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DITCHING TESTS WITH A $\frac{1}{10}$ -SIZE MODEL OF THE ARMY A-20A
AIRPLANE IN LANGLEY TANK NO. 2 AND
ON AN OUTDOOR CATAPULT

By George A. Jarvis and Margaret F. Steiner

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Army Air Forces, Air Technical Service Command
DITCHING TESTS WITH A $\frac{1}{10}$ -SIZE MODEL OF THE ARMY A-20A
AIRPLANE IN LANGLEY TANK NO. 2 AND
ON AN OUTDOOR CATAPULT

By George A. Jarvis and Margaret F. Steiner

SUMMARY

Tests with a dynamically similar model of the Army A-20A 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 behavior was studied by making visual observations, by recording longitudinal decelerations, and by taking motion pictures of the landings. From these studies the conclusions that follow were drawn.

If the waves are short, or the crests are parallel to the flight path, or the water is calm, a smooth ditching with the nose remaining clear will probably result if the airplane is landed laterally level in a tail-down attitude. The airplane should be in the lightest possible weight condition; partial power and full flaps should be used to make a landing as slowly as possible. In a swell the airplane should be landed parallel to the crest of the swell, if possible. If there is no swell, the airplane should be ditched along the waves across moderate winds; but when the condition of the sea indicates that higher winds exist (see "Aerology for Pilots," McGraw-Hill Book Co., Inc., 1943), then it may be advisable to land into the wind and attempt to contact a wave near the top on the windward side.

INTRODUCTION

Object of the tests.- The object of the tests was to determine the best way to make a forced landing of an Army A-20A airplane in the sea and to determine its probable behavior.

Requested.- The tests were made in accordance with the request of the Army Air Forces, Materiel Command, of March 26, 1943.

Date and place of tests.- The tests were made in smooth water at Langley tank no. 2 and in rough water at an outdoor catapult which was under the supervision of personnel of the impact basin. The catapult tests were made from November of 1943 through January of 1944. (The smooth-water tests were previously discussed in reference 1 but are included here in order to make this a complete report of all the tests.)

PROCEDURE

Description of Model

Scale.- The model was a $\frac{1}{10}$ -size dynamic model.

Type of construction.- The model was of wooden construction as described in reference 2. In some of the tests the bomb-bay doors and other covers were omitted to simulate their probable failure in an actual ditching.

Photographs.- Photographs of the model are shown in figure 1. Photographs of the model with gun blisters added are shown in figure 3.

Test Methods and Equipment

The apparatus and test procedure are described in reference 2.

Test Conditions

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

Gross weight.- 17,400 pounds (no bombs, half fuel load); 21,500 pounds (overload gross weight).

Location of center of gravity.- The center of gravity was located at 28.13 percent mean aerodynamic chord; the vertical location was 41.4 inches above the bottom of the fuselage.

Attitude of the fuselage reference line.- 13° (near-stall attitude), 10°, 9° (normal tail-down attitude), 6°, 4° (medium attitude), 2° (level landing attitude). The thrust line is at a positive angle of 2° with the reference line.

Landing gear.- Retracted.

Flap setting.- Tests were made with flaps up and flaps 40° down.

Landing speed.- The speed range on tank tests was from 80 to 120 miles per hour. The speeds used at the outdoor catapult were those representing a power-off, flaps-down landing as computed from data furnished by Douglas Aircraft Company, Inc. They are listed in table I.

Vertical velocity.- Tests were made in which the vertical velocities were varied from 2 to 20 feet per second.

Conditions of form or simulated damage.-

I - Simulated damage on the model representing the A-20A airplane.

- (a) No damage (fig. 1(c)).
- (b) Bomb-bay doors removed.
- (c) Bomb-bay doors and rear gun hatch removed.
- (d) Bomb-bay doors, rear gun hatch, and bombardier's sighting window removed (fig. 2). This condition simulated probable damage of the full-scale airplane.

- (e) Same as (d) with solid bulkheads added at the fore and aft end of the bomb bay.

II - Simulated damage on the model representing the A-20A airplane with gun blisters.

- (a) No damage (fig. 3).
- (b) Bomb-bay doors removed.
- (c) Bomb-bay doors and rear gun hatch removed.
- (d) Bomb-bay doors, rear gun hatch, and bombardier's sighting window removed.
- (e) Rear gun hatch removed.

Propellers.- Some tests were made with one blade of each propeller locked vertically downward; blades made of wood and also of aluminum were tried. Tests were also made with windmilling propellers made of sheet aluminum.

Conditions of seaway.- (a) Calm water.

- (b) Wave crests parallel to the flight path; range of wave heights was approximately 1 to 6 feet, wave lengths were about 20 to 120 feet.
- (c) The crests of the regular waves created artificially in the tank were perpendicular to the flight path. The wave heights ranged from 15 inches to $7\frac{1}{2}$ feet and the wave lengths ranged from 20 to 120 feet.

RESULTS

The results of the smooth-water tests, which included the conditions of damage listed under Test Conditions, are given in reference 1. Table II, which is taken from reference 1, is included in this report to provide a convenient reference of the decelerations measured in smooth-water tests. The results of the rough-water tests are presented in tables III and IV. A series of

photographs showing the behavior of the model in several ditchings is shown in figures 4 through 6. Time-history records of longitudinal decelerations are presented in figure 7.

DISCUSSION

In smooth-water tests in the tank and rough-water tests from the catapult diving did not occur in the landing runs at any time and the performance was good. In tank tests when the model landed across waves whose length was several times the length of the model a few dives were obtained at both high and low attitudes. These dives occurred when the model touched on a wave so that it was thrown in the air and re-entered the water in a nose-down attitude into an approaching wave.

If one wing was slightly lower than the other, violent turns frequently resulted with accompanying high decelerations.

Even in rough water and with damage simulated on the fuselage the performance was comparatively smooth but the maximum decelerations were high for this type of run, being 6g to 8g in most of the runs. It was observed that the nacelles raised considerable spray and since they are placed so low that they enter the water as soon as the whole of the fuselage bottom is in contact with the water, it seems that their resistance might account for the high decelerations.

Effect of speed and attitude.-- The maximum decelerations were generally highest at the highest speeds. The performance did not vary much with speed although during the low-attitude high-speed runs a great deal of heavy spray was raised by the nacelles throughout the run. This spray was about four or five times the height of the fuselage. It should be noted that all tests represent flared landings and speeds and attitudes refer to values at the first contact with the water.

Effect of flap setting.-- The flap setting had no appreciable effect on the ditching performance. (See reference 1.) When the flaps were down they were attached in such a manner that they generally folded up at the first impact giving a rough simulation of their failure.

Effect of wind and seaway.- In landing across long waves the model usually rode the waves or skipped from crest to crest. Occasionally, it was thrown clear of the water at first impact in both high- and low-attitude landings and entered again in a nose-down attitude into the leeward side of a wave. The first impact in landing across waves was generally very heavy; on several runs the bomb-bay doors were broken out even after being reinforced. The point of contact with respect to the wave crest at which the model first touched did not affect the behavior of the model consistently but in order to avoid high loads at the first impact it appeared to be best to make the first contact with the water on the windward side of the wave.

When the wave length was about half the length of the fuselage or less the model generally made a good run but the reinforced bomb-bay doors were torn out more frequently than in landings in longer waves.

Landings across moderate winds and parallel to the wave crests generally resulted in runs in which the performance was good regardless of point of contact on the wave. As wind and wave height increased it became more difficult to keep the model laterally level in the landings and some violent turns resulted when a wing and nacelle dug in first. In view of the fact that a cross-wind landing may result in a violent turn, when high winds exist, it may be better to take advantage of landing into the wind so as to reduce the water speeds and thus keep impact water loads to a minimum. Means of determining wind velocity by observing seaway are discussed in reference 3.

Effect of simulated damage.- The flat bottom of the fuselage is a good planing surface but since the water loads are high the present structure would probably fail in a ditching. The tests with the bomb doors removed resulted in good performance as the model trimmed up on the rear fuselage bottom at first, then planed on the nacelles until the water started impinging on the front of the nacelles. Decelerations recorded in table II indicate that when failure of the bomb-bay doors was simulated the deceleration was twice as high as when no damage was simulated.

Effect of sinking speed.- Tests were made with the complete model (representing the airplane with optimum structural performance) combined with severe conditions of seaway and high sinking speed. The results indicated that good ditching performance could be insured if the airplane were sufficiently reinforced even if the sinking speed was abnormally high.

Effect of propellers.- The locked wooden blades projecting downward did not break and had a detrimental effect on ditching; the locked aluminum blades projecting downward bent backwards and formed planing surfaces which were beneficial. Windmilling propellers had no appreciable effect on the maximum deceleration but the length of landing run was generally shortened.

Effect of gun blisters.- The gun blisters had no appreciable effect on the behavior of the model.

Effect of weight.- Although there is no evidence that weight alone had any effect on the ditching performance, some improvement would be expected from the lower landing speeds which are possible with the lighter weight.

CONCLUSIONS

From results of the tests with the $\frac{1}{10}$ -size model the following conclusions are drawn:

1. The airplane should be landed at the lightest possible weight in a tail-down attitude (10° , fuselage reference line).

2. The landing should be made with partial power on and with flaps fully extended to obtain the slowest possible landing speed.

3. The landing should be made with the wings laterally level, otherwise a violent turn may result.

4. In a swell the airplane should be landed parallel to the crest of the swell, if possible. If there is no swell, the airplane should be ditched along the waves across moderate winds but when the condition of the sea indicates that higher winds exist, then it may be advisable

to land into the wind and attempt to contact a wave near the top on the windward side.

5. In landings in calm water, in short waves, or parallel to the crests of long waves, the ditching performance will be smooth with the nose remaining clear throughout most of the run, even when some damage occurs to the bottom of the fuselage. The maximum deceleration will probably be between 2g and 8g.

6. In landing across long waves the airplane may dig into the wave in a dive if the tail contacts a wave so as to force the nose down before the airplane contacts the next wave; the maximum deceleration may exceed 8g.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., November 29, 1944

REFERENCES

1. Dawson, John R., and Jarvis, George A.: Ditching Tests With a 1/10-Size Model of the Army A-20A Airplane. I - Calm-Water Tests in NACA Tank No. 2. NACA MR, Nov. 18, 1943.
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.
3. Anon.: Aerology for Pilots. McGraw-Hill Book Co., Inc., 1943.

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TABLE I
LANDING SPEEDS REQUIRED AT THE OUTDOOR CATAPULT
[All values are full scale.]

Weight (lb)	Attitude fuselage reference line (deg)	Landing velocity (mph)
17,400	13	90
21,500	10	109
17,400	9	102
21,500	6	126
17,400	4	122
21,500	2	155

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TABLE II

MAXIMUM LONGITUDINAL DECELERATIONS ON $\frac{1}{10}$ -SIZE MODEL OF
 A-20A AIRPLANE WITH GUN BLISTERS LANDING ON CALM WATER
 [Gross weight 21,500 pounds full size; decelerations
 are given in multiples of the acceleration of
 gravity]

Attitude of fuselage reference line		10°			2°
		80	100	120	120
Speed, mph full scale		80	100	120	120
Model without openings simulating no structural damage in landing	No propellers	1.7			
Bomb-bay doors removed		4.9		4.7	
Bomb-bay doors and rear gun hatch removed		3.6		4.8	
Rear-gun hatch removed		1.3		3.4	4.2
Bomb-bay doors, rear gun hatch, and bombardier's sighting window removed		3.0		4.7	5.6
	Wind- milling propellers	2.7	3.2	3.6	5.7

NOTE: The windmilling propellers on the model were made from $\frac{1}{16}$ -inch thick aluminum; the tips generally bent when the propellers hit the water.

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TABLE III

TANK TESTS WITH A $\frac{1}{10}$ -SIZE MODEL OF THE A-20A AIRPLANE WITH GUN
BLISTERS LANDED ACROSS THE WAVES - NO DAMAGE SIMULATED

[Gross weight 21,500 pounds; all figures given refer to full scale]

Wave condition	Attitude fuselage reference line (deg)	Speed (mph)	Range maximum deceleration (g)	Point of contact	Remarks
Length - 20 ft	10	80	1.7 to 1.8		Rode the waves or skipped from crest to crest.
Height - 15 in.	10	100	1.2 to 3.8		Rode the waves.
	2	120	5.9 to 6.4		Rode the waves. (Bomb-bay doors were broken after being reinforced.)
Length - 120 ft Height - $\frac{1}{2}$ ft	10	80	1.9 to 2.6	A	Rode the waves
	10	80	2.2 to 6.8	B	Skipped from crest to crest or skipped and entered the following wave in slight dive.
	10	80	2.0 to 4.2	C	Rode the waves or skipped from crest to crest.
	10	100	4.4 to 4.7	A	Skipped from crest to crest, then nosed in or turned quickly at the end of the run.
	10	100	4.6	B	Skipped (turned and nosed in at end of run).
	10	100	6.5	C	Skipped (then ran deeply in a turn).
	2	120	8.4	A	Skipped off first wave and dived deeply in third wave.
	2	120	2.8 to 6.5	B	Rode the waves then turned violently; (in one run the model skipped and tore out the reinforced bomb-bay doors).
	2	120	5.0 to 5.6	C	Rode the waves, skipped. (In one run the model skipped then dived violently into third wave.)

Point of contacts: (A) on leeward side; (B) on crest; (C) on windward side.

NOTE: The water speeds were approximately representative of the full-scale values but no wind was available, so airspeeds were low and wing lift was less than model weight.

TABLE IV

TESTS AT THE OUTDOOR CATAPULT WITH A $\frac{1}{10}$ -SIZE MODEL
OF THE ARMY A-20A AIRPLANE WITH GUN BLISTERS

[All values are full scale.]

Weight (lb)	Attitude fuselage reference line (deg)	Range of maximum longitudinal deceleration (g)	Range of wave heights (parallel waves) (in.)	Remarks
17,400	13	3.8 to 5.4	0 to 60	Pitched up after contact. Smooth run resulted.
	9	5.4 to 7.7	0 to 60	Same as high attitude except some turns occurred and fairly heavy spray was raised.
	4	5.7 to 7.7	0 to 60	Porpoised slightly. Heavy spray raised during landing run.
21,500	10		0 to 30	Similar to 13°, 17,400 pounds.

NOTE: In the light-weight runs, the bomb-bay doors, rear gun hatch, and the bombardier's sighting window were removed. No damage was simulated in the heavy-weight runs.

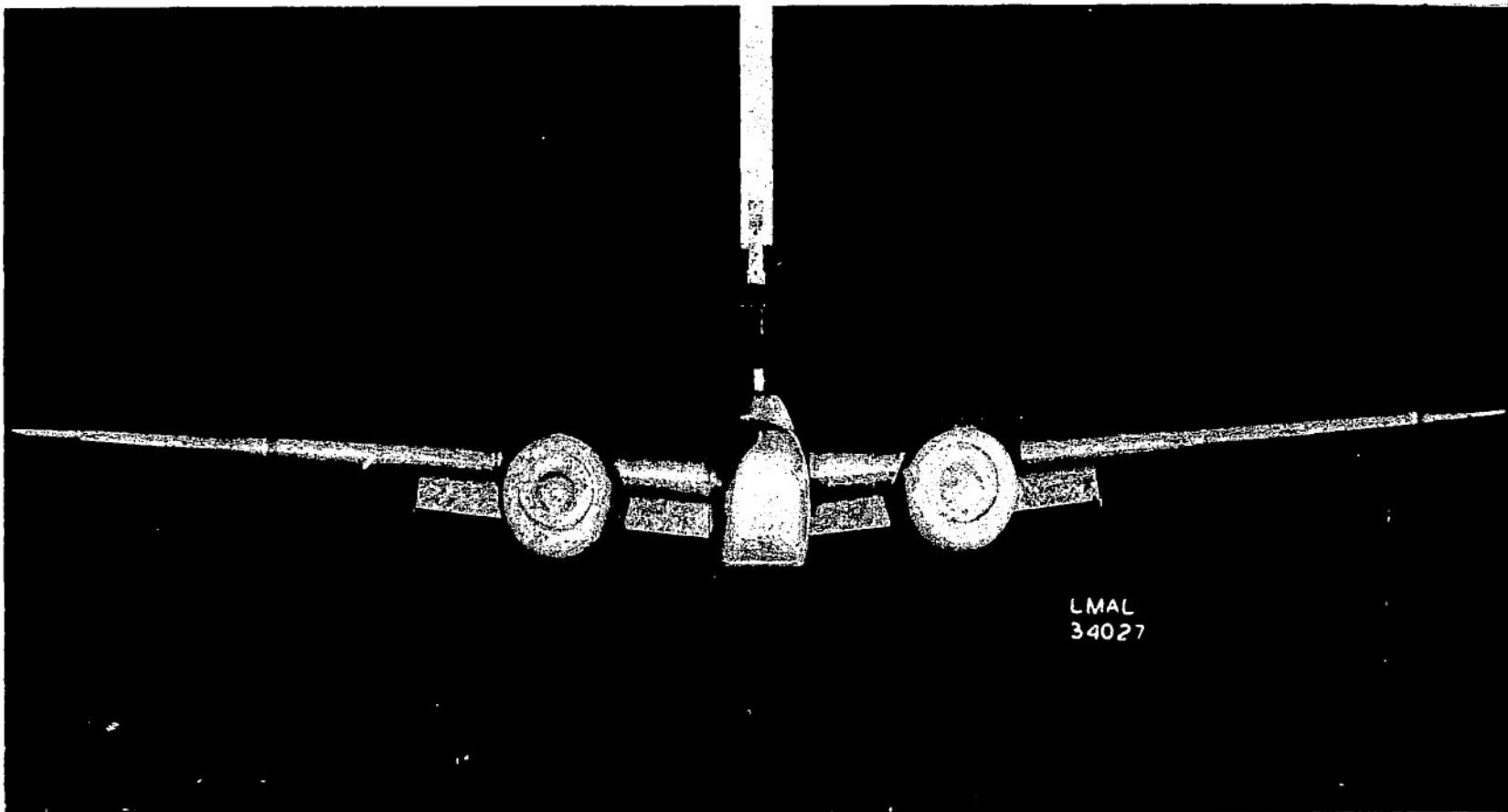


Figure 1(a).- Photographs of $\frac{1}{10}$ -size model of A-20A airplane without gun blisters. Front view.

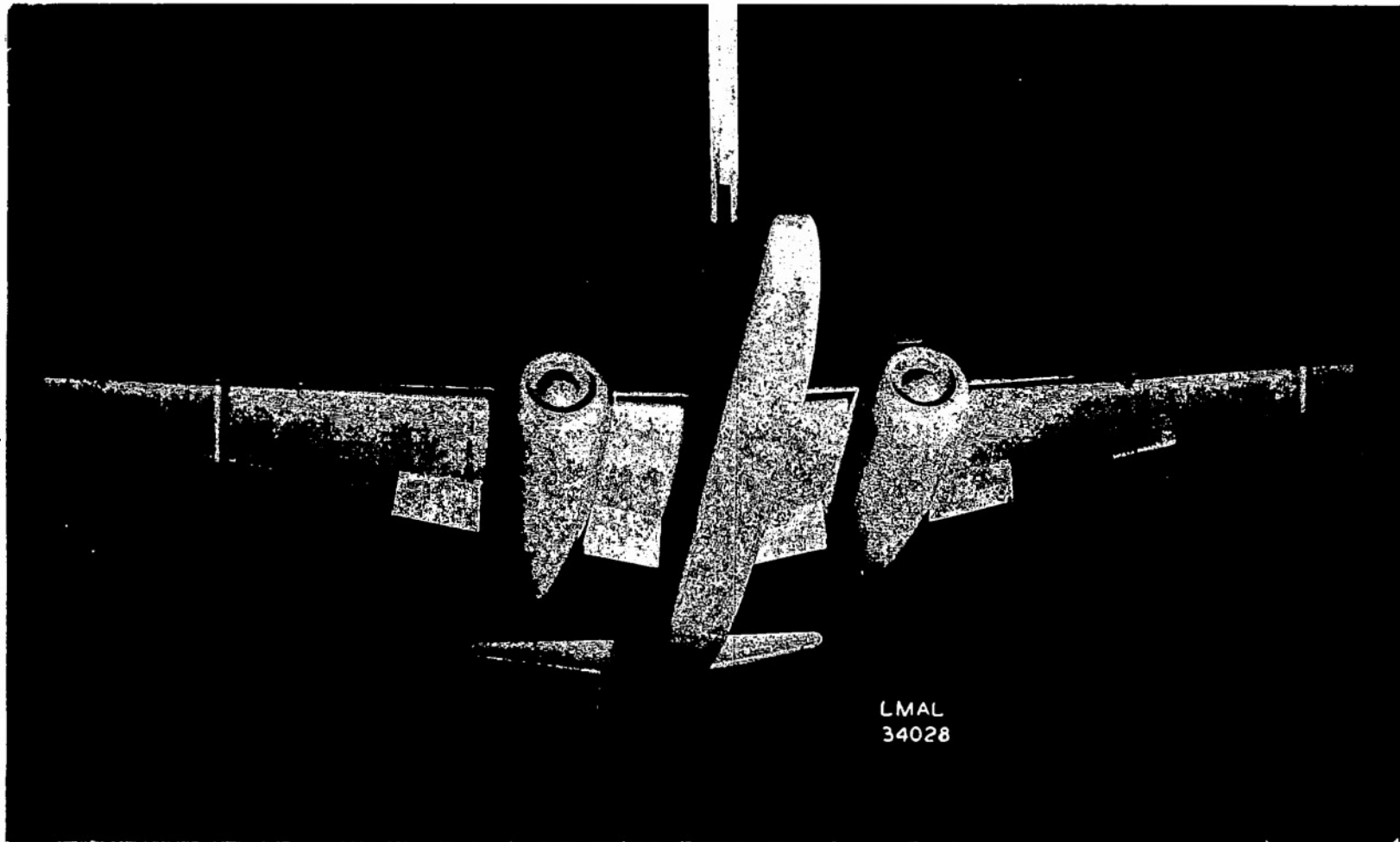


Figure 1(b).- Photographs of $\frac{1}{10}$ -size model of A-20A airplane without gun blisters. Bottom view.

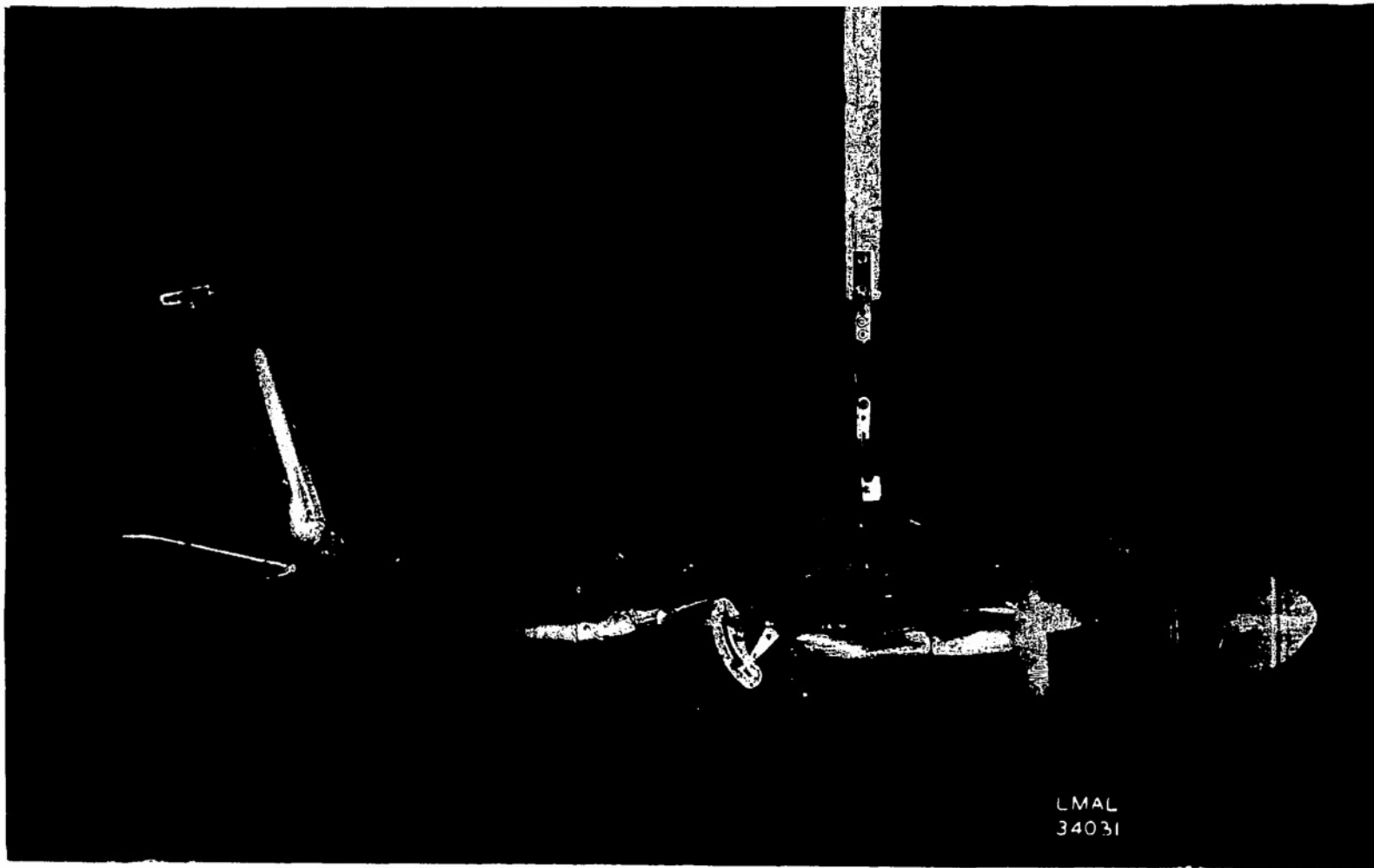


Figure 1(c).- Photographs of $\frac{1}{10}$ -size model of A-20A airplane without gun blisters. Side view.

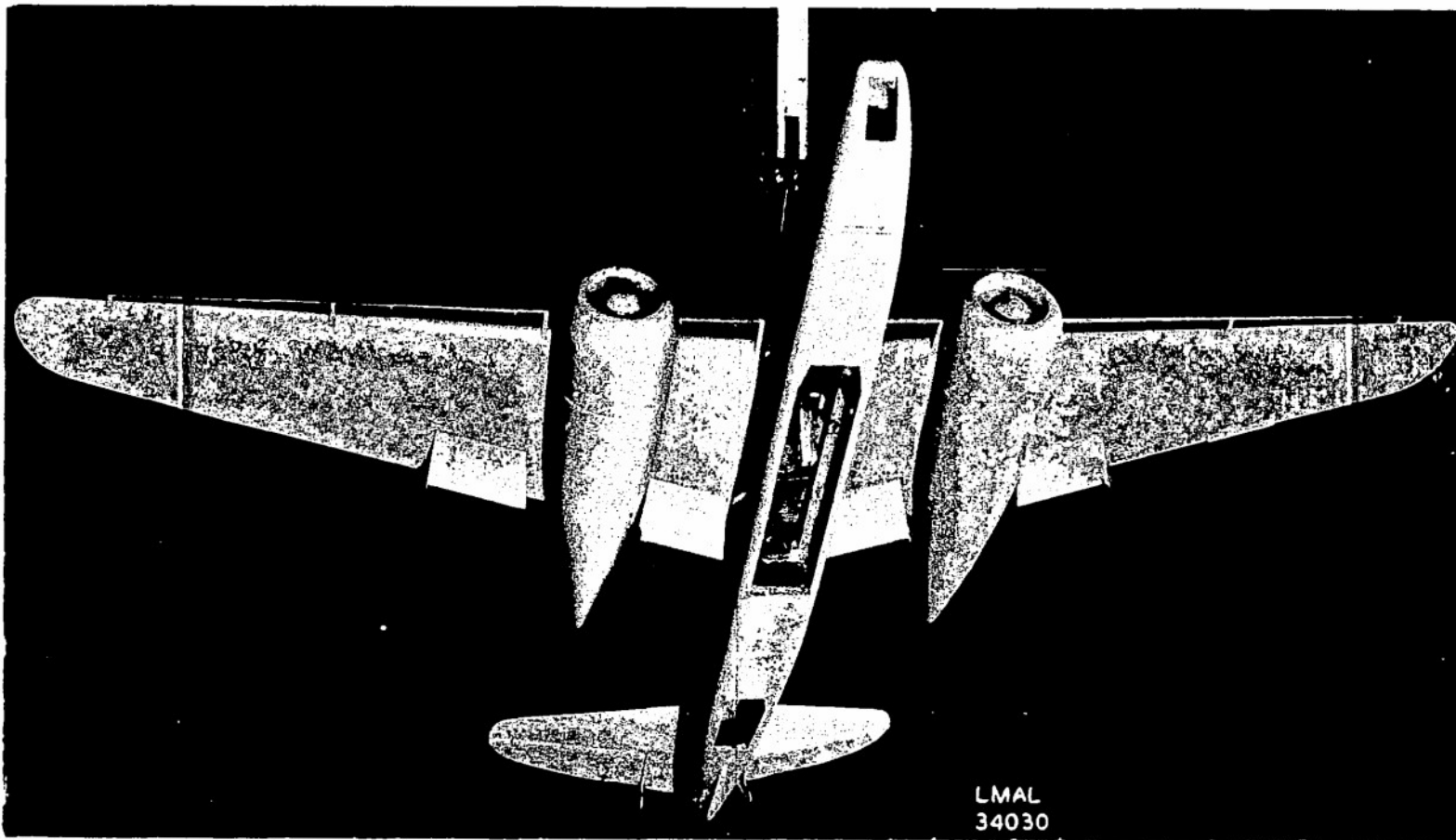


Figure 2.- Photograph of the model with openings simulating damage of rear gun hatch, bomb-bay doors, and bombardier's sighting window.

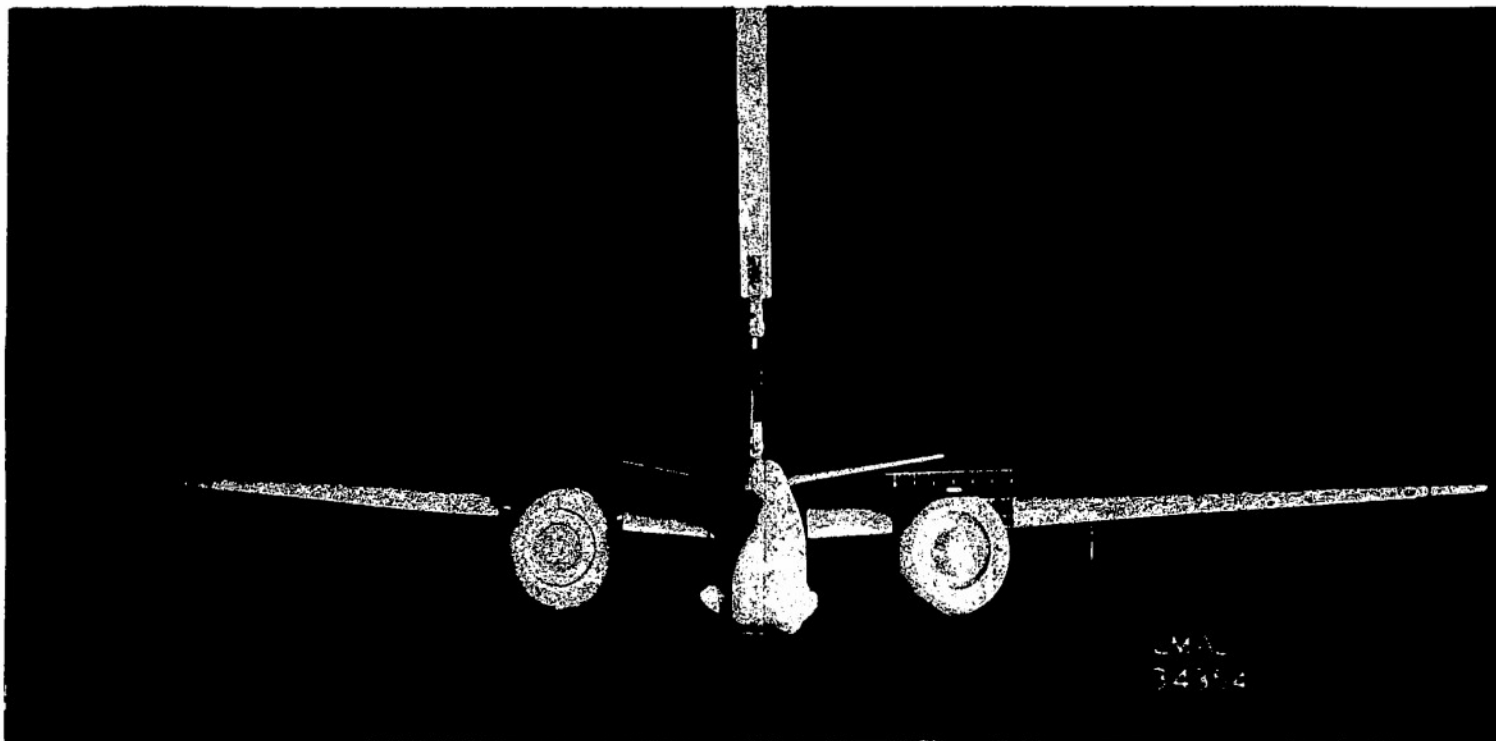


Figure 3(a).- Photograph of $\frac{1}{10}$ -size model of A-20A airplane with gun blisters added.
Front view.

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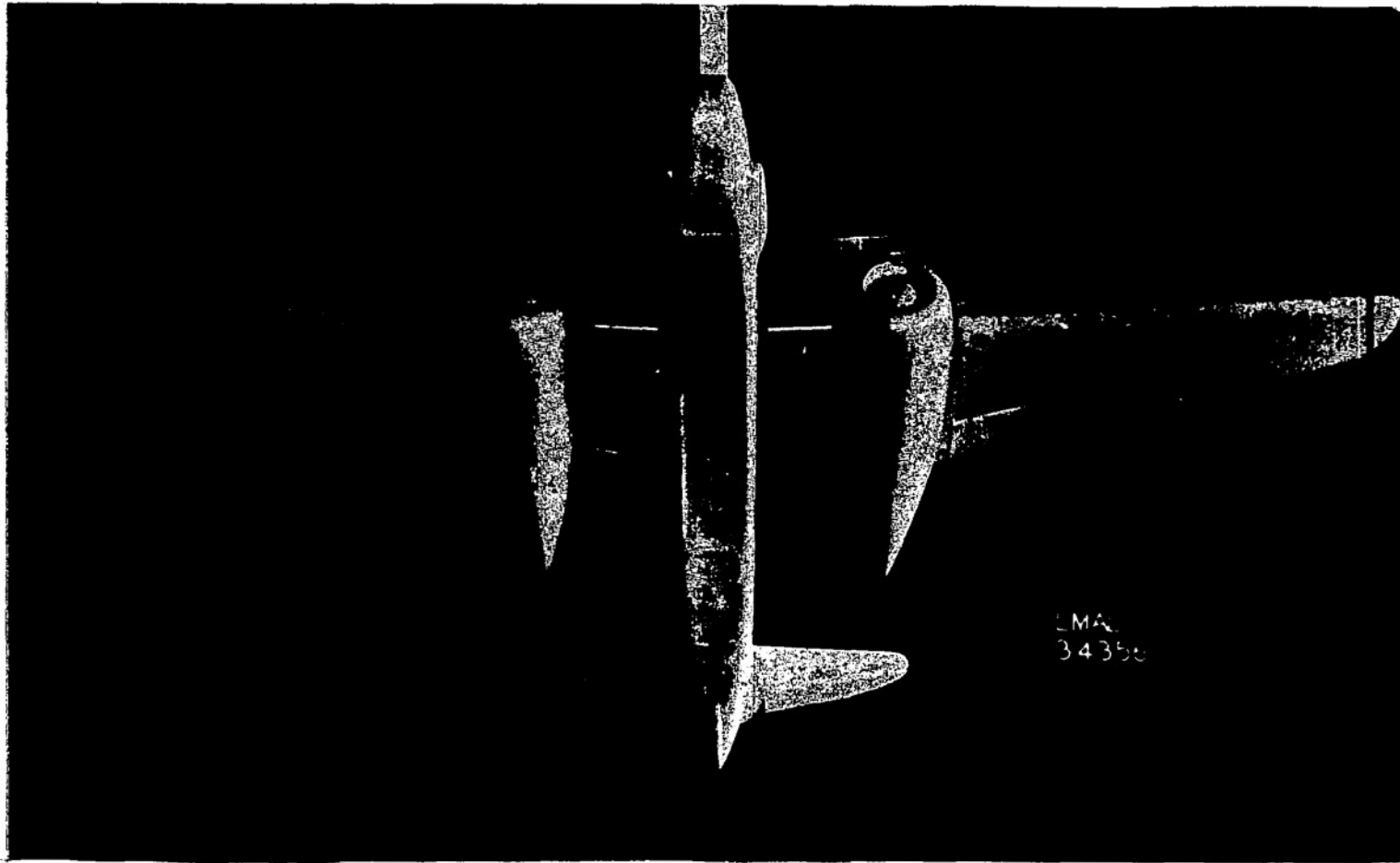


Figure 3(b).- Photograph of $\frac{1}{10}$ -size model of A-20A airplane with gun blisters added.
Bottom view.

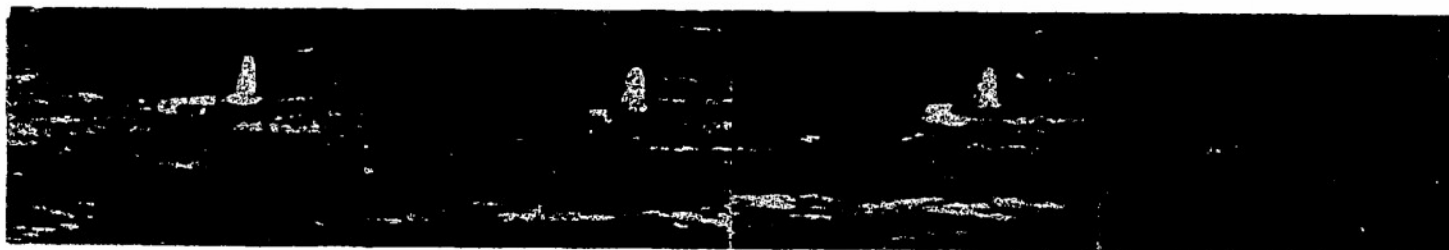


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.30

0



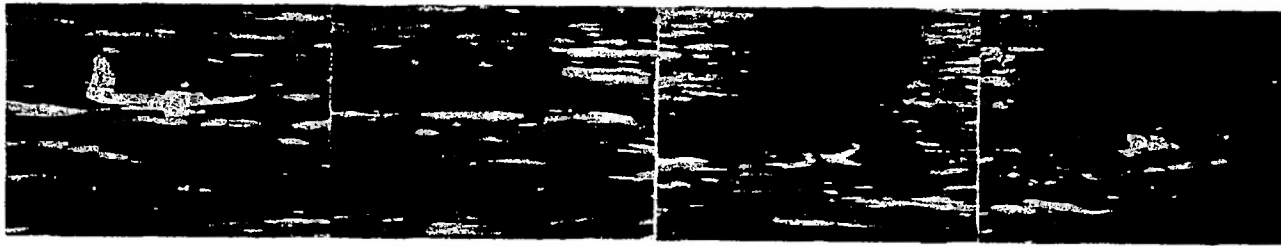
4.80

2.80

2.27

1.72

Figure 4.- Photographs of a ditching of a $\frac{1}{10}$ -size model of the Army A-20A airplane with gun blisters. The landing was made along the waves with flaps down. Simulated failure of bomb-bay doors, rear gun hatch, and bombardier's sighting window. (Full scale time indicated in seconds.) Attitude 13° , speed 90 miles per hour.

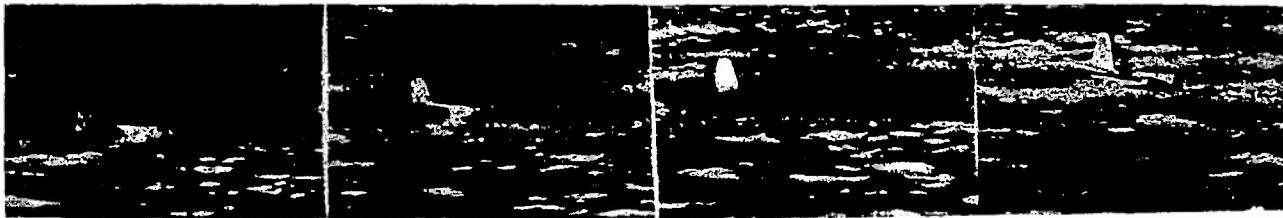


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.60

1.22



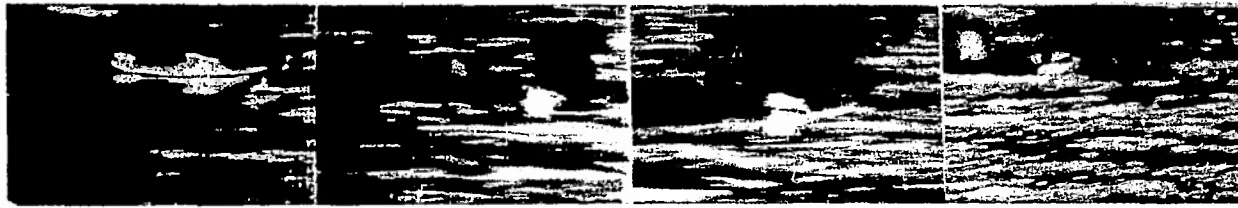
1.80

2.56

3.05

4.50

Figure 5.- Photographs of a ditching of a $\frac{1}{10}$ -size model of the Army A-20A airplane with gun blisters. The landing was made along the waves with flaps down. Simulated failure of bomb-bay doors, rear gun hatch, and bombardier's sighting window. (Full scale time indicated in seconds.) Attitude 9° , speed 102 miles per hour.

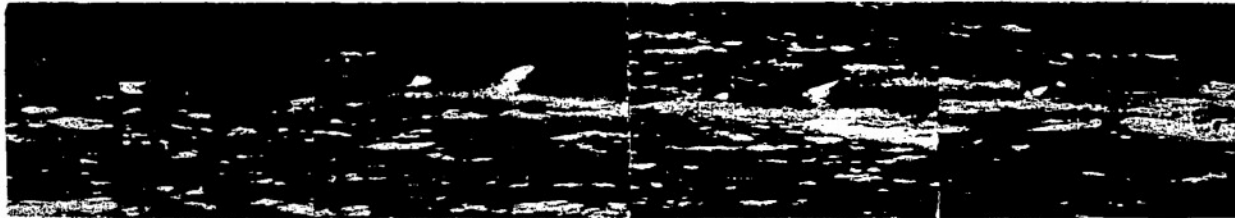


0

.30

.75

1.28



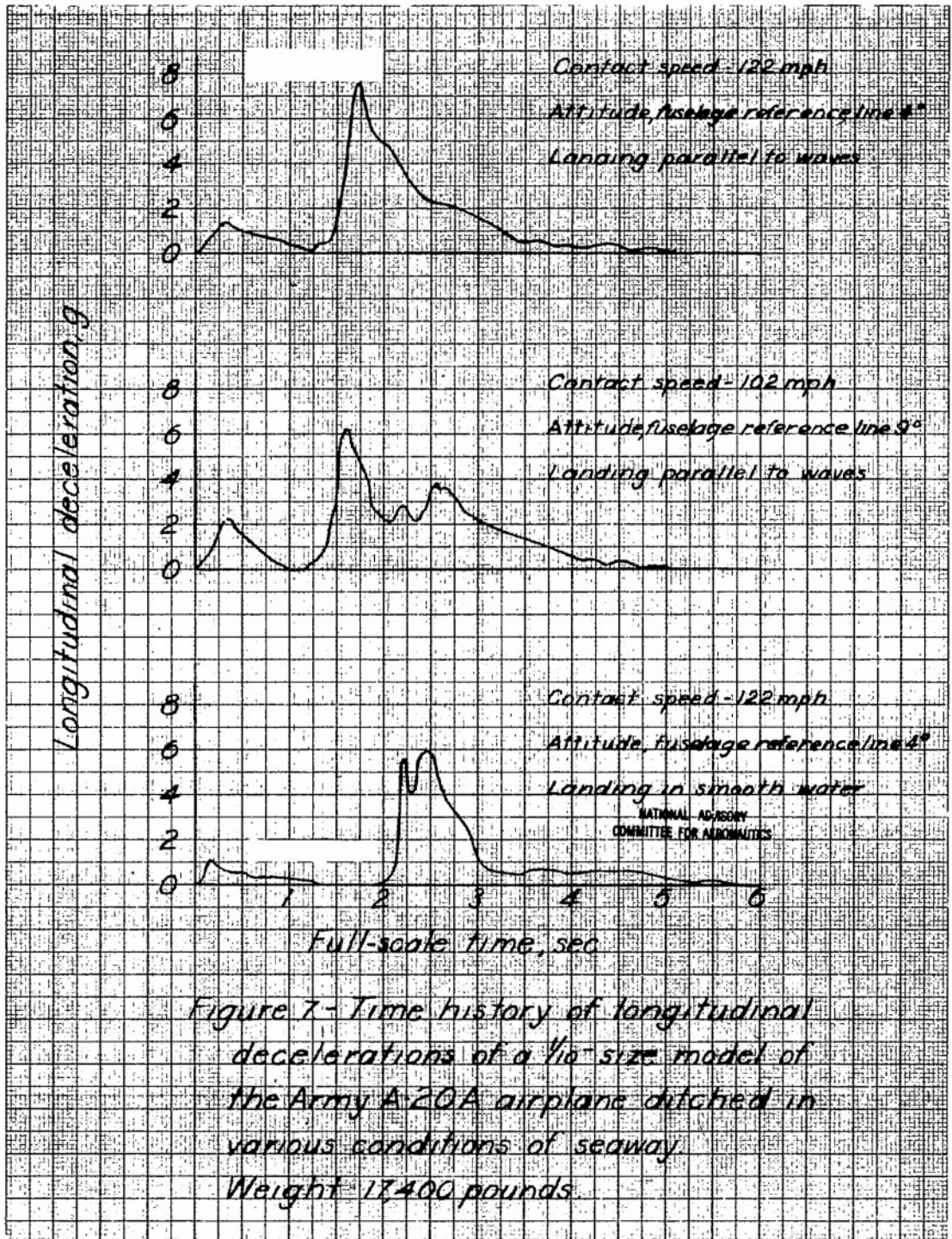
1.72

2.45

3.40

4.70

Figure 6.- Photographs of a ditching of a $\frac{1}{10}$ -size model of the Army A-20A airplane with gun blisters. The landing was made along the waves with flaps down. Simulated failure of bomb-bay doors, rear gun hatch, and bombardier's sighting window. (Full scale time indicated in seconds.) Attitude 4° , speed 122 miles per hour.



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