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RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

DITCHING INVESTIGATION OF A 1/25-SCALE MODEL OF
A 255,000-POUND TRANSPORT AIRPLANE

By John O. Windham

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Langley Field, Va.

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DITCHING INVESTIGATION OF A 1/25-SCALE MODEL OF
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SUMMARY

An investigation was made of a 1/25-scale dynamically similar model of a 255,000-pound transport airplane in order to study its behavior when ditched. The model was free-launched from the Langley tank no. 2 mono-rail carriage into calm water. Various landing attitudes, flap settings, speeds, and configurations were investigated.

It was concluded that the airplane should be ditched at a nose-high attitude (5° to 10°) with flaps down 45° . In a calm-water ditching at the recommended attitude, the airplane will probably nose in and then trim up and run smoothly. The cargo doors, section of fuselage bottom forward of the cargo doors, and main landing-gear pods will sustain appreciable damage. All passengers and crew members should exit from the airplane as soon as possible after the forward motion of the airplane has stopped since rapid flooding is likely and the airplane will quickly sink to the level of the high wing. Maximum longitudinal decelerations will be about $3g$ and maximum normal accelerations will be about $2g$ in a landing run of about 4 fuselage lengths.

If bottom damage to the airplane can be prevented by strengthening the area where damage occurs, the airplane will make a smooth run. In a calm-water ditching, maximum longitudinal decelerations of about $1\frac{1}{2}g$ and maximum normal accelerations of about $6g$ to $7g$ would be expected in a landing run of about 5 or 6 fuselage lengths.

If a hydroflap ditching aid is installed, the diving motion will be prevented and the airplane will make a fairly smooth run. Damage to the bottom and landing-gear pods should be slight. Maximum longitudinal decelerations in a calm-water ditching will be about $2g$ and maximum normal accelerations will be about $4g$ in a landing run of about 5 fuselage lengths.

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INTRODUCTION

A ditching investigation of a dynamic model of a 255,000-pound transport airplane was made to determine the best way to land the airplane on water. The investigation was requested by the Air Materiel Command, U. S. Air Force. This airplane was of special interest because of the large main landing-gear pods, the ramp-type cargo doors located in the rear section of the fuselage, and the rather large amount of longitudinal curvature in the rear portion of the fuselage bottom. A three-view drawing of the transport is shown in figure 1.

The ditchings were made in calm water at the Langley tank no. 2 mono-rail. In rough-water ditchings made perpendicular to the waves, more damage and violence of motion may occur, depending on the choice of ditching site and the portion of the wave contacted.

APPARATUS AND PROCEDURE

Description of Model

The 1/25-scale dynamic model of the transport airplane had a wing span of 7.18 feet, a fuselage length of 6.11 feet, and a gross weight of 16.32 pounds. Photographs of the model are shown in figure 2. The wings and empennage of the model were constructed of balsa wood with spruce or mahogany at areas of concentrated stress. The fuselage and main landing-gear pods were constructed of Fiberglas impregnated with Paraplex. Internal ballast was used to obtain scale weight and moments of inertia.

The model was constructed so that sections of the bottom of the fuselage and the main landing-gear pods could be removed and replaced by sections of known strength. These scale-strength bottom sections were designed and tested to fail under a uniformly distributed load of 290 lb/sq ft for the main landing-gear pods, 1,150 lb/sq ft for the cargo doors, and 1,730 lb/sq ft for the main bottom section (full-scale values estimated by manufacturer). The scale-strength bottoms shown in figures 3 and 4 were used to determine the location and the amount of damage that might occur in a ditching. A hydroflap ditching aid, the size and location of which were determined from model tests, is shown installed on the model in figures 4 and 5.

Test Methods and Equipment

The test methods and equipment used were similar to those used in previous ditching investigations. The model was attached to the launching

carriage on the Langley tank no. 2 monorail at the desired attitude with the control surfaces set to hold this attitude in flight. The model was then catapulted into the air, and the preset control surfaces kept the model at approximately the desired attitude during the glide from release to landing.

The results of the investigation were obtained from visual observations, motion-picture records, and time-history acceleration records. The accelerations were measured with an NACA two-component accelerometer placed in the pilot's cockpit. Both normal and longitudinal components of acceleration, measured with respect to the axis of the airplane, were recorded. The natural frequency of the accelerometer was 73 cps and it was damped to about 65 percent of critical damping. The accuracy with which the instrument could be read was estimated to be about $\pm \frac{1}{4}g$.

Test Conditions

All values given as follows refer to the full-scale airplane:

Gross weight.- The design gross weight of 255,000 pounds was simulated in the tests.

Moments of inertia.- The moments of inertia used in this investigation were as follows:

Rolling moment, slug-ft ²	5,130,000
Pitching moment, slug-ft ²	5,950,000
Yawing moment, slug-ft ²	11,130,000

Location of center of gravity.- The center of gravity was located at 25 percent of the mean aerodynamic chord and 55 inches (full scale) above the fuselage reference plane.

Landing attitude.- Ditchings were made at three attitudes: 10° (near lift-curve stall), 5° (intermediate), and 1° (near three wheel). The attitude was measured between the fuselage reference line and the smooth-water surface.

Landing flaps.- Tests were made with flaps full-up and full-down (45°).

Landing speed.- The landing speeds computed from power-off lift curves furnished by the manufacturer are listed in table I.

Landing gear.- All tests simulated ditchings with the landing gear retracted.

Fuselage conditions.- The model was tested in the following fuselage conditions:

- (a) Undamaged
- (b) Scale-strength bottoms installed
- (c) Scale-strength bottoms and hydroflap installed

RESULTS AND DISCUSSION

A summary of the results of the investigation is presented in table I. The notations used in the table are defined as follows:

ran smoothly	the model made no apparent oscillation about any axis and gradually settled into the water as the forward speed decreased
trimmed up	the model made a positive rotation about the lateral axis after contact with the water
trimmed down	the model made a negative rotation about the lateral axis after contact with the water
nosed in	the model decelerated rapidly in a nose-down attitude and the nose partially submerged into the water
dived	the model decelerated rapidly in a nose-down attitude and the nose submerged into the water
porpoised	the model undulated about the lateral axis with some part of the model always in contact with the water
skipped	the model cleared or rebounded from the water
oscillated in roll	the model undulated about the longitudinal axis alternately touching wing tips

Sequence photographs of model ditchings are shown in figure 6. Figure 7 presents time histories of attitude, longitudinal decelerations, and normal accelerations for the 5° landing attitude with flaps down 45° for the three different fuselage conditions. Figure 8 presents photographs of typical damage to the scale-strength bottoms obtained with and without the hydroflap at the 5° landing attitude with flaps down 45° .

Effect of Damage

In landings at the 10° and 5° attitudes with no damage simulated and the flaps down 45° , the model trimmed up soon after contact with the water. The attitude then decreased as the speed decreased until the attitude was near level. Toward the end of the run, one of the wing tips would touch the water and the model would turn in the direction of the lowered wing tip (fig. 7(a)). At the 1° landing attitude with flaps down 45° , the model trimmed up, skipped, and then behaved very much as it did at the higher landing attitudes. At the 10° and 5° landing attitudes with flaps up, the model trimmed up and skipped two or three times. At the 5° landing attitude, the model oscillated in roll during the landing run. Maximum longitudinal decelerations of $1\frac{1}{2}g$ to $2\frac{1}{2}g$ and maximum normal accelerations of $6g$ to $8\frac{1}{2}g$ were encountered in landing runs of 5 to 10 fuselage lengths (table I). The trimming up and skipping were attributed to the large amount of longitudinal curvature of the aft portion of the fuselage bottom (figs. 1 and 2(b)). This curvature is typical of rear-loading ramp-type transports where head clearance for large cargo packages is essential.

In landings at the 10° , 5° , and 1° attitudes with scale-strength bottoms installed and the flaps down 45° , the model nosed in, trimmed up to a near-level attitude, and then ran smoothly, sinking to the level of the high wing as the speed decreased (figs. 6(a) and 7(b)). At the 10° and 5° landing attitudes with flaps up, the model made a dive going deeper than with flaps down, but the behavior was similar for the remainder of the run. Maximum longitudinal decelerations of $2g$ to $5\frac{1}{2}g$ and maximum normal accelerations of $2g$ to $4\frac{1}{2}g$ were encountered in landing runs of 4 to 5 fuselage lengths (table I). The area of the fuselage bottom just forward of the cargo doors, the forward cargo door (ramp portion), and the main landing-gear pods sustained appreciable damage (fig. 8(a)). Damage to the landing-gear pods had no noticeable effect on behavior in the model ditchings other than to increase the flooding of the fuselage. The amount of damage to the fuselage bottom and the fact that the model sank to the level of the high wing indicate that rapid flooding will be likely and the passenger and crew compartments will be filled with water. This rapid flooding would make it expedient that all passengers and crew exit from the airplane as soon as possible after the forward motion of the airplane has stopped. Damage to the fuselage bottom just forward of the cargo doors produced a pitching-down moment which resulted in the diving motion. If this area of the bottom could be sufficiently strengthened to prevent damage, the diving motion would be eliminated.

Effect of Hydroflap Ditching Aid

The diving motion was prevented by installing the hydroflap ditching aid under the forward part of the fuselage bottom. The model with scale-strength bottoms and a hydroflap installed did not dive but made a porpoising run at the 10° landing attitude with flaps down 45° and a fairly smooth run with little change in attitude at the 5° landing attitude with flaps down 45° (figs. 6(b) and 7(c)). Typical damage to scale-strength bottom is shown in figure 8(b). Maximum longitudinal decelerations of $2g$ and maximum normal accelerations of $4g$ were encountered in landing runs of 4 to 5 fuselage lengths (table I).

Effect of Landing Attitude, Flap Setting, and Speed

The effect of landing attitude and flap setting on the behavior of the model depended on the speeds associated with the attitude and flap condition. At the higher speeds, the skipping was more frequent and the skips were longer, the dives were more abrupt and deeper, and the accelerations were greater than at the lower speeds. The landing flaps had little hydrodynamic effect on the behavior of the model since the high wing kept the flaps clear of the water during most of the landing run. The flap setting, however, was very influential with respect to landing speed, even more so than was landing attitude. Since a low landing speed is desired in a ditching, it would be preferable to ditch with flaps down (45°) at a nose-high landing attitude (5° to 10°).

CONCLUSIONS

A study of the results of an investigation of a $1/25$ -scale dynamically similar model of a 255,000-pound transport airplane gave the following conclusions:

1. The airplane should be ditched at a nose-high landing attitude (5° to 10°) with the flaps down 45° .
2. The airplane will probably nose in and then trim up and run smoothly in calm water. Maximum longitudinal decelerations of $3g$ and maximum normal accelerations of $2g$ are to be expected in a landing run of about 4 fuselage lengths.
3. The fuselage will sustain appreciable damage in the area just forward of the cargo doors, the forward cargo door (ramp portion), and the landing-gear pods. All passengers and crew members should exit from the airplane as soon as possible after the forward motion of the airplane has stopped since rapid flooding is likely and the airplane will quickly sink to the level of the high wing.

4. Damage to the fuselage bottom near the cargo doors produced a diving motion. If bottom damage can be prevented by strengthening the area where damage occurs, the airplane would make a smooth run in calm water. Maximum longitudinal decelerations of $1\frac{1}{2}g$ and maximum normal accelerations of $6g$ to $7g$ would be expected in a landing run of 5 to 6 fuselage lengths.

5. If a hydroflap ditching aid is installed under the forward part of the fuselage, the diving motion will be prevented and the airplane will make a fairly smooth run. Damage to the fuselage bottom and landing-gear pods will be slight. Maximum longitudinal decelerations of $2g$ and maximum normal accelerations of $4g$ are to be expected in a landing run of about 5 fuselage lengths.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 23, 1955.

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John O. Windham
Aeronautical Research Scientist

Approved:

John B. Parkinson
John B. Parkinson
Chief of Hydrodynamics Division

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TABLE I.- SUMMARY OF RESULTS OF DITCHING INVESTIGATION IN CALM WATER OF A 1/25-SCALE

MODEL OF A 255,000-POUND TRANSPORT AIRPLANE

[All values are full-scale]

Landing attitude, deg	Flap setting, deg	Landing speed, knots	Motions of model	Length of run, fuselage lengths	Maximum longitudinal deceleration, g units	Maximum normal acceleration, g units
Undamaged condition						
10	45	102	Trimmed up, ran smoothly	6.4	$1\frac{1}{2}$	6
10	0	137	Trimmed down, trimmed up, skipped (2) ^a	9.8	$2\frac{1}{2}$	$8\frac{1}{2}$
5	45	110	Trimmed up, ran smoothly	4.5	$1\frac{1}{2}$	7
5	0	155	Skipped (3) ^a , oscillated in roll	9.2	$2\frac{1}{2}$	8
1	45	120	Trimmed up, skipped (1) ^a , ran smoothly	8.3	2	6
Scale-strength bottoms installed						
10	45	102	Nosed in, trimmed up, ran smoothly	3.6	3	2
10	0	137	Dived, trimmed up, ran smoothly	4.9	$5\frac{1}{2}$	$3\frac{1}{2}$
5	45	110	Nosed in, trimmed up, ran smoothly	3.8	3	2
5	0	155	Dived, trimmed up, ran smoothly	5.3	5	$4\frac{1}{2}$
1	45	120	Nosed in, trimmed up, ran smoothly	3.7	2	3
Scale-strength bottoms and hydroflap installed						
10	45	102	Porpoised	4.0	$2\frac{1}{2}$	$4\frac{1}{2}$
5	45	110	Ran smoothly	4.5	2	4

^aNumber of skips indicated inside parentheses.

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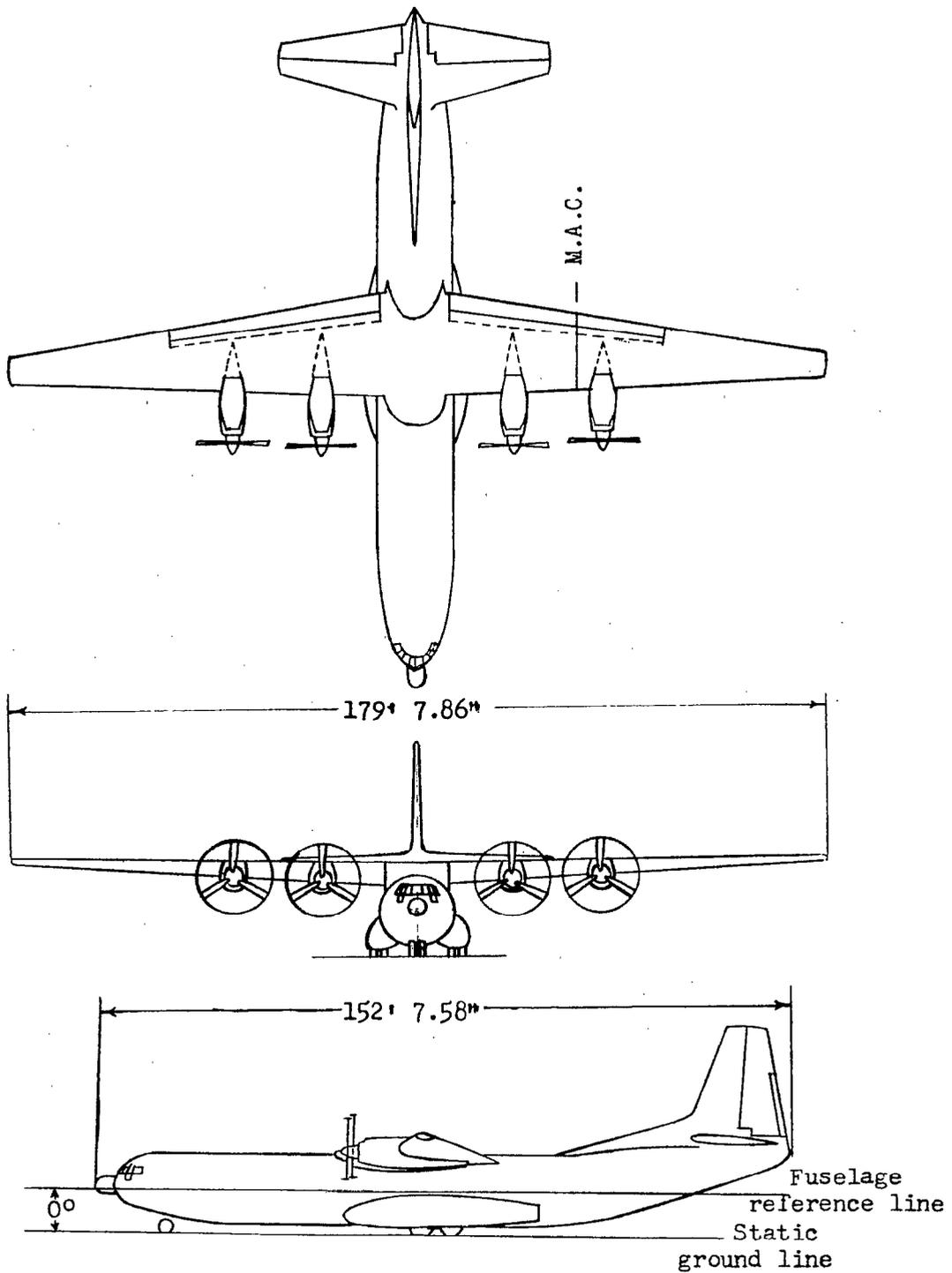
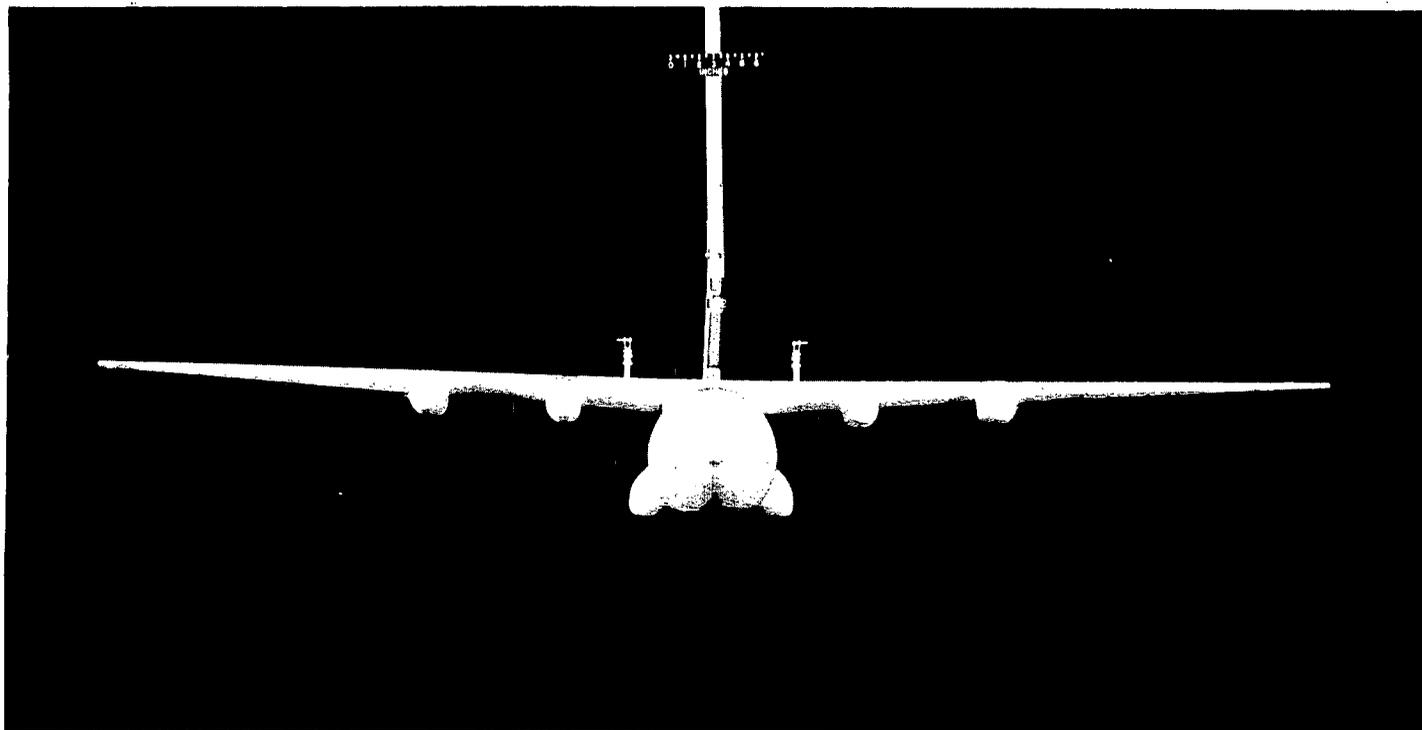


Figure 1.- Three-view drawing of a 255,000-pound transport airplane.

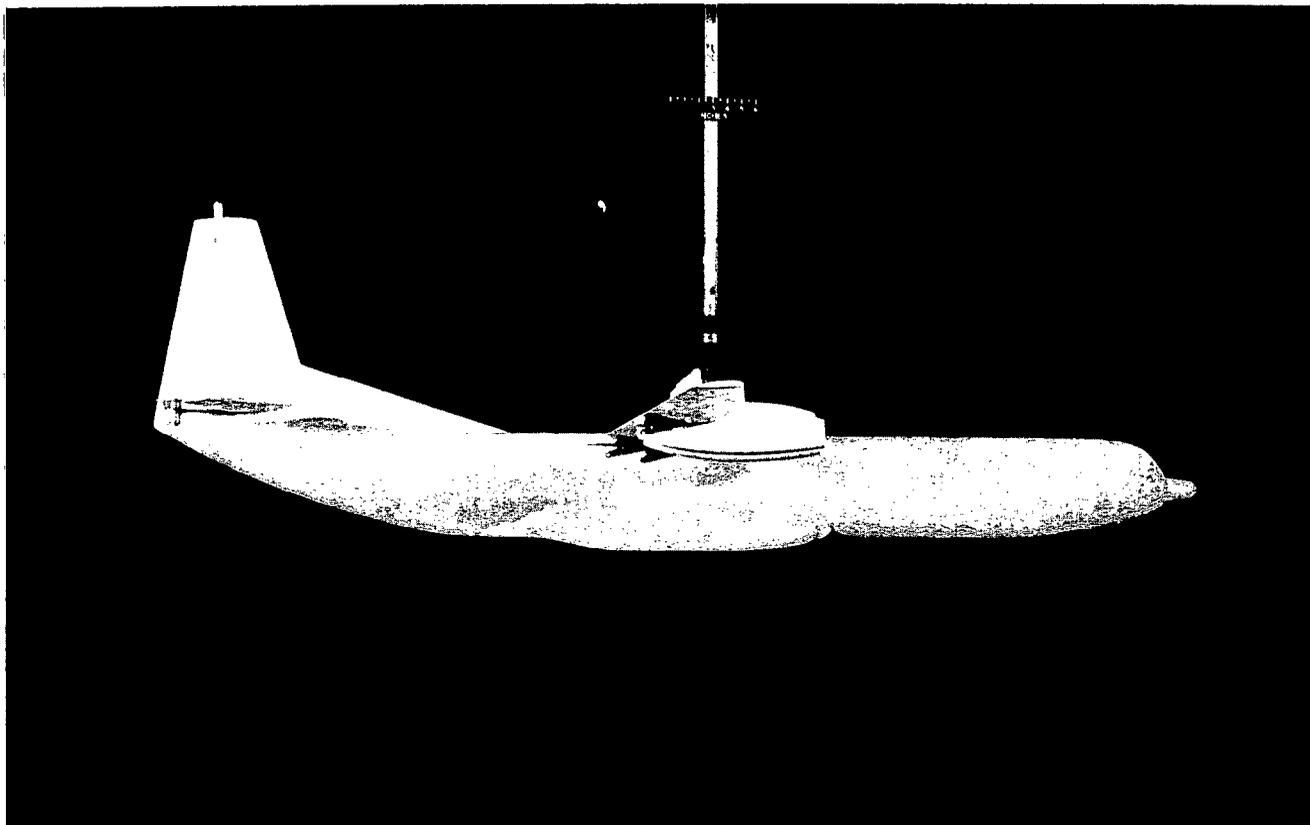
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(a) Front view.

L-85891

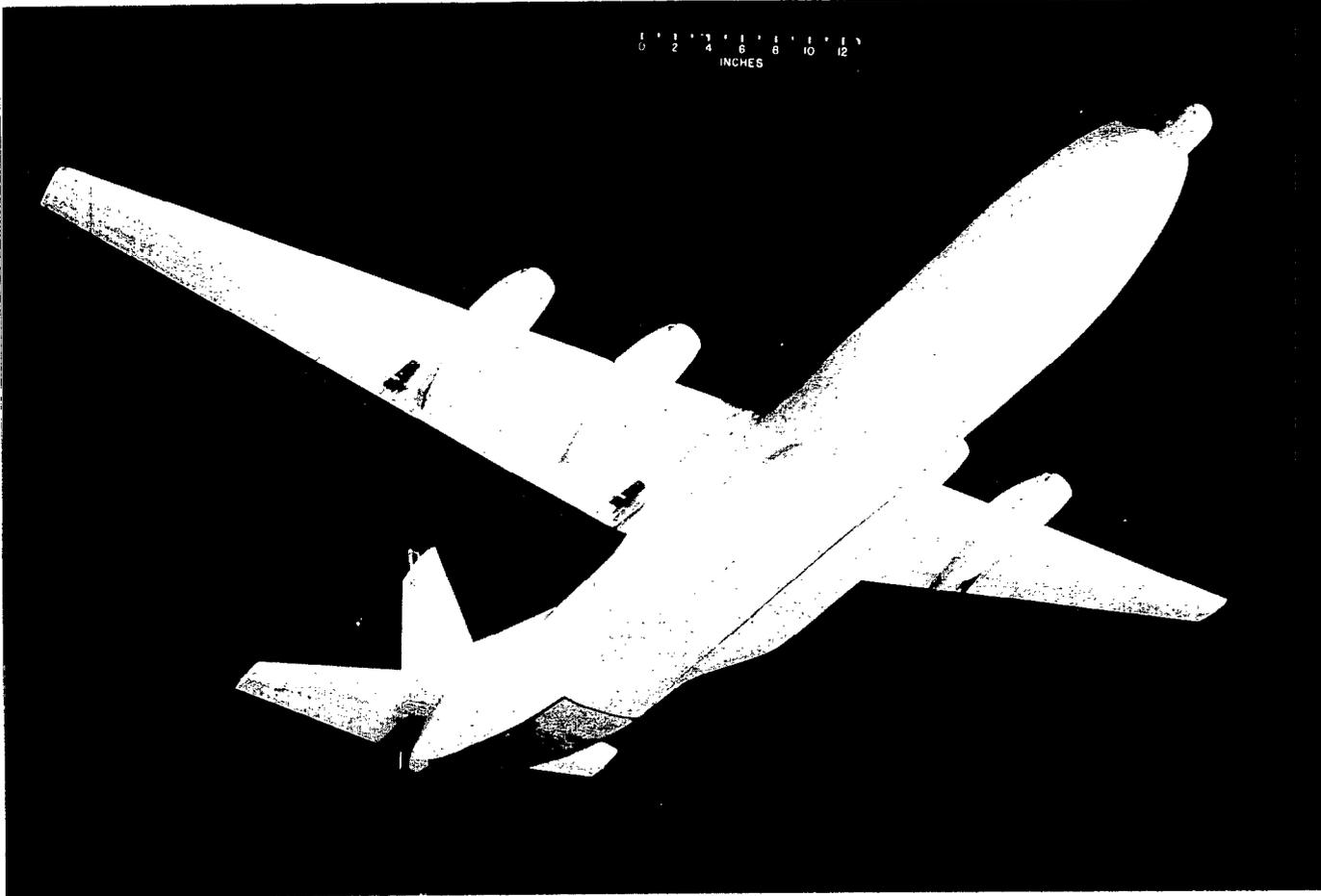
Figure 2.- Model of a 255,000-pound transport airplane.



(b) Side view.

L-85892

Figure 2.- Continued.



(c) Three-quarter bottom view.

L-86559

Figure 2.- Concluded.

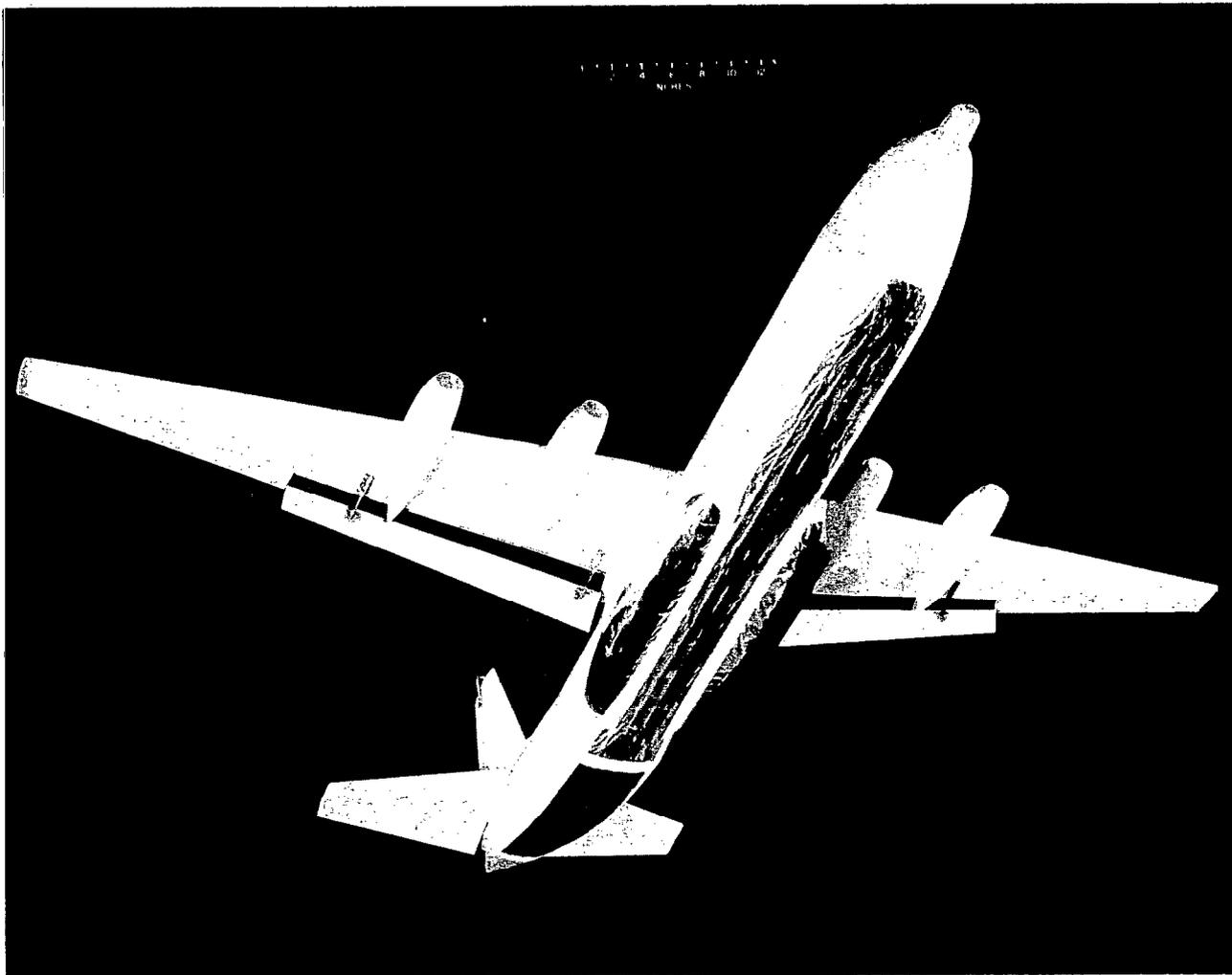
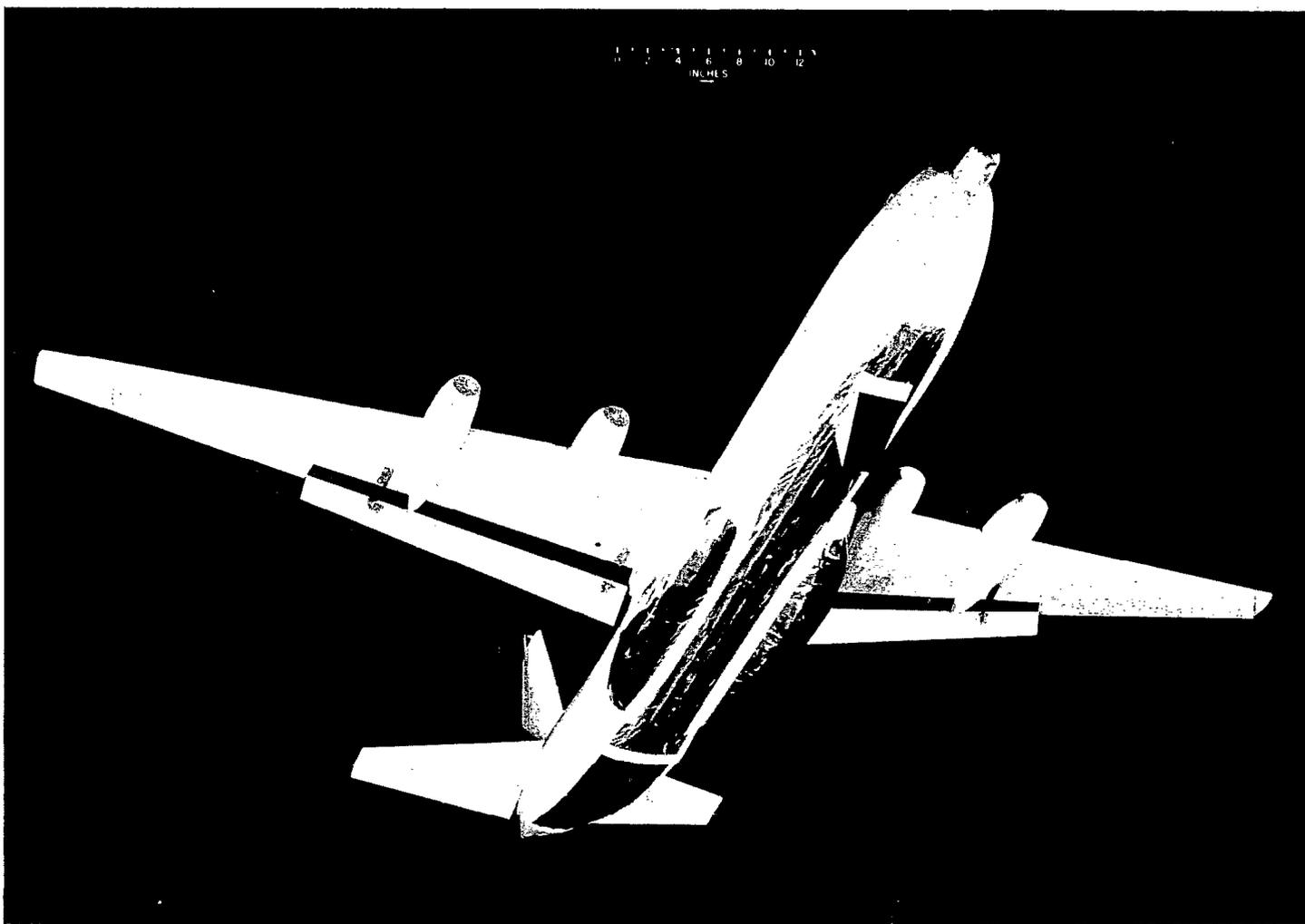


Figure 3.- Model with scale-strength bottoms installed. L-87445

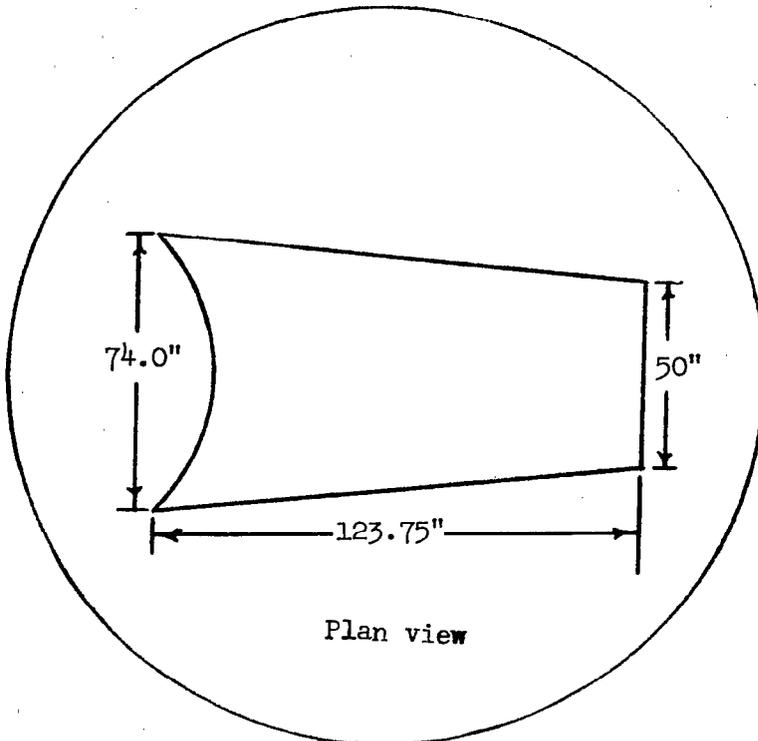
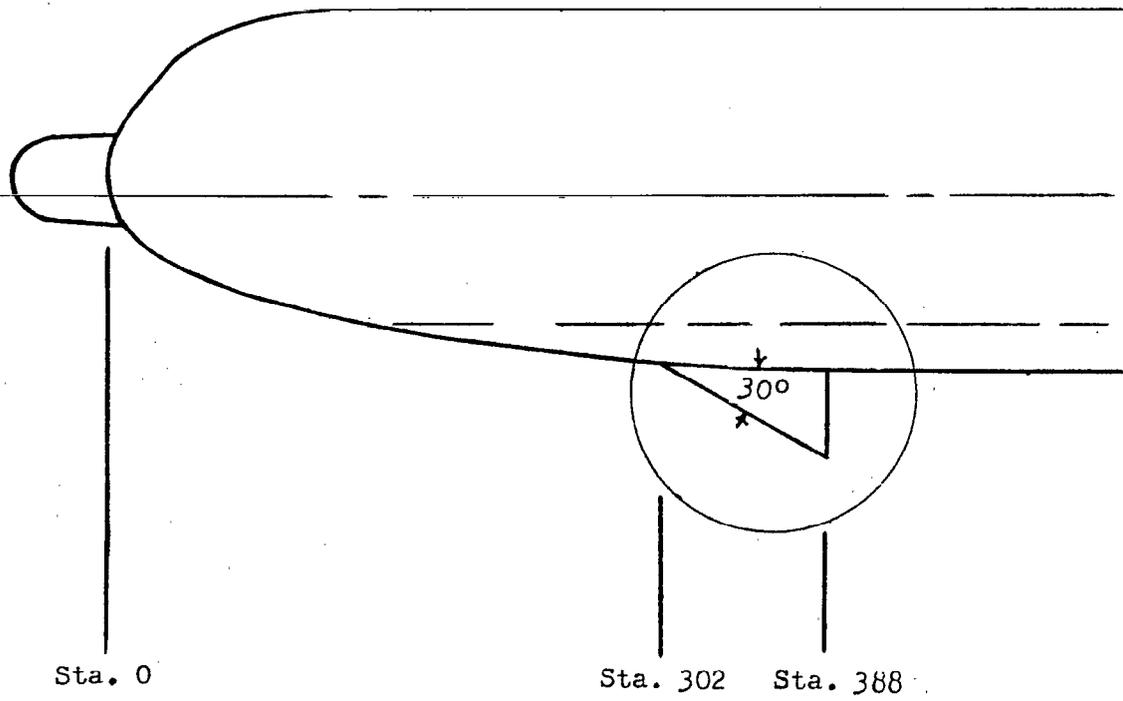


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Figure 4.- Model with scale-strength bottoms and hydroflap installed. L-87446

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Values are full scale

Figure 5.- Details of hydroflap installation.

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Near contact



175 ft



325 ft



513 ft

(a) Without hydroflap.

L-89345

Figure 6.- Sequence photographs of model ditching at the 5° landing attitude with the flaps down 45° and speed 110 knots. Scale-strength bottoms are installed. Distances after contact are indicated. All values are full scale.



Near contact



175 ft



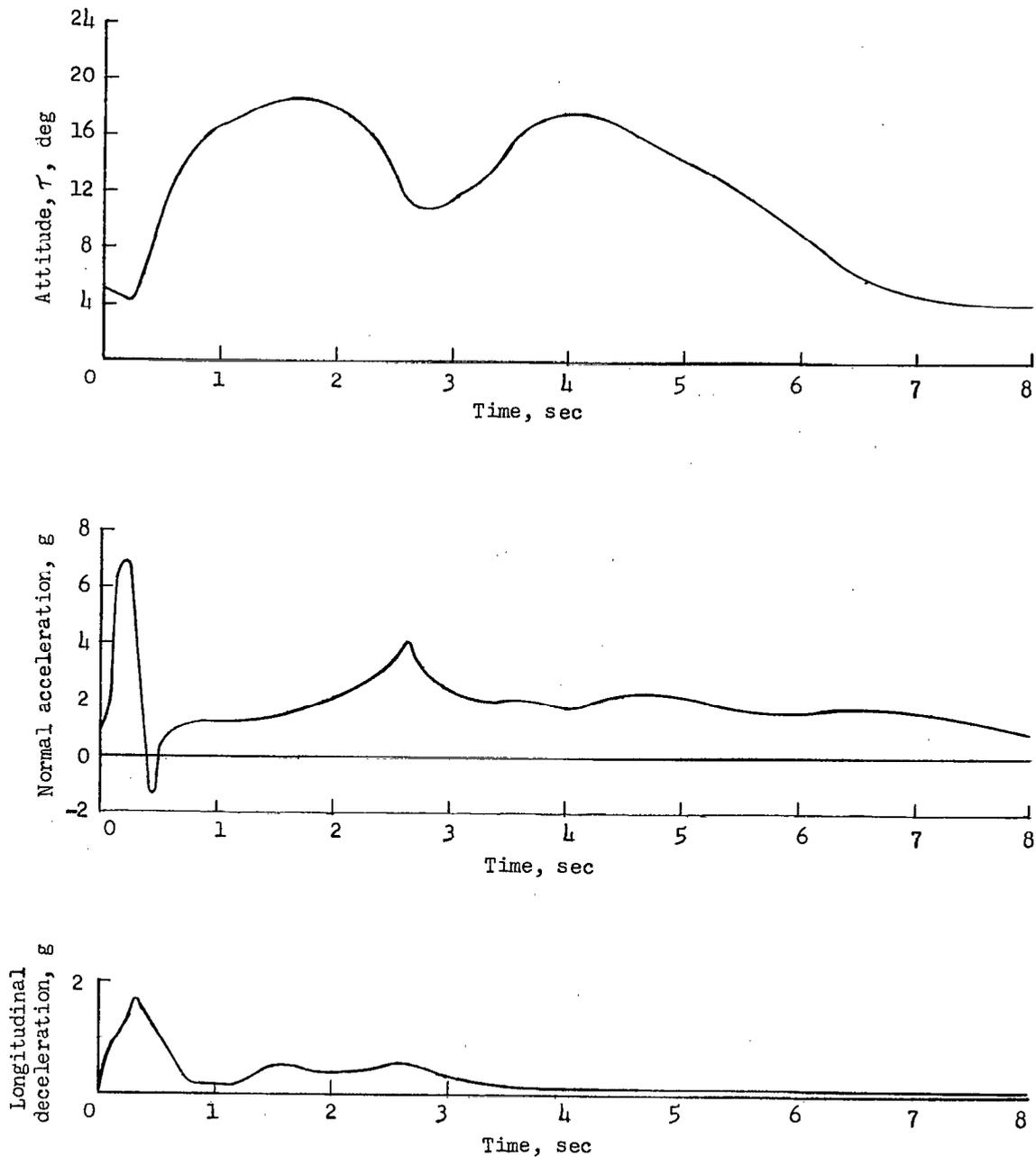
350 ft



638 ft

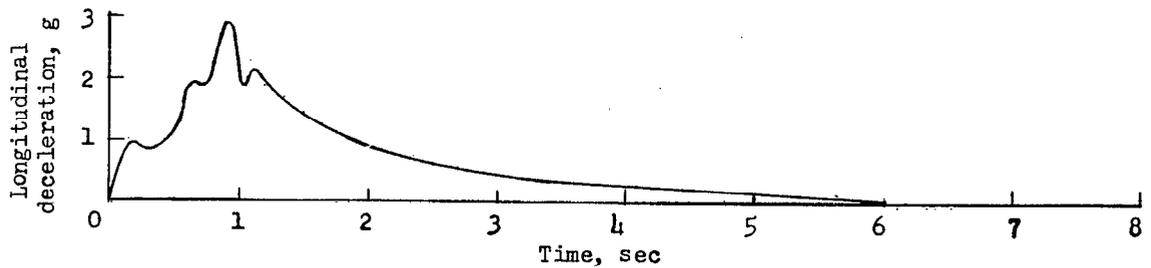
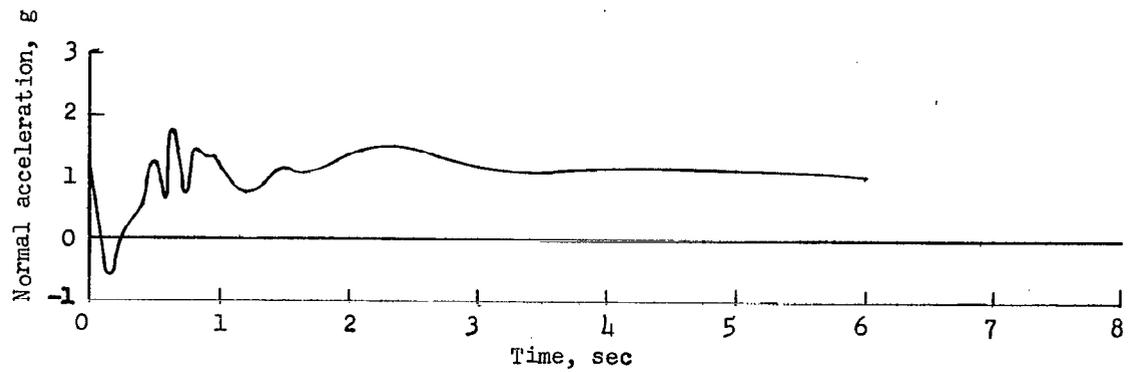
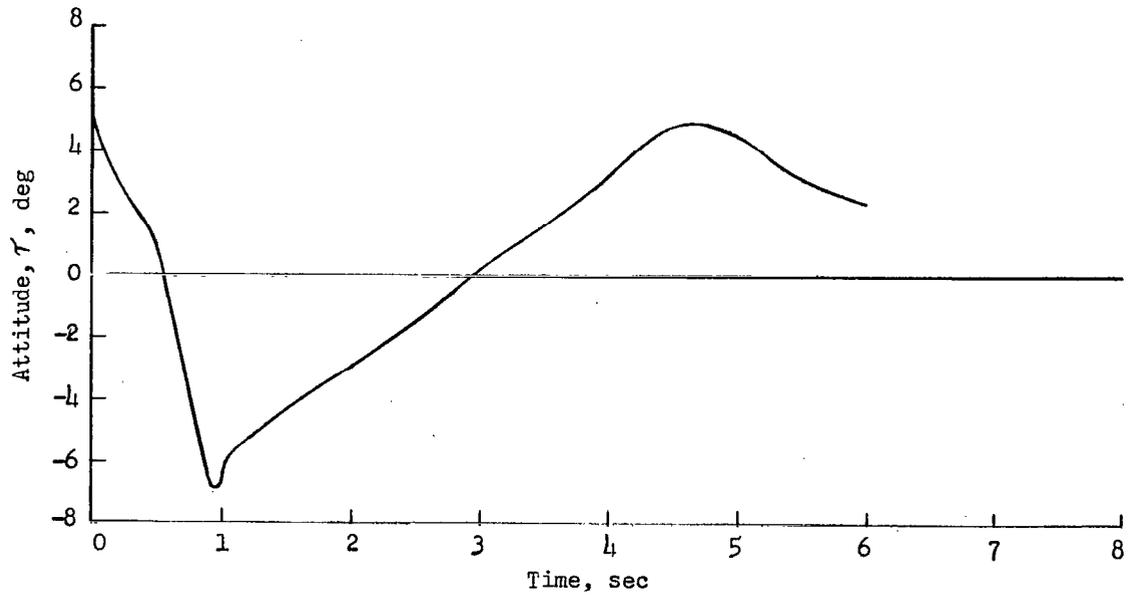
(b) With hydroflap. L-89346

Figure 6.- Concluded.



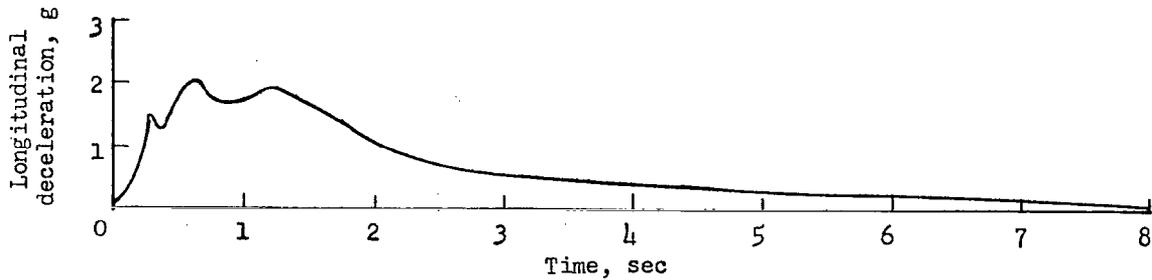
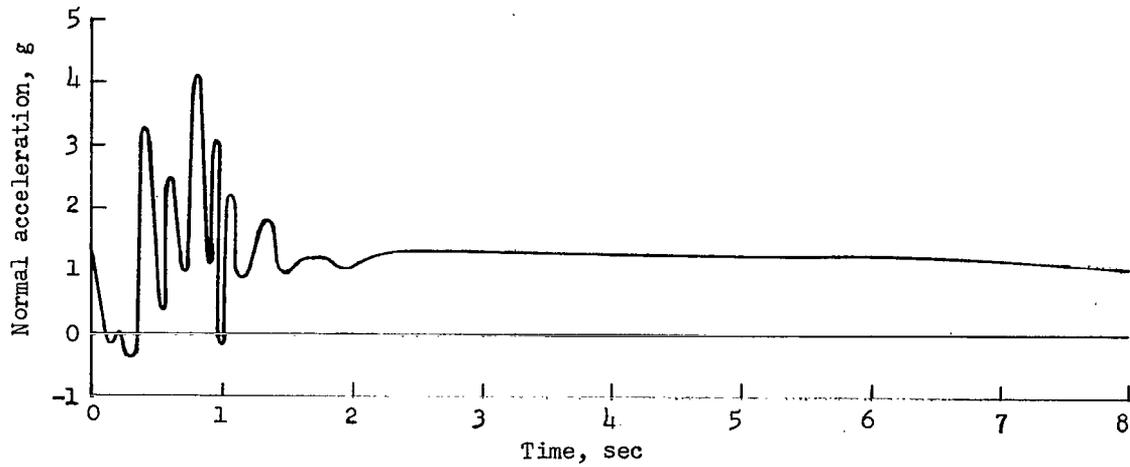
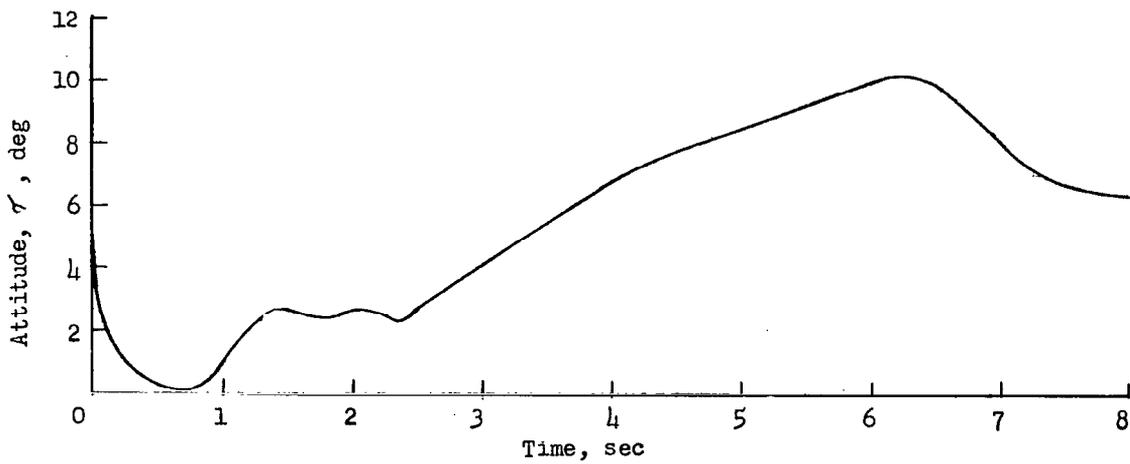
(a) Undamaged condition.

Figure 7.- Attitude, normal acceleration, and longitudinal deceleration curves at the 5° landing attitude with flaps down 45° and speed 110 knots. All values are full scale.



(b) Scale-strength bottoms installed.

Figure 7.- Continued.



(c) Scale-strength bottoms and hydroflap installed.

Figure 7.- Concluded.



(a) Without hydroflap.

L-89347

Figure 8.- Typical damage sustained by scale-strength bottom at 5° attitude with flaps down 45° and speed 110 knots.



(b) With hydroflap.

L-89348

Figure 8.- Concluded.