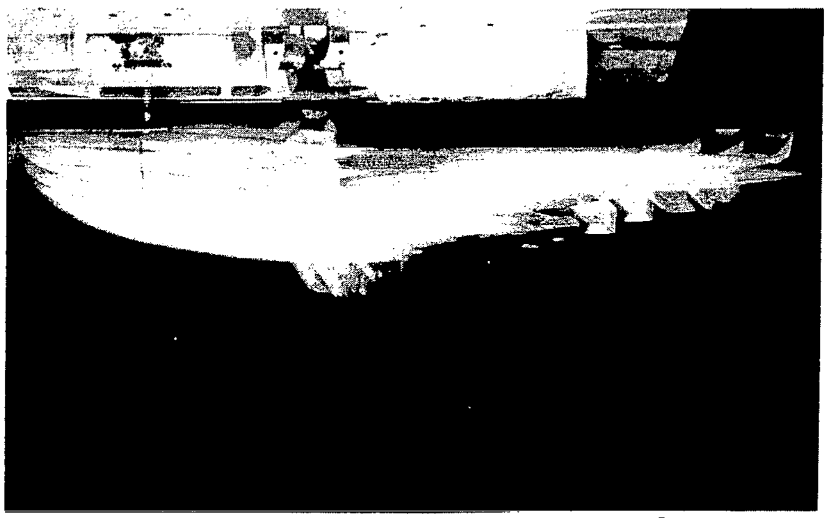


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Figure 8

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