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RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

DITCHING TESTS WITH A $\frac{1}{12}$-SCALE MODEL OF THE ARMY A-26 AIRPLANE IN LANGLEY TANK NO. 2 AND ON AN OUTDOOR CATAPULT

By

George A. Jarvis and Edward L. Hoffman

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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SUMMARY

Tests with a dynamically similar model of the Army A-26 airplane were made to determine the best way to land the airplane in calm and rough water and to determine its probable ditching performance. The model was ditched in calm water from the tank no. 2 towing carriage and in calm and rough water from an outdoor catapult. The behavior of the model was determined by making visual observations, by recording longitudinal decelerations, and by taking motion pictures of the landings.

The following conclusions were reached from the results of the tests:

1. The airplane should be ditched at a normal landing attitude (thrust line at 8°) with the flaps fully deflected and the wings laterally level.

2. The airplane should be ditched at as light a weight as possible.

3. Ditchings in waves should be made perpendicular to the waves attempting to made contact near tho crest just after the crest has been passed.

4. Violent dives will probably occur in calm and rough water, except when ditching across high waves.

5. A hydroflap installation will reduce decelerations and prevent diving.

INTRODUCTION

Tests were conducted in calm water in Langley tank no. 2 and in calm and rough water at an outdoor catapult in order to determine the best way to make a forced landing of an Army A-26 airplane and to determine its probable ditching behavior. These tests were requested by the Air Materiel Command, Army Air Forces, in their letter of March 26, 1943, WEL:AW: 50.

PROCEDURE

Description of the Model

The model used in the tests was a $\frac{1}{12}$-scale model of the A-26 airplane. Photographs of the model are shown in figures 1 to 3. The wing span was 70.0 inches and the length of the fuselage was 49.9 inches. The construction of the model was similar to that described in reference 1.

The flaps were attached to the wing with aluminum brackets as shown in figure 4. By adjusting the friction of the brackets, the flaps were made to fail at scale strength.

Test Methods and Equipment

The apparatus and test procedure used were similar to that described in reference 1.

Test Conditions

(All values given refer to the full-scale airplane.)

Gross weight.- The model was tested at weights corresponding to 25,730 pounds (normal gross weight) and 30,994 pounds (maximum gross weight).

Location of center of gravity.- The center of gravity was located at 28.4 percent of the mean aerodynamic chord and 5.1 inches above the thrust line.

Attitude of thrust line.- The attitudes at which the model was ditched were 13° (near-stall attitude), 8° (normal landing attitude), and 3° (3-wheel attitude). The attitude angle was measured between the thrust line and the water surface.

Landing gear.- The model was ditched with the landing gear in the retracted position.

Flap setting.- Tests were made with flaps at 0°, 25°, and 55°. Information obtained from the Douglas Aircraft Company indicated that the inboard flaps will fail at a load of 197 pounds per square foot and the outboard flaps will fail at a load of 191 pounds per square foot.

Landing speed.- In these tests, the speeds at which the model was released were determined by the speed necessary for the model to be airborne. Since the model did not have the slotted flap that is on the full-scale airplane, the landing speeds in the first tests were found to be excessive when the flaps were deflected. Some tank tests at normal gross weight were repeated with the gap between the wing and the deflected flap sealed so that the landing speeds were kept within ±10 miles per hour (full scale) of the landing speeds calculated from power-off lift curves obtained from reference 2. The purpose of repeating this portion of the tests was to investigate the effect of landing speeds on the ditching characteristics. The landing speeds used are listed in tables I through III.

Conditions of simulated damage.- Damage was simulated by removing various parts of the model. These parts have been assigned numbers as shown in figure 2 and as listed below.

Number of part	Name of part
1	All-purpose nose door
2	Nose-wheel doors
3	Bomb-bay doors
4	Lower-turret service door
5	Main landing gear doors
6	Aft end of nacelles
7	Undersurface of fuselage from station 315 (aft end of bomb bay) to lower turret
8	Lower turret

To make up the various conditions of damage tested the following combinations of parts were removed:

(a) No parts removed.
(b) 3
(c) 1, 2, 3, 4, 5
(d) 1, 2, 3, 4, 5, 8
(e) 8
(f) 4, 5, 8
(g) 3, 4, 8
(h) 3, 4
(j) 4, 5
(k) 2, 3, 4, 5, 6, 7, 8
(m) 2, 3, 4, 5, 6 (probable condition of damage)

Ditching aid.- The all-purpose nose door was braced open to form a hydroflap at 30° to the thrust line.

Conditions of seaway.- The model was ditched in three conditions of seaway.

(a) Calm water.

(b) Wave crests parallel to the flight path, height approximately 2 to 3 feet, length approximately 40 to 60 feet.

(c) Wave crests perpendicular to the flight path, height approximately 2 to 6 feet, length approximately 40 to 120 feet.

RESULTS AND DISCUSSION

Summaries of the results of the tests are presented in tables I to III.

The symbols used in defining the ditching behavior of the model are as follows:

b deep run - near the end of the run the model submerges partially, exhibiting a tendency to dive, although the attitude of the model is nearly level

d_1 violent dive - a dive in which the wings are submerged and the angle between the water surface and the thrust line is more than 30°

d_2 slight dive - a dive in which the wings are not submerged completely and the angle between the water surface and the fuselage thrust line is less than 30°

h smooth run - a run in which there is no apparent oscillation about any axis and during which the model settles into the water as the forward velocity decreases

p porpoising - an undulating motion about the transverse axis in which some part of the model is always in contact with the water surface

s skipping - an undulating motion about the transverse axis in which the model clears the water surface completely - in general, the motion is more severe than porpoising and greater damage would probably occur.

t sharp turn - a violent angular motion about a vertical axis, generally caused by one nacelle digging into the water

Diving was prevalent throughout the tests on this model. Occasionally ditchings with favorable characteristics were obtained at some conditions of damage, but since the attitudes and flap deflections at which these runs occurred were not consistent, these favorable characteristics could not be assured in full-scale ditchings. However, by using the all-purpose nose door as a hydroflap the diving was eliminated.

When the model dived the maximum deceleration ranged from 2.2g to 7.9g. When the model did not dive the maximum deceleration ranged from 1.6g for a smooth run to 6.0g for a sharp turn.

Photographs showing the characteristic behavior are shown in figure 5. Figure 6 gives typical time histories of longitudinal decelerations.

Effect of Attitude

Although diving occurred throughout the tests regardless of attitude, the landing attitude did have some effect on the ditching characteristics. The diving occurred most consistently at the 13° attitude. The sharp turns usually occurred at the 3° attitude. (See table I.) Porpoising runs (obtained with the hydroflap) appeared least violent at the 8° landing attitude.

Since landings at the 13° and 3° attitudes most consistently resulted in the most violent behaviors, the normal landing attitude of 8° appeared to be the most favorable ditching attitude.

Effect of Flaps

Deflection of the flaps did not have a noticeable detrimental effect on the ditching performance. When the model was ditched with the flaps deflected, partial or complete failure usually occurred. When, at times, the flaps did not fail, the ditching performance did not appear any more violent.

Since the flaps did not have a detrimental effect on the ditching performance, it would be advantageous to use full flap deflection of 55° in order to obtain slower landing speeds.

Effect of Weight

Diving did not occur as frequently, but sharp turns occurred more frequently when the weight was increased. (See table II.) When the hydroflap was used, increasing the weight did not change the type of ditching run, but from a study of the motion pictures the porpoising appeared much more violent. Longitudinal decelerations did not vary with any consistency as the weight was varied. (See table II.)

The airplane should therefore be ditched at as light a weight as possible.

Effect of a Wing-Low Landing

If the model was ditched with one wing lower than the other, even though the difference was small, a sharp turn resulted. These turns were caused by the nacelle on the low side digging into the water. (See fig. 5(c).) Longitudinal decelerations as high as 6.0g were obtained in these turns. (See tables I and II and fig. 6.)

Ditchings should be made with the wings as laterally level as possible to avoid sharp turns.

Effect of Simulated Damage

In general, the ditching behavior was violent or unsatisfactory (without hydroflap) regardless of the condition of damage. (See table I.) Favorable ditching characteristics could not be assured at any particular condition, even though favorable characteristics were obtained at some scattered points.

Effect of Hydroflap

By bracing the all-purpose nose door open at an angle of 30° with the thrust line so that it acted as a hydroflap, all diving was eliminated. The decelerations listed in tables II and III give a distorted view of the value of a hydroflap since only maximum values are given. In ditchings with a hydroflap, these maximum values are caused by the initial impact of the landing, but the deceleration has such a short duration that its importance is less than the tables imply. This initial peak deceleration is also obtained in ditchings without a hydroflap, but is followed by an even higher peak whose duration is much longer. The typical time-history records (fig. 6) give a clearer picture of these decelerations, but still do not show the entire value of a hydroflap because the records obtained without a hydroflap were made into a headwind that gave a ground speed of 78 miles per hour while the records with a hydroflap were made with a ground speed of 93 miles per hour. It was found that landing into the headwind decreased the initial peak deceleration about 1g, so in order to make a more direct comparison between the time-history records it may be assumed that the peak values obtained without a hydroflap should be increased approximately 1g.

Effect of Landing Speed

The results of the tank tests (with the gap between the wing and the deflected flap sealed) that were repeated to investigate the effect of landing speeds on ditching characteristics are presented in table II. A comparison of longitudinal decelerations was not made, but the slower landing speeds gave shorter landing runs. The type of ditching behavior did not vary. These results are in agreement with information obtained from reference 3.

Effect of Wind and Seaway

For the rough-water landings at the catapult, the wave height obtained for a given wind velocity is smaller than the wave height obtained in the open sea for the same wind velocity. The wave heights are consequently lower than they should be to correspond to the ground speeds at which the model lands.

When this model was ditched either parallel or perpendicular to the crests of waves less than 2 feet high the ditching behavior was not changed by the waves. Landing parallel to the crests of higher waves often resulted in runs in which a nacelle dug in the crest of a wave and caused an extremely violent turn. In the landings without a hydroflap that were made perpendicular to high waves, deep runs and slight dives were obtained instead of the violent dives that were obtained from landings perpendicular to small waves.

Since there was little difference in behavior regardless of the direction of landing when this airplane was ditched in small waves, and since the behavior was improved by landing perpendicular to the waves when ditched in large waves; this airplane should always be ditched perpendicular to the waves. These results are contrary to those obtained for most other ditching models where it has been found best to land parallel to the wave crests except when high winds exist.

If possible, contact should be made near the crest of the wave just after the crest has been passed, in order to decrease the impact loads and to prevent the tail from being thrown into the air, thus causing the airplane to make contact again at a negative attitude.

CONCLUSIONS

From the results of the tests with the $\frac{1}{12}$-scale model, the following conclusions were reached:

1. The airplane should be ditched at a normal landing attitude (thrust line at 8°) with the flaps fully deflected and the wings laterally level.

2. The airplane should be ditched at as light a weight as possible.

3. Ditchings in waves should be made perpendicular to the waves attempting to make contact near the crest just after the crest has been passed.

4. Violent dives will probably occur in calm and rough water, except when ditching across high waves.

5. A hydroflap installation will reduce decelerations and prevent diving.

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REFERENCES

1. Fisher, Lloyd J., and Steiner, Margaret F.: Ditching Tests with a $\frac{1}{12}$-Size Model of the Army B-26 Airplane in NACA Tank No. 2 and on an Outdoor Catapult. NACA MR, Aug. 15, 1944.

2. Stone, David G., and Muse, Thomas C.: Power-Off and Power-On Tests of the 0.2375-Scale Model of the Douglas XA-26 Airplane in the NACA 19-Foot Pressure Tunnel. II - Stability Characteristics. NACA MR, Army Air Forces, May 4, 1944.

3. Jarvis, George A., and Fisher, Lloyd J.: Correlation Tests of the Ditching Behavior of an Army B-24D Airplane and a $\frac{1}{16}$-Size Model. NACA MR No. L6A03, 1946.

TABLE I.- SUMMARY OF RESULTS OF DITCHING TESTS IN CALM WATER IN LANGLEY TANK NO. 2 WITH A $\frac{1}{12}$-SCALE MODEL OF THE ARMY A-26 AIRPLANE AT VARIOUS CONDITIONS OF SIMULATED DAMAGE WITHOUT A HYDROFLAP

[All values are full scale
Gross weight - 25,730 pounds]

Attitude of thrust line (deg)		13				8				3			
*Damage condition	Flaps** (deg)	Speed	Max	Run	Remarks	Speed	Max	Run	Remarks	Speed	Max	Run	Remarks
Undamaged	0	118	7.9	5	d_1	132	4.3	12	s t				
	25	106	4.8	4	d_1	125	1.6	11	h	133	4.9	8	s t
	55	104	5.1	3	d_1	111	---	10	h	118	2.2	8	s d_1
	55									118	2.9	8	s t
3	0	123	---	5	d_1	136	---	7	d_1				
	25	110	---	4	d_1	125	---	4	d_1	125	4.3	7	t
	55	109	---	3	d_1	127	6.0	6	d_1	115	---	3	d_2
	55					127	6.0	5	t				
1,2,3,4,5,	0	118	---	3	d_1	132	---	6	t				
	25	110	---	2	d_1	126	---	6	t	133	---	2	d_1
	25									133	---	4	t
	55	106	---	3	d_1	119	---	4	d_1	120	---	2	d_1
1,2,3,4,5,8	0	118	---	3	d_2	132	---	5	d_2				
	25									132	---	3	s d_1
	25									132	---	6	s t
	55	104	---	4	b	118	---	4	d_1	119	---	4	s d_1
	55									119	---	5	s t
8	0	118	---	5	d_1	132	---	2	d_1				
	25									134	---	9	s t
	55	104	---	2	d_1	118	---	8	s h	118	---	4	s d_1
4,5.8	0	118	---	7	d_2	132	---	4	d_2				
	25									134	---	5	s d_1
	25									134	---	8	s t
	55	111	---	6	d_1	118	---	8	d_1	118	---	7	s t
3,4,8	0	118	---	5	d_2	132	---	7	s b				
	25									132	---	2	d_1
	55	104	---	4	d_1	119	---	5	s b	119	---	2	d_1
3,4	0	118	---	4	d_2	132	---	7	p b				
	25									132	---	4	s t
	55	104	---	4	d_1	118	---	6	b	119	---	5	d_2
	55									119	---	4	s t
4,5	0	118	---	4	d_1	132	---	9	p				
	0					132	---	6	p b				
	25									132	---	7	s b
	55	104	---	7	d_1	118	---	4	d_2	119	---	7	s
2,3,4,5,6,7,8	0	118	---	6	b	132	---	7	s b				
	25									132	---	4	d_1
	25									132	---	6	t
	55		---	7	p,b	122	---	6	d_1	119	---	6	d_2

*Damage condition: each number under this heading indicates a part which was removed to simulate damage.

1. All-purpose nose door.
2. Nose-wheel doors.
3. Bomb-bay doors.
4. Lower turret service door.
5. Main landing-gear doors.
6. Aft end of nacelles.
7. Undersurface of fuselage from station 315 (aft end of bomb bay) to lower turret.
8. Lower turret.

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**Column headings are explained as follows:

Speed Speed in miles per hour.
Max Average maximum longitudinal deceleration in multiples of the acceleration of gravity.
Run Length of landing run in multiples of the length of the airplane.
Remarks Notations under this heading have the following meaning:

b. Ran deeply.
d_1. Dived violently.
d_2. Dived slightly.
h Ran smoothly.
p. Porpoised.
s. Skipped.
t. Turned sharply.

TABLE II.- SUMMARY OF RESULTS OF DITCHING TESTS IN CALM WATER IN LANGLEY TANK NO. 2 WITH A $\frac{1}{12}$-SCALE MODEL OF THE ARMY A-26 AIRPLANE WITH THE PROBABLE CONDITION OF DAMAGE SIMULATED

[All values are full scale]

Gross weight (lb)	Configuration	Attitude of thrust line (deg) → / *Flaps (deg) **	13				8				3			
			Speed	Max	Run	Remarks	Speed	Max	Run	Remarks	Speed	Max	Run	Remarks
25,730	Without hydroflap	0	118	---	5	d_1	132	6.5	5	d_1				
		25									135	---	5	s t
		25									130	7.0	3	s d_1
		55	109	4.0	3	d_1	122	---	6	d_1	123	---	8	d_1t
		55									123	---	4	d_1
		55-s	99	---	3	d_1	99	---	2	d_1	116	---	2	d_1
	With hydroflap	0	118	---	6	p b	134	3.9	8	p				
		25									141	4.9	8	p b
		55	111	---	8	p	123	---	8	p	123	---	9	p
		55-s	99	---	4	p	99	---	5	p	116	---	6	p
30,994	Without hydroflap	0	130	5.0	6	d_1	144	4.9	9	s b				
		0	130	5.4	7	p b	144	4.2	9	s t				
		25									142	4.0	7	s t
		55	115	4.3	5	d_1	123	---	10	s b	125	4.4	6	s b
		55	115	5.7	6	p b	123	4.2	8	s t	125	3.9	5	s t
	With hydroflap	0	130	3.3	7	p	146	5.4	12	p				
		25									146	3.8	12	p b
		55	116	4.1	6	p b	122	3.8	10	p	125	3.9	8	p b

*Flaps: An "s" after the angle of flap deflection indicates that the gap between the wing and the deflected flap was sealed to reduce the landing speed.

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**Column headings are explained as follows:

Speed Speed in miles per hour
Max Average maximum longitudinal deceleration in multiples of the acceleration of gravity.
Run Length of landing run in multiples of the length of the airplane.
Remarks Notations under this heading have the following meaning:
- b Ran deeply.
- d_1 Dived violently.
- p Porpoised.
- s Skipped.
- t Turned sharply.

TABLE III.- SUMMARY OF RESULTS OF DITCHING TESTS IN CALM AND ROUGH WATER MADE FROM AN OUTDOOR CATAPULT WITH A $\frac{1}{12}$-SCALE MODEL OF THE ARMY A-26 AIRPLANE WITH THE PROBABLE CONDITION OF DAMAGE SIMULATED

[All values are full scale
Gross weight - 25,730 pounds,
Landing attitude - 8°
Flap deflection - 55°
Airspeed - 99 miles per hour]

Condition of seaway	Calm			Perpendicular waves				Parallel waves		
Configuration \ *	Ground speed	Max	Remarks	Ground speed	Max	Wave height	Remarks	Ground speed	Wave height	Remarks
Without hydroflap	98	---	d_1	78 70 68	4.0 --- ---	2 4 6	d_1 b d_2	110	3	d_1
With hydroflap	96	3.7	p	73	---	2	p	120 105 114	2 3 3	p p t

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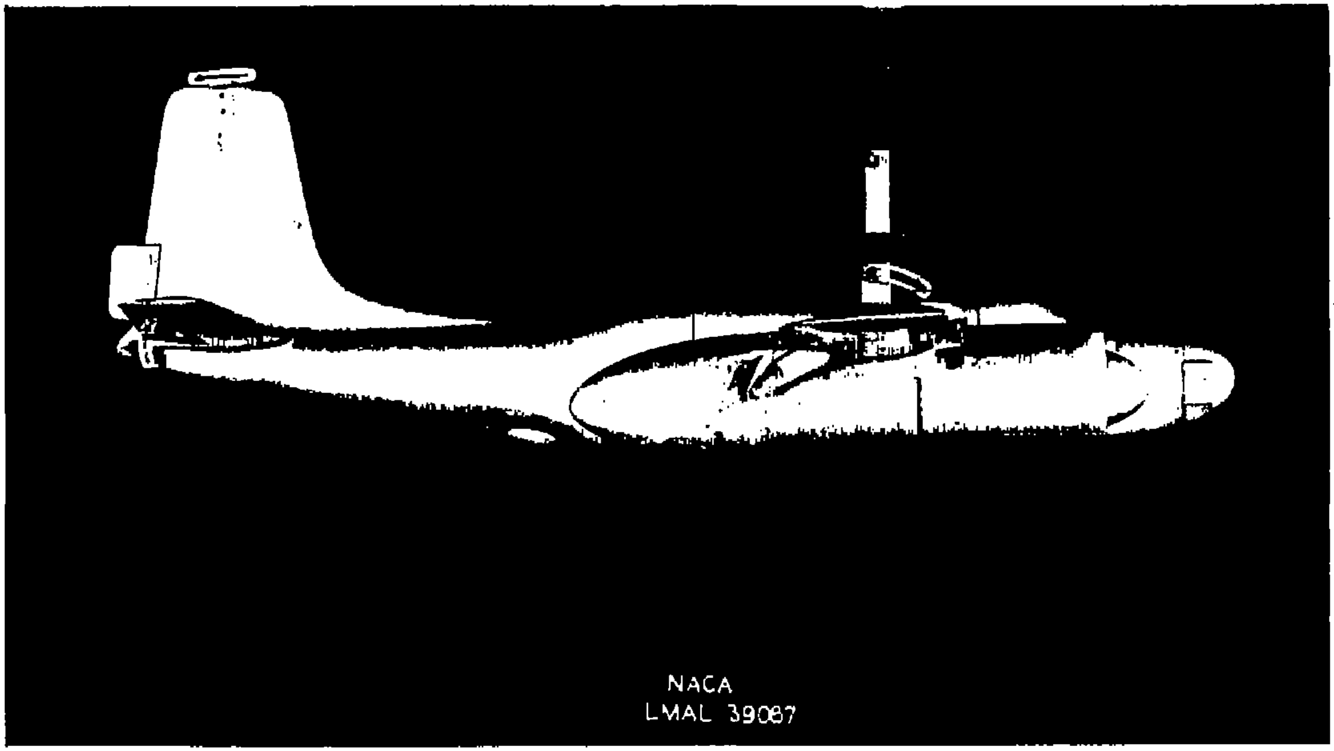
*Column headings are explained as follows:
- Ground speed — Ground speed in miles per hour.
- Max — Average maximum longitudinal deceleration in multiples of the acceleration of gravity.
- Wave height — Wave height from trough to crest in feet
- Remarks — Notations under this heading have the following meaning:
  - b Ran deeply.
  - d_1 Dived violently.
  - d_2 Dived slightly.
  - p Porpoised.
  - t Turned sharply.



(a) Side view.

Figure 1.- Photograph of a $\frac{1}{12}$-scale ditching model of the Army A-26 airplane.

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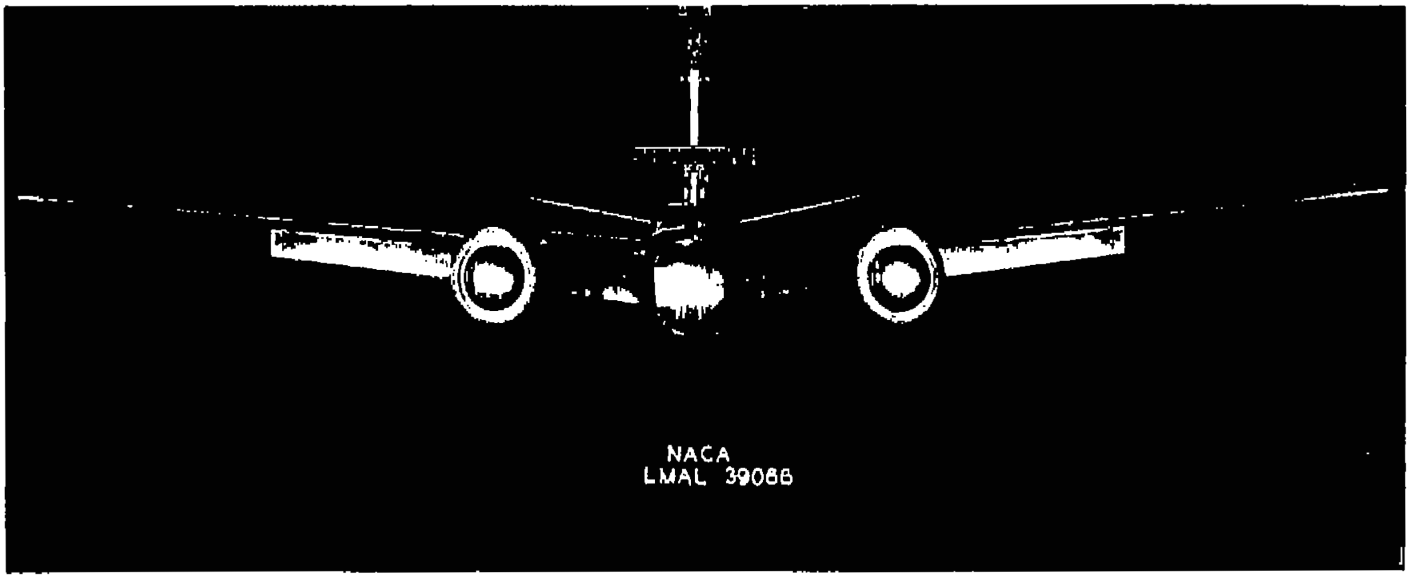

(b) Front view.

Figure 1.- Continued.

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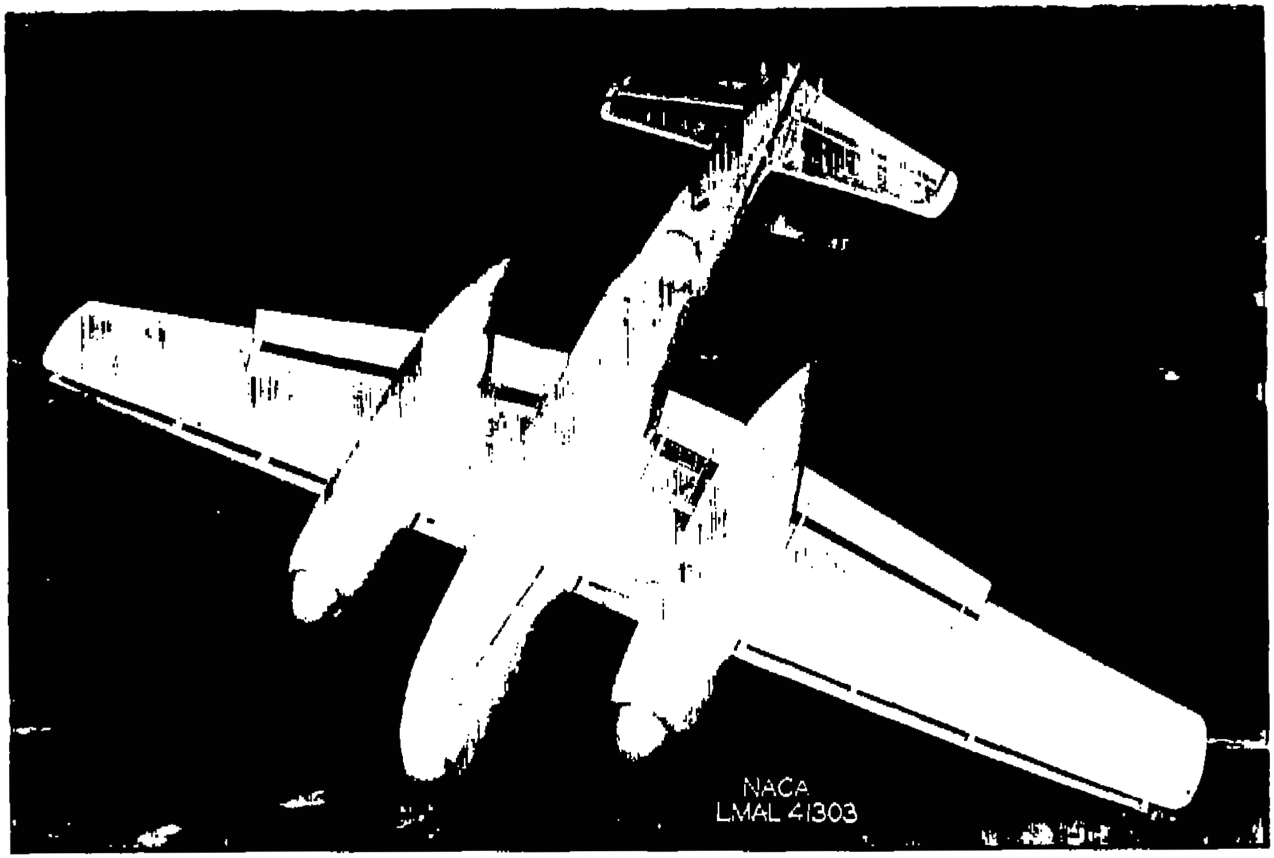

(c) Three-quarter view.

Figure 1.- Concluded.

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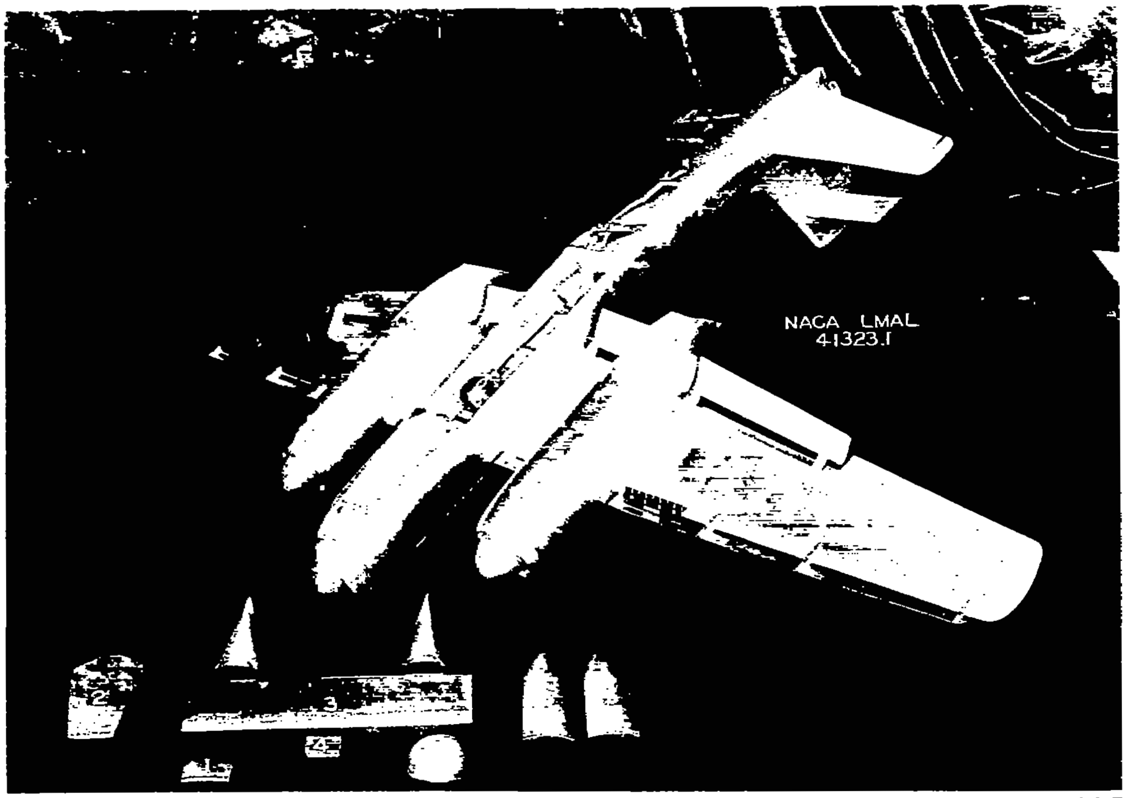

Figure 2.- Ditching model showing sections removed to simulate the various conditions of damage.

List of Parts

1.- All-purpose nose door.
2.- Nose-wheel doors.
3.- Bomb-bay doors,
4.- Lower turret-service door.
5.- Main landing-gear doors.
6.- Aft end of nacelles.
7.- Undersurface of fuselage from Sta. 315 (aft end of bomb-bay) to lower turret.
8.- Lower turret.

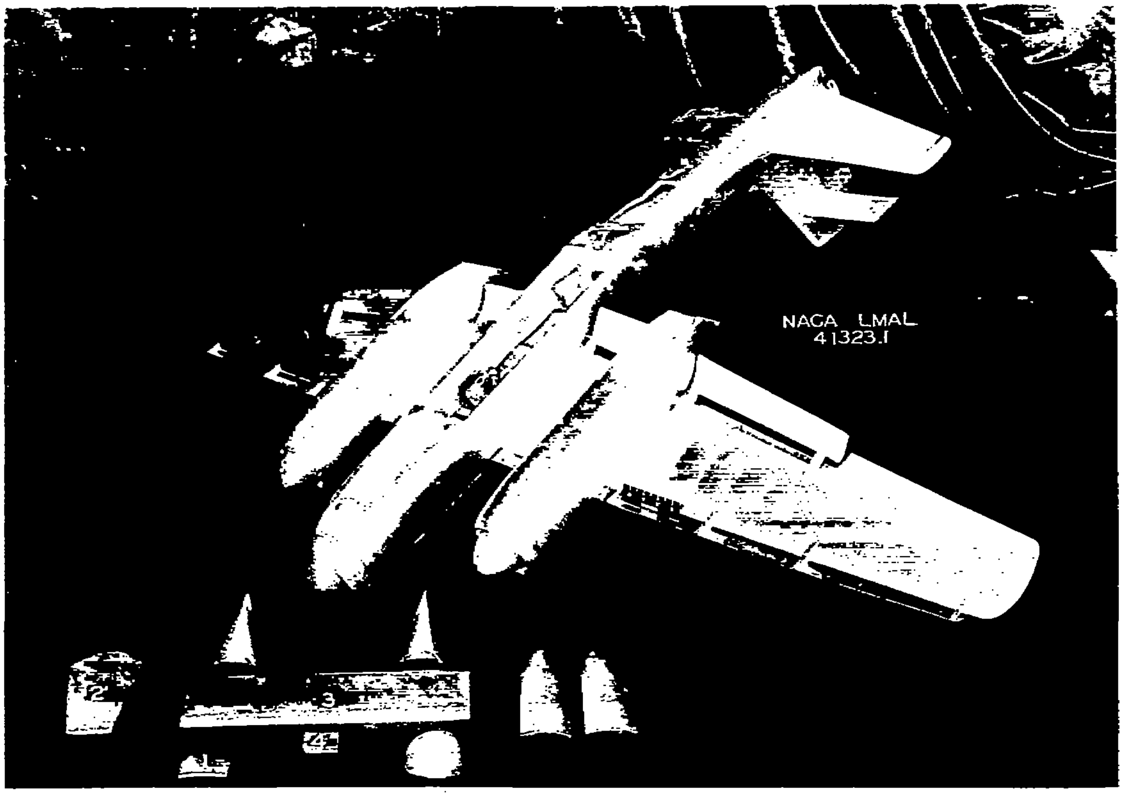

Figure 2.- Ditching model showing sections removed to simulate the various conditions of damage.

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List of Parts

1.- All-purpose nose door.
2.- Nose-wheel doors.
3.- Bomb-bay doors.
4.- Lower turret-service door.
5.- Main landing-gear doors.
6.- Aft end of nacelles.
7.- Undersurface of fuselage from Sta. 315 (aft end of bomb-bay) to lower turret.
8.- Lower turret.

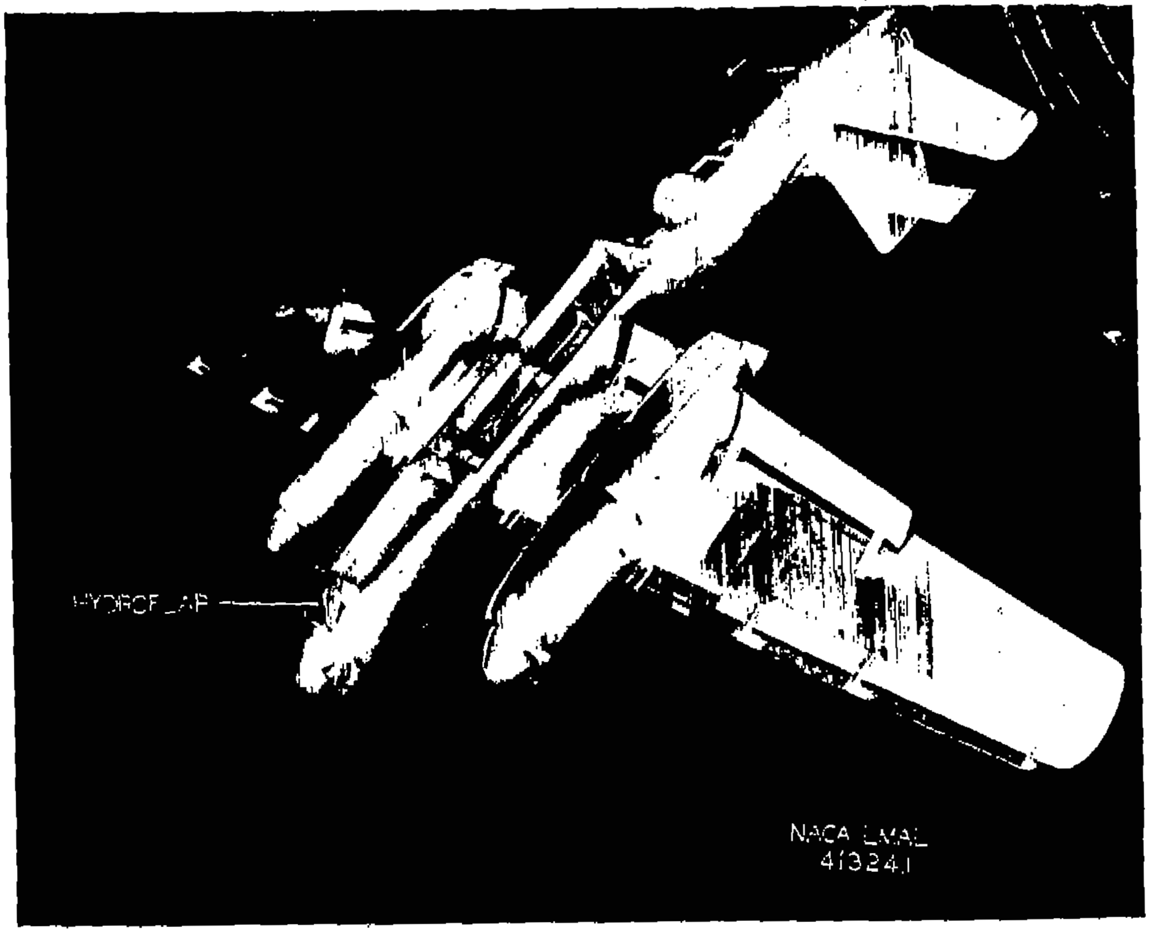

Figure 3.- Ditching model with probable condition of damage simulated and with all-purpose nose door braced opened to form a hydroflap.

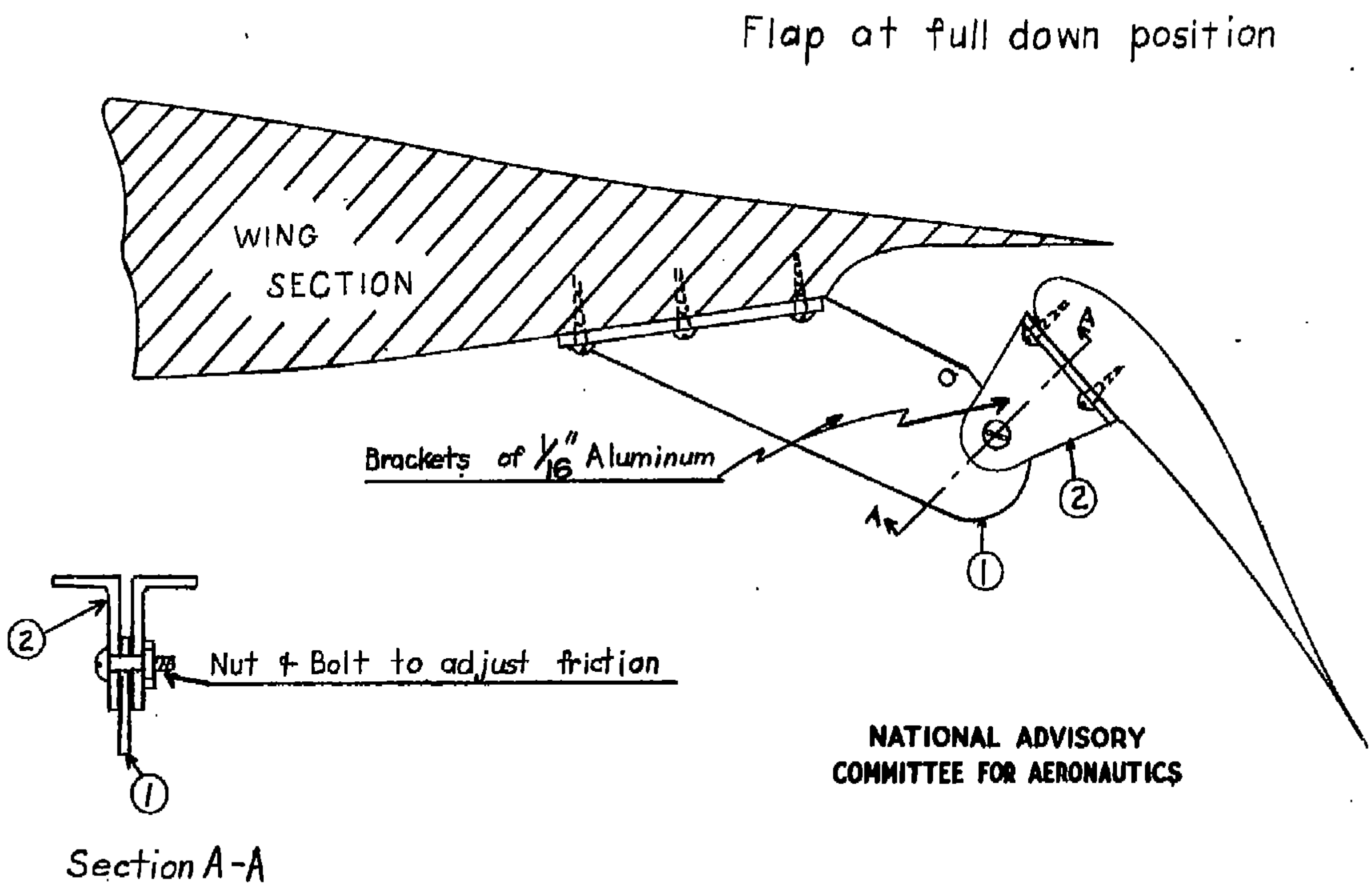

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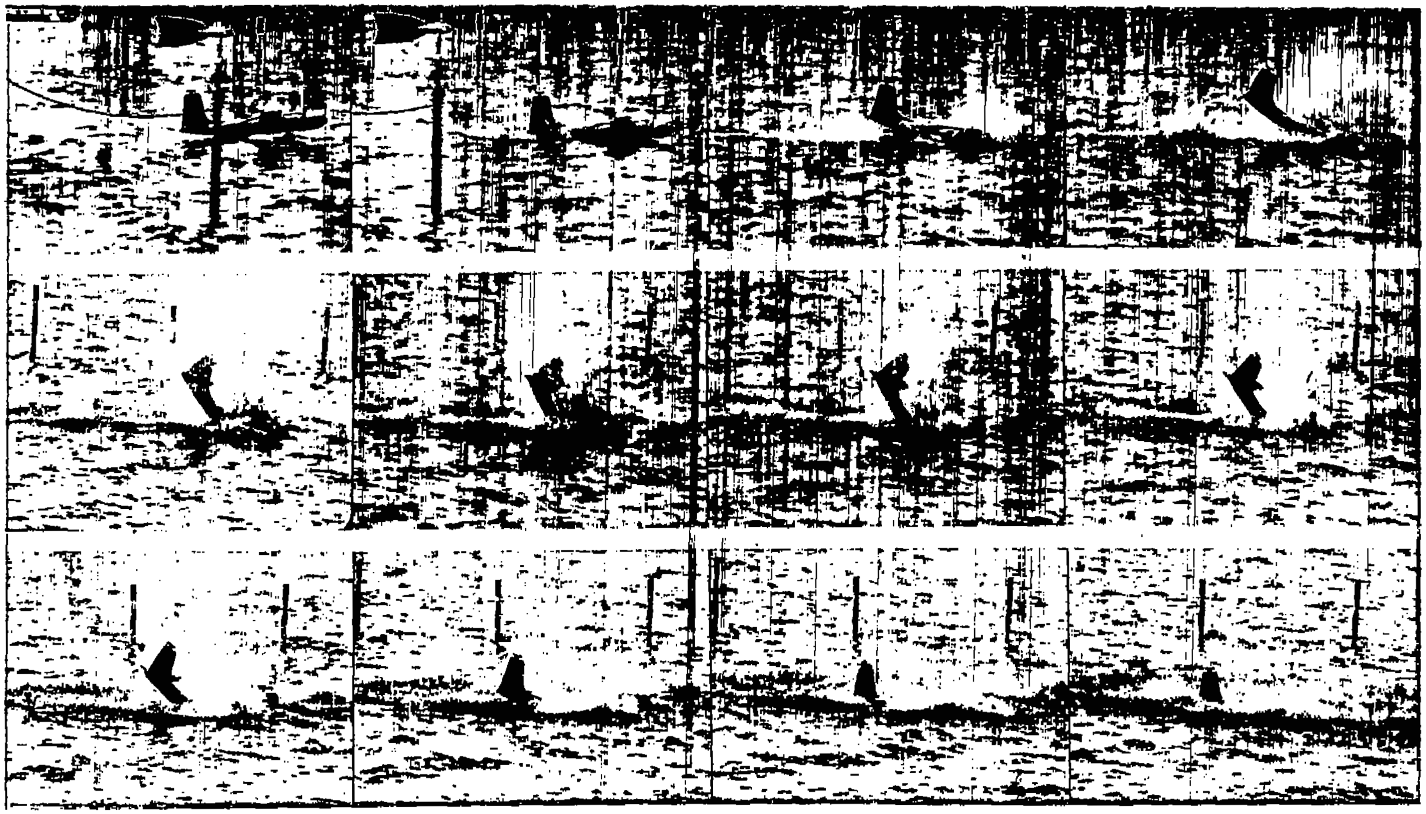
Figure 4.- Friction hinge for scale-strength flaps



(a) Typical violent dive; ground speed, 78 mph; oncoming waves 2 feet high.

Figure 5.- Photographs at 0.433 second time interval of A-26 model ditching. Attitude of thrust line, 8°; flap deflection, 55°; normal gross weight.

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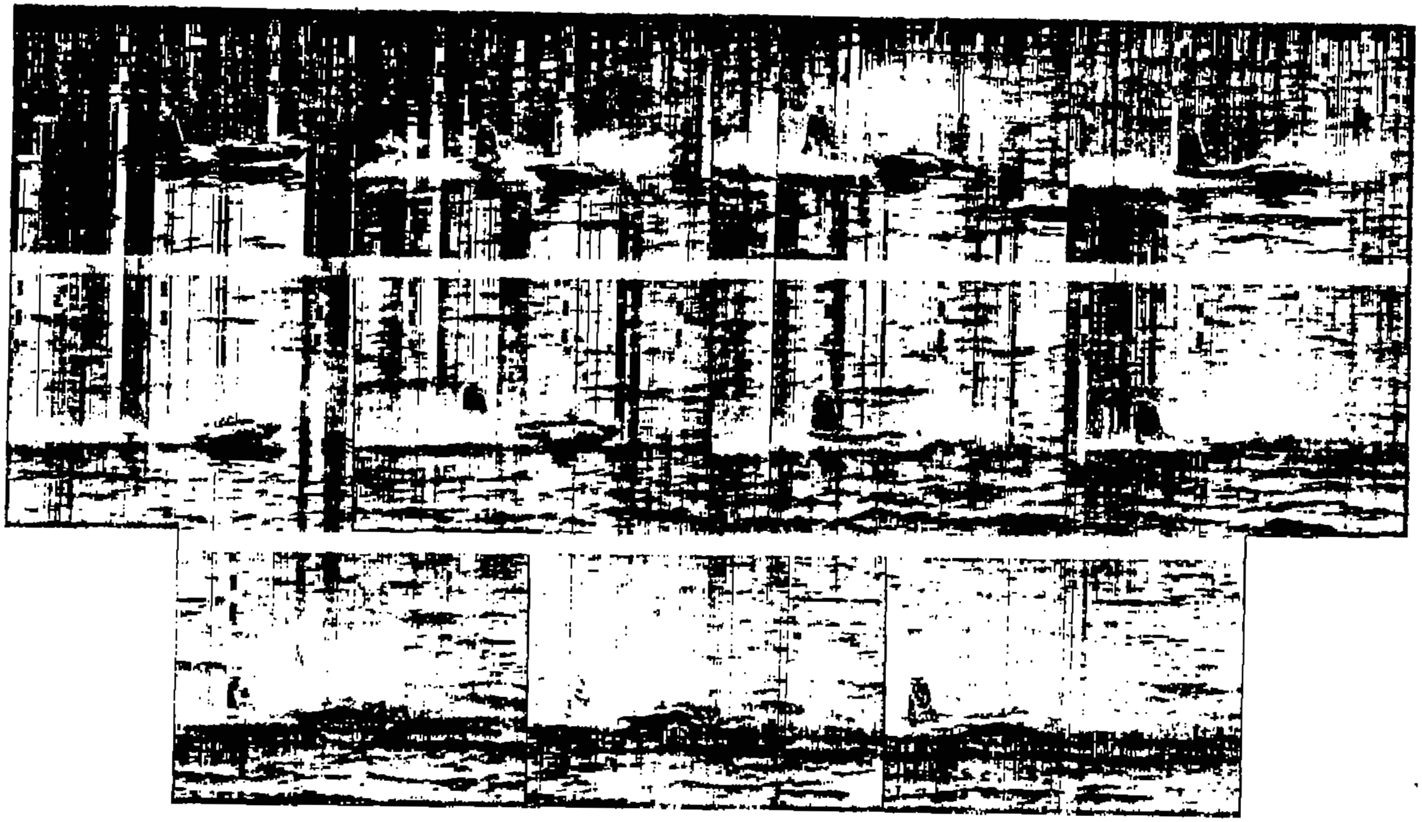

(b) Typical porpoising run obtained with hydroflap; ground speed, 100 mph; calm water.

Figure 5.- Continued.

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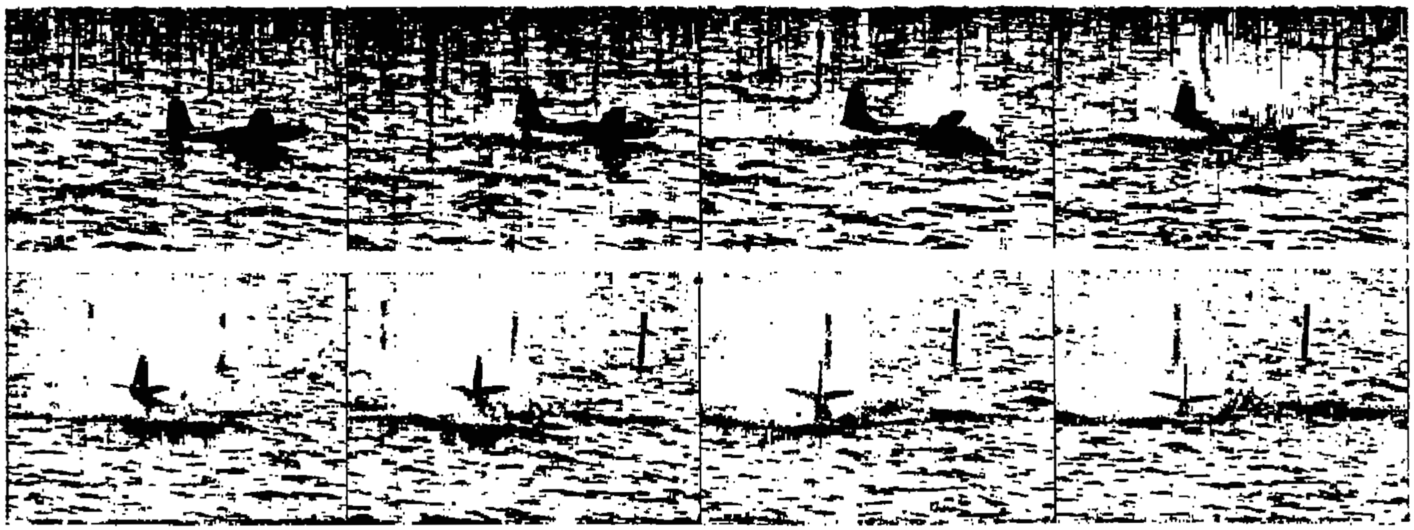

(c) Sharp turn caused by wing-low landing, ground speed, 78 mph; oncoming waves 2 feet high.

Figure 5.- Concluded.

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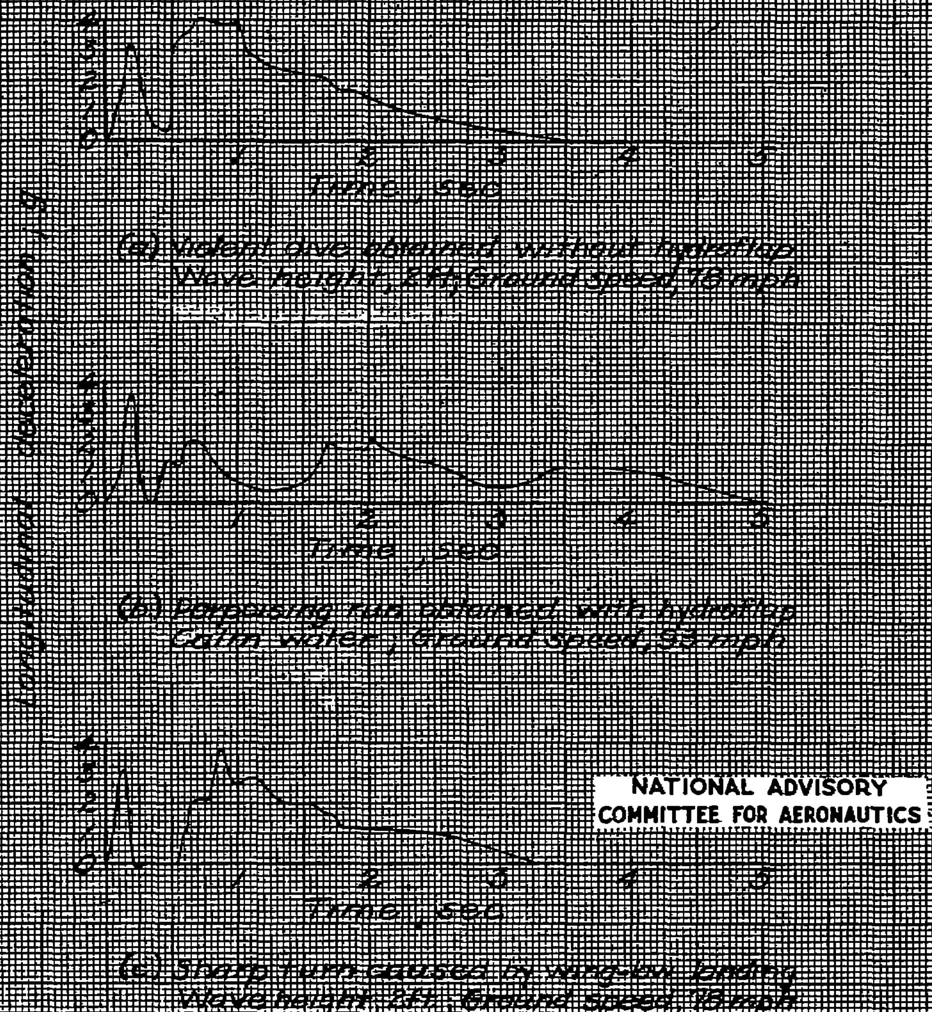

Figure 6. - Typical time-histories of longitudinal decelerations for ditching tests of a 1/12 scale model of an Army A-26 airplane.
Gross weight, 25,750 lb; landing attitude 6°;
Flap deflection, 55°.
(All values are full-scale.)