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CORRELATION TESTS OF THE DITCHING
BEHAVIOR OF AN ARMY B-24D AIRPLANE
AND A $\frac{1}{16}$ -SIZE MODEL

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Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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NACA LANGLEY MEMORIAL AERONAUTICAL LABORATORY

MEMORANDUM REPORT

for the

Air Technical Service Command, Army Air Forces

MR No. L6A03

CORRELATION TESTS OF THE DITCHING
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SUMMARY

Tests were conducted to correlate model and full-scale ditching performances for the Army B-24D airplane. A dynamically similar model of the B-24D airplane was ditched in calm water in Langley tank no. 2 and from an outdoor catapult. A full-scale B-24D airplane was ditched under controlled conditions in calm water in the James River near Langley Field, Va. The behaviors of both model and full-scale airplane were ascertained by making visual observations, by recording time histories of decelerations, and by taking motion picture records of the ditchings. The results are presented in the form of sequence photographs and time-history curves for attitudes, vertical and horizontal displacements, and longitudinal decelerations.

Conclusions based on one full-scale test and several model tests were as follows:

1. Wing lift was an important factor in model ditching tests and the most accurate simulation of full-scale performance was obtained by ditching the model at such speeds as were necessary to obtain the correct lift even though ground speed and airspeed were slightly in error.
2. The time-history curves for attitudes and horizontal and vertical displacements for model and full-scale tests were in reasonable agreement.
3. The maximum longitudinal decelerations for model and full-scale ditchings did not necessarily occur at

the same part of the run and the full-scale maximum deceleration was about 50 percent greater.

4. The dynamic behavior of the model was affected very little by the break in the fuselage that occurred near the end of the run.

INTRODUCTION

In model investigations of the present type it is desirable to obtain a check on the accuracy of the work by correlation with full-scale tests as some factors that cannot conveniently be made to have the correct scale relationship to the full-size prototype are neglected. By maintaining the correct scale relationship for those factors that have a major influence on the quantities that it is desired to measure, model tests can be made to yield useful results that are only slightly in error because of the factors that are not to scale.

A considerable number of ditching tests have been made with dynamic models for the purpose of evaluating the ditching performance of actual airplanes. Reports of survivors from airplane ditchings have indicated that the model results have been substantially correct as far as could be determined but quantitative data have been unobtainable from such reports. Furthermore, an actual ditching is so hazardous that the crew must direct all their attention towards measures for survival and accurate observations cannot be expected of them under such conditions.

With the cooperation of the Air Technical Service Command, Army Air Forces, an experimental full-scale ditching has been made with a B-24D airplane. In order to minimize damage and the hazards to the pilots, the airplane was reinforced extensively. One of the purposes of this experiment was to determine if airplane and model performances would be in agreement. A series of photographs were made of the full-scale ditching with an Army K-24 aerial camera. Other data for the full-scale ditching were obtained from phototheodolite records made by the Langley Flight Research Division and from accelerometer records made by the Langley Impact Loads section (reference 1).

Extensive damage to the fuselage can generally be expected in a ditching. Since this damage changes the configuration of the fuselage it affects the motion of the airplane. In making model tests a range of damage conditions is generally investigated and the variation in ditching performance thereby obtained gives the range of performance that may be expected in a number of full-scale ditchings as a consequence of variation in the amount of damage that may occur.

Of the various damage conditions that had been investigated in the model tests, there were none that very closely simulated the damage sustained by the airplane in the full-scale experiment because the airplane was reinforced at places that were very weak and normally considered to fail in ditching. In order to obtain a complete and rigorous comparison, tests have been made with the damage that occurred in the full-scale ditching accurately simulated on the model and in these tests the motion of the model was more completely recorded than it is in the usual model tests. The results from the more complete model test are herein compared with those from the full-scale experiment.

The tests were requested by the Air Technical Service Command, Army Air Forces, on March 26, 1943. The model tests were made in Langley tank number 2 and on an outdoor catapult. The full-scale tests were made in the James River near Langley Field, Va.

APPARATUS AND PROCEDURE

An Army B-24D airplane stripped of all excess equipment was used in the full-scale test. The nose windows, the bomb bays, and the belly turret hole were covered with steel plate and the entire bottom was reinforced with steel and plywood ribs. A photograph of the airplane after ditching is shown in figure 1. A large transverse dent was made in the steel plate at

the after part of the rear bomb bays very soon after contact with the water; a portion of the fuselage just aft of the steel plate over the belly turret hole was torn away; and when the airplane nosed down so that the nose entered the water, the area around the nose-wheel doors was demolished. Near the end of the run, the fuselage was broken almost in two parts at the leading edge of the wing.

A $\frac{1}{16}$ -size dynamically similar model of the airplane was used in the model tests. A description of the type of construction used on the model is given in reference 2. Photographs of the model as tested are shown in figure 2. Complete damage was simulated on the model by removing the damaged sections. Dents were simulated by making indentations in the model. The break in the fuselage of the full-scale airplane was simulated on the model by cutting the fuselage in two parts and hinging it at the top. The two parts of the fuselage were held together by a calibrated restraint which broke at approximately the same part of the ditching run as did the fuselage of the full-scale airplane. The "broken fuselage" is shown in figure 2(b). Damage was simulated on the model before the model was ditched whereas damage to the full-scale airplane occurred progressively during the ditching. In order to determine if the breaking of the fuselage had any effect on the performance of the model, a few tests were made in which the fuselage was not permitted to break.

The apparatus and test procedures used in the model tests were similar to those described in reference 2. The usual motion pictures were taken during the tests but horizontal and vertical reference lines and a timer were provided in the background so that more accurate data on the motions of the model could be obtained. Time histories of attitude and horizontal and vertical displacements of the model were measured from the motion picture records. However, the motion pictures obtained in the catapult tests did not permit measurement of vertical displacements with sufficient accuracy to be usable. A number of runs were made in the model tests but data were read from only a few runs. In the tank tests, data were read for six runs in which the fuselage broke and for one run in which the fuselage did not break. In the catapult tests, data were read for one run in which the fuselage broke. Decelerations were measured with a special recording accelerometer developed for use in model ditching tests.

The airplane was ditched at a gross weight of 44,100 pounds with the center of gravity at 30.9 percent of the mean aerodynamic chord. The flaps were down 40° and the attitude of the thrust line at contact with the water was 7.7° . The landing was made into a quartering wind blowing approximately 5 miles per hour. The water surface was slightly rippled. Partial power was used and the ground speed at the instant of landing was 97 miles per hour.

The model was ditched at conditions as nearly as possible comparable to those of the airplane. The lift increment obtained on the airplane by the use of partial power was not available on the unpowered model. Consequently in the model tests in order for the model to be fully airborne it had to be landed at greater than scale airspeed. This could be done either by landing at greater than scale ground speed or into a head wind. The tank tests reported herein were made at scaled ground speeds corresponding to 97 and 102 miles per hour. When there was no head wind in the tank, the model was not fully airborne at the 97 miles per hour speed but was fully airborne at the 102 miles per hour speed. On some runs there was sufficient head wind to make the model airborne at the 97 miles per hour ground speed. The head wind was present in the tank because of wind blowing through an opening made in the siding of the tank building to provide light for high-speed motion pictures of the ditching tests. In the outdoor catapult test, the model was landed at a scaled ground speed corresponding to 97 miles per hour with a head wind sufficient to make the model fully airborne. The smooth water surface in the tank corresponded to a glassy calm. In the catapult test, the water was slightly rippled.

RESULTS AND DISCUSSION

The results of the model tests and the full-scale test are compared by time-history curves of attitude, vertical and horizontal displacement, and longitudinal decelerations in figure 3. Typical results of the full-scale, catapult, and tank tests are given. The shaded areas of figure 3 show envelopes of data for four runs made in the tank tests. The results for the airborne model at ground speeds corresponding to both 97 and 102 miles per hour are included in this envelope. Ditchings corresponding to 102 miles per hour tended to be nearer

the top of the envelopes than those corresponding to 97 miles per hour. Because of instrument failure, decelerations were obtained on only two runs in the tank tests so an envelope for decelerations is not shown. Figure 3 also shows results of tests in which the model was not fully airborne at a ground speed corresponding to 97 miles per hour. Sequence photographs of the full-scale and airborne model ditching tests are shown in figure 4.

In the first second after contact the attitude of the full-scale airplane increased from about $7\frac{1}{2}^{\circ}$ to about 14° . (See fig. 3.) At this high attitude the wing seemed to lose lift and the airplane fell off on the port side, settling in the water very quickly. At the end of the run the airplane dived slightly and the fuselage was broken just forward of the wing. The length of the ditching run was about 435 feet and the duration was about 6.2 seconds. The highest longitudinal deceleration for the full-scale test (2.7g) occurred when the nose settled into the water after the wing stalled (probably the point at which maximum damage occurred).

The airborne model in both tank and catapult tests nosed down slightly when it first touched the water but nosed up to about 13° in about 1.4 seconds (full scale) after contact. As the speed reduced, the nose plowed deep in the water and the run ended in a slight dive. The restraint broke near the end of the run allowing the nose to pivot about the hinge. The average length of run in the tank test was about 370 feet (full scale) and the duration was about 5.8 seconds (full scale). The highest longitudinal decelerations (1.6g and 1.9g) occurred at the beginning of the ditching run (maximum damage was in effect at this time). The length of run in the catapult tests was about 320 feet (full scale) and the duration was about 5.4 seconds (full scale). The highest longitudinal deceleration (2g) occurred when the nose settled deepest into the water.

In general, the curves for the test in which the fuselage did not break fell between the envelopes of the curves for the tests in which the fuselage broke. The break in the fuselage occurred very near the end of the run after a great deal of the energy was spent.

The curves for the tests in which the model was not fully airborne show typical results. In one case the model did not nose up as much as when airborne and the vertical and horizontal displacements were smaller. In the other case the model dived.

It is apparent that when the wing lift was inadequate the model gave a less accurate simulation of the motion of the airplane than it did when the model was fully airborne. The results of the present tests indicate that the most accurate results are obtained by landing models at such speeds as are necessary to obtain the correct lift and accepting the small errors in ground speed and airspeed that are unavoidable.

In the present tests when the model was airborne it made the same type of run that the airplane did. An evaluation of the ditching performance of the airplane would not be appreciably affected by the differences in attitude and displacements that were obtained in the full-scale and model tests. However, maximum decelerations were about 50 percent lower in the model tests than in the full-scale tests and they did not occur at the same part of the ditching run. These differences are due in part to the fact that damage was simulated on the model before ditching, whereas damage on the airplane occurred progressively during ditching. The differences are also due in part to the statistical problem of comparing one full-scale test with a number of model tests from which a scattering of points were obtained. If an equivalent number of full-scale and model tests had been made, it is possible that a similar scattering of points would have occurred and an envelope of the results of the full-scale tests and an envelope of the results of the model tests would have overlapped.

CONCLUSIONS

There is a statistical problem in comparing one full-scale test with several model tests from which a scattering of points were obtained and with this in mind the conclusions for the present tests are as follows:

1. Wing lift was an important factor in model ditching tests and the most accurate simulation of

full-scale performance was obtained by ditching the model at such speeds as were necessary to obtain the correct lift even though ground speed and airspeed were slightly in error.

2. The time history curves for attitudes and horizontal and vertical displacements for both model and full-scale tests were in reasonable agreement.

3. The maximum longitudinal decelerations for model and full-scale ditchings did not necessarily occur at the same part of the run and the full-scale maximum deceleration was about 50 percent greater.

4. The dynamic behavior of the model was affected very little by the break in the fuselage that occurred near the end of the run.

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1. Steiner, Margaret F.: Accelerations and Bottom Pressures Measured on a B-24D Airplane in a Ditching Test. NACA MR No. L4K14, 1944.
2. Fisher, Lloyd J., and Steiner, Margaret F.: Ditching Tests with a 1/12 Size Model of the Army B-26 Airplane in NACA Tank No. 2 and on an Outdoor Catapult. NACA MR, Aug. 15, 1944.

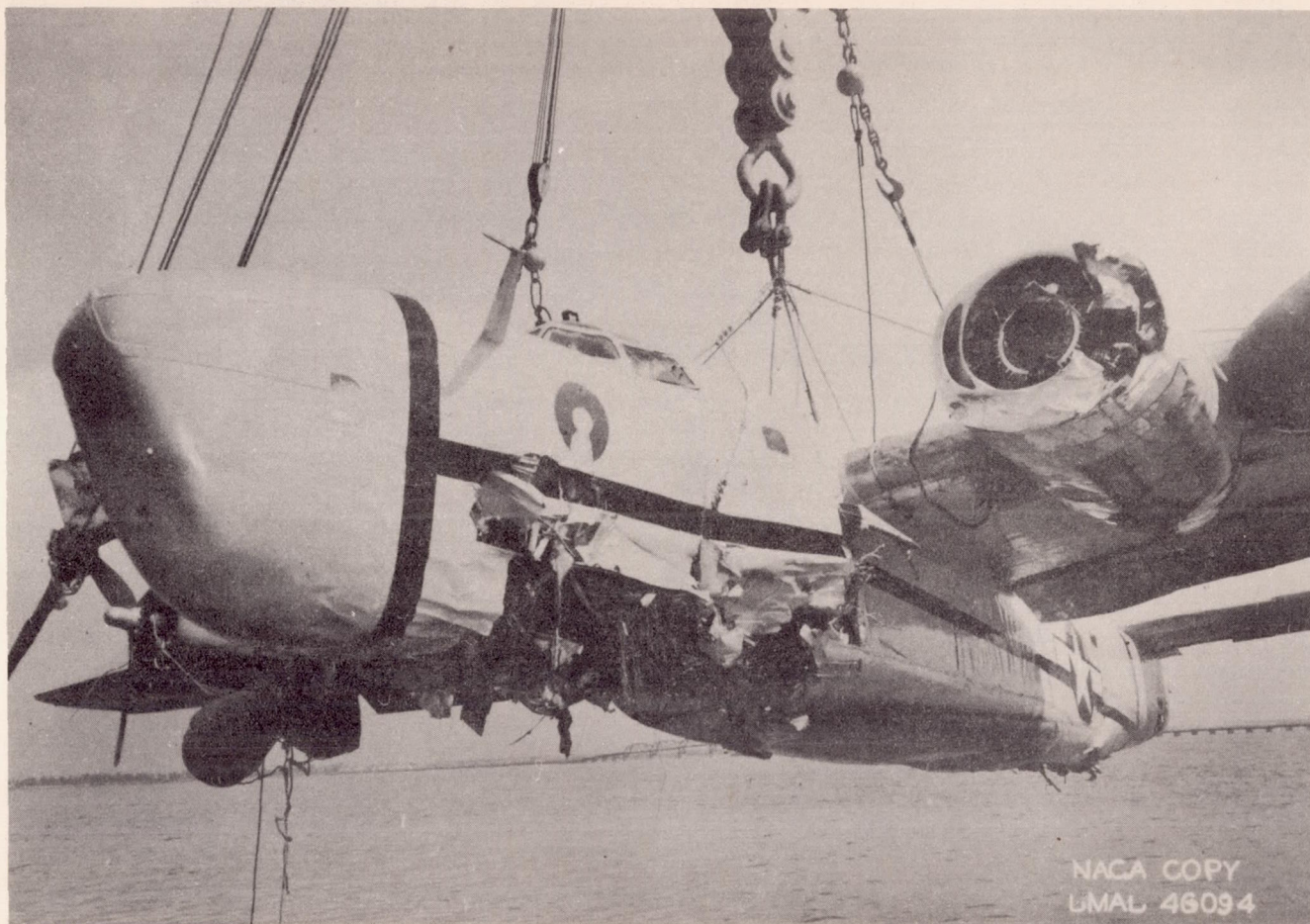
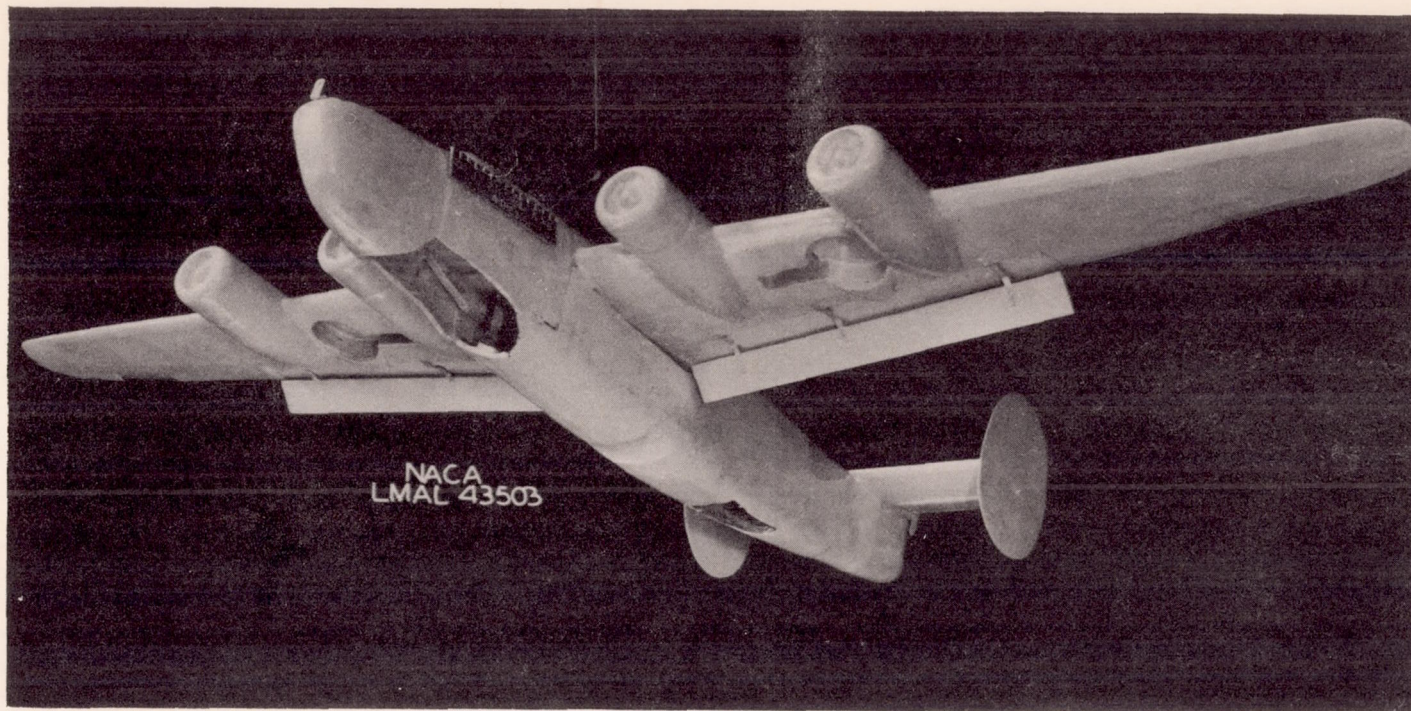


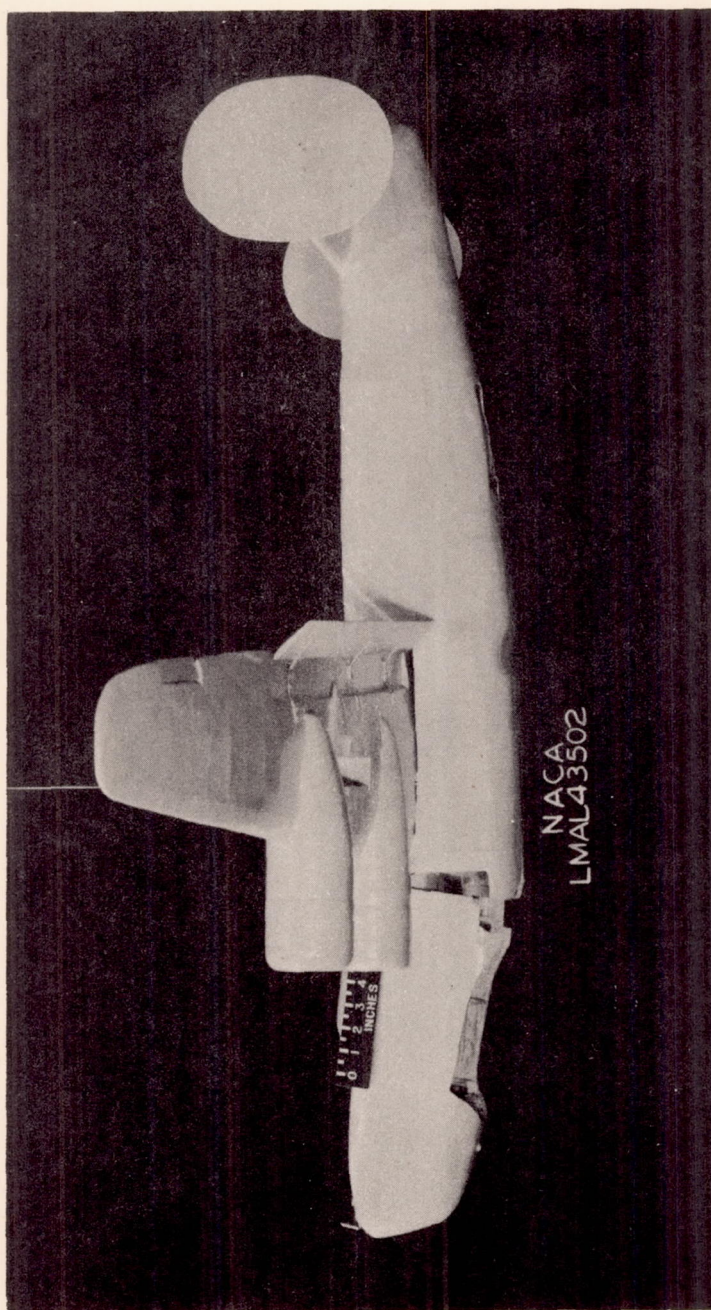
Figure 1.- Photograph showing the damage sustained by the Army B-24D airplane in the test ditching.



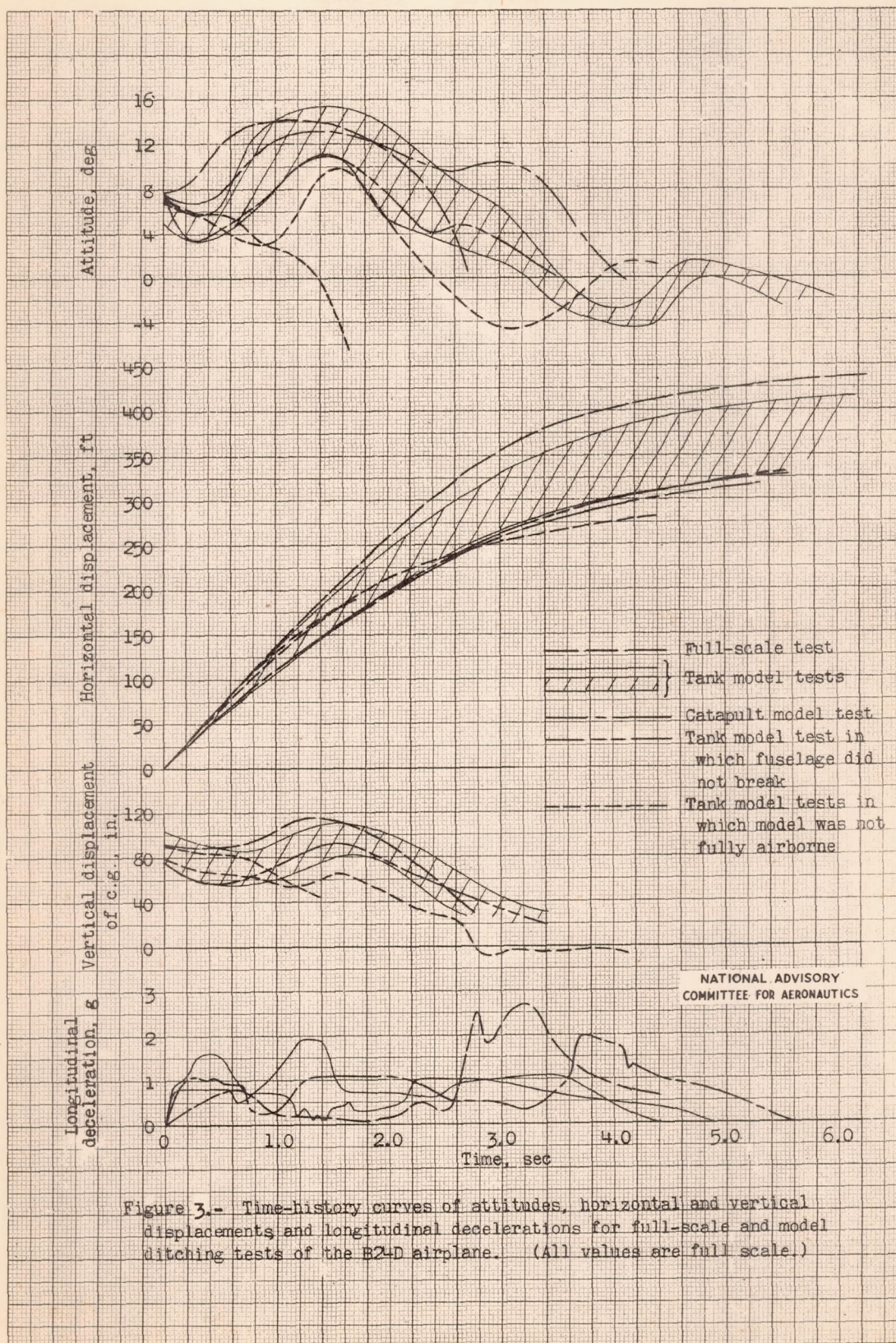
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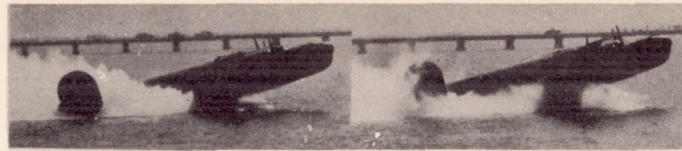
Figure 2.- Photograph of a $\frac{1}{16}$ -size model of the Army B-24D airplane showing damage to the fuselage which simulates the damage sustained by the full-scale B-24D in the test ditching.

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(b) Fuselage broken.
Figure 2.- Concluded.





.79

1.13

Time, sec. (full scale)
Full-scale test



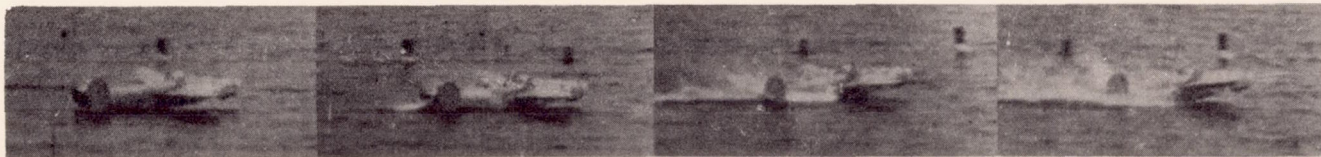
0

.33

.67

1.00

Time, sec. (full scale)
Model test (tank)



0

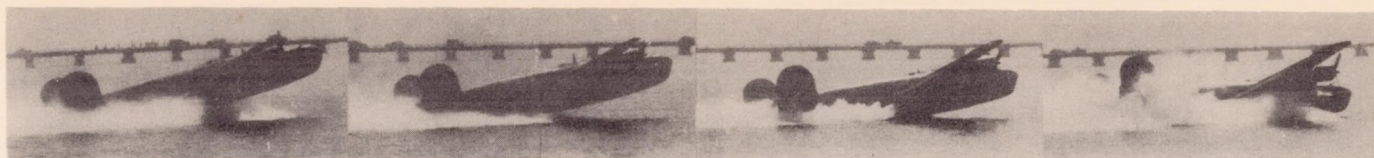
.33

.67

1.00

Time, sec. (full scale)
Model test (catapult)

Figure 4.- Sequence photographs of full-scale and $\frac{1}{16}$ -size model ditching tests of the Army B-24D airplane.



1.48

1.82

2.17

2.51

Time, sec. (full scale)
Full-scale test



1.33

1.67

2.33

2.67

Time, sec. (full scale)
Model test (tank)



1.33

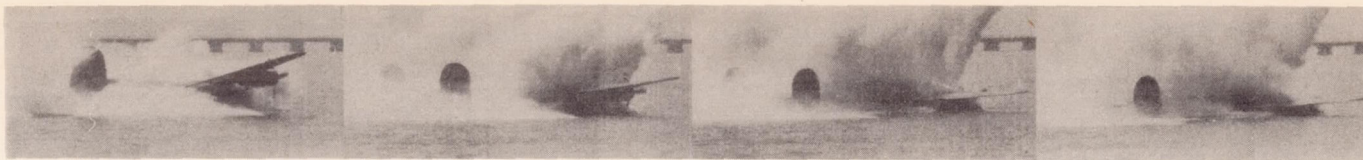
1.67

2.33

2.67

Time, sec. (full scale)
Model test (catapult)

Figure 4.- Continued.



2.86

3.20

3.55

3.89

Time, sec. (full scale)
Full-scale test



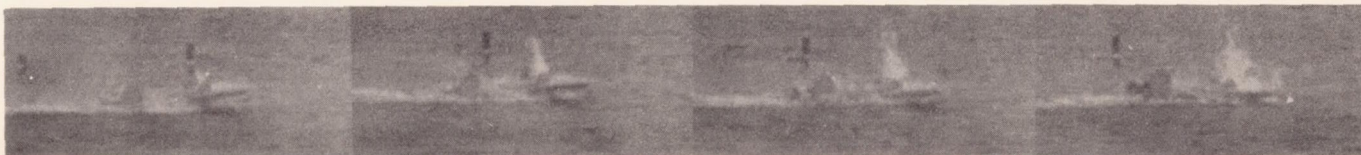
3.00

3.33

3.67

4.00

Time, sec. (full scale)
Model test (tank)



3.00

3.33

3.67

4.00

Time, sec. (full scale)
Model test (catapult)

Figure 4. Continued.

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4.24

4.58

4.93

5.27

Time, sec. (full scale)
Full-scale test



4.33

4.67

5.00

5.33

Time, sec. (full scale)
Model test (tank)



4.33

4.67

5.00

5.33

Time, sec. (full scale)
Model test (catapult)

Figure 4.- Continued.

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5.62

5.96

6.31

6.65

Time, sec. (full scale)
Full scale test



5.67

6.00

6.33

6.67

Time, sec. (full scale)
Model test (tank)



5.67

6.00

6.33

6.67

Time, sec. (full scale)
Model test (catapult)

Figure 4.- Concluded.