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DITCHING INVESTIGATION OF A 1/30-SCALE DYNAMIC MODEL OF A HEAVY JET TRANSPORT AIRPLANE

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16. Abstract

An investigation was made to determine the ditching characteristics of a heavy jet transport airplane. A 1/30-scale dynamic model was used for the tests which were made with the landing gear retracted and with the landing gear extended in various positions. The test results indicated that the most favorable condition for ditching is a 7° landing attitude with the flaps down 40°, a landing speed of 70.5 m/sec (137 knots), the nose gear retracted, and the main gear fully extended. There will most likely be some damage to the fuselage bottom and most of the main landing gear will probably be torn away.

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DITCHING INVESTIGATION OF A 1/30-SCALE DYNAMIC MODEL OF A HEAVY JET TRANSPORT AIRPLANE

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SUMMARY

An investigation was made to determine the ditching characteristics of a heavy cargo and transport jet airplane. Tests were made with the landing gear retracted and with the landing gear extended in various positions. A 1/30-scale dynamic model was used to determine behavior patterns, accelerations, and to some extent the location and amount of damage which might be expected. Ditchings were made in calm water and in a rough-water condition (simulated sea state 4).

The test results indicated that the most favorable condition for ditching is a 7° landing attitude with the flaps down 40°, a landing speed of 70.5 m/sec (137 knots), the nose gear retracted, and the main gear fully extended. Indications are that damage will be less severe with the main landing gear extended than with the main landing gear retracted. There will most likely be some damage to the fuselage bottom and most of the main landing gear will probably be torn away.

INTRODUCTION

Ditching investigations have been made for many different airplane designs. A compilation of data and a summary of the results of many of these studies are presented in reference 1. For a number of years, the airplane shapes and sizes were not too different from those reported in reference 1 and adequate predictions could be made of the ditching characteristics. However, the present-day jet transport airplane is much larger and heavier than any of the airplanes for which dynamic model ditching tests have been made previously. The design configuration and structural features of the cargo and transport airplanes also are such that a dynamic-model ditching investigation was needed to determine overall motions, accelerations, and the approximate location and amount of damage which might be expected during ditching. In addition, the large number of main landing-gear wheels (24) and the ability of the landing gear to be extended to various positions offer the possibility of an optimum ditching configuration since other wheels-down dynamic-model ditching investigations (refs. 1 and 2) have shown a wide variation of ditching performance with landing gear extended. The Department of the Air Force supplied the 1/30-scale model which was used for the tests.

This report presents results of ditchings made in calm water and in rough water (sea state 4; wave height 2.4 m (8 ft), full scale) by using a 1/30-scale dynamic model of a heavy jet transport airplane. A three-view sketch of the airplane is shown in figure 1. The model was tested at various combinations of landing attitudes, flap settings, and landing-gear positions. Impact accelerations were obtained and the dynamic behavior was recorded by motion-picture photography. The investigation was conducted in the Langley impacting structures facility.

The units used for the physical quantities defined in this paper are given both in the International System of Units and in the U.S. Customary Units (ref. 3). Measurements and calculations were made in U.S. Customary Units. Factors relating these two systems of units are given in an appendix.

DESCRIPTION OF MODEL AND INSTRUMENTATION

A 1/30-scale dynamic model of the cargo and transport airplane (fig. 2) was used for the ditching investigation. Table I gives the scale relationships used to convert the model data to full-scale values and all values given herein have been converted to full scale. The model was constructed principally of fiber glass and plastic. Lead ballast was located within the model so that the center of gravity, mass, and moments of inertia were as listed in table II. The mass was the lowest possible for the model as constructed. The moments of inertia given in table II for the full-size airplane are scaled up from the measured values of the 1/30-scale model.

The model was constructed so that part of the fuselage bottom could be removed and replaced with an approximately scale-strength section. Figure 3 shows the location of the removable section of the fuselage bottom where the scale-strength sections were installed on the model. Figure 3(a) shows the landing-gear-retracted configuration and figure 3(b) shows the landing-gear-extended configuration. The scale-strength sections were constructed of cardboard bulkheads and balsa-wood stringers and were covered with aluminum foil. The aluminum foil was not scale strength and it only served as a cover to distribute the water load to the scale-strength structure. Failure loads were controlled by the size of the balsa wood stringers and the thickness of the cardboard bulkheads. Failure loads which were simulated in the tests are given in table II. Tests with the landing gear retracted were made with scale-strength fuselage bottom sections which simulated a failure strength of 83 to 117 kN/m^2 (12 to 17 psi) and 241 kN/m^2 (35 psi). Tests with the landing gear extended were made with scale-strength fuselage-bottom sections which simulated a failure strength of 103 kN/m^2 (15 psi). Scale-strength sections for the model were constructed by the National Aeronautics and Space Administration. A new scale-strength section was required for each test run.

The landing gear was installed on the model with aluminum struts which had a necked-down scale-strength section at the estimated failure points (estimated by the manufacturer, supplied by the Air Force). Figure 4 shows a photograph of the main landing gear installed on the model. The main-landing-gear struts were designed to fail under 890 kN (200 000 lbf) (full scale) horizontal drag load applied to the axle. The nose-landing-gear strut was designed to fail under a 667 kN (150 000 lbf) (full scale) horizontal drag load applied at the axle. A new set of landing-gear struts was required for each test run.

The flaps were installed so that they could be held in the down position at approximately scale strength. In order to accomplish this installation, a calibrated string was fastened around each flap fitting and a corresponding wing fitting so that loads within ± 10 percent of the ultimate design load 120 kN (27 000 lbf; full scale) would cause the scale-strength connection to break. When the scale-strength connections failed, the flaps became detached from the model.

The engine nacelles were installed at approximately scale strength in a manner similar to that described for the landing flaps. Each nacelle strut had a parting line near the nacelle, and the strut and the nacelle were connected with a calibrated string which failed within ± 10 percent of the ultimate design load (716 kN (161 000 lbf), full scale). When scale-strength connections failed, the nacelles became detached from the model.

Normal and longitudinal accelerations were measured near the pilot's compartment with linear strain-gage accelerometers. Angular (pitch) accelerations were measured about the center of gravity with a matched pair of linear accelerometers suitably connected electrically. When tests were made with the landing gear extended, normal accelerations were also measured at the center of gravity with a linear strain-gage accelerometer. The longitudinal accelerometer had a range of $\pm 12g$ and a natural frequency of about 125 Hz. The normal accelerometers each had a range of $\pm 100g$ and a natural frequency of about 65 Hz. All the accelerometers were damped to about 65 percent of critical damping. The response of the recording galvanometers was flat to about 1000 Hz. A trailing cable supported by an overhead guide wire was used to transmit the accelerometer signals to the oscillograph recorders. The acceleration axes and the force directions are identified in figure 5.

TEST CONDITIONS

Pertinent test parameters are listed in table II. All tests were made with the engine nacelles attached with a scale-strength connection. The landing gear and flaps when down were also attached with scale-strength connections.

Landing attitude.- Tests were made at an attitude of 12° which is near the stall-warning attitude, at an attitude of $9\frac{1}{2}^{\circ}$ which is a medium high attitude, at an attitude of 7^{o} which is near the normal landing attitude, and at an attitude of 4^{o} which is a medium low attitude.

Flap settings.- Most of the tests were made with the flaps at 40^{o} which is the full-down position. Some tests were made with the flaps at 0^{o} which is the fully retracted position.

Landing speed.- The following landing speeds were simulated for the various attitudes and flap settings:

Landing attitude, deg	Flap setting, deg	Landing speed			
		Horizontal		Vertical	
		m/sec	knots	m/sec	ft/sec
12	40	64.8	126	0.76	2.5
$9\frac{1}{2}$	40	67.9	132	.76	2.5
7	40	70.5	137	.76	2.5
4	40	78.7	153	.76	2.5
12	0	83.3	162	.76	2.5
7	0	90.5	176	.76	2.5
7	40	70.5	137	2.7	9
4	40	78.7	153	2.7	9

Landing gear.- Tests were made with the landing gear retracted, extended, and kneeling. When the main landing gear is in the kneeling position, the wheels are partially retracted inside the wheel well, and it was felt that such an arrangement could influence the ditching performance of the airplane. (When the airplane is on the ground, the kneeling position is used as an aid in loading and unloading cargo.) Tests were made with the landing gear extended in the following configurations:

(1) Nose gear extended; main gear extended

(2) Nose gear retracted; main gear extended

(3) Nose gear retracted; main gear kneeling

Fuselage bottom.- Tests were made with the landing gear retracted and with the removable section of the fuselage bottom (fig. 3(a)) as follows:

(1) Removable section designed to fail under a pressure of 83 to 117 kN/m^2 (12 to 17 psi, full scale). The manufacturer's data indicated this strength for the airplane fuselage bottom.

(2) Removable section designed to fail under a pressure of 241 kN/m^2 (35 psi, full scale). These sections were made over twice as strong as the 83 to 117 kN/m^2 (12 to 17 psi) in order to determine whether there would be a significant change in damage and ditching behavior due to a big change in fuselage-bottom strength.

Tests were made with the landing gear extended and the removable section of the fuselage bottom (fig. 3(b)) replaced with a section which was designed to fail under a pressure of 103 kN/m^2 (15 psi, full scale).

Water condition.- Ditching tests were made in both calm and rough water. The rough water simulated a sea state 4 with waves 2.4 meters (8 ft) high and 61 meters (200 ft) long, crest to crest (full scale). Ditchings were made into oncoming waves.

Launch conditions.- The combinations of landing attitude, flaps setting, landing-gear position, landing speed (horizontal), sink speed (vertical), and water conditions which were used in the test are given in table III. The investigation was conducted by launching the model as a free body by means of a catapult. The catapult with the 1/30-scale model ready for launching is shown in figure 6. The model left the launching carriage at scale speed and the predetermined landing attitude with the control surfaces set so that the attitude did not change appreciably during the brief free flight from catapult release to water contact.

RESULTS AND DISCUSSION

Two motion-picture film supplements were made, one for the part of the ditching investigation with the landing gear retracted (Film serial L-1111, reel 1) and one for the part of the ditching investigation with the landing gear extended (Film serial L-1111, reel 2). A request card and a description of the film will be found at the end of this paper. All data have been converted to full-scale values by use of the scale relationships given in table I.

Landing Gear Retracted

Results for landing-gear-retracted conditions are presented in summary form in table IV. Typical time-history plots of longitudinal and normal acceleration for tests with scale-strength bottom sections are shown in figures 7 to 17. Figures 18 to 20 show photographs of typical damage to the scale-strength fuselage-bottom sections.

The location of the scale-strength section of the fuselage bottom for tests with the landing gear retracted is shown in figure 3(a). Some damage always occurred to the fuselage bottom. The scale-strength sections are approximations of the full-scale structure and the damage photographs of the model presented in figures 18 to 20 are shown to indicate approximate amounts of damage in the areas of the fuselage bottom where damage is likely to occur. The typical behavior (table IV) was a fairly smooth run in which most of the flaps failed and one or more of the engine nacelles tore away. Flap failure and engine loss on a high wing configuration such as the heavy jet transport airplane are of little consequence in a ditching runout. On the other hand, fuselage-bottom failure could be a serious problem in a full-scale ditching. However, the rugged cargo floor of the airplane about 1.5 m (5 ft) (full scale) above the fuselage bottom should afford appreciable protection from water flow through holes in the fuselage bottom. Figure 18 shows the bottom damage to the model for the 83 to 117 kN/m^2 (12 to 17 psi) scale-strength sections and figure 19 shows the damage to the model for the 241 kN/m^2 (35 psi) sections. The damage was slightly less for the 241 kN/m^2 (35 psi) sections but there was no significant change in behavior.

Calm-water ditchings; 12° attitude.- Typical time-history acceleration curves for ditchings in calm water with scale-strength bottom section having a failure strength of 83 to 117 kN/m^2 (12 to 17 psi) at a landing attitude of 12°, with the flaps down 40°, and a landing speed of 64.8 m/sec (126 knots) are shown in figure 7. The maximum longitudinal acceleration was about 3g whereas the maximum normal acceleration was about 17g. Shortly after initial water contact, the rear section of the scale-strength fuselage was damaged and this damage allowed the strong bulkheads in this area to produce a large drag load and caused the model to trim down. When the nose section impacted the water, the 17g peak normal acceleration occurred (fig. 7(b)) and the front section of the scale-strength section sustained considerable damage (fig. 18(a)). The total landing run was about 4 fuselage lengths.

Typical time-history acceleration curves for ditchings in calm water with a fuselage-bottom section having a failure strength of approximately 241 kN/m^2 (35 psi) at a landing attitude of 12°, with the flaps down 40°, and a landing speed of 64.8 m/sec (126 knots) are shown in figure 8. The maximum longitudinal acceleration was about 4g whereas the maximum normal acceleration was about 15g. Shortly after initial water contact, the model trimmed down to a slightly negative attitude and the nose became submerged momentarily; the model then trimmed up to a positive attitude and ran smoothly for a total length of landing run of about 3 fuselage lengths. Figure 19(a) shows typical damage to the scale-strength fuselage-bottom section. The damage was most severe to the extreme rear part of the scale-strength section.

Typical time-history acceleration curves for ditchings in calm water with a scale-strength fuselage-bottom section having a failure strength of 83 to 117 kN/m^2 (12 to

17 psi) at a landing attitude of 12°, with the flaps at 0°, and a landing speed of 83.3 m/sec (162 knots) are shown in figure 9. The maximum longitudinal acceleration was about 7g whereas the maximum normal acceleration was about 16g. A comparison of figures 7 and 9 shows that the normal accelerations were about the same for ditchings with the flaps at 0° and down 40° whereas the maximum longitudinal acceleration was about twice as great for the ditchings with the flaps at 0°. Shortly after initial water contact, the model trimmed down and the nose submerged momentarily; the model then trimmed up to a near-level attitude and ran smoothly. The total length of landing run was about 4 fuselage lengths. The major damage to the scale-strength fuselage-bottom section occurred near the rear section. A photograph of typical damage is shown in figure 18(b).

Typical time-history acceleration curves for ditchings in calm water with a fuselage-bottom section having a failure strength of approximately 241 kN/m^2 (35 psi) at a landing attitude of 12°, with the flaps at 0°, and a landing speed of 83.3 m/sec (162 knots) are shown in figure 10. The maximum longitudinal acceleration was about 5g whereas the maximum normal acceleration was about 20g. Shortly after initial water contact, the model trimmed down to a slightly negative attitude and the nose submerged momentarily; the model then trimmed up to a positive attitude and ran smoothly for a total length of landing run of about 3 fuselage lengths. Figure 19(b) shows typical damage to the scale-strength fuselage-bottom section. The damage was most severe to the extreme rear part of the scale-strength section.

Calm-water ditchings; 7° attitude.- Typical time-history acceleration curves for ditchings in calm water with scale-strength fuselage-bottom section having a failure strength of 83 to 117 kN/m^2 (12 to 17 psi) at a landing attitude of 7°, with the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots) are shown in figure 11. The maximum longitudinal acceleration of about $3\frac{1}{2}$g is about the same as occurred for similar conditions at a landing attitude of 12° whereas the maximum normal acceleration of about 6g is less than one-half as much as occurred for ditchings at a landing attitude of 12°. (Compare figs. 7 and 11.) The motions of the model for a landing attitude of 7°, with the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots) were very mild. The model trimmed down to a near-level attitude and ran smoothly for a total distance of about 4 fuselage lengths. The rear half of the scale-strength fuselage bottom was damaged severely and there was also considerable damage to the front half. A photograph of typical damage is shown in figure 18(c).

Typical time-history acceleration curves for ditchings in calm water with a fuselage-bottom section having a failure strength of approximately 241 kN/m^2 (35 psi) at a landing attitude of 7°, with the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots) are shown in figure 12. The maximum longitudinal acceleration was about 3g whereas the maximum normal acceleration was about 4g. The model trimmed down to a near-level attitude and ran smoothly for a total distance of about 4 fuselage lengths.

The rear half of the scale-strength fuselage bottom was damaged severely and there was also considerable damage to the front half. A photograph of typical damage is shown in figure 19(c). As may be seen in table IV, there was very little difference in the test results with the 83 to 117 kN/m^2 (12 to 17 psi) and the 241 kN/m^2 (35 psi) (full-scale) fuselage-bottom removable sections.

Although the amount of damage to the scale-strength fuselage bottom was severe (fig. 18(c)) when the model was ditched at a landing attitude of 7°, with the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots), it is believed that this condition would be the most favorable for a ditching because of the much lower normal accelerations. The 7° attitude is approximately the normal landing attitude for the airplane; thus, the pilot can probably make his most precise landing at this attitude.

Typical time-history acceleration curves for ditchings in calm water at a landing attitude of 7°, with the flaps at 0°, a landing speed of 90.5 m/sec (176 knots), and a 241 kN/m^2 (35 psi) (full scale) fuselage-bottom removable section are shown in figure 13. The maximum longitudinal acceleration was about 6g and the maximum normal acceleration was about 10g. The model porpoised some during the first part of the run and then ran smoothly. The total landing run was about 6 fuselage lengths. There was no significant difference in the amount of damage to the scale-strength fuselage-bottom sections for ditchings at a landing attitude of 7°, with the flaps down 40°, and with the flaps at 0°. (See figs. 19(c) and 19(d).)

Rough-water ditchings; 12° attitude.- Tests in rough water with scale-strength fuselage-bottom sections which simulated 241 kN/m^2 (35 psi) (full-scale) failure load at the 12° landing attitude, the flaps down 40°, and a landing speed of 64.8 m/sec (126 knots) resulted in a maximum longitudinal acceleration of about 6g. (See fig. 14.) This value was about twice that for the same condition in calm water. (See table IV.) The maximum normal acceleration of about 12g was a little less than the maximum normal acceleration in calm-water ditchings at a landing attitude of 12° with the flaps down 40°. The model trimmed down shortly after initial contact with the water and then ran smoothly; it followed the wave contours throughout the latter part of the run. Typical damage is shown in figure 20(a).

Figure 15 shows typical acceleration curves which were obtained when the model was ditched at a landing attitude of 12°, with the flaps at 0°, a landing speed of 83.3 m/sec (162 knots), and a scale-strength fuselage-bottom section which simulated 241 kN/m^2 (35 psi) (full scale). The maximum longitudinal acceleration was about 5g and the maximum normal acceleration was about 18g; these values are about the same maximum acceleration values as were obtained in calm water at a landing attitude of 12° with the flaps at 0°. The model trimmed down shortly after contact with the water, ran smoothly, and the nose of the model ploughed through the wave crests. The total landing run was about 3 fuselage lengths. Typical damage is shown in figure 20(b).

Rough-water ditchings; 7° attitude.- Tests in rough water with scale-strength fuselage-bottom sections which simulate 241 kN/m^2 (35 psi) (full scale) failure load at a landing attitude of 7°, with the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots) resulted in a maximum longitudinal acceleration of about 4g. (See fig. 16.) This condition was about the same as that in calm water. (See table IV.) The maximum normal acceleration of about $\pm 7g$ was slightly less than the maximum normal acceleration obtained in calm-water ditchings at the 7° landing attitude and the flaps down 40°. Figure 20(c) shows a photograph of the scale-strength fuselage-bottom section with the resultant damage. The model trimmed down to a near-level attitude shortly after initial contact with the water, trimmed up, and the nose of the model ploughed through the wave crests. The total landing run was about 5 fuselage lengths.

Figure 17 shows typical acceleration curves which were obtained when the model ditched in rough water at a landing attitude of 7°, with the flaps at 0°, a landing speed of 90.5 m/sec (176 knots), and with a scale-strength fuselage-bottom section which simulated a 241 kN/m^2 (35 psi) failure load (full scale). The maximum longitudinal acceleration was about 9g and the maximum normal acceleration was about 10g. The model dived after making a run of about one or two fuselage lengths. Damage to the scale-strength fuselage bottom is shown in figure 20(d), and because of the dive, some damage to the fuselage-nose section could be expected.

Landing Gear Extended

Results for landing-gear-extended conditions are presented in summary form in table V and include longitudinal and normal acceleration near the pilot's compartment, normal acceleration near the center of gravity (given in g units), and angular acceleration (rad/sec^2). A typical plot for each test condition (figs. 21 to 39) shows the time at which the maximum impact acceleration occurred for the longitudinal and the normal acceleration near the pilots' compartment.

All tests were made with a scale-strength fuselage-bottom section installed as in figure 3(b). The scale-strength sections are approximations of the full-scale structure and the damage photographs of the model presented as figures 40 to 44 are shown to indicate the approximate amounts of damage and the areas of the fuselage bottom where damage is likely to occur.

Calm-water ditchings; all landing gear extended.- Typical time-history acceleration curves for ditching in calm water with all landing gear extended at a landing attitude of 12°, with the flaps down 40°, and a landing speed of 64.8 m/sec (126 knots) are shown in figure 21. The maximum longitudinal acceleration was about $3\frac{1}{2}g$ whereas the maximum normal acceleration was about 8g. Shortly after initial water contact, the model trimmed down, trimmed up, and ran deeply for a total distance of about 3 fuselage lengths. Considerable damage resulted to the aft section of the scale-strength fuselage-bottom section, and there was very little damage to the forward section. (See fig. 40(a).) The rear main gear struts usually failed, whereas the front main gear struts and the nose gear struts usually did not fail.

Typical time-history acceleration curves for ditchings in calm water with all landing gear extended at a landing attitude of 7°, the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots) are shown in figure 22. The maximum longitudinal acceleration was about 3g whereas the maximum normal acceleration was about 4g. The maximum acceleration values for the 7° landing attitude are much lower than the maximum acceleration values for the same condition at the 12° landing attitude. (See table V.) The model made a porpoising run for a total distance of about 6 fuselage lengths. There was considerable damage to the extreme rear and front sections of the scale-strength fuselage-bottom section. (See fig. 40(b).) All the scale-strength landing-gear struts usually failed at the 7° landing attitude and it is believed that the failure of the nose gear caused additional damage to the front section of the fuselage bottom. Since the nose-gear failure apparently contributed to the damage to the fuselage, most of the tests were made with the nose gear retracted.

<u>Calm-water ditching; nose gear retracted; main gear extended</u>.- Typical time-history acceleration curves for ditchings in calm water with the nose gear retracted and the main gear extended at a landing attitude of 12°, the flaps down 40°, and a landing speed of 64.8 m/sec (126 knots) are shown in figure 23. The maximum longitudinal acceleration was about 5g whereas the maximum normal acceleration was about 12g. The model porpoised some and then ran smoothly for a total landing run of about 4 fuselage lengths. There was considerable damage to the rear section of the scale-strength fuselage-bottom section, and there was very little damage to the front section. (See fig. 41(a).) All the main landing-gear struts usually failed.

Typical time-history acceleration curves for ditchings in calm water with the nose gear retracted and the main gear extended at a landing attitude of $9\frac{1}{2}^{\circ}$, the flaps down 40°, and a landing speed of 67.9 m/sec (132 knots) are shown in figure 24. The maximum longitudinal acceleration was about 3g and the maximum normal acceleration was about 9g. The model trimmed down and ran smoothly for a total landing run of about 6 fuselage lengths. There was extensive damage to the front and middle sections of the scale-strength fuselage-bottom section, whereas there was very little damage to the aft section. (See fig. 41(c).) All the main landing-gear struts usually failed.

Typical time-history acceleration curves for ditching in calm water with the nose gear retracted and the main gear extended at a landing attitude of 7°, the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots) are shown in figure 25. The maximum longitudinal acceleration was about 3g whereas the maximum normal acceleration was about 6g. The model trimmed down to a near-level attitude, trimmed up, and ran smoothly for a total landing run of about 5 fuselage lengths. There was very little damage to the scale-strength fuselage-bottom section. (See fig. 41(e).) All the main landing gear did not always fail and the main landing gear apparently afforded some protection to the scale-strength fuselage-bottom section.

Typical time-history acceleration curves for ditching in calm water with the nose gear retracted and the main gear extended at a landing attitude of 4°, flaps 40°, and a landing speed of 78.7 m/sec (153 knots) are shown in figure 26. The maximum longitudinal acceleration was about 2g whereas the maximum normal acceleration was about 9g. The model porpoised some and then ran smoothly for a total landing run of about 7 fuselage lengths. Damage to the rear half of the scale-strength fuselage-bottom section was very severe. (See fig. 41(g).) There was also moderate damage to the front section. All the main landing gear failed.

Typical time-history acceleration curves for ditchings in calm water with the nose gear retracted and the main gear extended at a landing attitude of 7°, with the flaps at 0°, and a landing speed of 90.5 m/sec (176 knots) are shown in figure 27. The maximum longitudinal acceleration was about 5g whereas the maximum normal acceleration was about 10g. The model ran smoothly for a total distance of about 6 fuselage lengths and made a sharp turn near the end of the landing run. There was severe damage throughout the entire length of the scale-strength fuselage-bottom section. (See fig. 42.) All the main landing gear were torn away.

Typical time-history acceleration curves for ditchings in calm water with the nose gear retracted and the main gear kneeling at a landing attitude of 12°, the flaps down 40°, and a landing speed of 64.8 m/sec (126 knots) are shown in figure 28. The maximum longitudinal acceleration was about 4g whereas the maximum normal acceleration was about 12g. Shortly after initial water contact, the model trimmed down, trimmed up, and ran smoothly for a total landing run of about 3 fuselage lengths. There was considerable damage to the extreme rear section of the scale-strength fuselage-bottom section and slight damage to the front section. (See fig. 43(a).) The main landing gear usually did not fail.

Typical time-history acceleration curves for ditchings in calm water with the nose gear retracted and the main gear kneeling at a landing attitude of $9\frac{1}{2}^{\circ}$, the flaps down 40°, and a landing speed of 67.9 m/sec (132 knots) are shown in figure 29. The maximum longitudinal acceleration was about 6g whereas the maximum normal acceleration was about 6g. The model trimmed down and ran smoothly for a total landing run of about 5 fuselage lengths. There was considerable damage to the rear section of the scale-strength fuselage-bottom section and the front section was slightly damaged. (See fig. 43(c).) The front main landing gear usually did not fail.

Typical time-history acceleration curves for ditching in calm water with the nose gear retracted and the main gear kneeling at a landing attitude of 7°, the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots) are shown in figure 30. The maximum longitudinal acceleration was about 3g whereas the maximum normal acceleration was about 5g. The model trimmed down and ran smoothly for a total landing run of about 6 fuselage lengths. There was considerable damage to the rear section of the scale-strength fuselage-bottom section and there was some damage to the front section. (See fig. 43(e).) The front main landing gear usually did not fail.

Effect of vertical (sink) speed during calm-water ditching.- Most of the ditching investigation was conducted with the model having a sink speed of about 0.76 m/sec (2.5 ft/sec) (full scale) but a few tests were made in calm water with the model having a sink speed of approximately 2.7 m/sec (9 ft/sec) (full scale). Typical time-history acceleration curves for ditchings in calm water with the nose gear retracted and the main gear kneeling at a landing attitude of 7°, the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots) are shown in figure 38. The maximum longitudinal acceleration was about 11g whereas the maximum normal acceleration was about 14g. The acceleration values for the high sink speed are $2\frac{1}{2}$ to 4 times greater than those for the low sink speeds. The model porpoised and then ran smoothly for a total landing run of about 4 fuselage lengths. The rear section of the scale-strength fuselage-bottom section was damaged severely and there was moderate damage to the front section. (See fig. 44(a).) All the main landing gear were torn away.

Typical time-history acceleration curves for ditchings in calm water with the nose gear retracted and the main gear kneeling at a landing attitude of 4°, the flaps down 40°, and a landing speed of 78.7 m/sec (153 knots) are shown in figure 39. The maximum longitudinal acceleration was about 11g whereas the maximum normal acceleration was about 19g. The model ran smoothly, porpoised, and then ran smoothly for a total landing run of about 4 fuselage lengths. Damage was severe to the entire scale-strength fuselage-bottom section. (See fig. 44(b).) All the main landing gear were torn away. These data indicate that as low a sink speed as feasible would be the most desirable for a ditching.

Rough-water ditchings; nose gear retracted; main gear extended.- Typical time-history acceleration curves for ditchings into oncoming waves with the nose gear retracted and the main gear extended at a landing attitude of 12°, the flaps down 40°, and a landing speed of 64.8 m/sec (126 knots) are shown in figure 31. The maximum longitudinal acceleration was about 4g whereas the maximum normal acceleration was about 16g. The model trimmed down to a near-level attitude, the nose ploughed through the wave crests, and the model ran smoothly for a total landing run of about 4 fuselage lengths. The resultant damage was severe to the rear section of the scale-strength fuselage-bottom section whereas the front section sustained moderate damage (fig. 41(b)). This damage was somewhat more than that obtained in the calm-water ditchings. (See fig. 41(a).) All the landing gear were torn away.

Typical time-history acceleration curves for ditchings into oncoming waves with the nose gear retracted and the main gear extended at a landing attitude of $9\frac{1}{2}^{\circ}$, the flaps down 40°, and a landing speed of 67.9 m/sec (132 knots) are shown in figure 32. The maximum longitudinal acceleration was about 6g whereas the maximum normal acceleration was about 20g. The model trimmed down and ran smoothly for a total landing run of about 4 fuselage lengths. There was some damage throughout most of the scale-strength fuselage-bottom section with more extensive damage to the rear section. The damage is not readily apparent in the photograph (fig. 41(d)) because the aluminum foil skin did not fail.

Typical time-history acceleration curves for ditchings into oncoming waves with the nose gear retracted and the main gear extended at a landing attitude of 7°, the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots) are shown in figure 33. The maximum longitudinal acceleration was about 6g whereas the maximum normal acceleration was about 20g. The model trimmed down to a near-level attitude and ran smoothly for a total landing run of about 5 fuselage lengths. There was some damage throughout most of the scale-strength fuselage-bottom section. (See fig. 41(f).) The forward section was damaged most severely and all the main landing gears were torn away.

Typical time-history acceleration curves for ditchings into oncoming waves with the nose gear retracted and the main gear extended at a landing attitude of 4°, the flaps down 40°, and a landing speed of 78.7 m/sec (153 knots) are shown in figure 34. The maximum longitudinal acceleration was about 5g whereas the maximum normal acceleration was about 10g. The model ran smoothly and made a sharp turn for a total landing run of about 6 fuselage lengths. The scale-strength fuselage-bottom section was damaged severely throughout the entire length. (See fig. 41(h).) All the main landing gears were torn away.

Rough-water ditching; nose gear retracted; main gear kneeling.- Typical time-history acceleration curves for ditchings into oncoming waves with the nose gear retracted and the main gear kneeling at a landing attitude of 12°, the flaps down 40°, and a landing speed of 64.8 m/sec (126 knots) are shown in figure 35. The maximum longitudinal acceleration was about 5g whereas the maximum normal acceleration was about 17g. The model trimmed down to a near-level attitude, the nose ploughed through the wave crests, and the model ran smoothly for a total landing run of about 4 fuselage lengths. The scale-strength fuselage-bottom section was damaged considerably on the front and rear sections whereas the center section sustained very little damage. (See fig. 43(b).) The front main landing gears usually were not torn away.

Typical time-history acceleration curves for ditchings into oncoming waves with the nose gear retracted and the main gear kneeling at a landing attitude of $9\frac{1}{2}^{\circ}$, the flaps down 40°, and a landing speed of 67.9 m/sec (132 knots) are shown in figure 36. The maximum longitudinal acceleration was about 7g whereas the maximum normal acceleration was about 19g. The nose ploughed through the wave crests and the model ran smoothly for a total landing run of about 4 fuselage lengths. There was some damage throughout the entire length of the scale-strength fuselage-bottom section. (See fig. 43(d).) All the main landing gears were torn away.

Typical time-history acceleration curves for ditchings into oncoming waves with the nose gear retracted and the main gear kneeling at a landing attitude of 7°, the flaps down 40°, and a landing speed of 70.5 m/sec (137 knots) are shown in figure 37. The maximum longitudinal acceleration was about 6g whereas the maximum normal acceleration was about 22g. The nose ploughed through the wave crests and the model ran smoothly for a total landing run of about 5 fuselage lengths. The scale-strength fuselage-bottom section was damaged throughout the entire length, more extensive damage occurring at the extreme front and rear sections. (See fig. 43(f).) All the main landing gears were torn away.

General Comments

Typical ditching behavior was a fairly smooth and sometimes porpoising run. Most of the flaps and one or more of the engine nacelles were torn away during calm-water ditchings. All the engine nacelles were torn away during rough-water ditchings. Flap failure and engine loss on a high wing configuration such as the heavy jet transport are of little consequence in a ditching runout. On the other hand, fuselage-bottom failure could be a serious problem in a full-scale ditching. However, the main landing gear apparently afforded some protection to the fuselage bottom on the initial water impact. The rugged cargo floor (about 1.5 m (5 ft), full scale) above the fuselage bottom should afford appreciable protection from water flow through holes in the fuselage bottom. The dynamic model tests indicated that the large size of the airplane should cause no unanticipated ditching problems.

The maximum acceleration values encountered in rough-water ditchings were slightly greater at the 7° attitude than at the other nose-high landing attitudes which were tested but the amount of damage to the scale-strength fuselage-bottom section was about the same. In calm water the maximum accelerations and damage were less at the 7° landing attitude than at the other landing attitudes. It is believed that the 7° landing attitude would, in general, be the most favorable for a ditching. The 7° attitude is approximately the normal landing attitude for the heavy jet transport airplane; thus, the pilot can probably make his most precise landing at this attitude.

Although the maximum acceleration values at a landing attitude of 7° were lowest with the nose gear extended, it is believed that a safer ditching would be made with the nose gear retracted because with the nose gear extended there was a tendency for more damage to occur on the front section of the fuselage bottom and, hence, a more serious flooding condition resulted.

The damage to the scale-strength fuselage-bottom section at a landing attitude of 7° was about the same with the main landing gear fully extended or in the kneeling position. Indications are that damage was less severe with the landing gear extended than with the landing gear retracted. The maximum acceleration values at the 7° landing attitude were, in general, slightly lower with the main gear fully extended. Although not critical, it appears that the main gear in the fully extended position is slightly more favorable.

CONCLUDING REMARKS

The results of the ditching investigation of a dynamic model of a heavy jet transport airplane indicate the most favorable condition for a ditching of those tested is a 7° landing attitude with the flaps down 40°, a landing speed of 70.5 m/sec (137 knots), the nose gear retracted, and the main gear fully extended. There will most likely be some damage to the fuselage bottom and most of the main landing gear will be torn away. The test results indicate that the fuselage-bottom damage will probably be less severe with the main landing gear extended than with the main landing gear retracted. The rugged cargo floor (about 1.5 m (5 ft), full scale) above the fuselage bottom should afford appreciable protection from water flow through holes in the fuselage bottom. In a calm-water ditching, the maximum longitudinal acceleration should be about 4g and the maximum normal acceleration about 8g. Ditching into oncoming waves 2.4 meters by 61 meters (8 ft by 200 ft, full scale) may result in a maximum longitudinal acceleration of about 7g and a maximum normal acceleration of about 21g. Fuselage-bottom damage will probably be more severe in rough water than in calm water.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., November 30, 1971.

APPENDIX A

CONVERSION OF SI UNITS TO U.S. CUSTOMARY UNITS

Conversion factors for the units used herein are given in the following table:

Physical quantity	SI Unit	Conversion factor (*)	U.S. Customary Unit
Length	meters (m)	0.0254	inches (in.)
		0.3048	feet (ft)
Mass	kilograms (kg)	0.454	pounds mass (lbm)
Force	newtons (N)	4.448	pounds force (lbf)
Moment of inertia . .	kilogram-meters^2 (kg-m^2)	1.35582	slug-feet^2 (slug-ft^2)
Velocity	meters/second (m/sec)	0.5144	knots (kt)
		0.3048	feet/second (ft/sec)
Pressure	newtons/meter^2 (N/m^2)	6.89×10^3	pounds force/inch^2 (psi)

*Divide value given in SI Unit by conversion factor to obtain equivalent value in U.S. Customary Unit.

Prefixes to indicate multiples of units are as follows:

Prefix	Multiple
kilo (k)	10^3
centi (c)	10^{-2}

REFERENCES

1. Fisher, Lloyd J.; and Hoffman, Edward L.: Ditching Investigations of Dynamic Models and Effects of Design Parameters on Ditching Characteristics. NACA Rep. 1347, 1958. (Supersedes NACA TN 3946.)
2. Thompson, William C.: Rough-Water Ditching Investigation of a Model of a Jet Transport With the Landing Gear Extended and With Various Ditching Aids. NASA TN D-101, 1959.
3. Comm. on Metric Pract.: ASTM Metric Practice Guide. NBS Handbook 102, U.S. Dep. Com., Mar. 10, 1967.

TABLE I.- SCALE RELATIONSHIPS

[λ = Scale of model = 1/30]

Quantity	Full-scale value	Scale factor	Model value
Length	l	λ	λl
Force	F	λ^3	$\lambda^3 F$
Moment of inertia	I	λ^5	$\lambda^5 I$
Mass	m	λ^3	$\lambda^3 m$
Time	t	$\sqrt{\lambda}$	$\sqrt{\lambda} t$
Speed	V	$\sqrt{\lambda}$	$\sqrt{\lambda} V$
Linear acceleration	a	1	a
Angular acceleration	α	λ^{-1}	$\lambda^{-1}\alpha$
Pressure	p	λ	λp

TABLE II.- PERTINENT DIMENSIONS AND TEST CONDITIONS FOR HEAVY JET TRANSPORT AIRPLANE AND MODEL

Parameter	Full-scale airplane		1/30-scale model	
Mass	337 095 kg	742 500 lbm	12.5 kg	27.5 lbm
Overall length	75.0 m	246.0 ft	2.50 m	8.2 ft
Wing span	67.9 m	220.7 ft	2.26 m	7.4 ft
Center-of-gravity location	25% mean aerodynamic chord	25% mean aerodynamic chord	25% mean aerodynamic chord	25% mean aerodynamic chord
Moments of inertia:				
Yaw	[a] 98.8×10^6 kg-m^2	[a] 72.9×10^6 slug-ft^2	[a] 4.1 kg-m^2	[a] 3.0 slug-ft^2
	[b] 95.6×10^6 kg-m^2	[b] 70.5×10^6 slug-ft^2	[b] 3.9 kg-m^2	[b] 2.9 slug-ft^2
Pitch	[a] 72.5×10^6 kg-m^2	[a] 53.5×10^6 slug-ft^2	[a] 3.0 kg-m^2	[a] 2.2 slug-ft^2
	[b] 59.2×10^6 kg-m^2	[b] 43.7×10^6 slug-ft^2	[b] 2.4 kg-m^2	[b] 1.8 slug-ft^2
Roll	[a] 39.6×10^6 kg-m^2	[a] 29.2×10^6 slug-ft^2	[a] 1.6 kg-m^2	[a] 1.2 slug-ft^2
	[b] 42.7×10^6 kg-m^2	[b] 31.5×10^6 slug-ft^2	[b] 1.8 kg-m^2	[b] 1.3 slug-ft^2
Failure strength of fuselage bottom	[a] 241 kN/m^2	[a] 35 psi	[a] 8.1 kN/m^2	[a] 1.17 psi
	[a] 83 to 117 kN/m^2	[a] 12 to 17 psi	[a] 2.8 to 3.9 kN/m^2	[a] 0.40 to 0.57 psi
	[b] 103 kN/m^2	[b] 15 psi	[b] 3.4 kN/m^2	[b] 0.50 psi
Main-landing-gear strut failure load	890 kN	200 000 lbf	32.9 N	7.4 lbf
Nose-landing-gear strut failure load	667 kN	150 000 lbf	24.9 N	5.6 lbf
Flap-attachment failure load	120 kN	27 000 lbf	4.4 N	1.0 lbf
Nacelle-strut failure load	716 kN	161 000 lbf	26.7 N	6.0 lbf
Wave size	2.4 m by 61 m	8 ft by 200 ft	8.1 cm by 203 cm	3.2 in. by 80 in.

[a] Tests with landing gear retracted.
[b] Tests with landing gear extended.

TABLE III.- CONDITIONS INVESTIGATED

[All values are full scale]

(a) Landing gear retracted and a sink speed of 0.76 m/s (2.5 ft/sec)

Landing attitude, deg	Flap setting, deg	Landing speed		Water surface, (a)	Removable fuselage-bottom section
		knots	m/sec		
12	40	126	64.8	Calm	83 to 147 kN/m^2 (12 to 17 psi)
7	40	137	70.5		
12	0	162	83.3		
12	40	126	64.8		241 kN/m^2 (35 psi)
7	40	137	70.5		
12	0	162	83.3		
7	0	176	90.5		
12	40	126	64.8	Waves	
7	40	137	70.5		
12	0	162	83.3		
7	0	176	90.5		

[a] Waves 2.4 m (8 ft) high by 61 m (200 ft) long, crest to crest.

(b) Scale-strength fuselage-bottom removable section 103 kN/m^2 (15 psi)

Landing attitude, deg	Flap setting, deg	Landing gear position	Landing speed		Sink speed		Water surface (a)
			knots	m/sec	ft/sec	m/sec	
12	40	Nose gear extended; main gear extended	126	64.8	2.5	0.76	Calm
7		Nose gear extended; main gear extended	137	70.5			
12		Nose gear retracted; main gear extended	126	64.8			
$9\frac{1}{2}$			132	67.9			
7			137	70.5			
4			153	78.7			
7	0		176	90.5			
12	40		126	64.8			Waves
$9\frac{1}{2}$			132	67.9			
7			137	70.5			
4			153	78.7			
12		Nose gear retracted; main gear kneeling	126	64.8			Calm
$9\frac{1}{2}$			132	67.9			
7			137	70.5			
12			126	64.8			Waves
$9\frac{1}{2}$			132	67.9			
7			137	70.5			
7			137	70.5	9	2.7	Calm
4			153	78.7	9	2.7	Calm

[a] Waves 2.4 m by 61 m (8 ft by 200 ft).

TABLE IV.- SUMMARY OF RESULTS OF DYNAMIC MODEL DITCHING INVESTIGATION OF HEAVY JET TRANSPORT AIRPLANE WITH LANDING GEAR RETRACTED AND WITH SCALE-STRENGTH FUSELAGE BOTTOM SECTIONS

[All values are full scale]

Failure strength of removable section		Landing attitude, deg	Flaps, deg	Landing speed		Water surface	Maximum impact accelerations			Run distance, fuselage lengths	Chronological behavior of model (a)
kN/m^2	psi			m/sec	knots		Longitudinal, g-units	Normal, g-units	Angular, rad/sec^2		
83 to 117	12 to 17	12	40	64.8	126	Calm	2.8	17.1	4.10	3.7	w-h
							2.5	17.3	3.90	2.5	
							3.5	19.8	4.72	4.9	
							3.6	13.9	3.72	2.5	
							3.3	18.7	4.92	3.7	
241	35						3.3	14.2	4.00	2.5	w-n-u-h
							3.5	14.8	4.14	3.7	
83 to 117	12 to 17	12	0	83.3	162	Calm	5.3	20.8	6.72	3.1	w-n-u-h
							6.8	15.9	4.63	3.7	
241	35						5.5	17.9	5.82	3.7	w-n-u-h
							5.9	17.1	8.30	2.5	
83 to 117	12 to 17	7	40	70.5	137	Calm	2.4	7.2	1.81	4.3	w-h
							3.6	5.9	-2.74	3.7	
							3.0	5.2	1.94	3.7	
241	35						3.1	4.6	1.76	3.7	w-h
							2.5	3.9	1.90	3.1	
							4.2	7.6	----	2.5	
241	35	7	0	90.5	176	Calm	6.1	10.0	-3.76	6.1	p-h
							6.8	16.4	6.13	3.1	
241	35	12	40	64.8	126	Waves	6.0	11.9	6.45	3.1	w-h-c
							5.3	11.4	7.42	3.7	
							4.7	11.2	7.33	3.7	
241	35	12	0	83.3	162	Waves	5.7	25.0	5.42	3.1	w-h-e
							5.4	18.1	4.52	3.1	
							7.9	15.0	7.42	1.8	
							8.6	17.7	8.25	3.1	
241	35	7	40	70.5	137	Waves	---	---	----	4.4	w-u-e
							3.9	7.3	±5.7	4.8	
241	35	7	0	90.5	176	Waves	8.0	17.7	13.5	2.5	d
							9.0	10.4	9.0	1.5	

[a] In this column, the letters indicate the following motions:

w trimmed down – the attitude of the model decreased shortly after contact with the water.
h ran smoothly – the model made a very stable run.
n nosed in – the nose of the model submerged momentarily.
u trimmed up – the attitude of the model increased while running in the water.
p porpoised – the model undulated about the transverse axis with some part of the model always in contact with the water.
c the model followed the wave contours.
e the nose of the model ploughed through the wave crests.
d dived – the model stopped abruptly with the nose of the model submerged.

TABLE V.- SUMMARY OF RESULTS OF DYNAMIC MODEL DITCHING INVESTIGATION OF HEAVY JET TRANSPORT AIRPLANE WITH LANDING GEAR EXTENDED AND WITH SCALE-STRENGTH FUSELAGE BOTTOM SECTION

[All values are full scale]

Landing attitude, deg	Flap setting, deg	Landing-gear position	Landing speed		Sink speed		Water surface	Maximum impact accelerations				Run distance, fuselage lengths	Chronological behavior of model
			knots	m/sec	m/sec	ft/sec		Longitudinal, g-units	Normal, g-units (a)	Normal, g-units (b)	Angular, rad/sec^2		(c)
12	40	Nose down; main down	126	64.8	0.76	2.5	Calm	4.7	8.4	2.4	3.7	2.9	w-u-b
7	40	Nose down; main down	137	70.5				3.1	4.3	2.7	2.2	5.6	p
12	40	Nose up; main down	126	64.8				5.1	12.2	4.2	3.7	4.2	p-h
$9\frac{1}{2}$	40		132	67.9				3.0	9.8	4.5	3.0	5.6	w-h
7	40		137	70.5				3.2	8.3	4.0	2.6	4.8	w-u-h
4	40		153	78.7				2.7	10.4	5.4	4.1	6.8	p-h
7	0		176	90.5				5.6	10.4	7.1	3.4	6.2	h-t
12	40		126	64.8			Waves	7.3	16.0	10.1	5.2	3.5	w-e-h
$9\frac{1}{2}$	40		132	67.9				7.1	21.8	10.3	10.1	4.3	w-h
7	40		137	70.5				7.5	21.3	6.9	10.5	4.7	w-h
4	40		153	78.7				7.4	22.0	9.0	10.3	6.2	h-t
12	40	Nose up; main kneeling	126	64.8			Calm	4.4	12.4	7.3	3.9	3.1	w-u-h
$9\frac{1}{2}$	40		132	67.9				5.7	6.6	5.4	3.0	4.2	w-h
7	40		137	70.5				4.1	5.1	4.2	1.9	5.7	w-h
12	40		126	64.8			Waves	9.2	21.6	8.8	7.1	3.5	w-e-h
$9\frac{1}{2}$	40		132	67.9				7.3	21.9	10.9	8.9	4.4	e-h
7	40		137	70.5				10.5	22.1	9.1	11.0	5.2	e-h
7	40		137	70.5	2.7	9	Calm	11.0	14.4	19.1	-10.9	3.6	p-h
4	40		153	78.7	2.7	9	Calm	12.7	22.2	15.3	-7.0	3.9	h-p-h

[a] Normal accelerations measured near pilot's compartment.

[b] Normal accelerations measured near center of gravity.

[c] In this column, the letters indicate the following motions:

w	trimmed down – the attitude of the model decreased shortly after contact with the water.
h	ran smoothly – the model made a very stable run.
u	trimmed up – the attitude of the model increased while running in the water.
p	porpoised – the model undulated about the transverse axis with some part of the model always in contact with the water.
e	the nose of the model ploughed through the wave crests.
t	turned sharply – the model pivoted quickly about a vertical axis.
b	ran deeply – the model settled deeply into the water with little change in attitude.

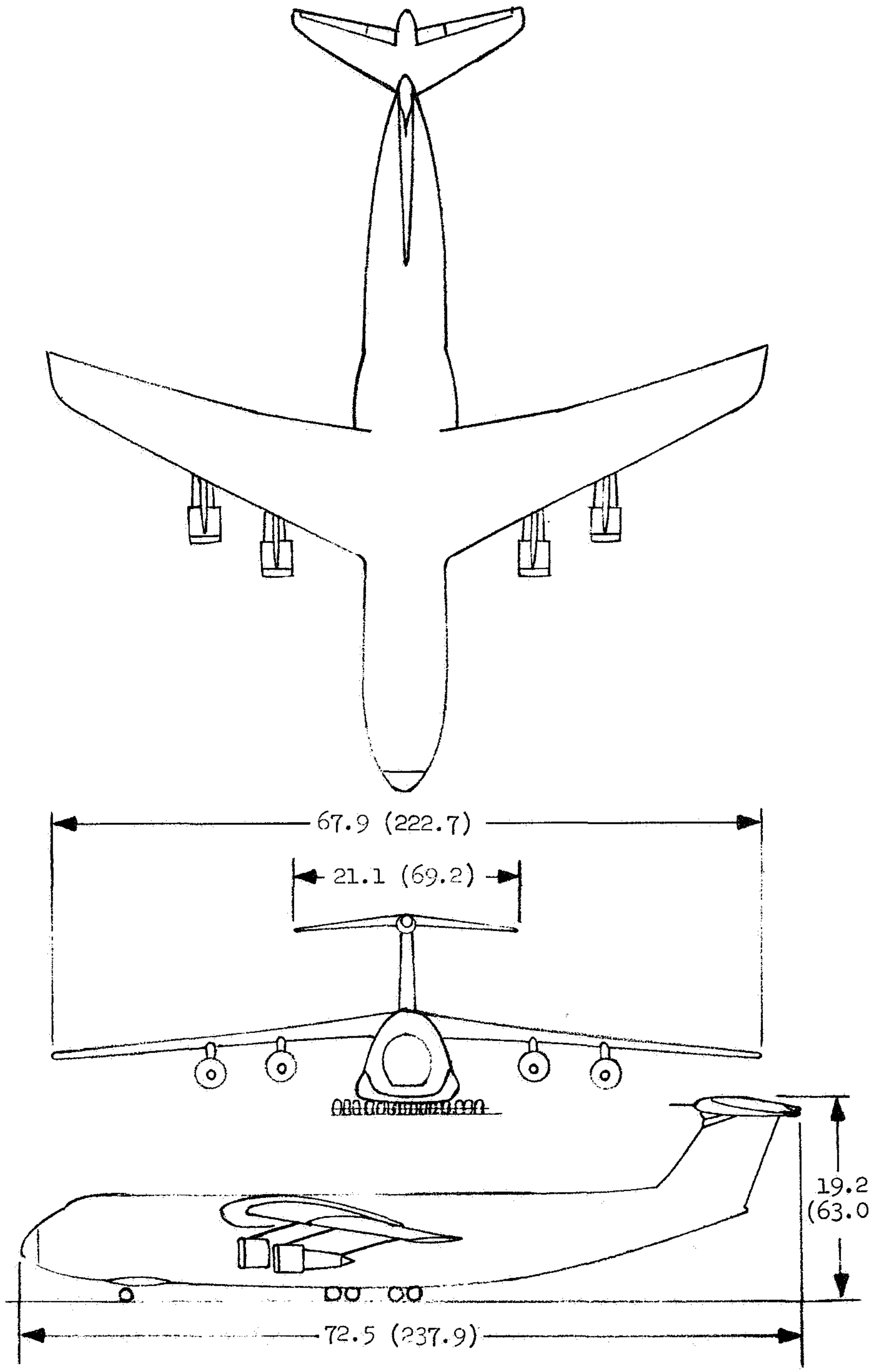
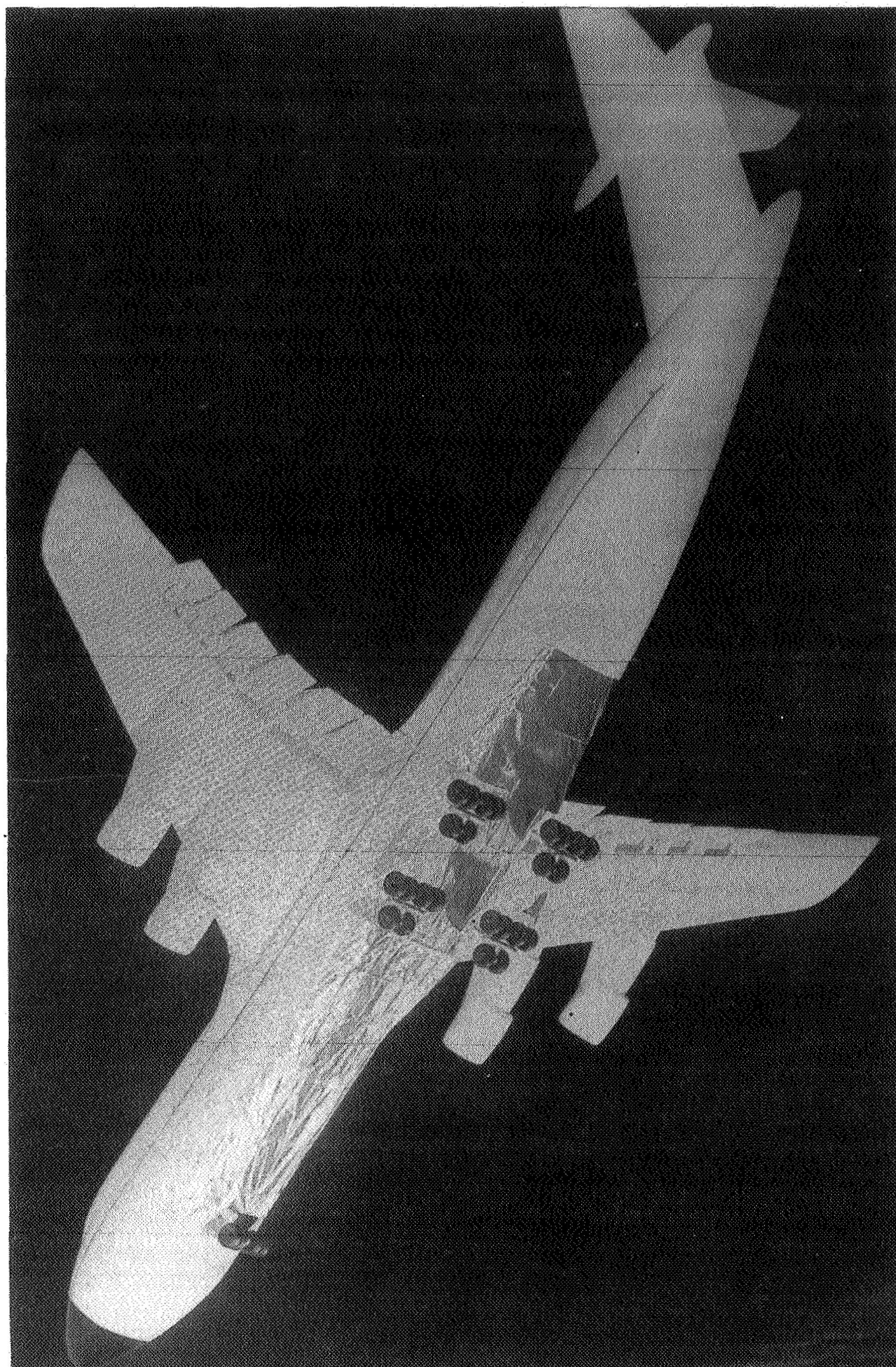
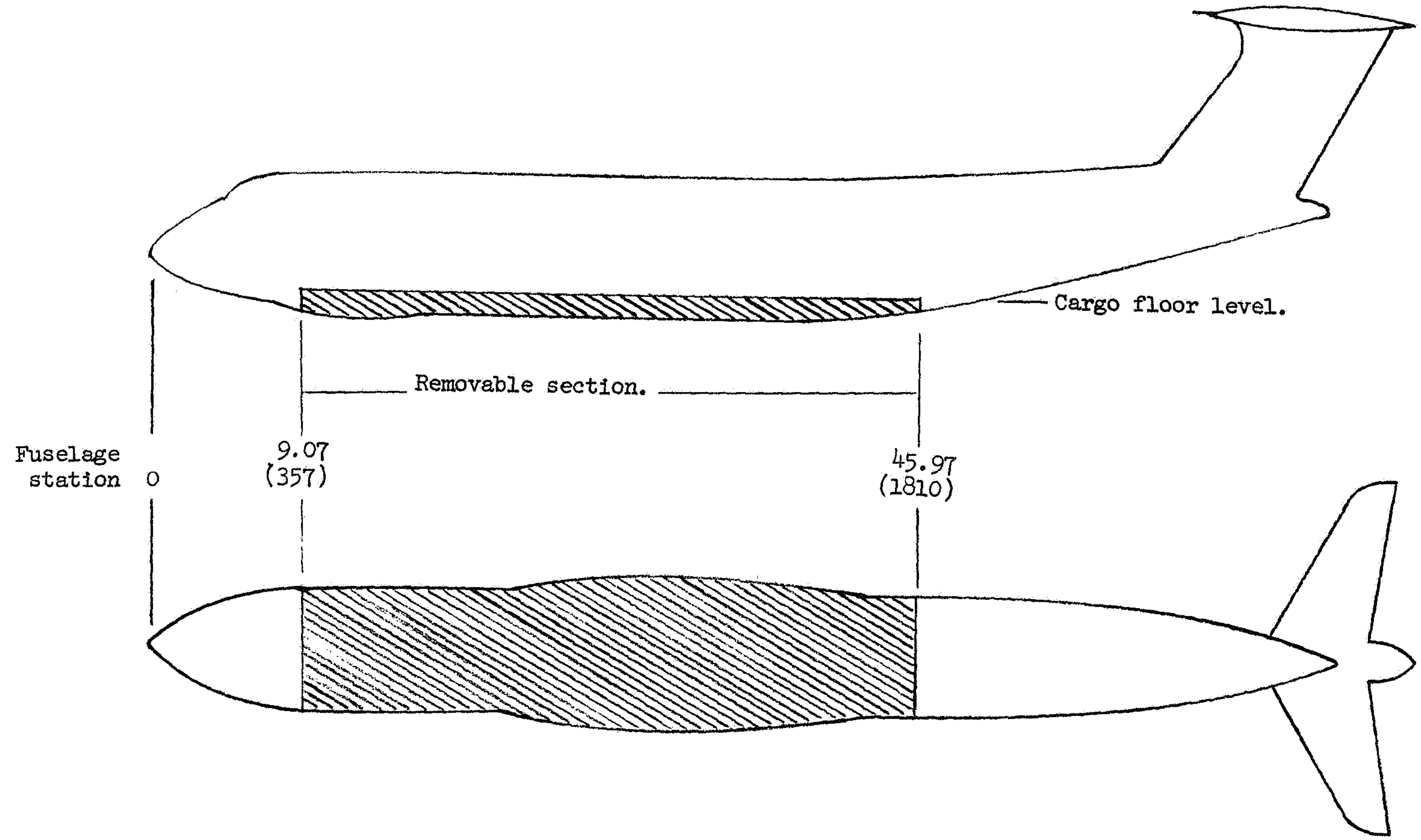


Figure 1.- General arrangement of test airplane. Dimensions are full-scale values and are given in meters (ft).



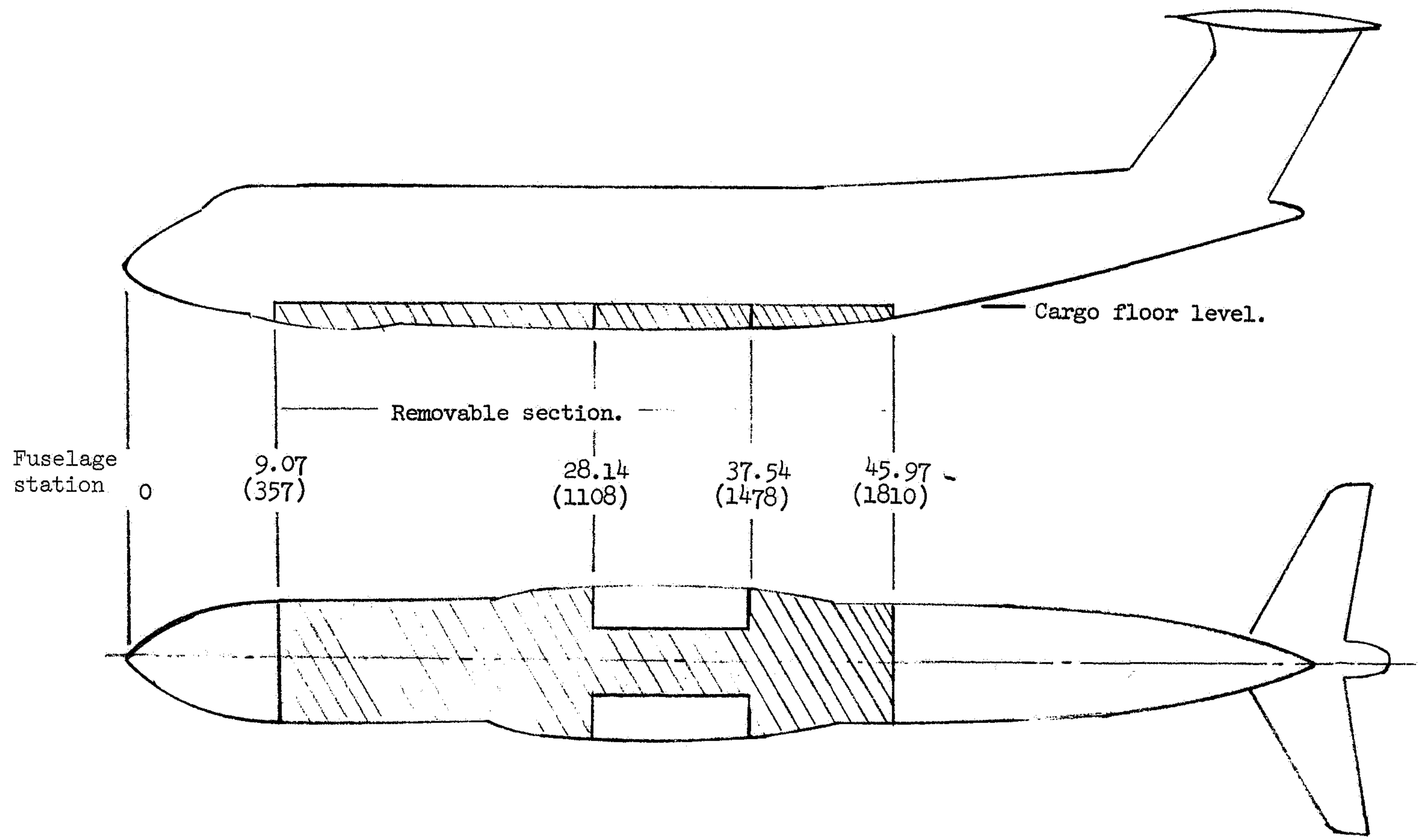
L-69-8028

Figure 2.- 1/30-scale ditching model.



(a) Landing gear retracted.

Figure 3.- Sketch of 1/30-scale model fuselage showing removable section of bottom in which scale-strength sections were used. Dimensions are full-scale values and are given in meters (inches).



(b) Configuration for landing gear extended.

Figure 3.- Concluded.

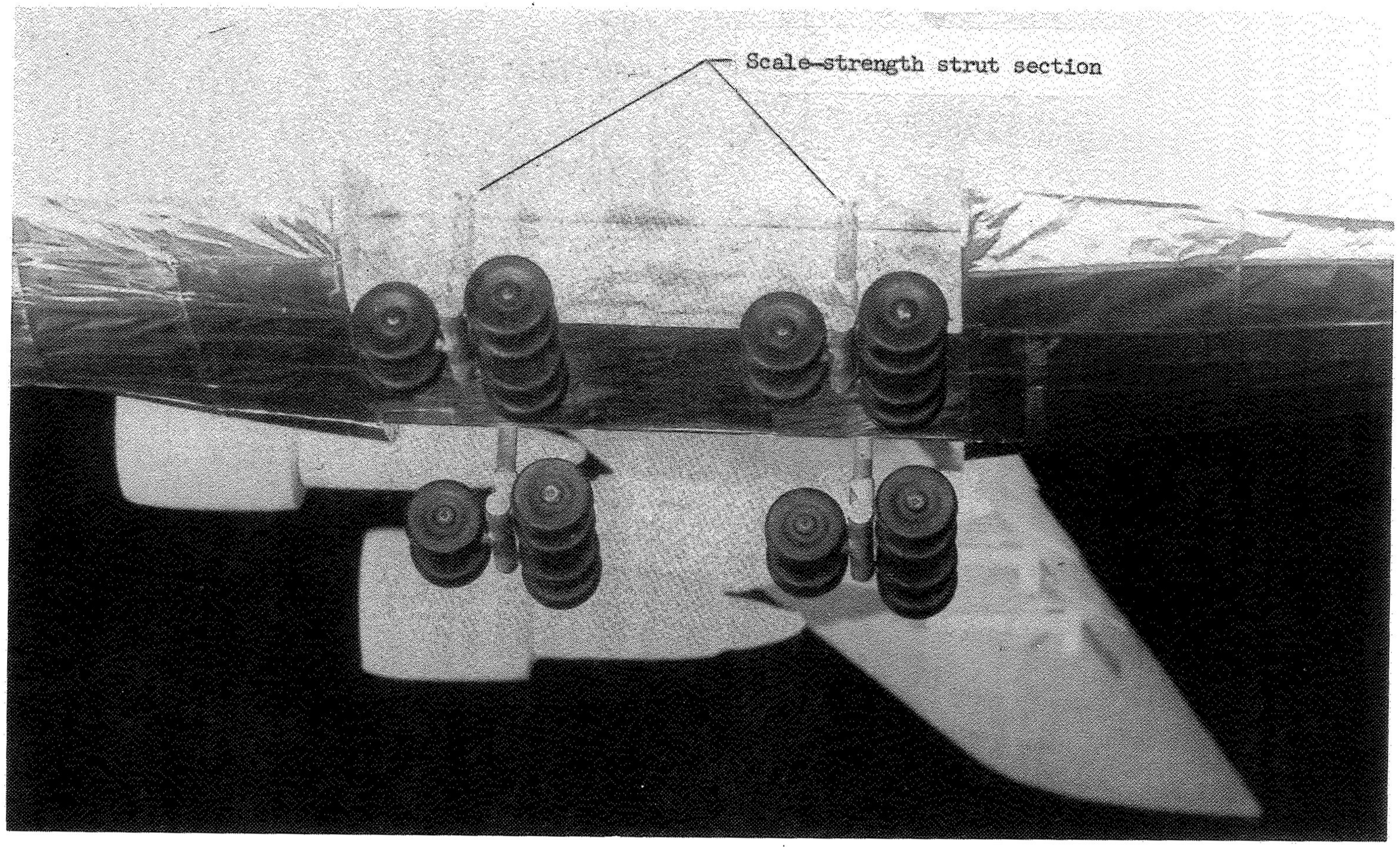


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Figure 4.- Main landing gear with scale-strength struts.

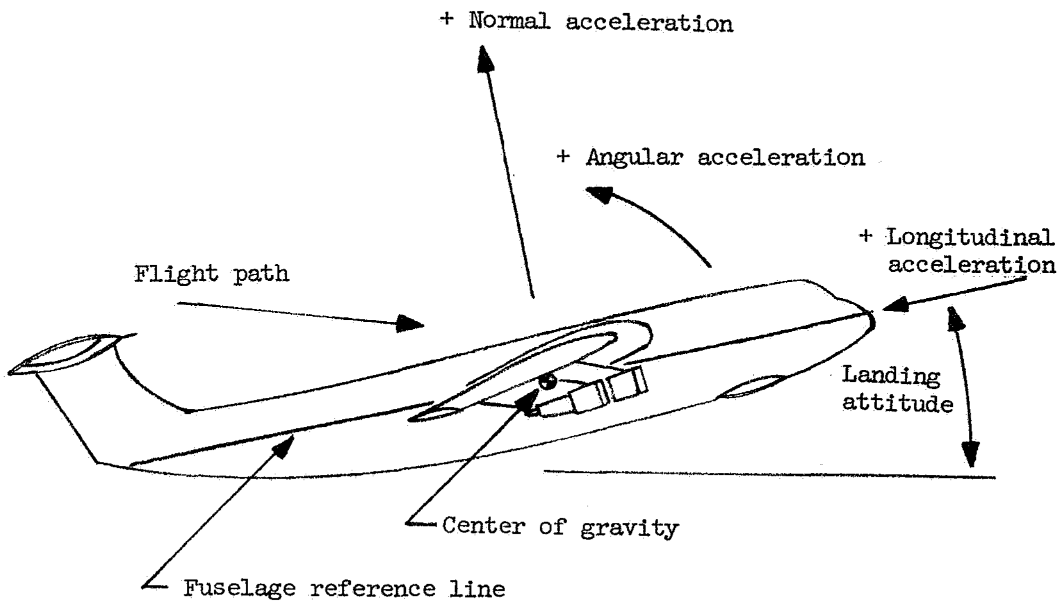
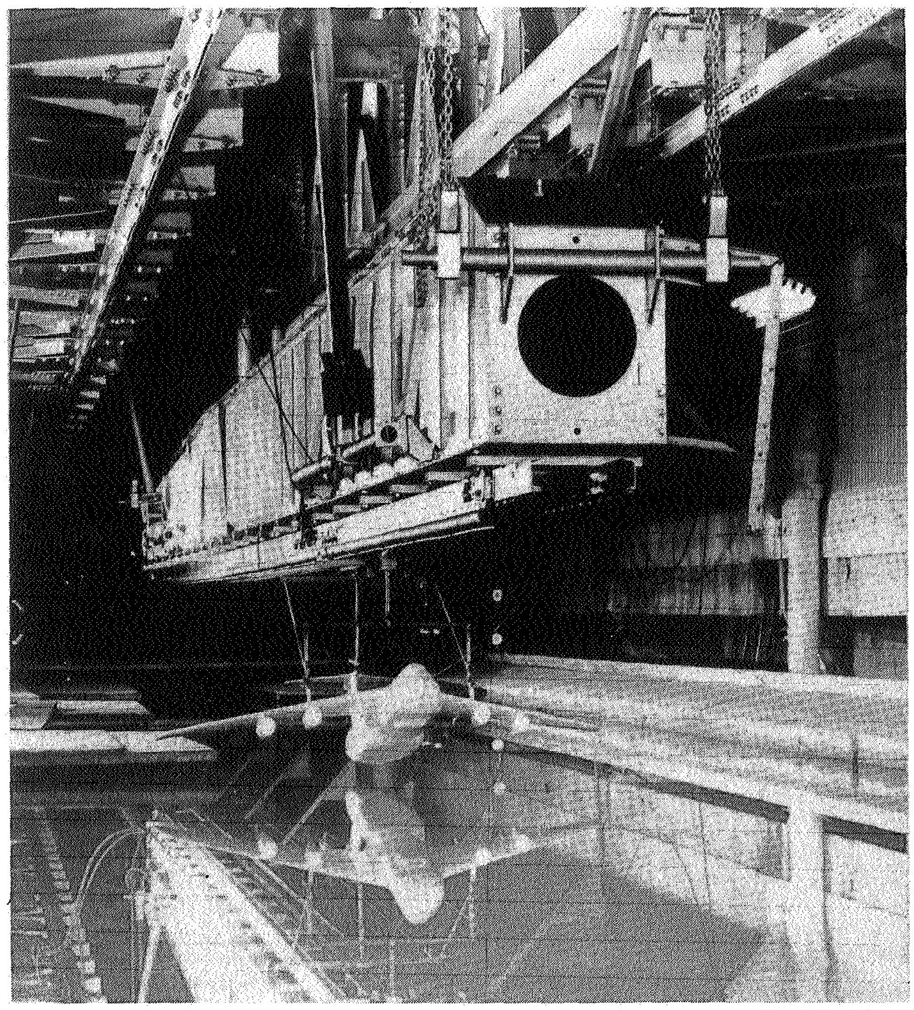
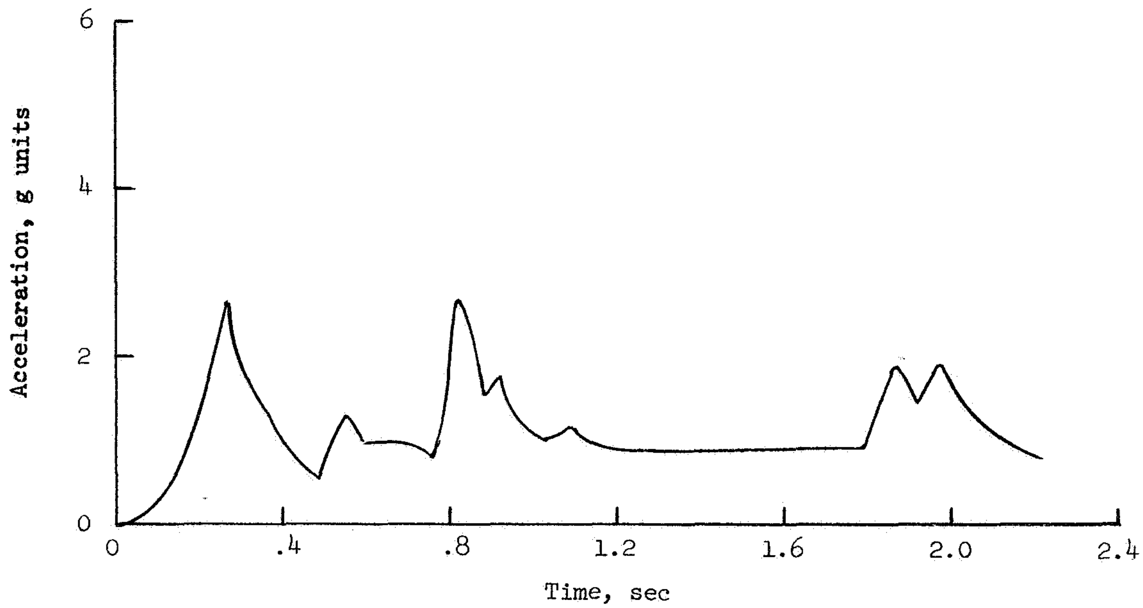


Figure 5.- Sketch identifying acceleration axes, attitude, and flight path.

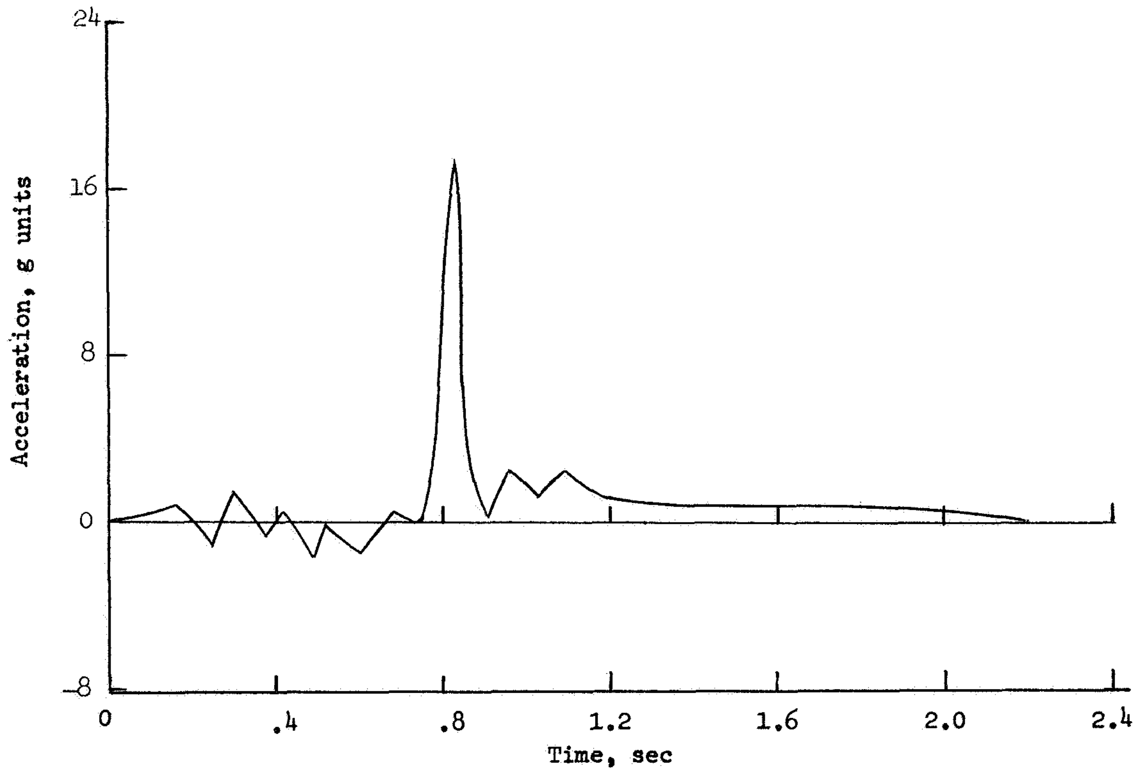


L-68-1828

Figure 6.- Catapult with model ready for launching.

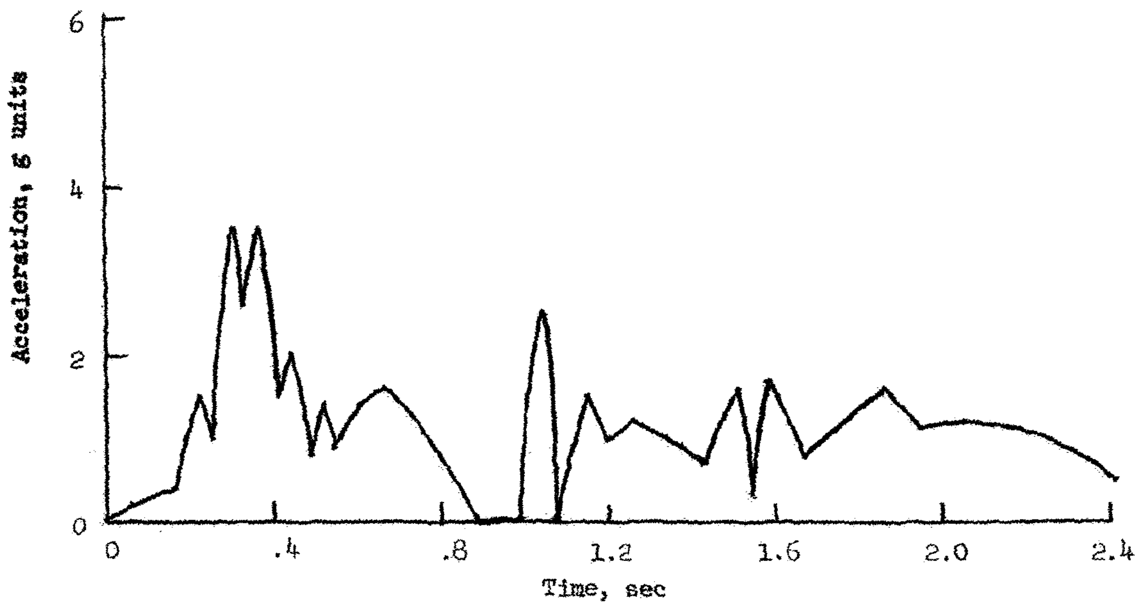


(a) Longitudinal acceleration.

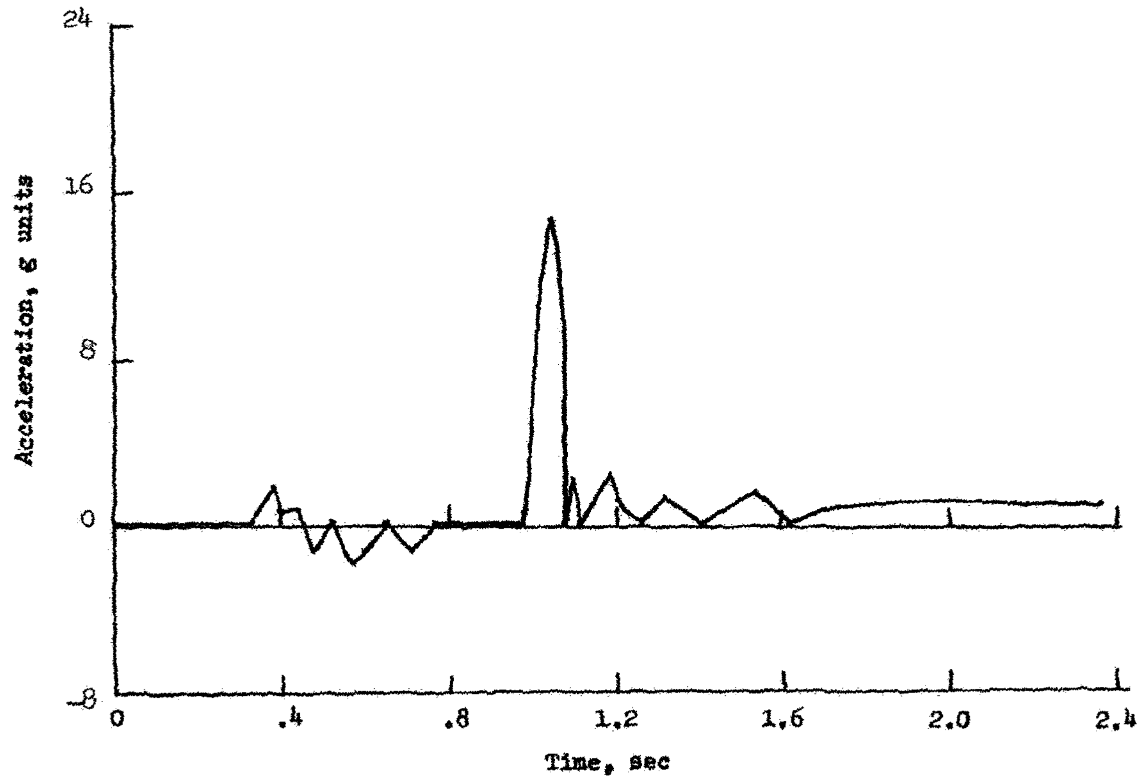


(b) Normal acceleration.

Figure 7.- Typical acceleration curves for ditching in calm water. Landing gear, retracted; attitude, 12°; flaps, 40°; fuselage-bottom failure strength, 83 to 117 kN/m^2 (12 to 17 psi); landing speed, 64.8 m/sec (126 knots). All values are full scale.

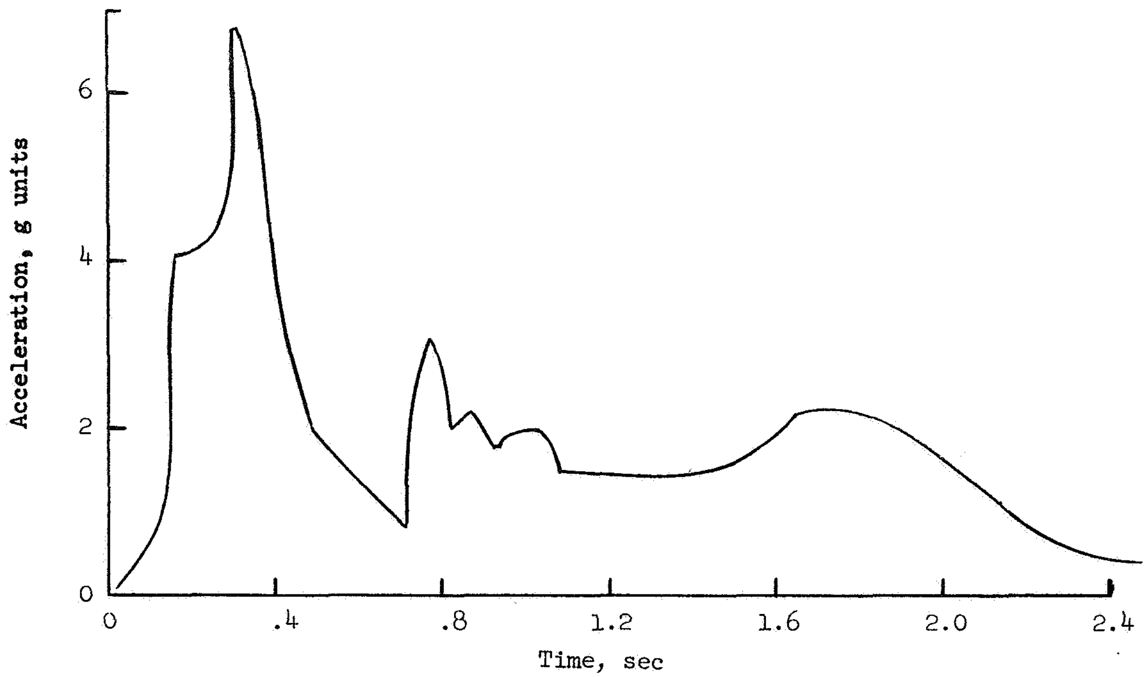


(a) Longitudinal acceleration.

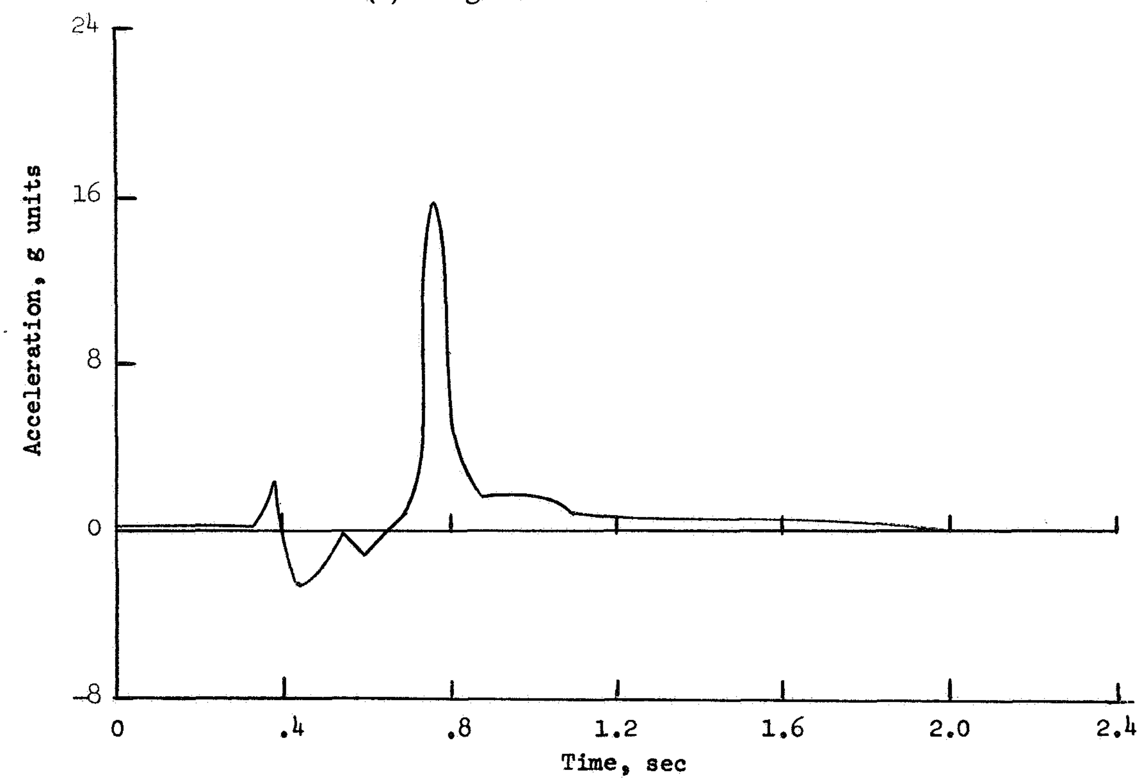


(b) Normal acceleration.

Figure 8.- Typical acceleration curves for ditching in calm water. Landing gear, retracted; attitude, 12°; flaps, 40°; fuselage-bottom failure strength, 241 kN/m^2 (35 psi); landing speed, 64.8 m/sec (126 knots). All values are full scale.

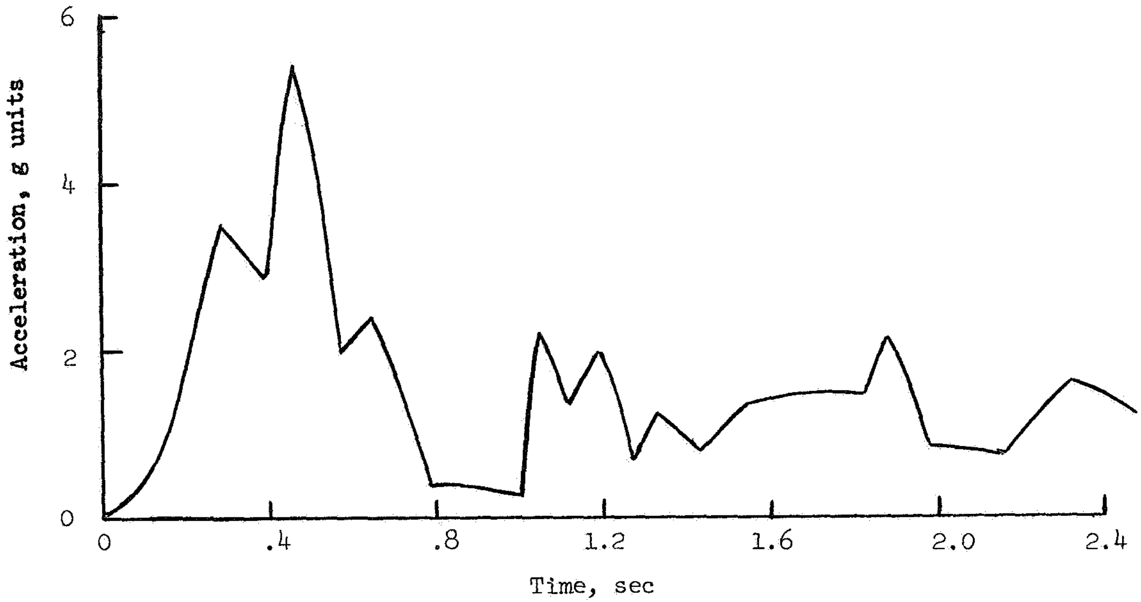


(a) Longitudinal acceleration.

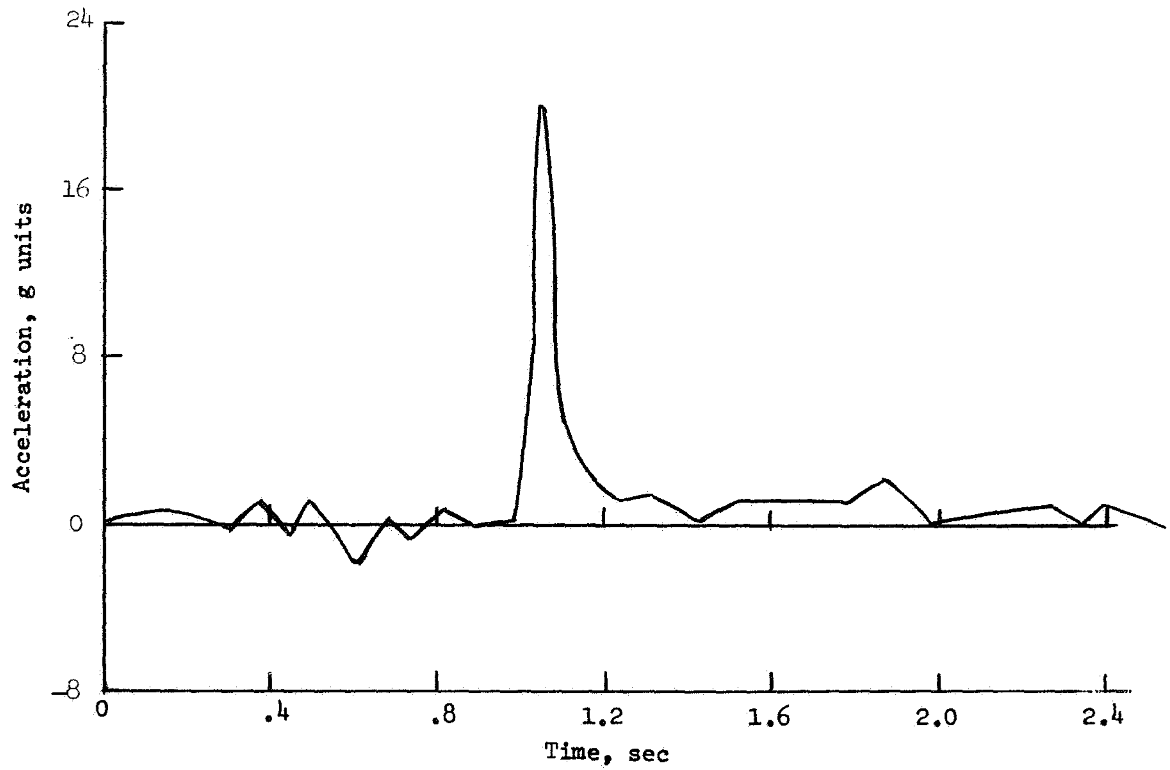


(b) Normal acceleration.

Figure 9.- Typical acceleration curves for ditching in calm water. Landing gear, retracted; attitude, 12°; flaps, 0°; fuselage-bottom failure strength, 83 to 117 kN/m^2 (12 to 17 psi); landing speed, 83.3 m/sec (162 knots). All values are full scale.

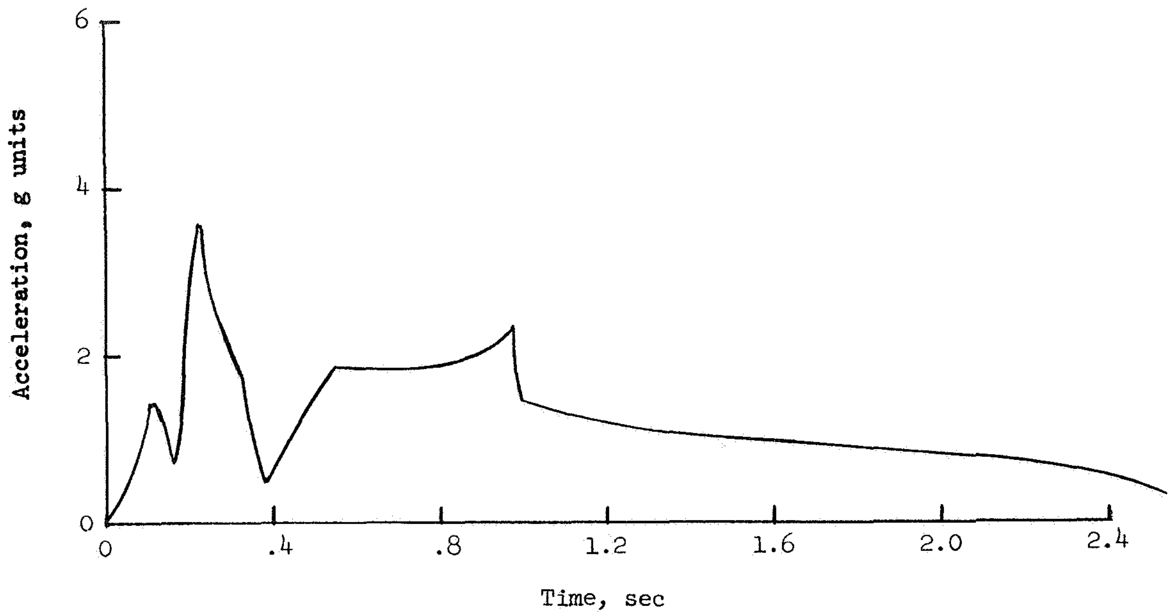


(a) Longitudinal acceleration.

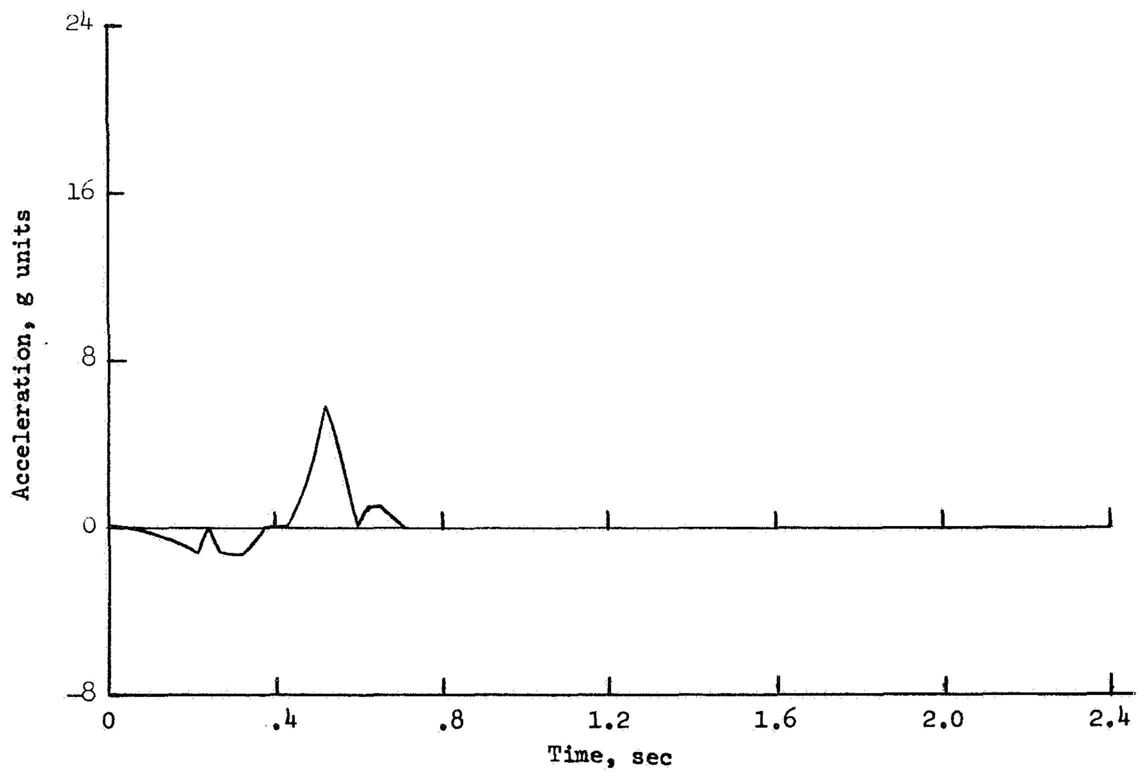


(b) Normal acceleration.

Figure 10.- Typical acceleration curves for ditching in calm water. Landing gear, retracted; attitude, 12°; flaps, 0°; fuselage-bottom failure strength, 241 kN/m^2 (35 psi); landing speed, 83.3 m/sec (162 knots). All values are full scale.

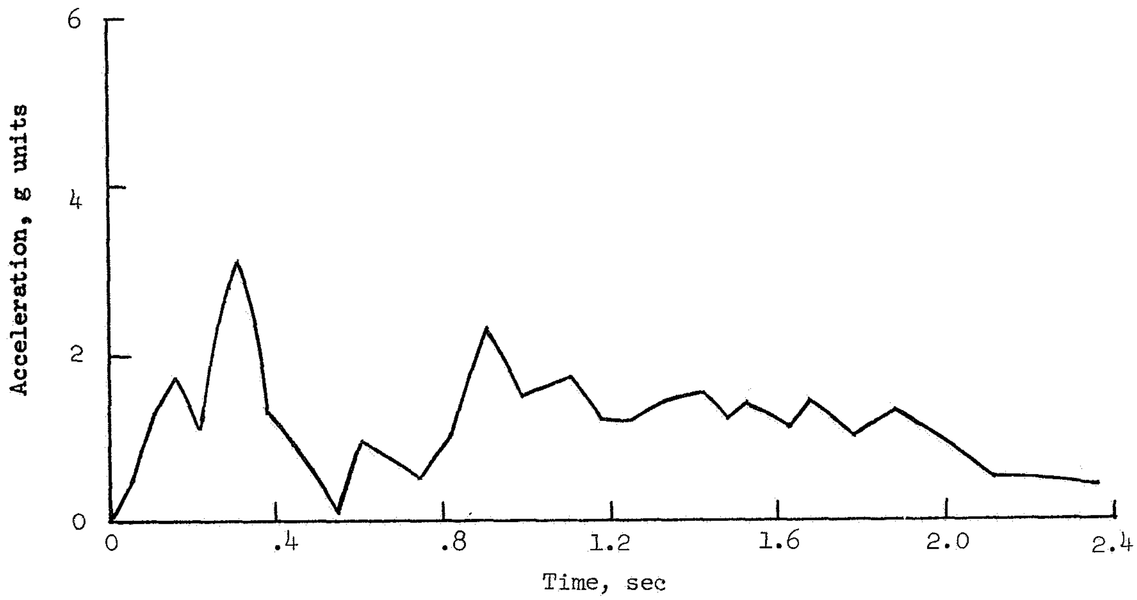


(a) Longitudinal acceleration.

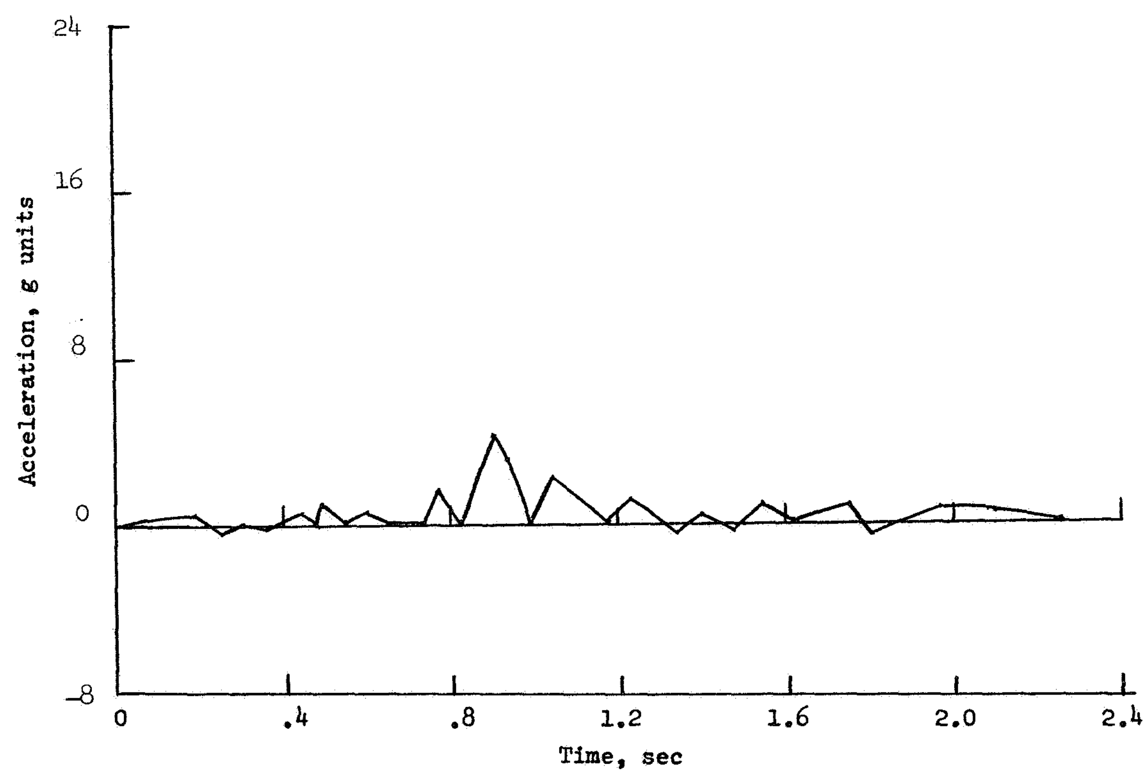


(b) Normal acceleration.

Figure 11.- Typical acceleration curves for ditching in calm water. Landing gear, retracted; attitude, 7°; flaps, 40°; fuselage-bottom failure strength, 83 to 117 kN/m^2 (12 to 17 psi); landing speed, 70.5 m/sec (137 knots). All values are full scale.

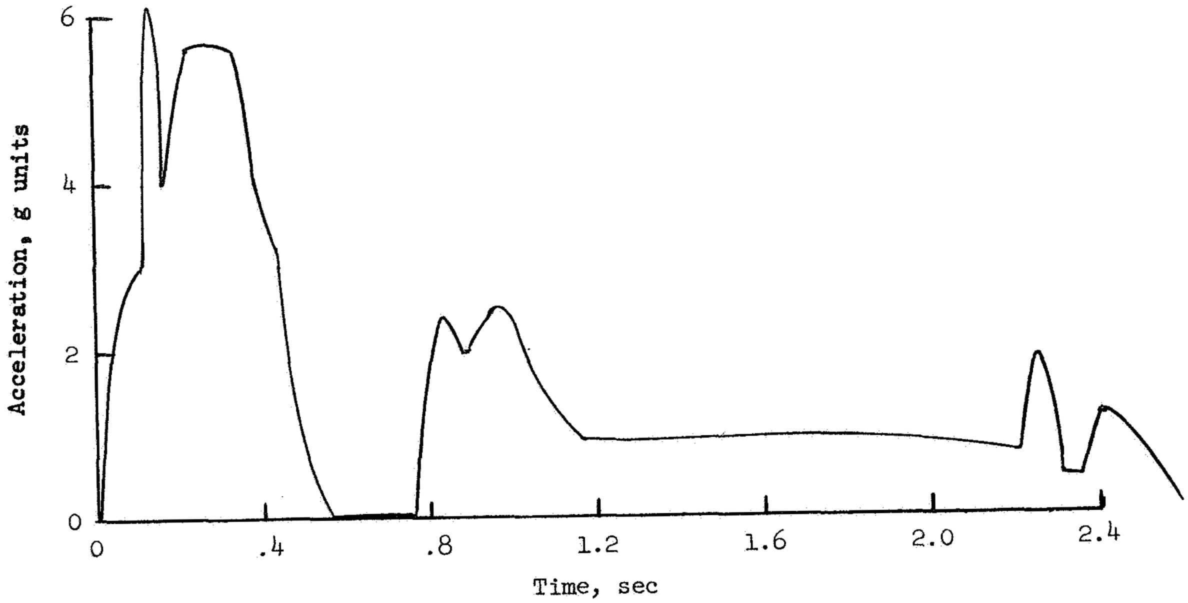


(a) Longitudinal acceleration.

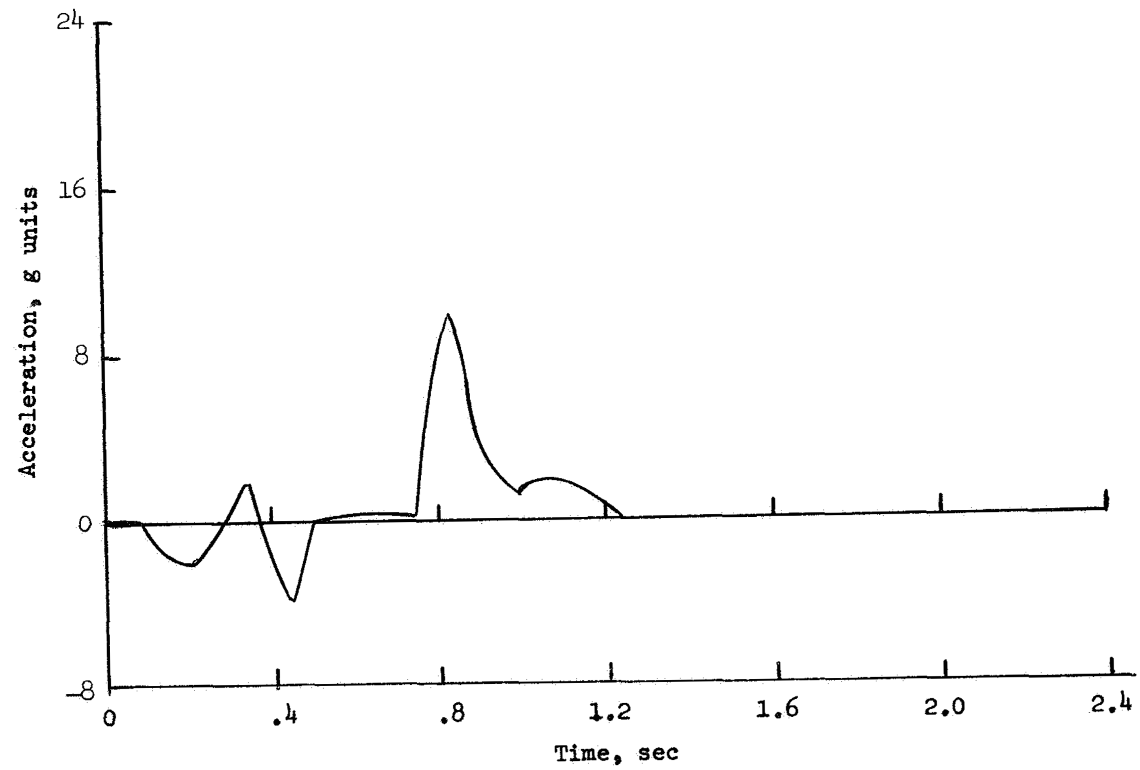


(b) Normal acceleration.

Figure 12.- Typical acceleration curves for ditching in calm water. Landing gear, retracted; attitude, 7°; flaps, 40°; fuselage-bottom failure strength, 241 kN/m^2 (35 psi); landing speed, 70.5 m/sec (137 knots). All values are full scale.

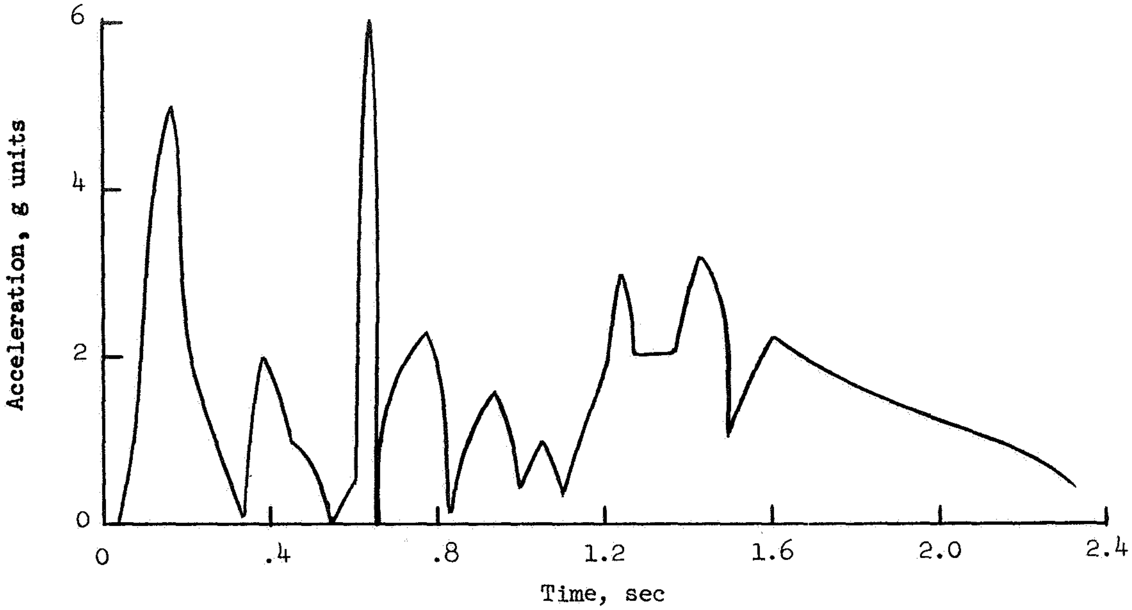


(a) Longitudinal acceleration.

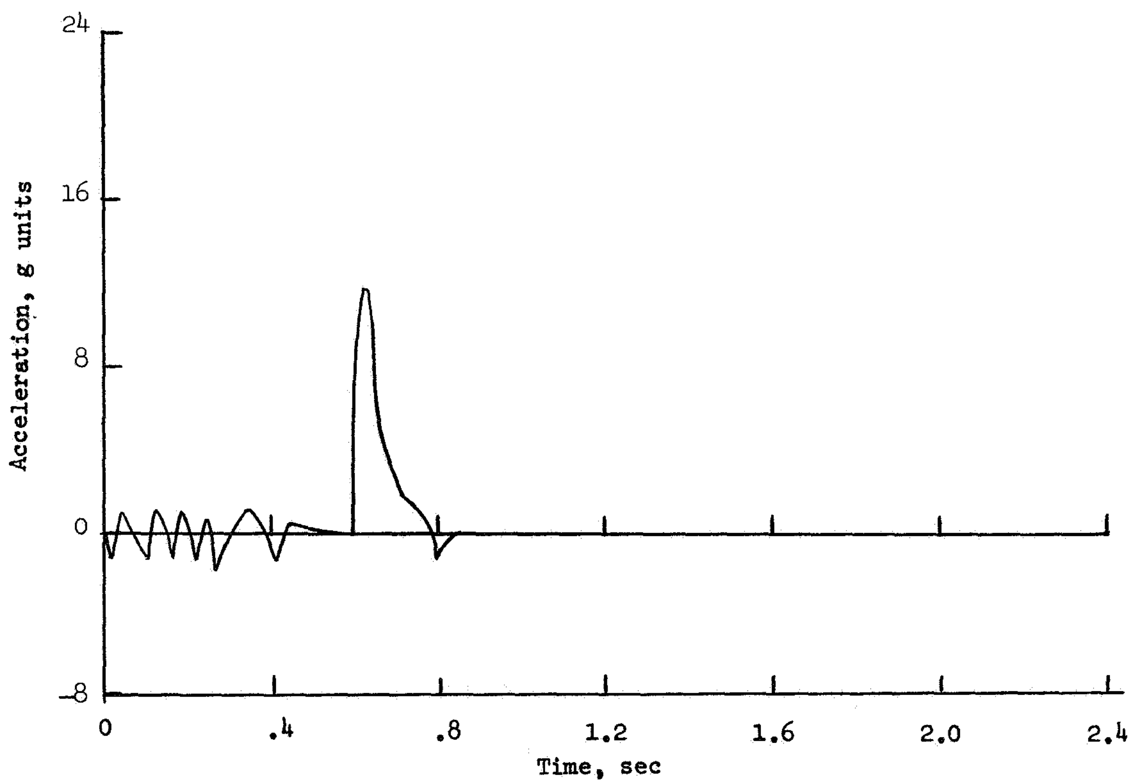


(b) Normal acceleration.

Figure 13.- Typical acceleration curves for ditching in calm water. Landing gear, retracted; attitude, 7°; flaps, 0°; fuselage-bottom failure strength, 241 kN/m^2 (35 psi); landing speed, 90.5 m/sec (176 knots). All values are full scale.

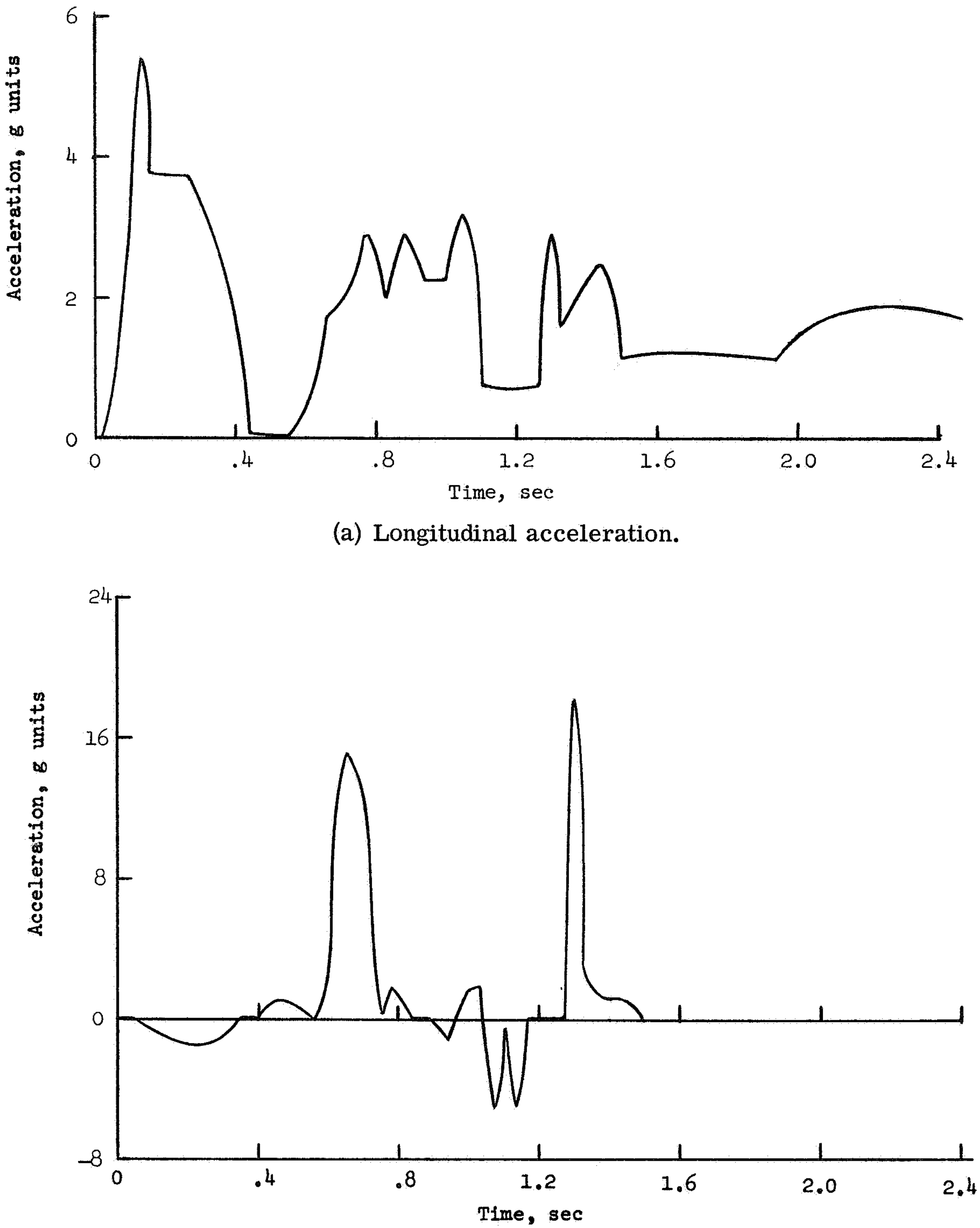


(a) Longitudinal acceleration.



(b) Normal acceleration.

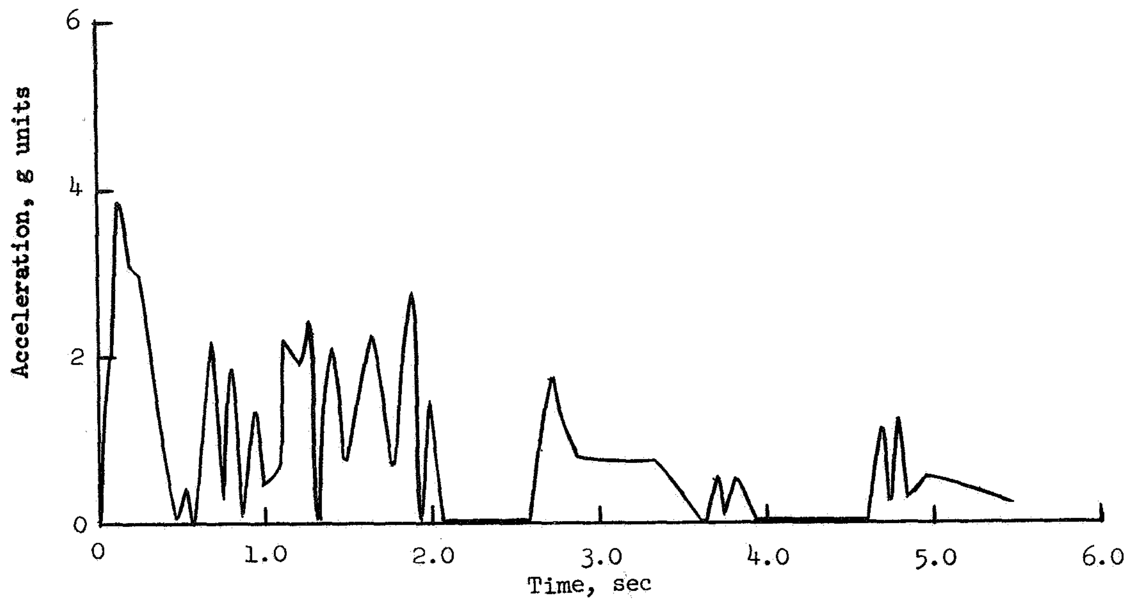
Figure 14.- Typical acceleration curves for ditching in rough water. Landing gear, retracted; attitude, 12°; flaps, 40°; fuselage-bottom failure strength, 241 kN/m^2 (35 psi); landing speed, 64.8 m/sec (126 knots). All values are full scale.



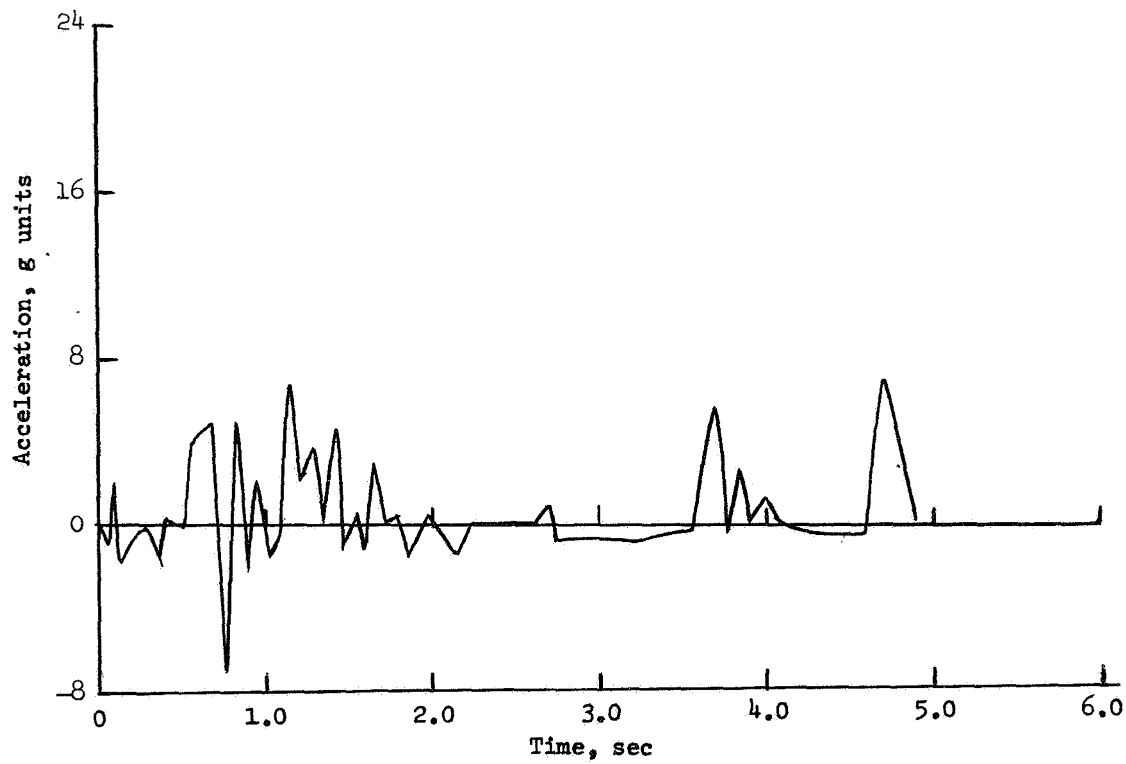
(a) Longitudinal acceleration.

(b) Normal acceleration.

Figure 15.- Typical acceleration curves for ditching in rough water. Landing gear, retracted; attitude, 12°; flaps, 0°; fuselage-bottom failure strength, 241 kN/m^2 (35 psi); landing speed, 83.3 m/sec (162 knots). All values are full scale.

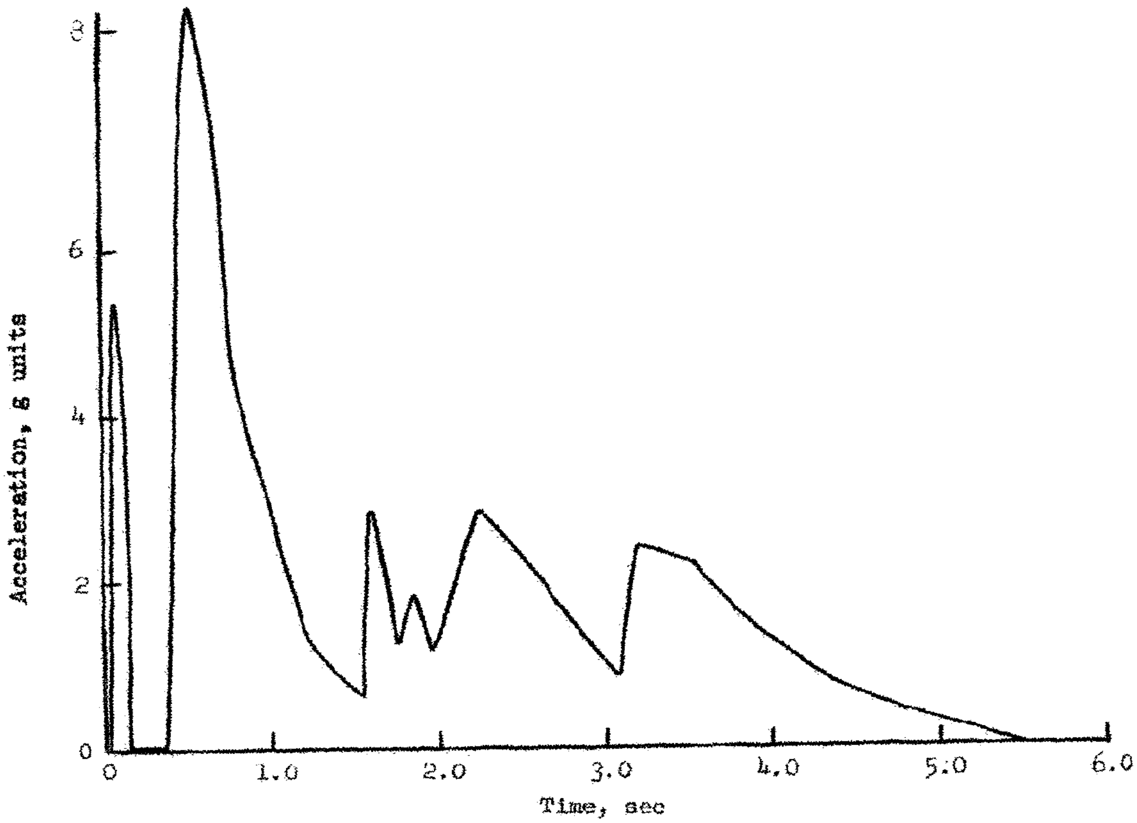


(a) Longitudinal acceleration.



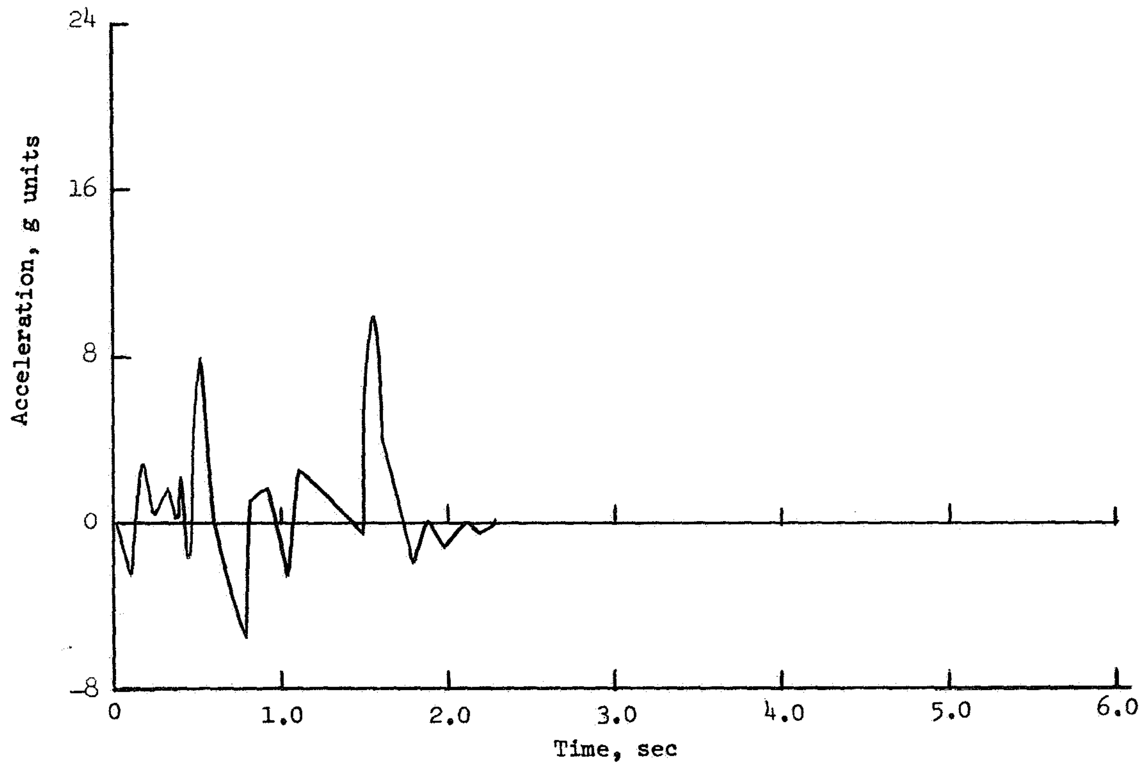
(b) Normal acceleration.

Figure 16.- Typical acceleration curves for ditching in rough water. Landing gear, retracted; attitude, 7^{o}; flaps, 40^{o}; fuselage bottom-failure strength, 241 kN/m^2 (35 psi); landing speed, 70.5 m/sec (137 knots). All values are full scale.



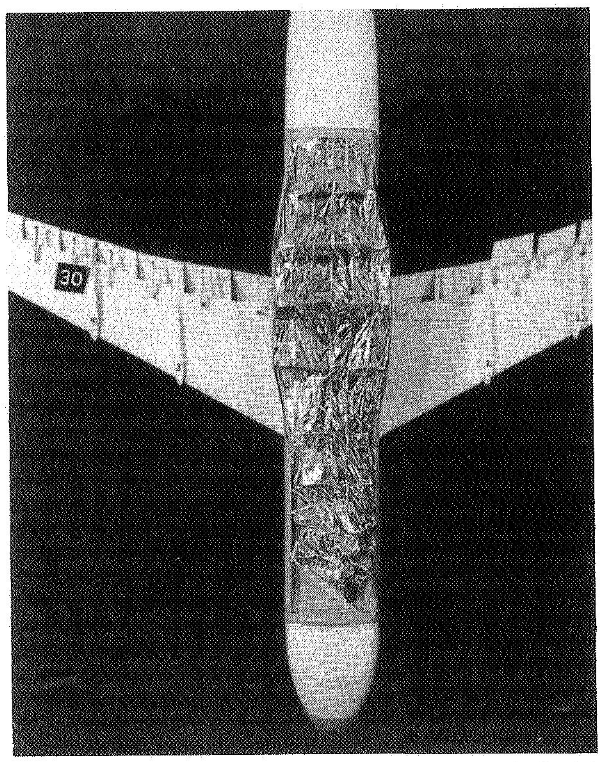
(a) Longitudinal acceleration.

Figure 17.- Typical acceleration curves for ditching in rough water. Landing gear, retracted; attitude, 7°; flaps, 0°; fuselage-bottom failure strength, 241 kN/m^2 (35 psi); landing speed, 90.5 m/sec (176 knots). All values are full scale.



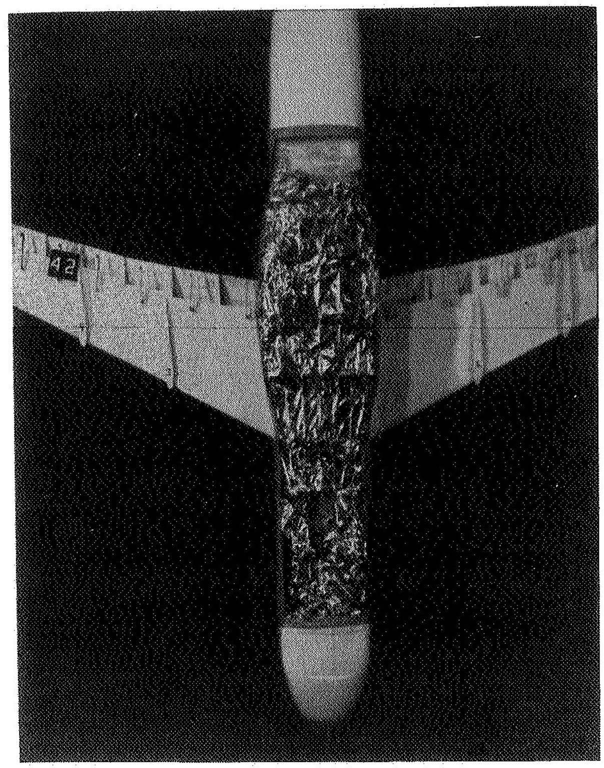
(b) Normal acceleration.

Figure 17.- Concluded.



L-69-3595

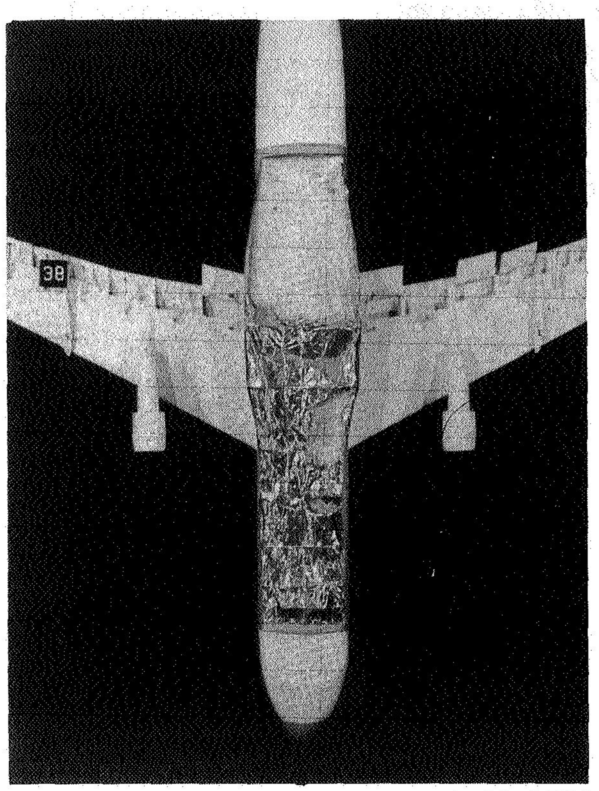
(a) Landing attitude, 12°; flaps, 40°; landing speed, 64.8 m/sec (126 knots).



L-69-3594

(b) Landing attitude, 12°; flaps, 0°; landing speed, 83.3 m/sec (162 knots).

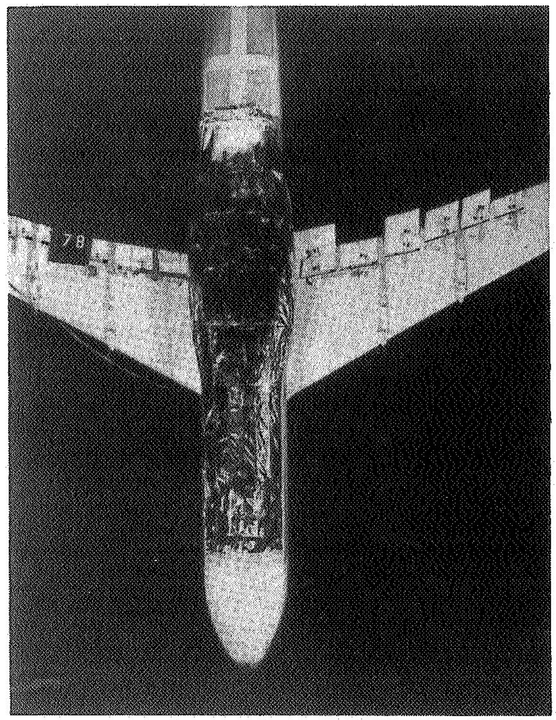
Figure 18.- Typical damage to fuselage-bottom sections that simulated a failure strength of 83 to 117 kN/m^2 (12 to 17 psi) in calm-water ditchings. All values are full scale.



L-69-3596

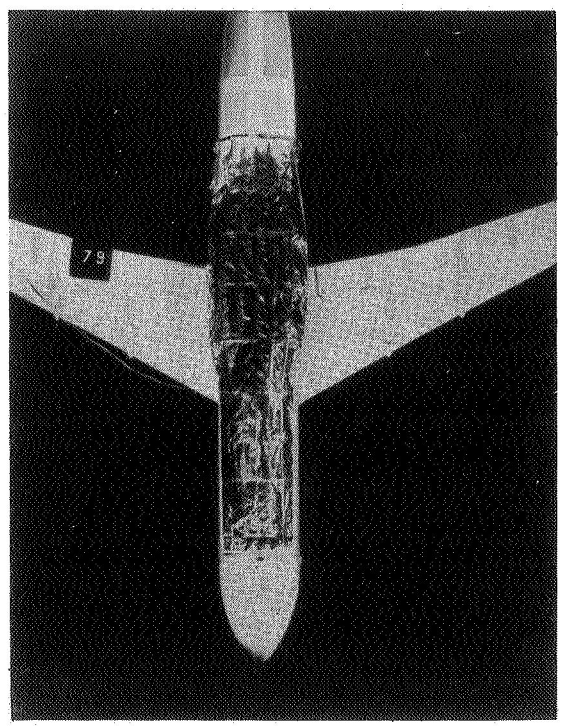
(c) Landing attitude, 7°; flaps, 40°; landing speed, 70.5 m/sec (137 knots).

Figure 18.- Concluded.



L-68-7338

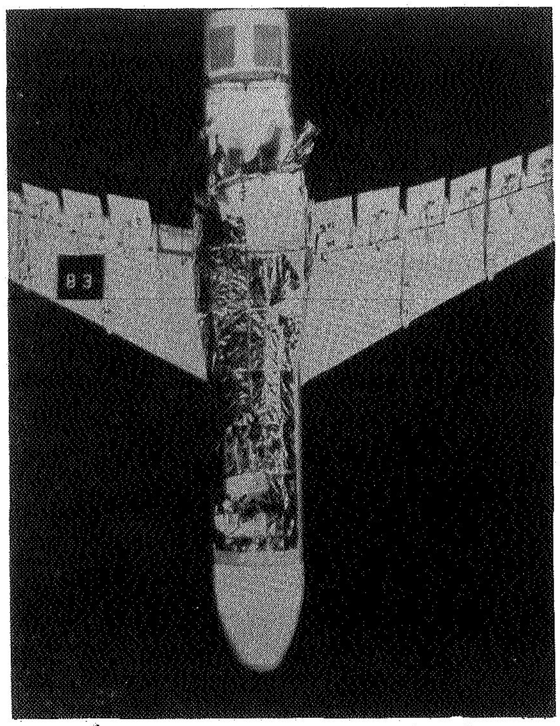
(a) Landing attitude, 12°; flaps, 40°; landing speed, 64.8 m/sec (126 knots).



L-68-7337

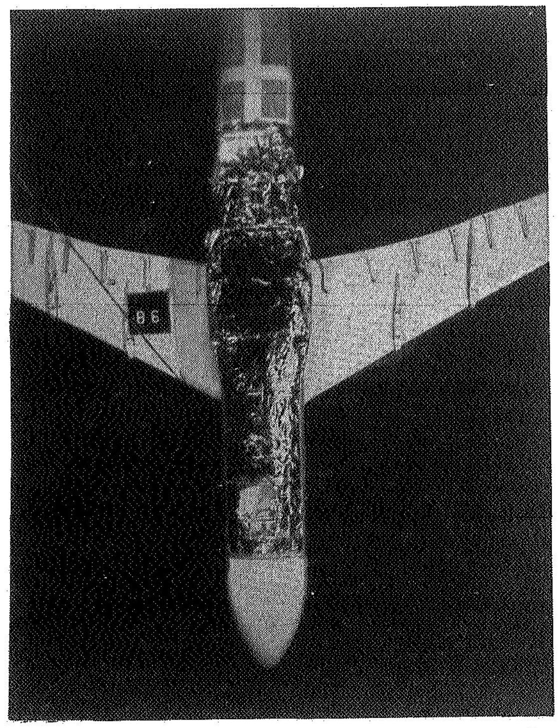
(b) Landing attitude, 12°; flaps, 0°; landing speed, 83.3 m/sec (162 knots).

Figure 19.- Typical damage to fuselage-bottom sections that simulated a failure strength of 241 kN/m^2 (35 psi) in calm-water ditchings. All values are full scale.



L-68-7336

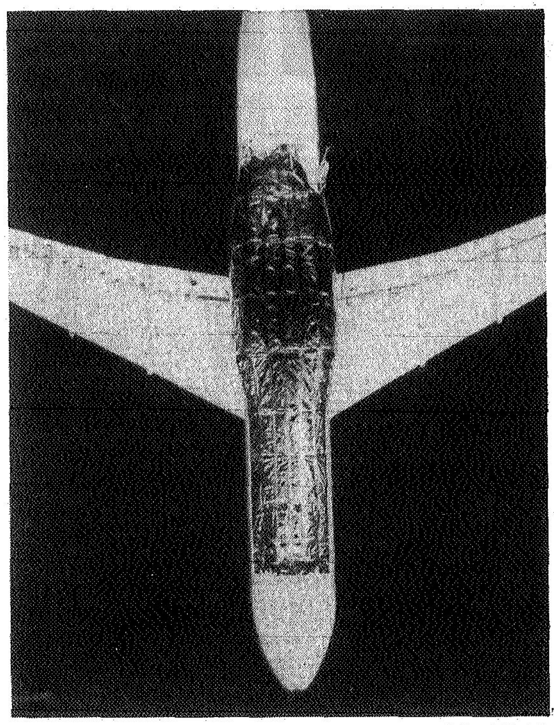
(c) Landing attitude, 7°; flaps, 40°; landing speed, 70.5 m/sec (137 knots).



L-68-7335

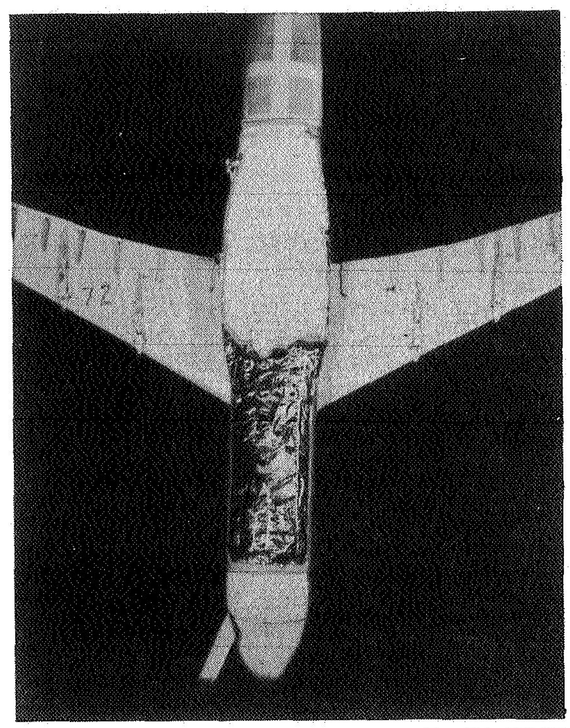
(d) Landing attitude, 7°; flaps, 0°; landing speed, 90.5 m/sec (176 knots).

Figure 19.- Concluded.



L-68-7340

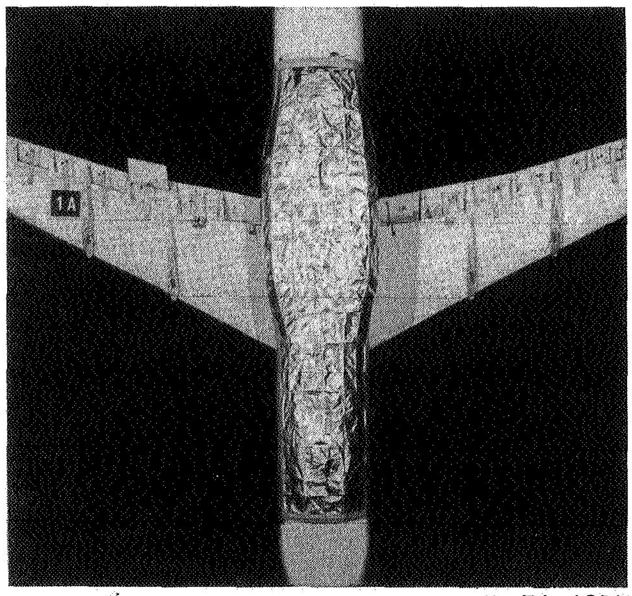
(a) Landing attitude, 12^{o}; flaps, 40^{o}; landing speed, 64.8 m/sec (126 knots).



L-68-7339

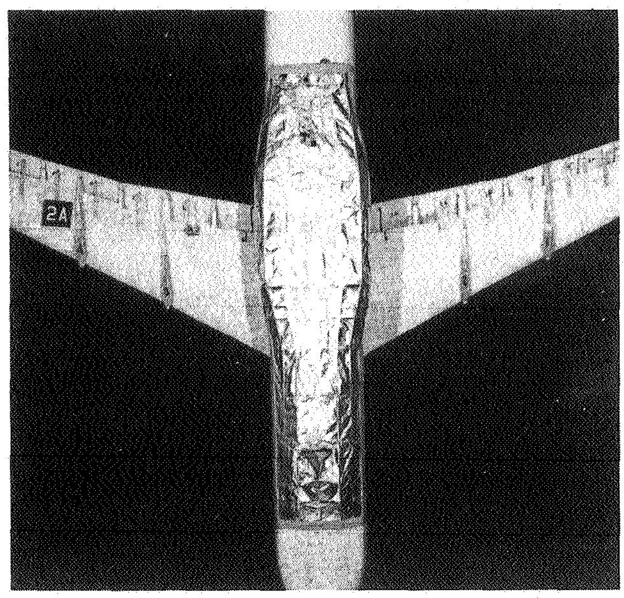
(b) Landing attitude, 12^{o}; flaps, 0^{o}; landing speed, 83.3 m/sec (162 knots).

Figure 20.- Typical damage to fuselage-bottom sections that simulated a failure strength of 241 kN/m^2 (35 psi) when ditched into oncoming waves 2.4×61 m (8×200 ft). All values are full scale.



L-71-1277

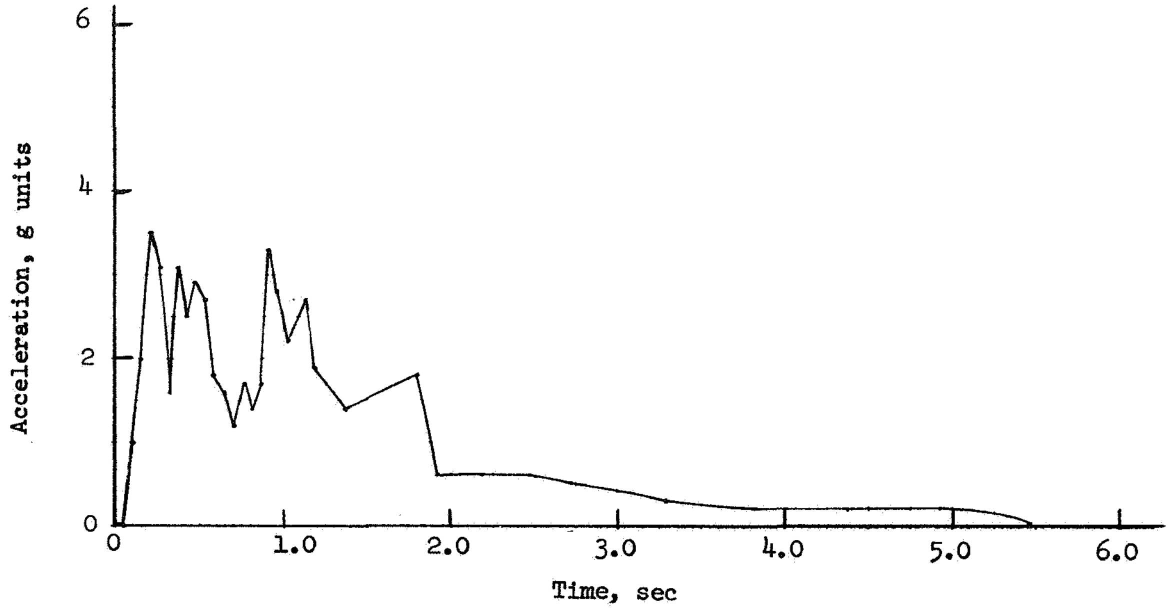
(c) Landing attitude, 7°; flaps, 40°; landing speed, 70.5 m/sec (137 knots).



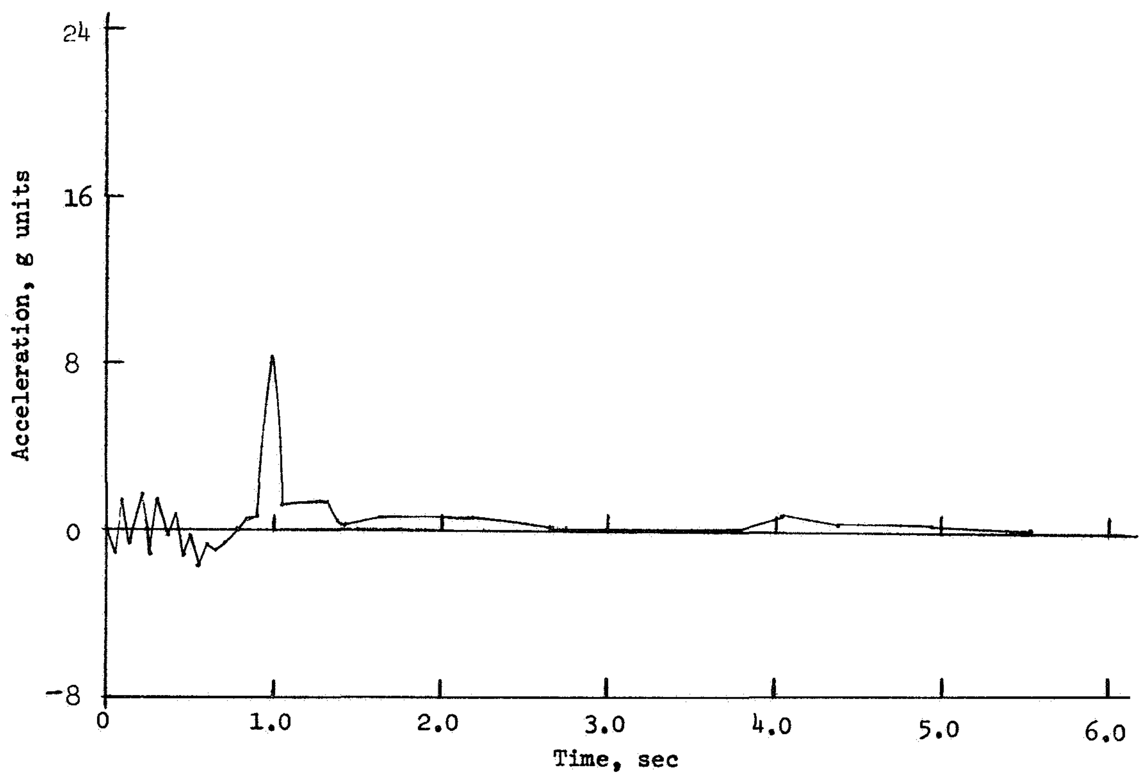
L-71-1278

(d) Landing attitude, 7°; flaps, 0°; landing speed, 90.5 m/sec (176 knots).

Figure 20.- Concluded.

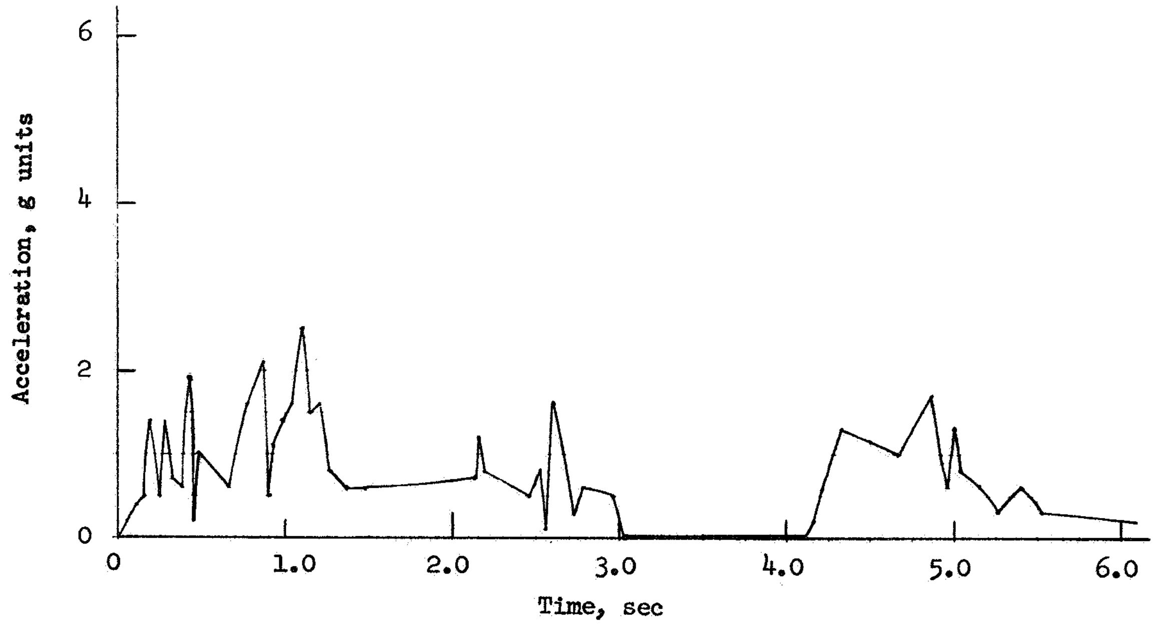


(a) Longitudinal acceleration.

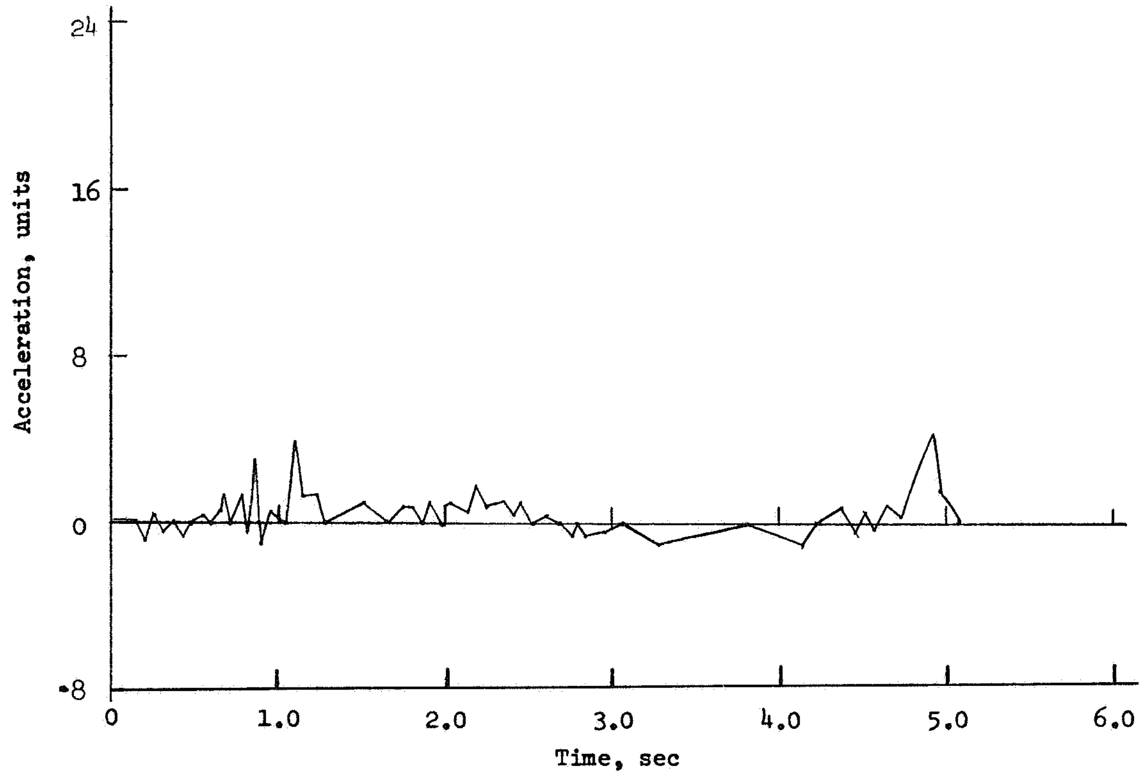


(b) Normal acceleration.

Figure 21.- Typical acceleration curves for ditching in calm water. Landing attitude, 12°; flaps, 40°; nose gear, extended; main gear, extended; landing speed, 64.8 m/sec (126 knots). All values are full scale.

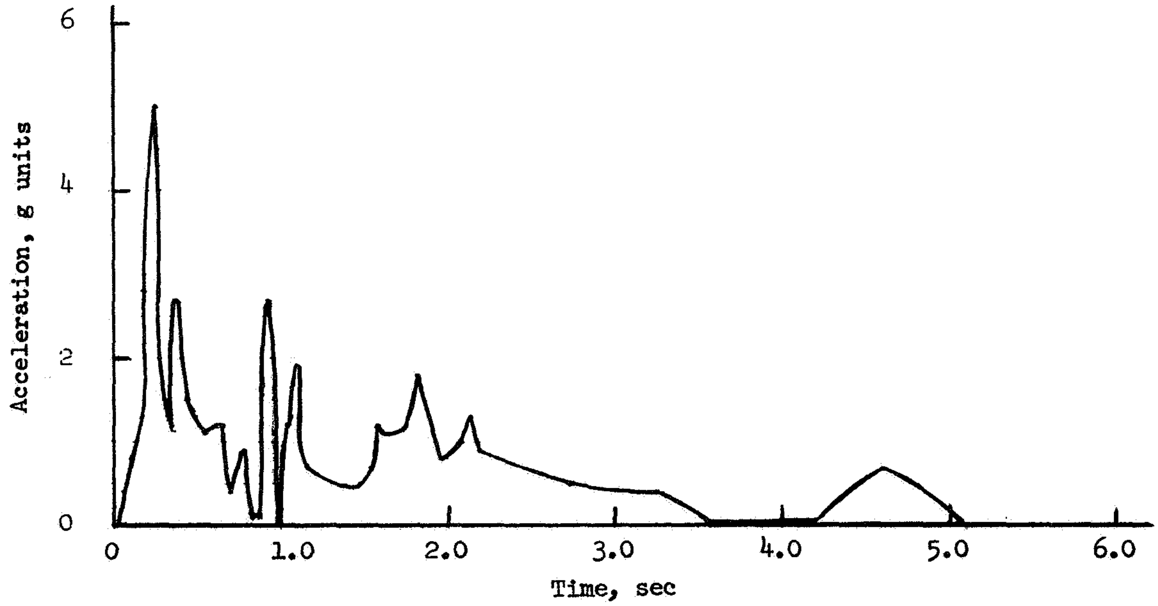


(a) Longitudinal acceleration.

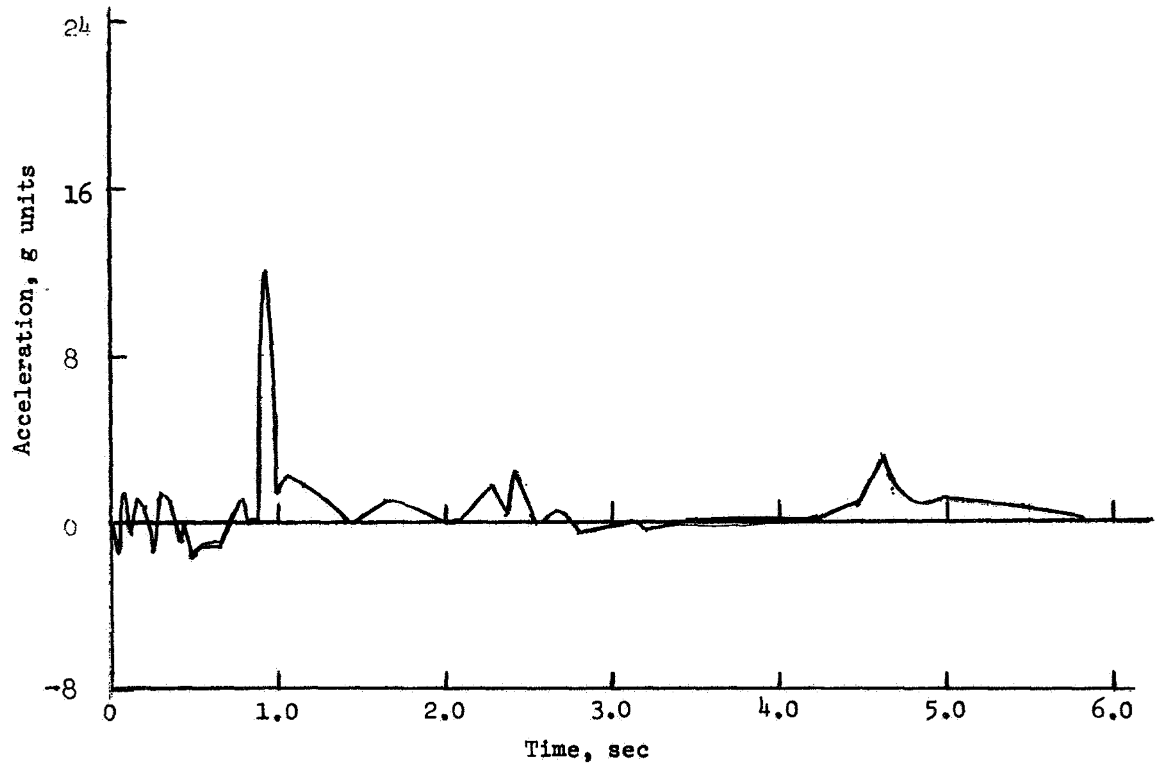


(b) Normal acceleration.

Figure 22.- Typical acceleration curves for ditching in calm water. Landing attitude, 7°; flaps, 40°; nose gear, extended; main gear, extended; landing speed, 70.5 m/sec (137 knots). All values are full scale.

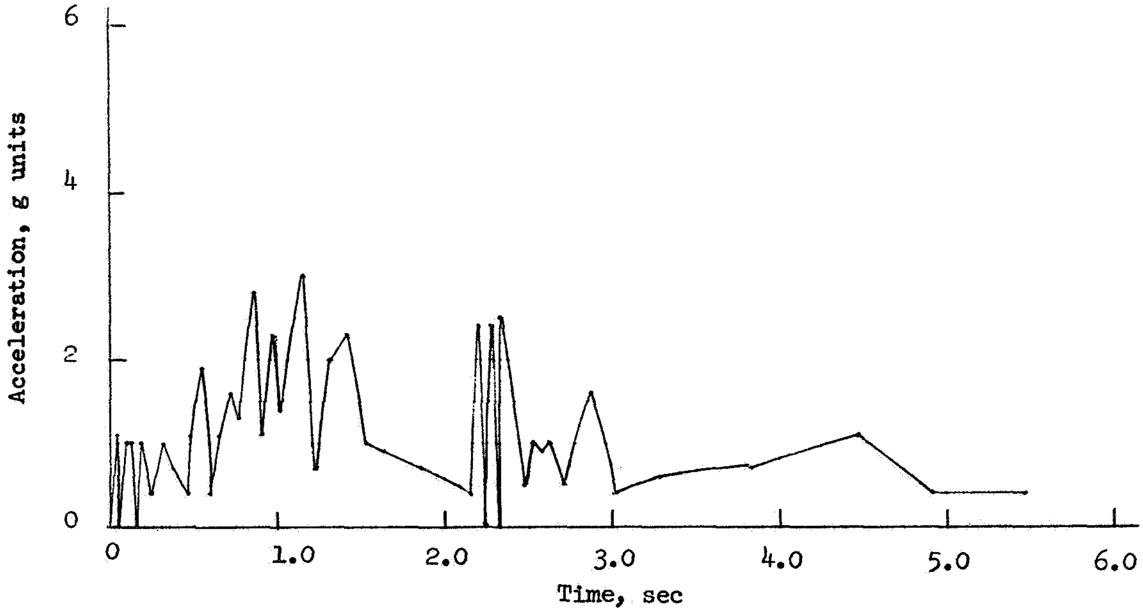


(a) Longitudinal acceleration.

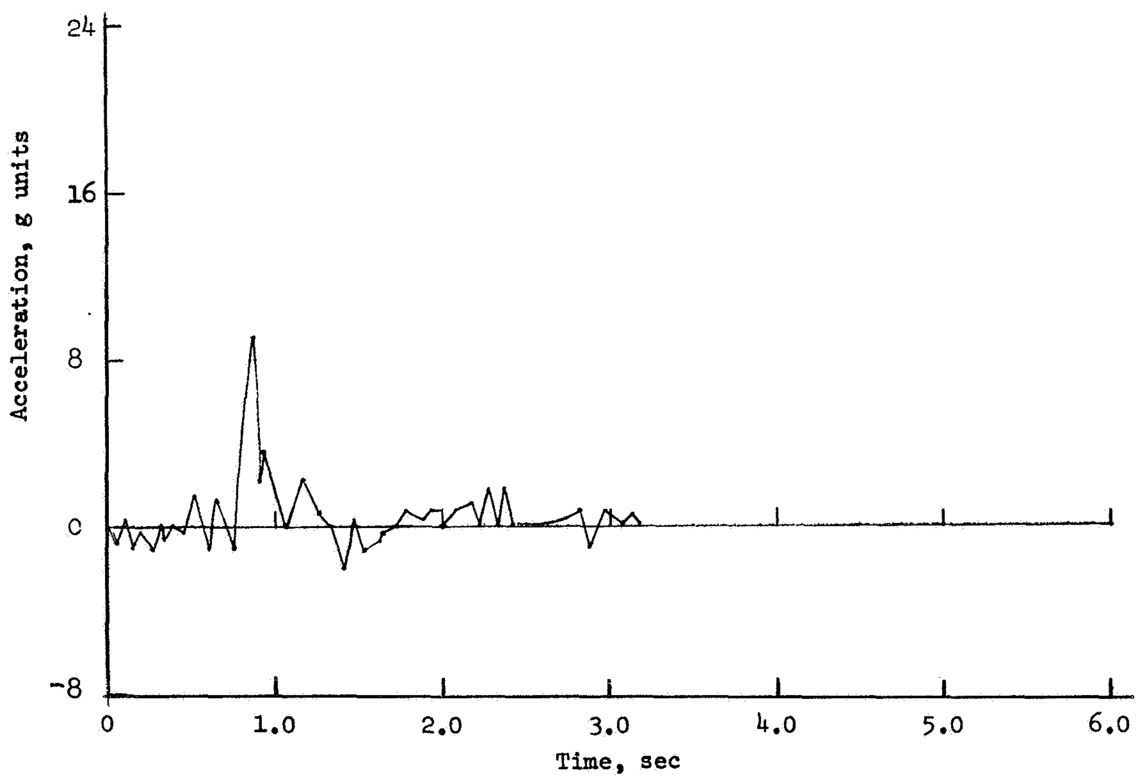


(b) Normal acceleration.

Figure 23.- Typical acceleration curves for ditching in calm water. Landing attitude, 12°; flaps, 40°; nose gear, retracted; main gear, extended; landing speed, 64.8 m/sec (126 knots). All values are full scale.

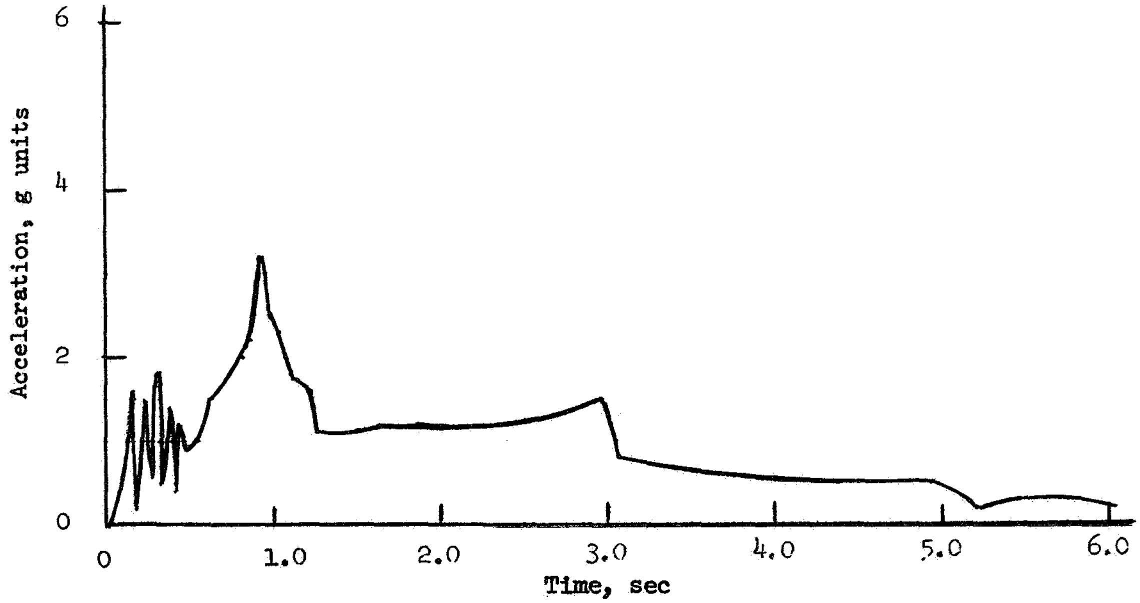


(a) Longitudinal acceleration.

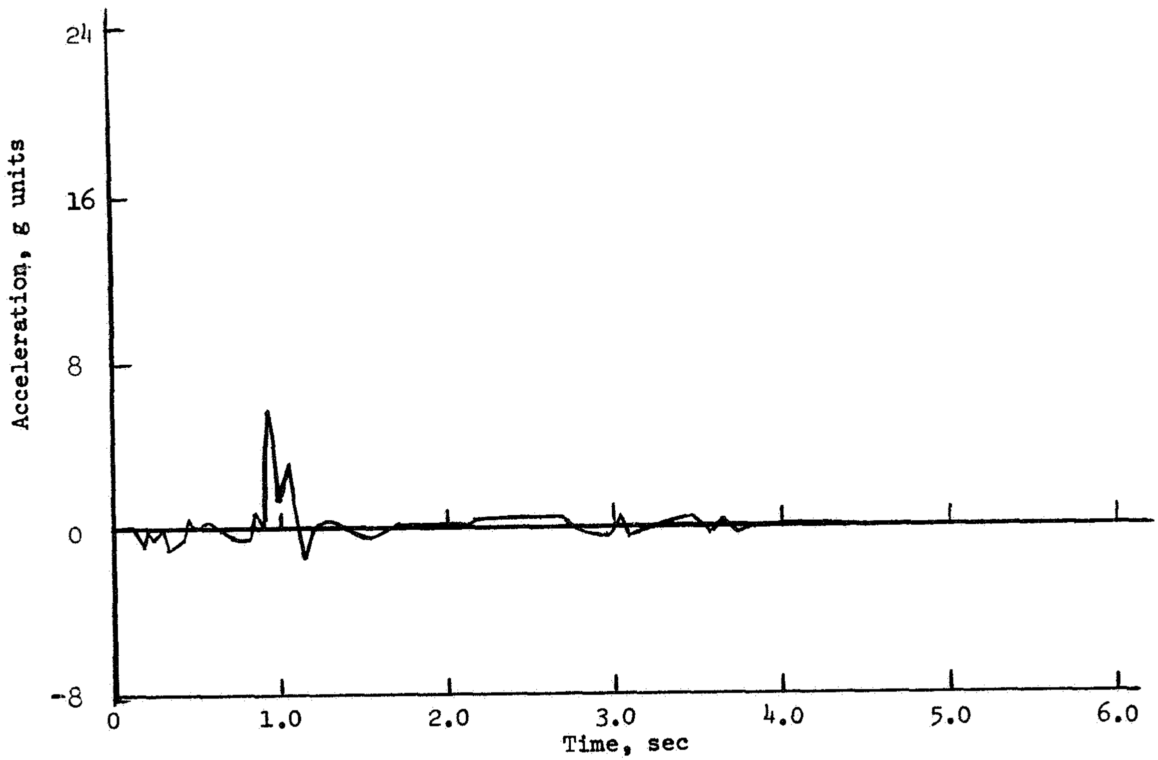


(b) Normal acceleration.

Figure 24.- Typical acceleration curves for ditching in calm water. Landing attitude, $9\frac{1}{2}^{\circ}$; flaps, 40°; nose gear, retracted; main gear, extended; landing speed, 67.9 m/sec (132 knots). All values are full scale.

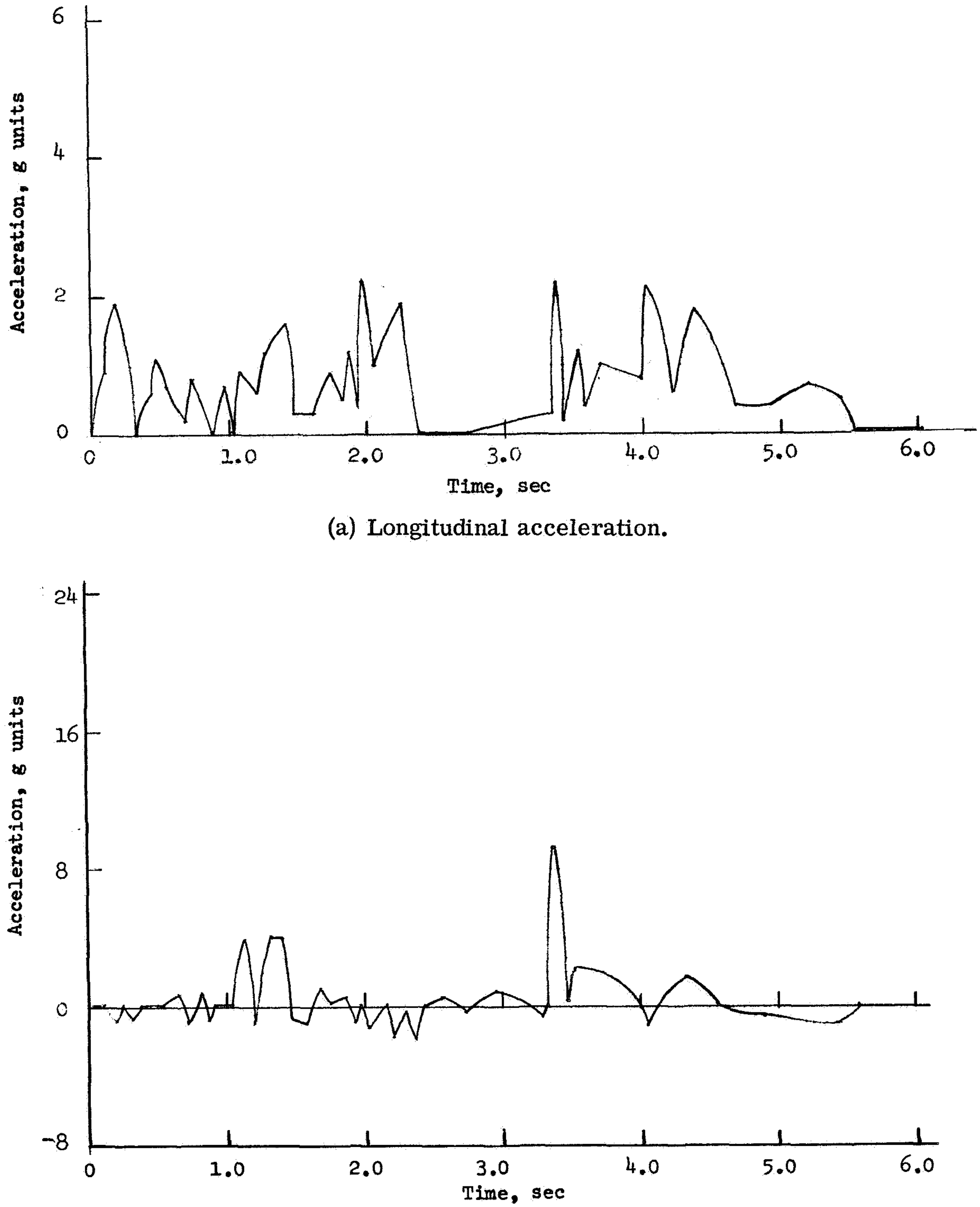


(a) Longitudinal acceleration.



(b) Normal acceleration.

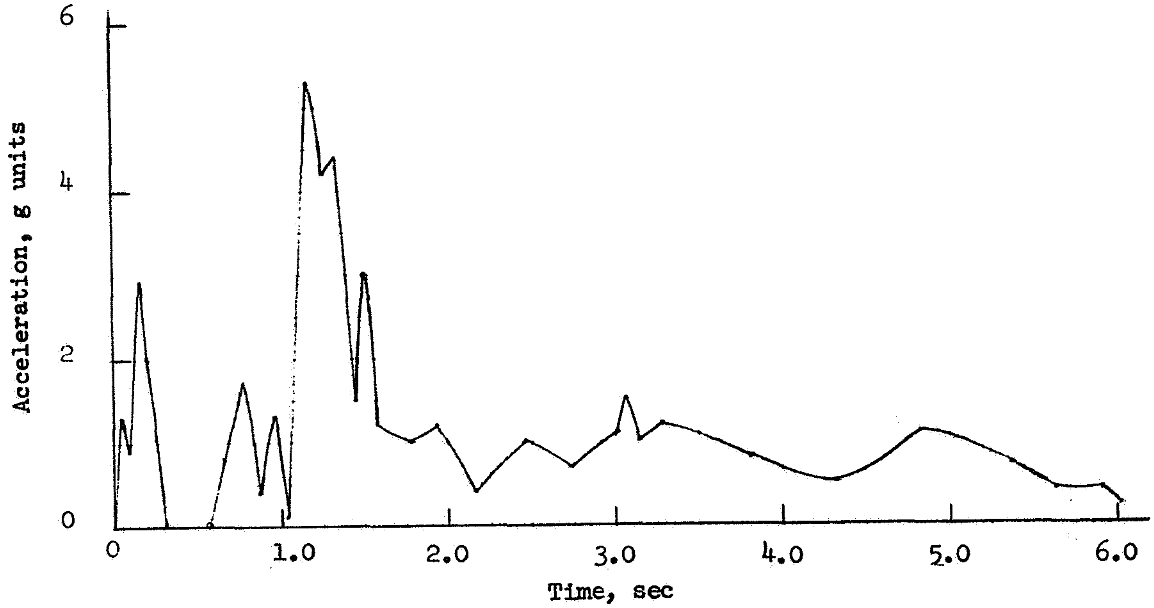
Figure 25.- Typical acceleration curves for ditching in calm water. Landing attitude, 7°; flaps, 40°; nose gear, retracted; main gear, extended; landing speed, 70.5 m/sec (137 knots). All values are full scale.



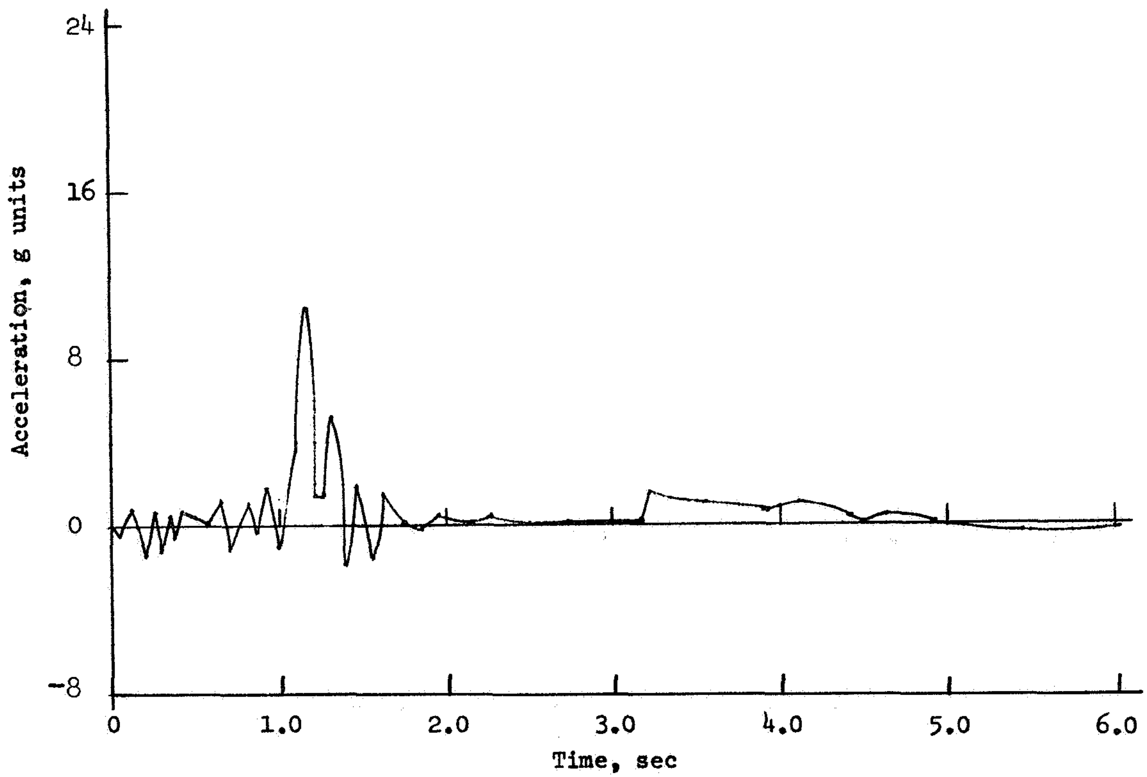
(a) Longitudinal acceleration.

(b) Normal acceleration.

Figure 26.- Typical acceleration curves for ditching in calm water. Landing attitude, 4°; flaps, 40°; nose gear, retracted; main gear, extended; landing speed, 78.7 m/sec (153 knots). All values are full scale.

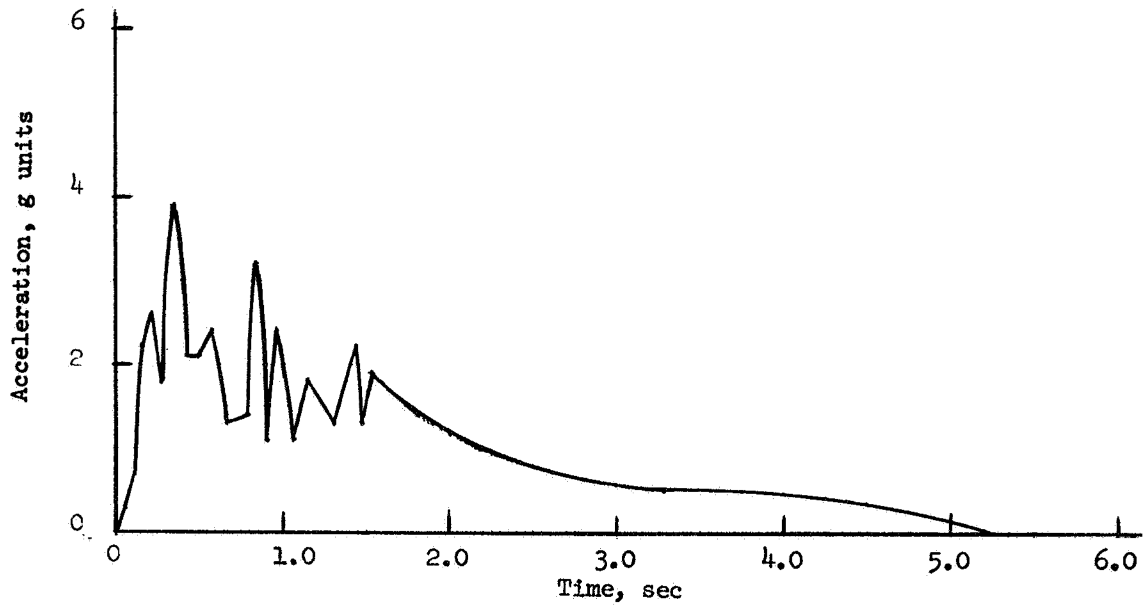


(a) Longitudinal acceleration.

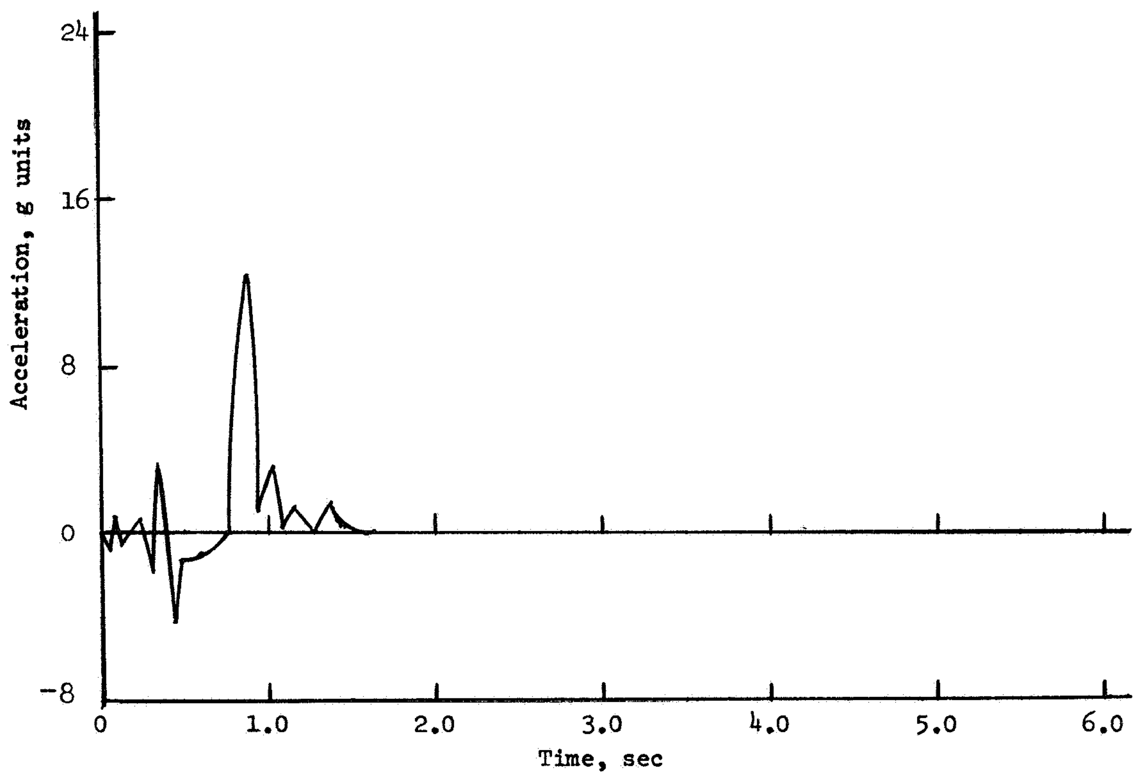


(b) Normal acceleration.

Figure 27.- Typical acceleration curves for ditching in calm water. Landing attitude, 7°; flaps, 0°; nose gear, retracted; main gear, extended; landing speed, 90.5 m/sec (176 knots). All values are full scale.

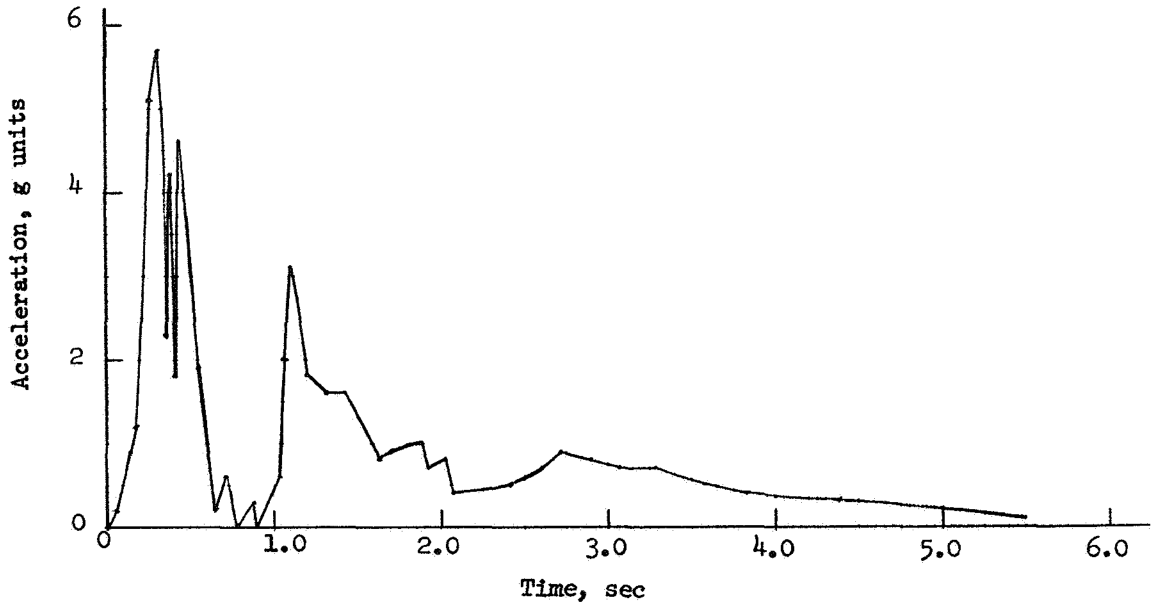


(a) Longitudinal acceleration.

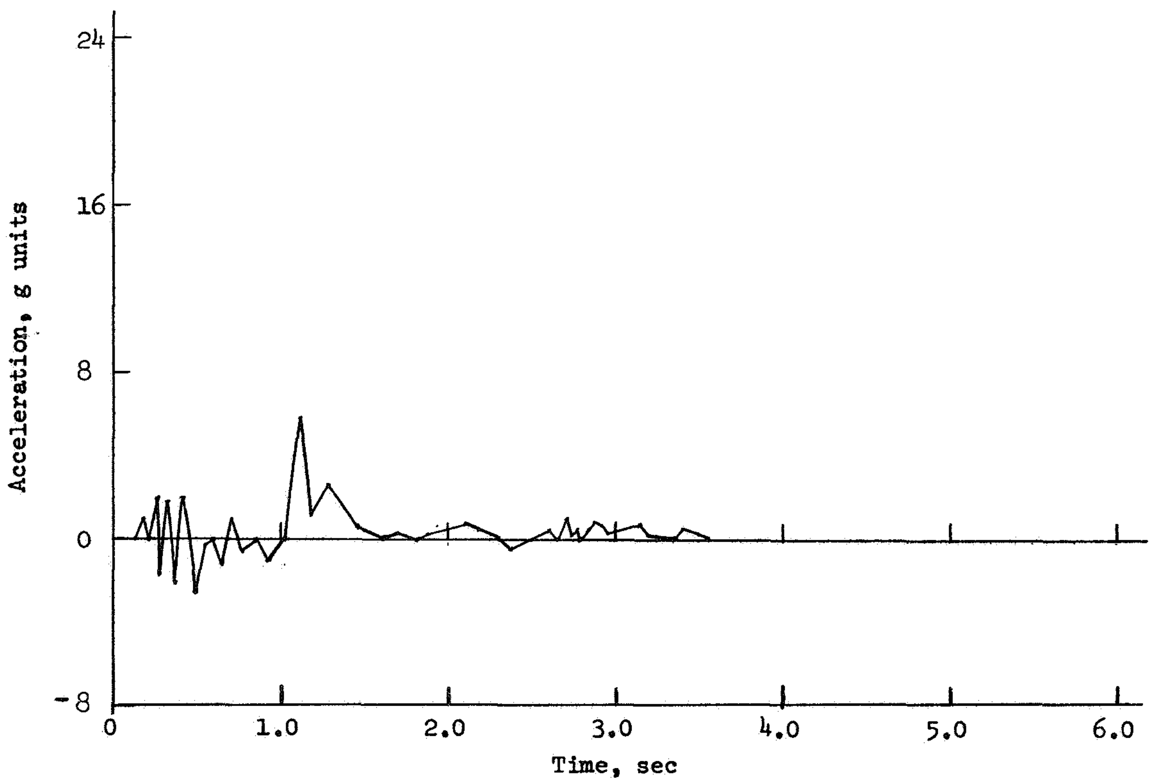


(b) Normal acceleration.

Figure 28.- Typical acceleration curves for ditching in calm water. Landing attitude, 12°; flaps, 40°; nose gear, retracted; main gear, kneeling; landing speed, 64.8 m/sec (126 knots). All values are full scale.

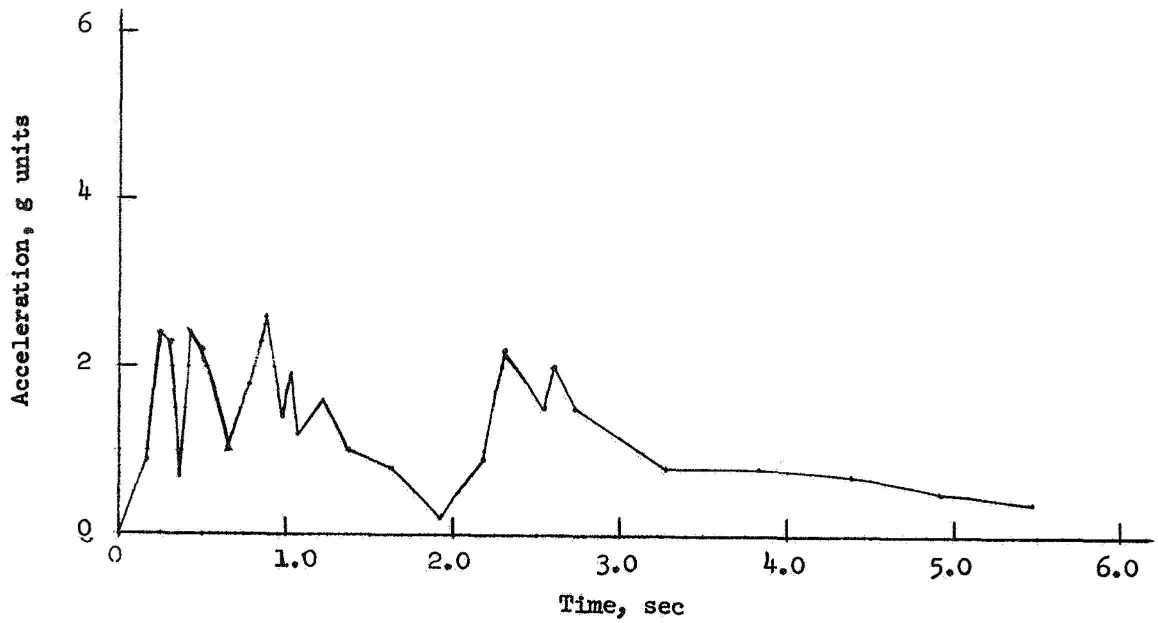


(a) Longitudinal acceleration.

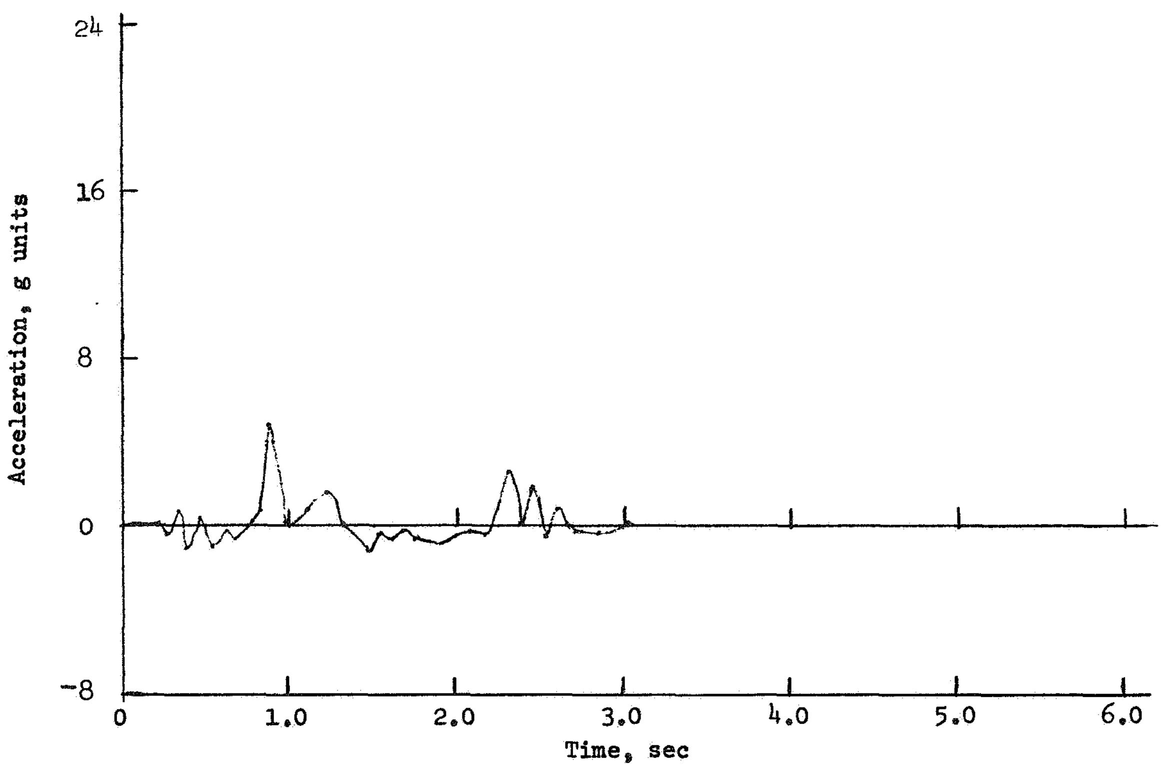


(b) Normal acceleration.

Figure 29.- Typical acceleration curves for ditching in calm water. Landing attitude, $9\frac{1}{2}^{\circ}$; flaps, 40°; nose gear, retracted; main gear, kneeling; landing speed, 67.9 m/sec (132 knots). All values are full scale.

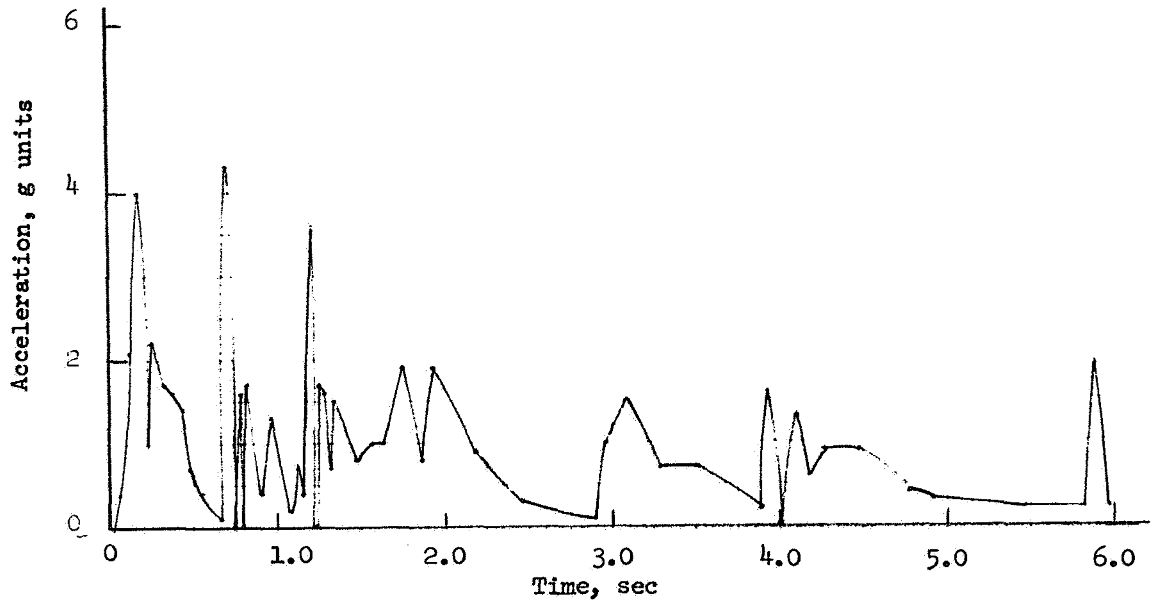


(a) Longitudinal acceleration.

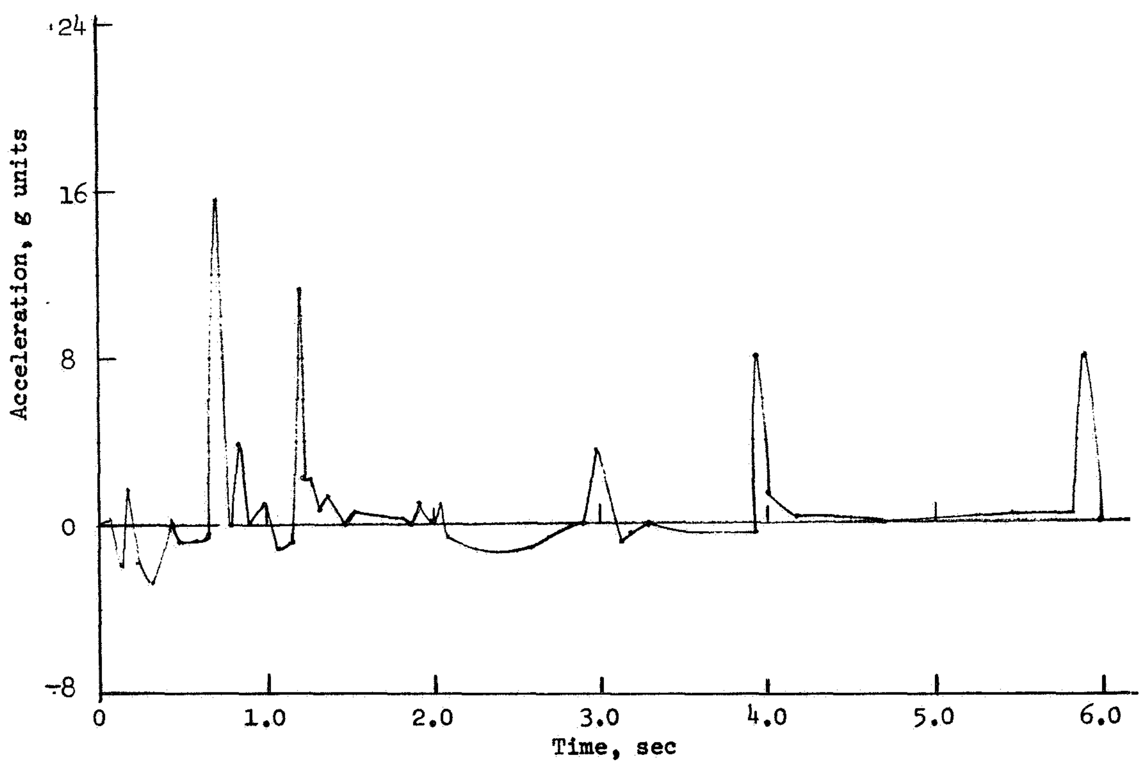


(b) Normal acceleration.

Figure 30.- Typical acceleration curves for ditching in calm water. Landing attitude, 7°; flaps, 40°; nose gear, retracted; main gear, kneeling; landing speed, 70.5 m/sec (137 knots). All values are full scale.

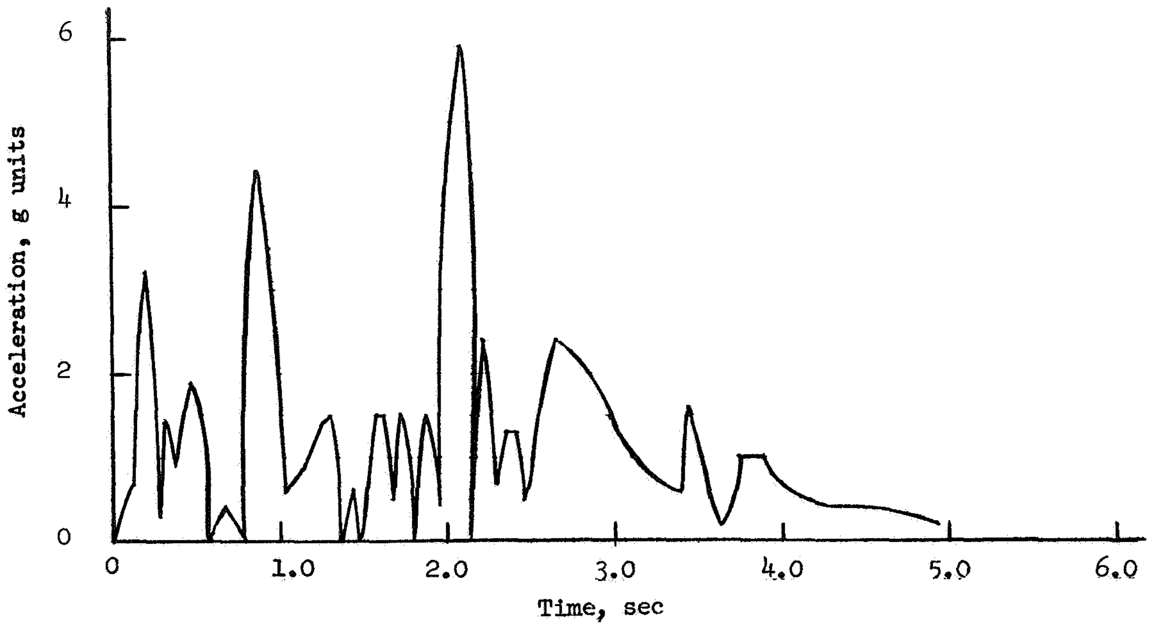


(a) Longitudinal acceleration.

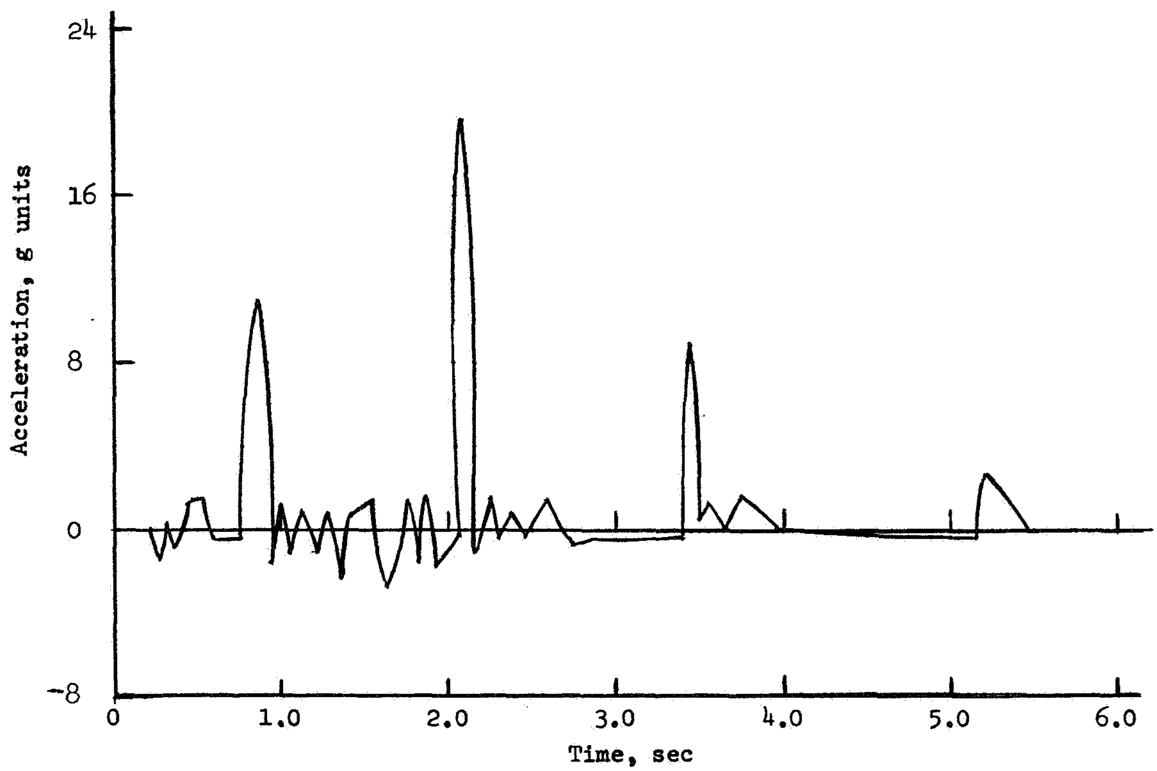


(b) Normal acceleration.

Figure 31.- Typical acceleration curves for ditching in rough water. Landing attitude, 12°; flaps, 40°; nose gear, retracted; main gear, extended; landing speed, 64.8 m/sec (126 knots). All values are full scale.

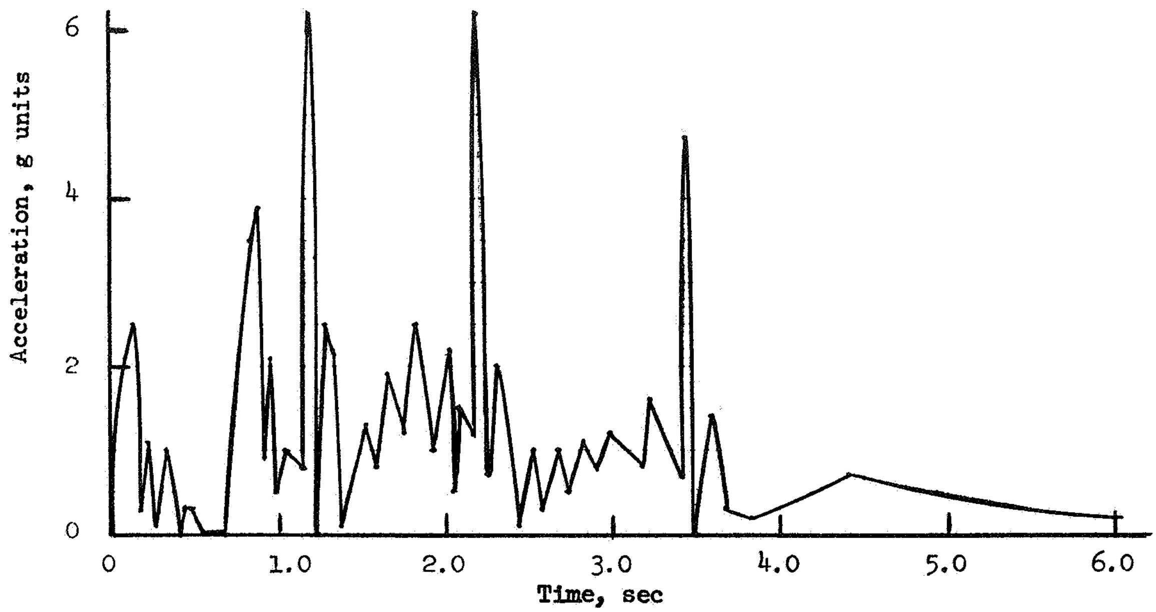


(a) Longitudinal acceleration.

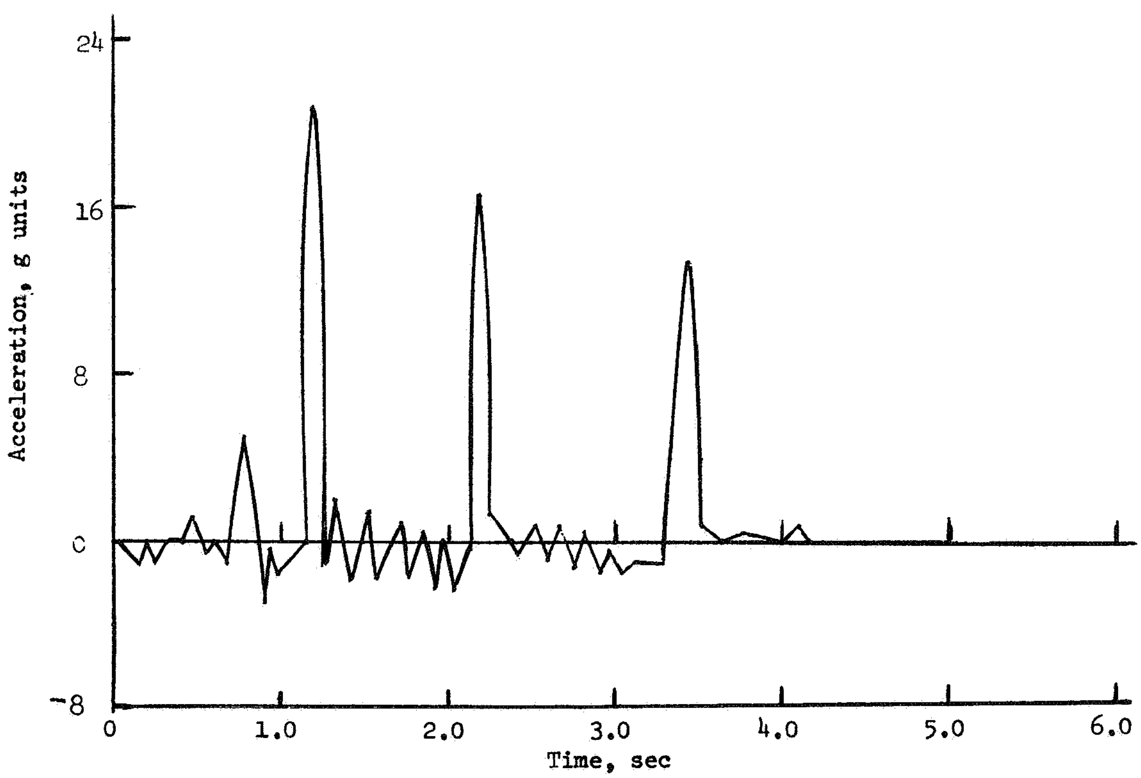


(b) Normal acceleration.

Figure 32.- Typical acceleration curves for ditching in rough water. Landing attitude, $9\frac{1}{2}^{\circ}$; flaps, 40°; nose gear, retracted; main gear, extended; landing speed, 67.9 m/sec (132 knots). All values are full scale.

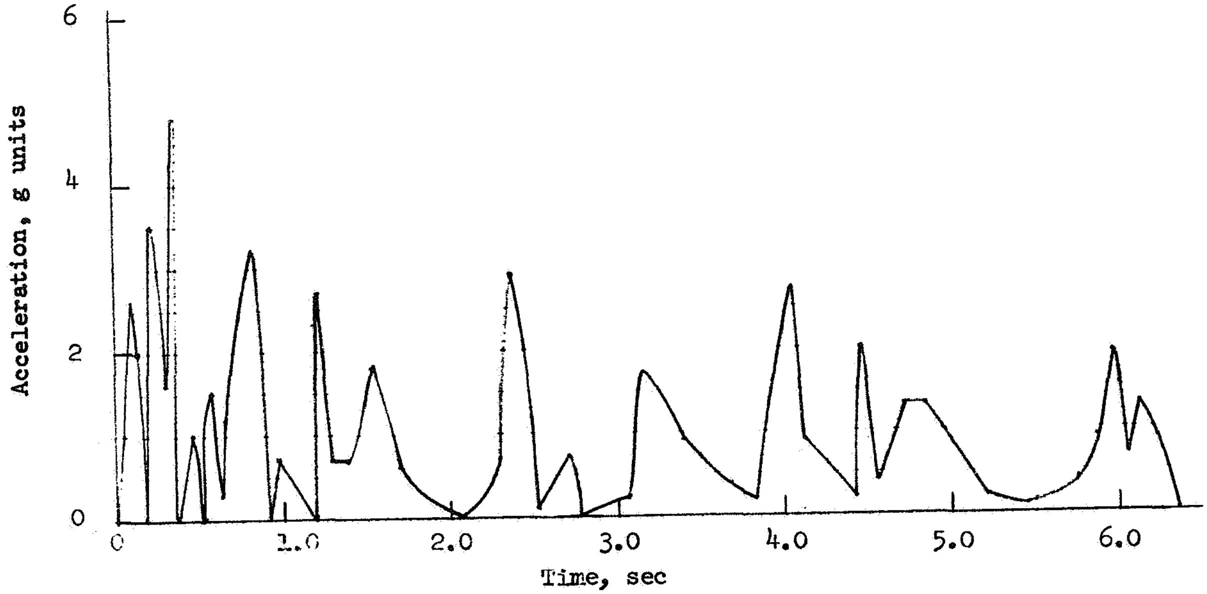


(a) Longitudinal acceleration.

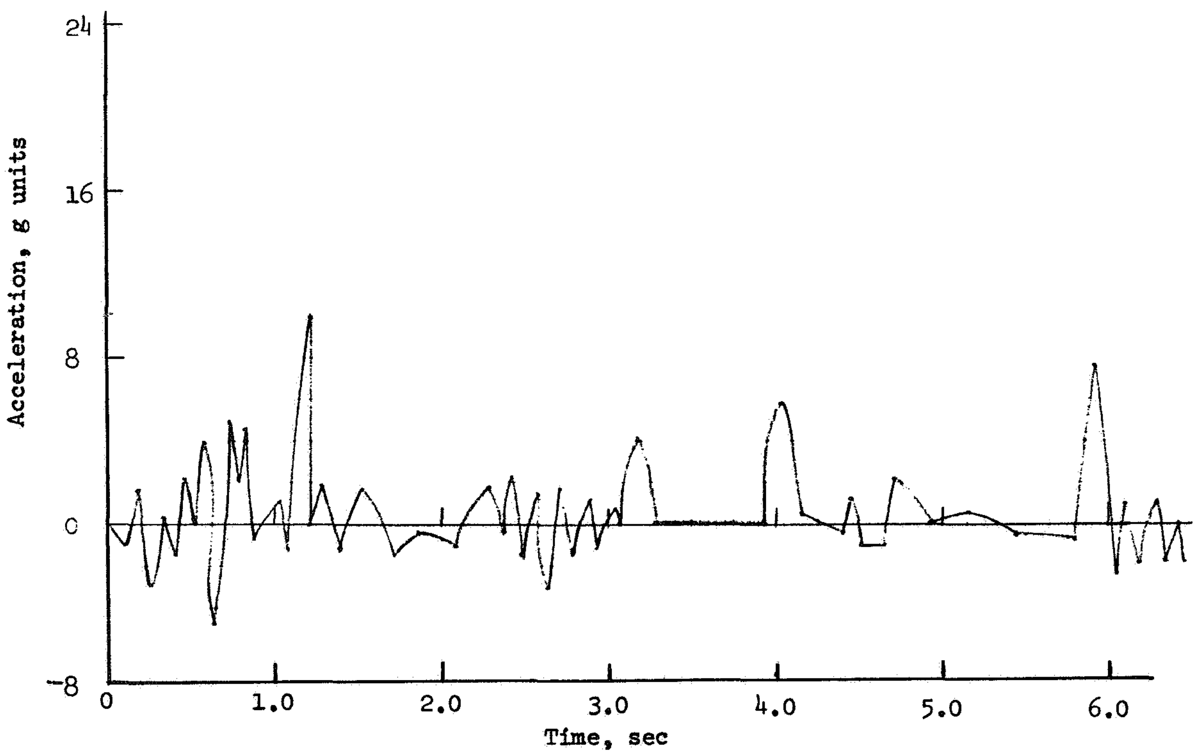


(b) Normal acceleration.

Figure 33.- Typical acceleration curves for ditching in rough water. Landing attitude, 7°; flaps, 40°; nose gear, retracted; main gear, extended; landing speed, 70.5 m/sec (137 knots). All values are full scale.

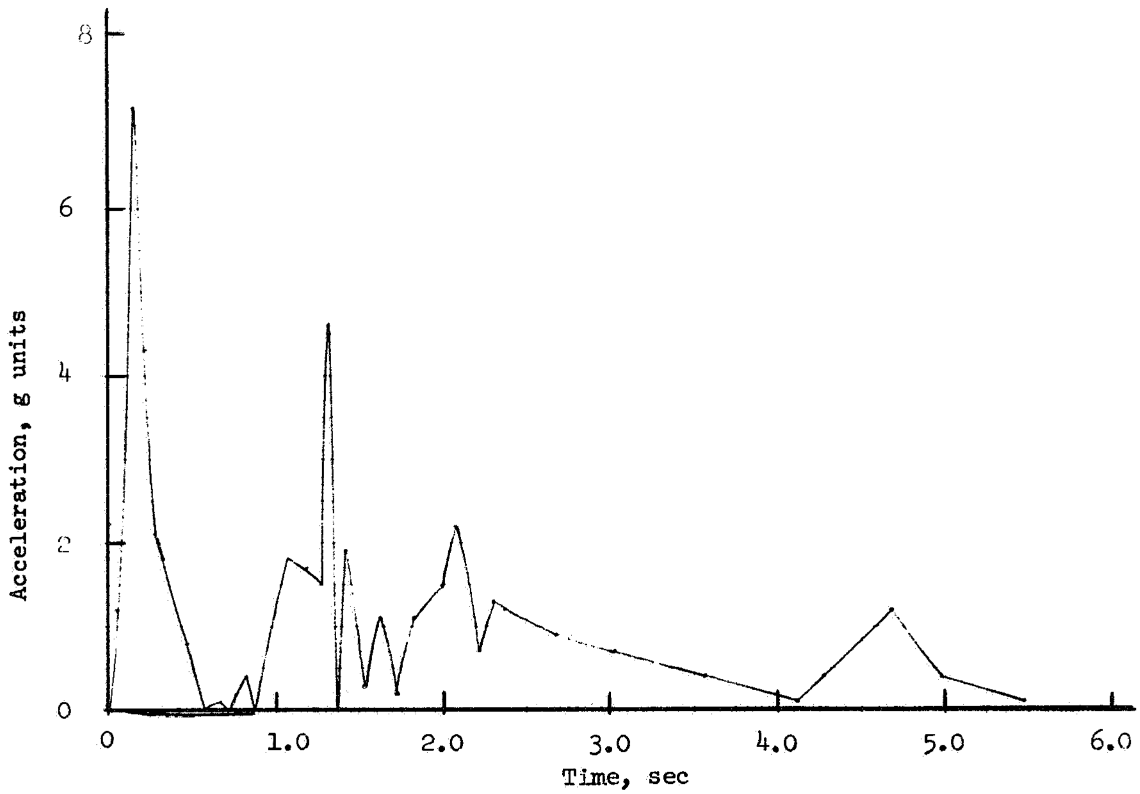


(a) Longitudinal acceleration.



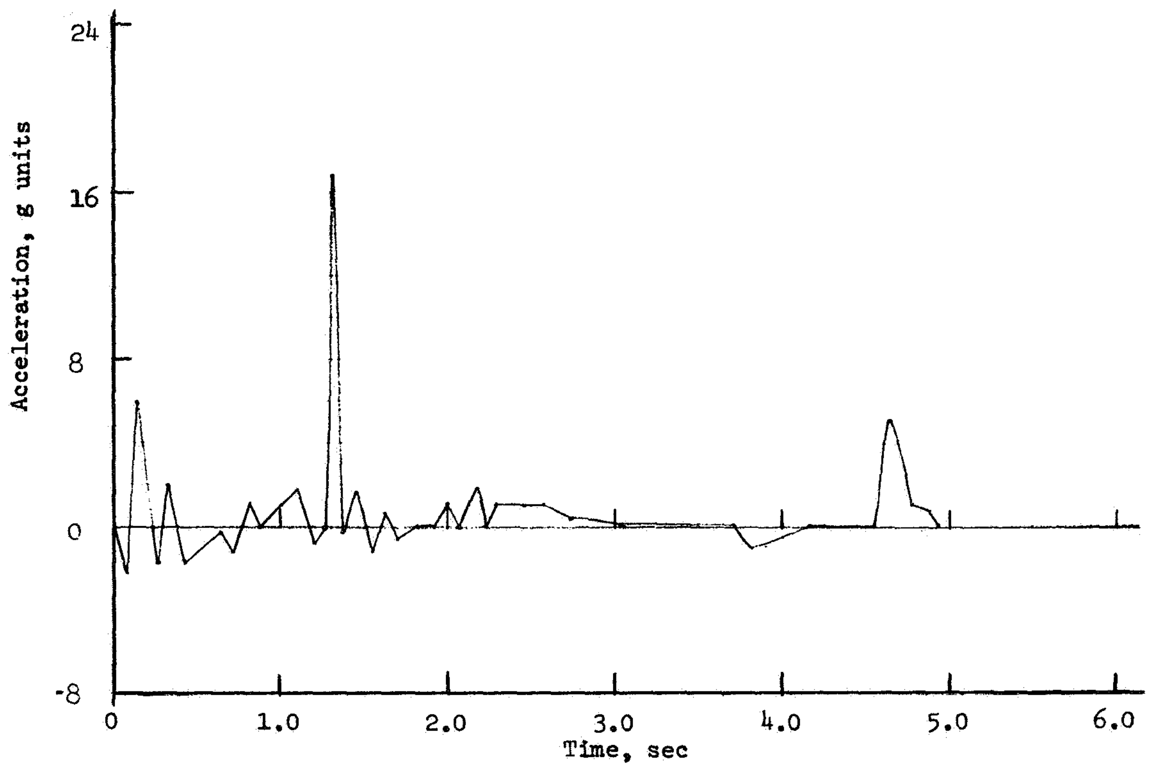
(b) Normal acceleration.

Figure 34.- Typical acceleration curves for ditching in rough water. Landing attitude, 4°; flaps, 40°; nose gear, retracted; main gear, extended; landing speed, 78.7 m/sec (153 knots). All values are full scale.



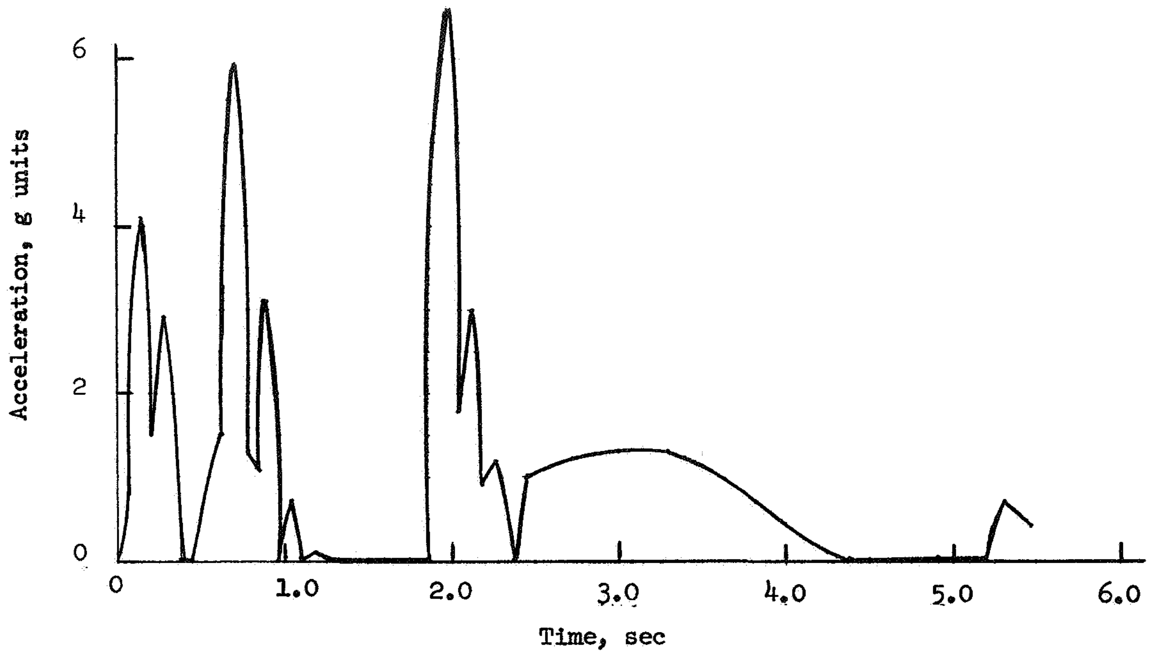
(a) Longitudinal acceleration.

Figure 35.- Typical acceleration curves for ditching in rough water. Landing attitude, 12°; flaps, 40°; nose gear, retracted; main gear, kneeling; landing speed, 64.8 m/sec (126 knots). All values are full scale.

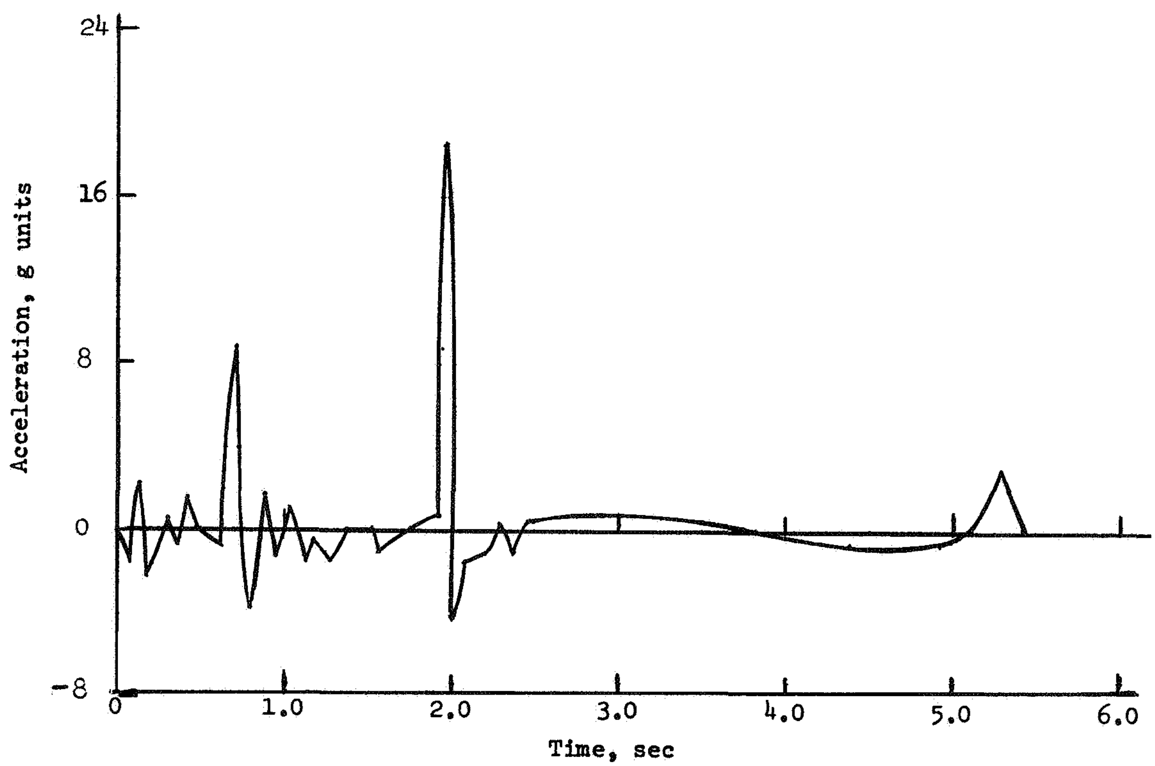


(b) Normal acceleration.

Figure 35.- Concluded.

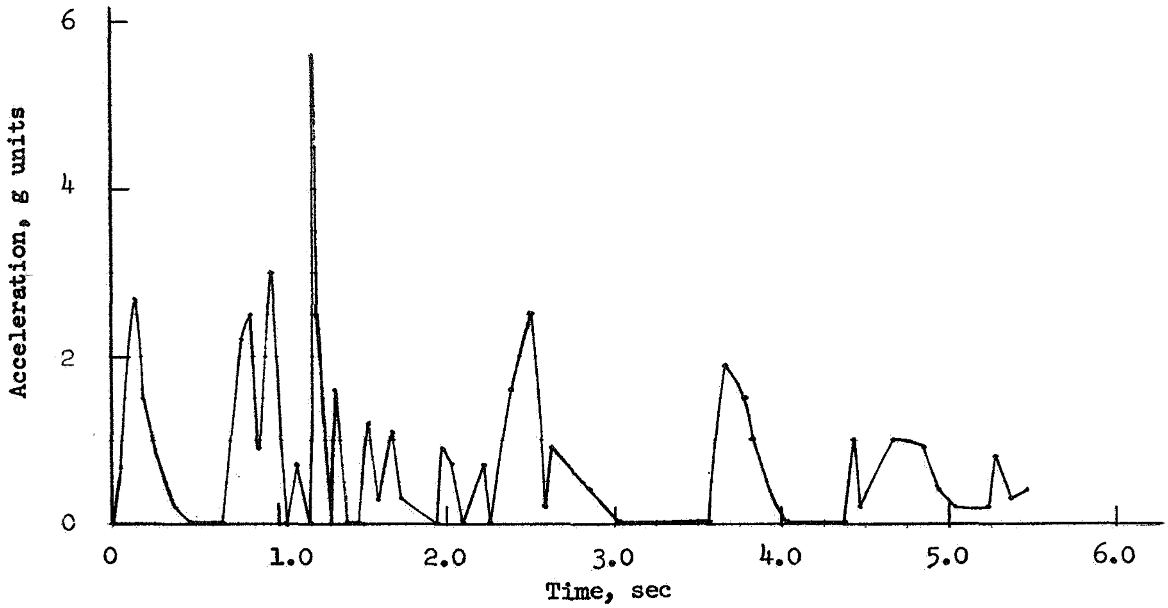


(a) Longitudinal acceleration.

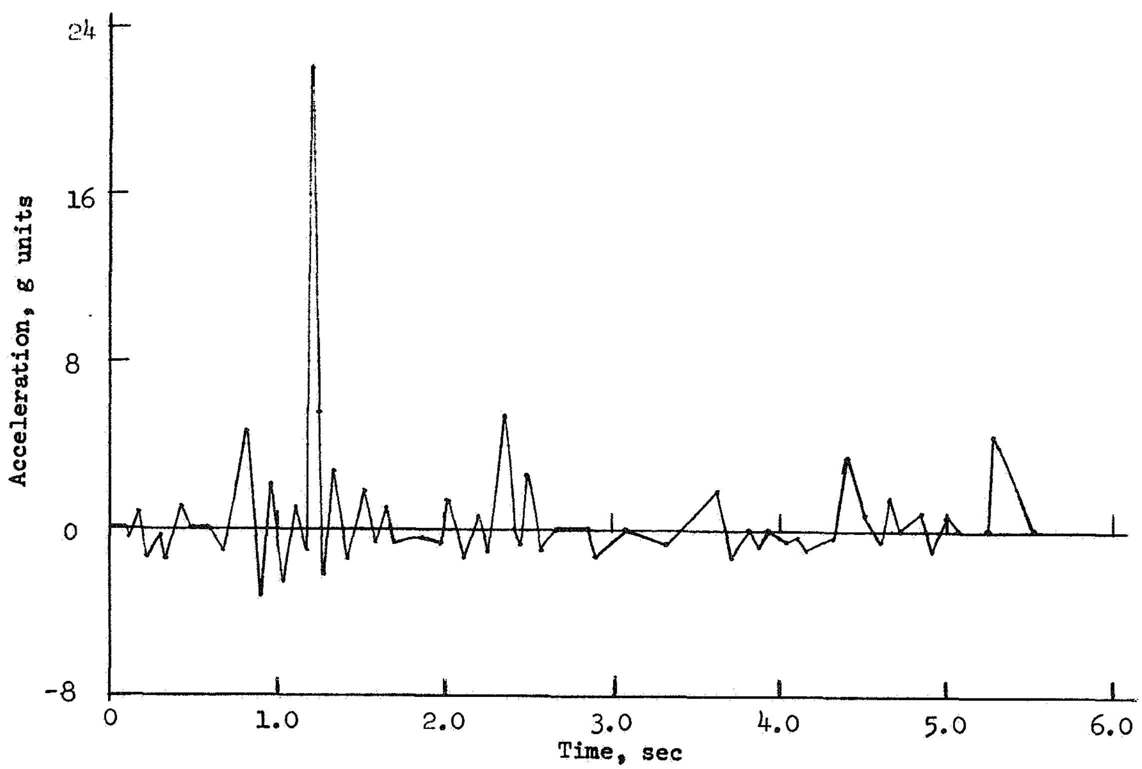


(b) Normal acceleration.

Figure 36.- Typical acceleration curves for ditching in rough water. Landing attitude, $9\frac{1}{2}^{\circ}$; flaps, 40°; nose gear, retracted; main gear, kneeling; landing speed, 67.9 m/sec (132 knots). All values are full scale.

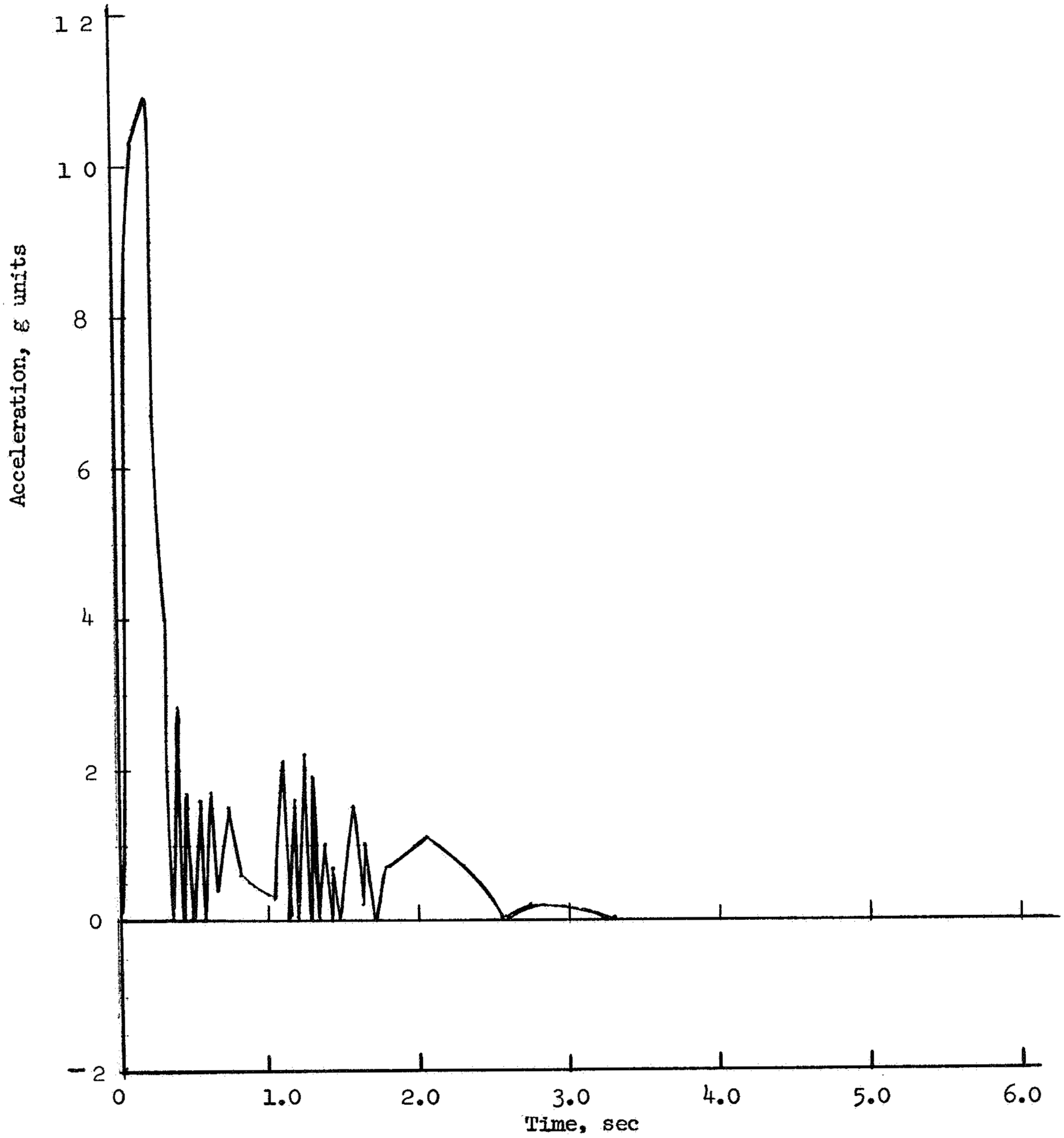


(a) Longitudinal acceleration.



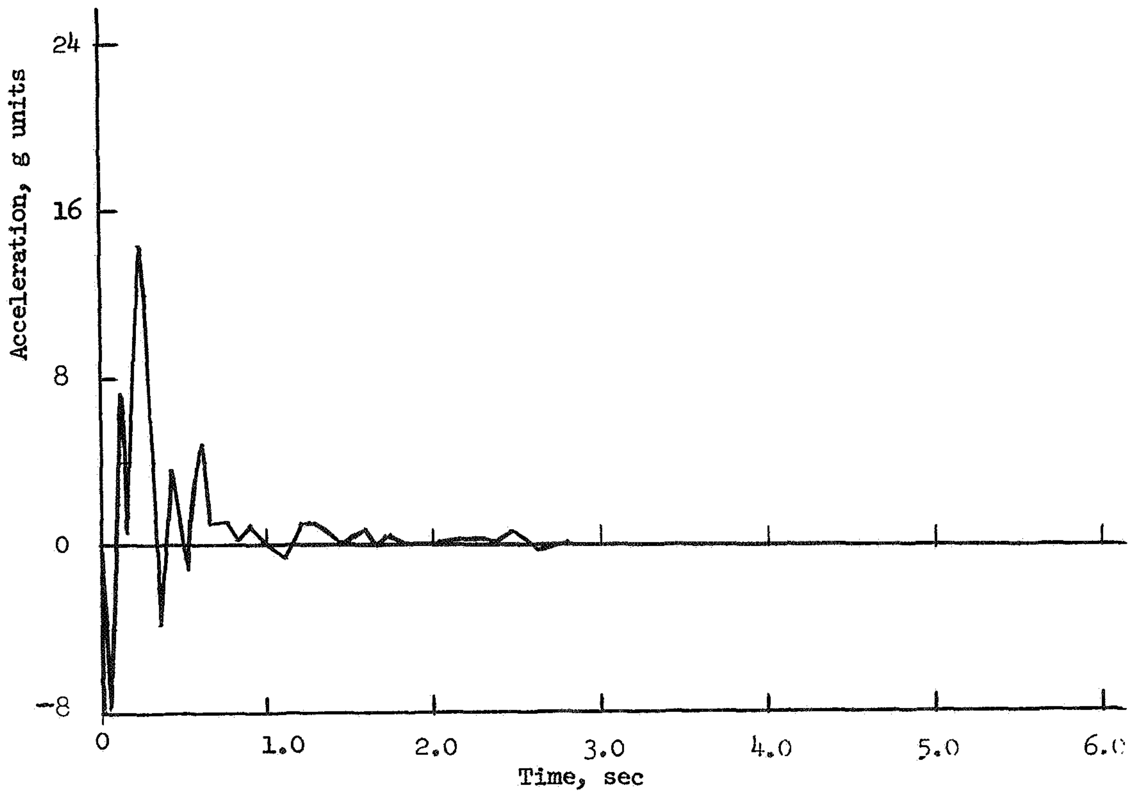
(b) Normal acceleration.

Figure 37.- Typical acceleration curves for ditching in rough water. Landing attitude, 7°; flaps, 40°; nose gear, retracted; main gear, kneeling; landing speed, 70.5 m/sec (137 knots). All values are full scale.



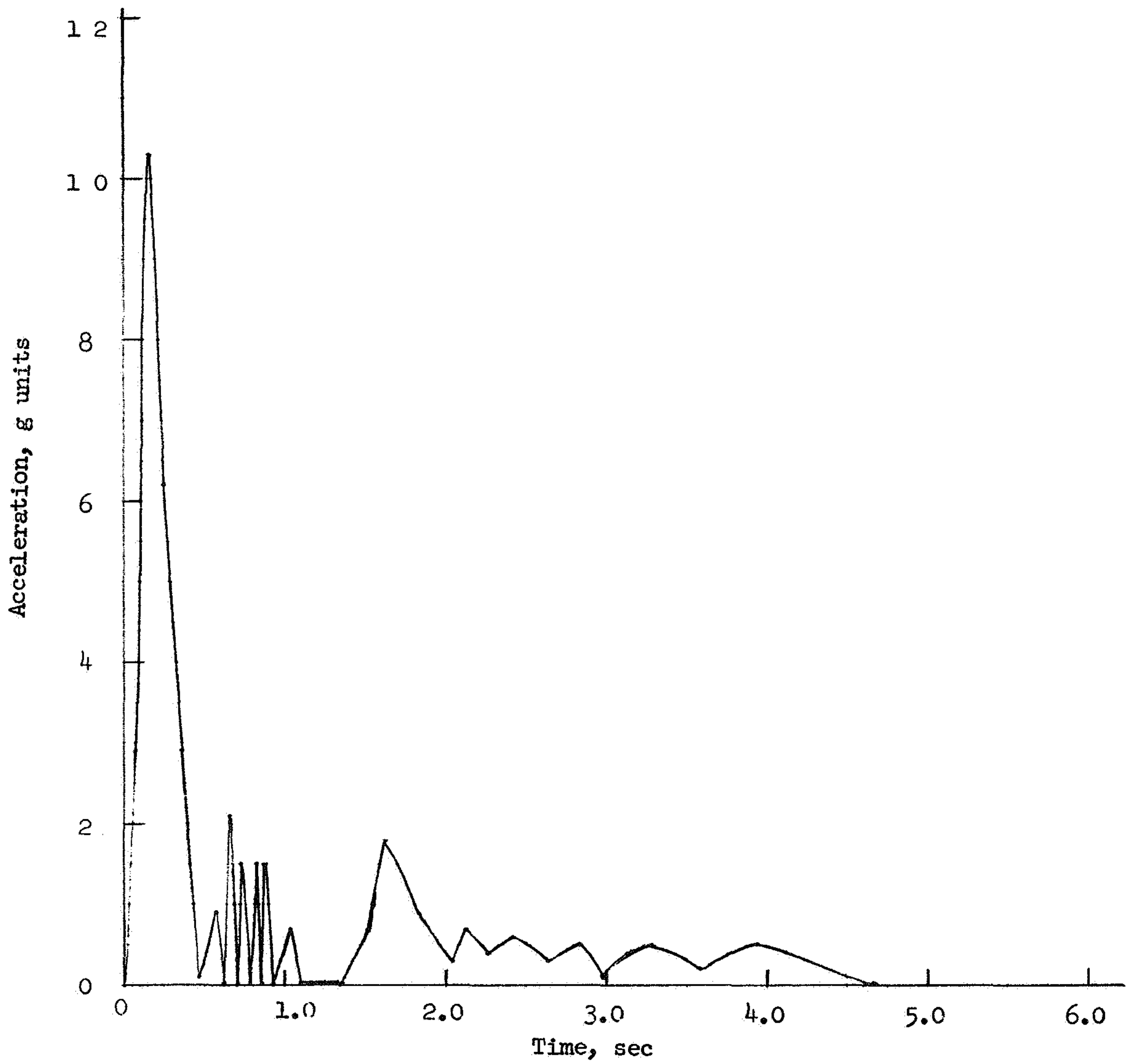
(a) Longitudinal acceleration.

Figure 38.- Typical acceleration curves for ditching in calm water. Landing attitude, 7°; flaps, 40°; nose gear, retracted; main gear, kneeling; sink speed, 2.7 m/sec (9 ft/sec); landing speed, 70.5 m/sec (137 knots). All values are full scale.



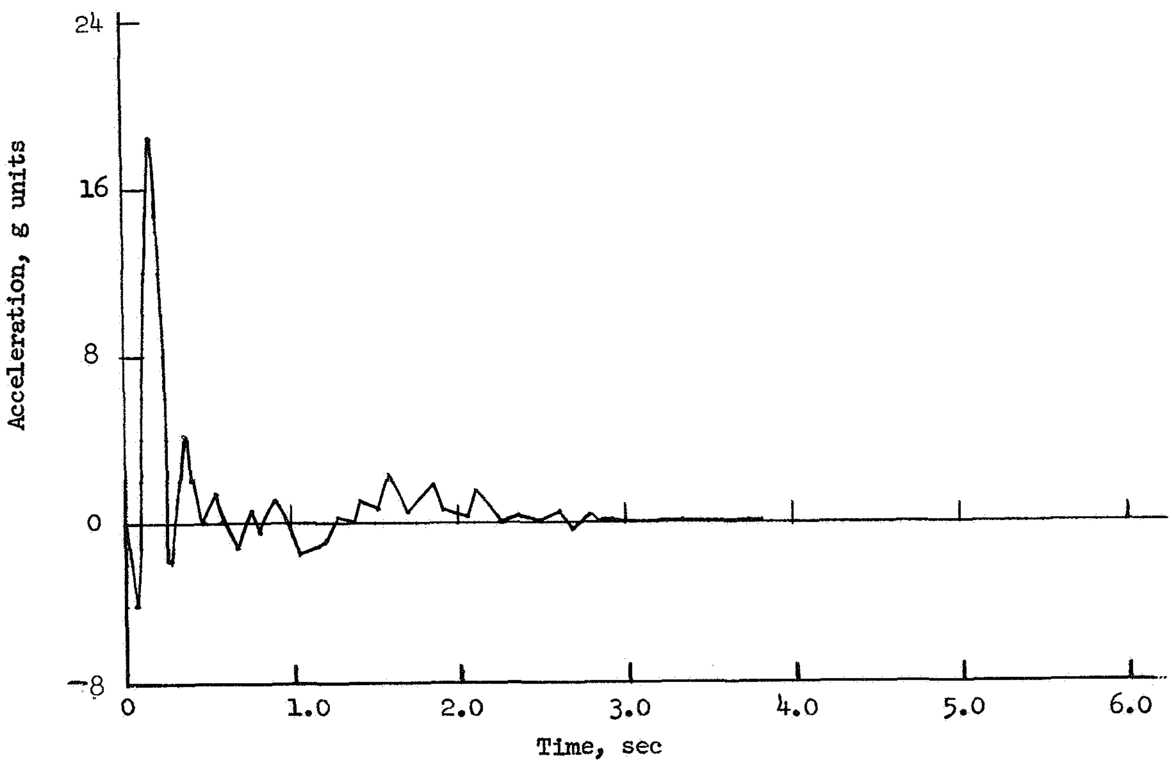
(b) Normal acceleration.

Figure 38.- Concluded.



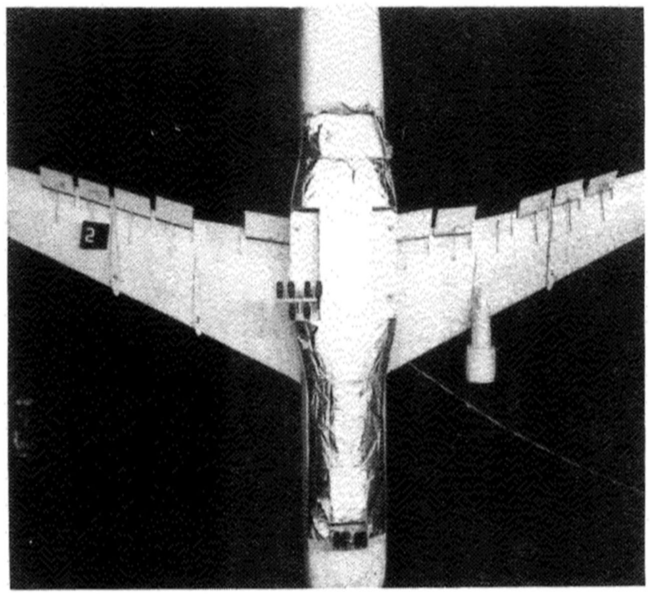
(a) Longitudinal acceleration.

Figure 39.- Typical acceleration curves for ditching in calm water. Landing attitude, 4°; flaps, 40°; nose gear, retracted; main gear, kneeling; sink speed, 2.7 m/sec (9 ft/sec); landing speed, 78.7 m/sec (153 knots). All values are full scale.

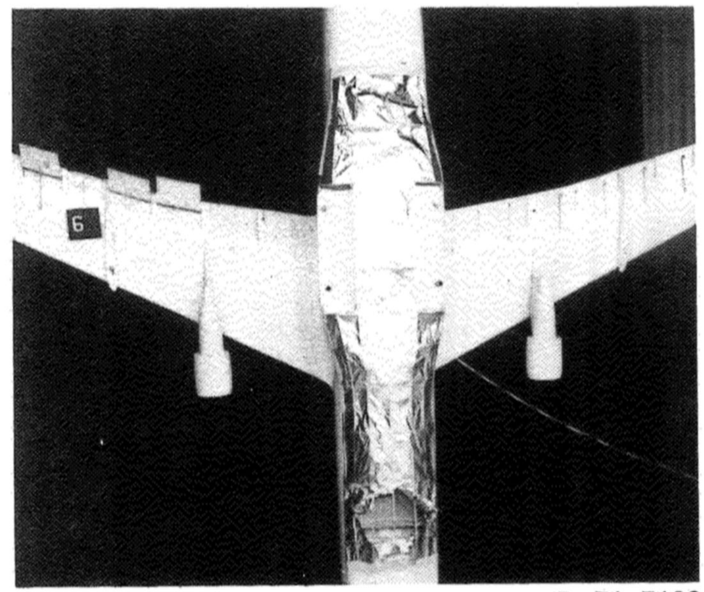


(b) Normal acceleration.

Figure 39.- Concluded.



(a) Landing attitude, 12^{o}; flaps, 40^{o}; speed, 65 m/sec (126 knots).



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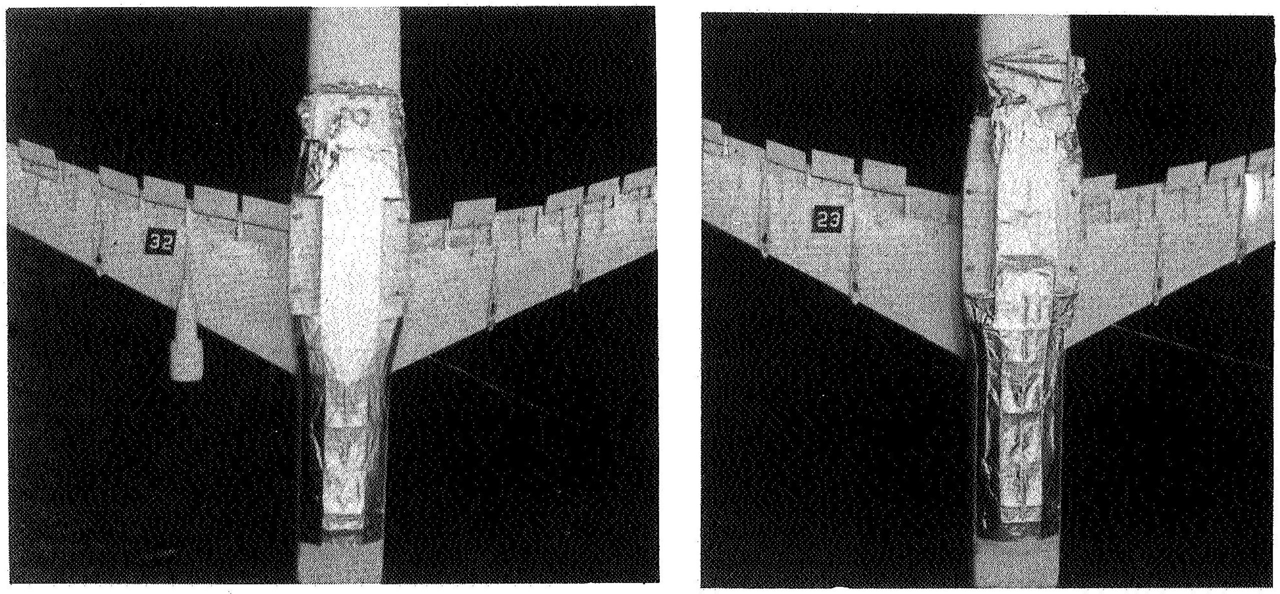
(b) Landing attitude, 7^{o}; flaps, 40^{o}; speed, 71 m/sec (137 knots).

Figure 40.- Photographs of typical damage for ditchings in calm water with all landing gear fully extended. All values are full scale.

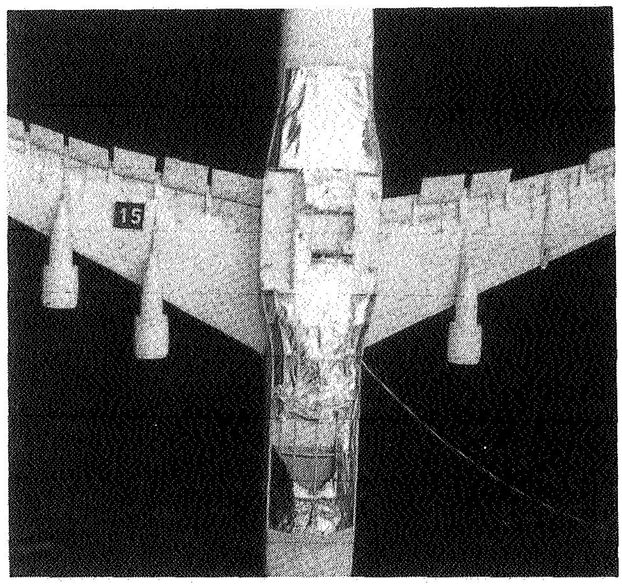


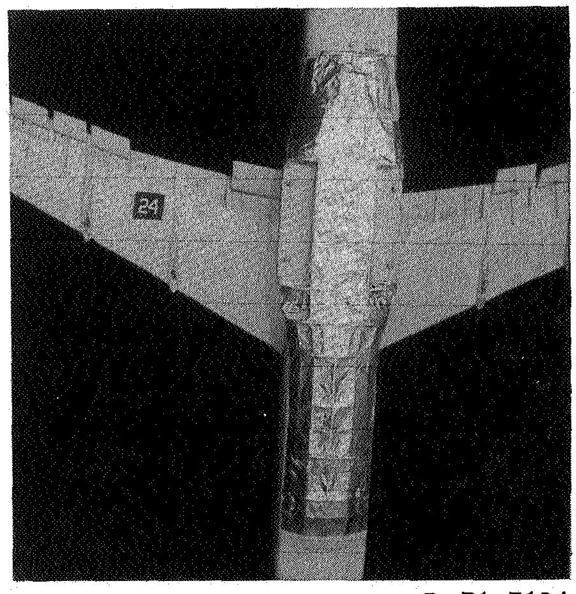
L-71-7133

(a) Landing attitude, 12°; speed, 65 m/sec (126 knots); water surface, calm.

(b) Landing attitude, 12°; speed, 65 m/sec (126 knots); water surface, rough.

Figure 41.- Photographs of typical damage for ditchings with nose gear retracted and main gear fully extended. All values are full scale.



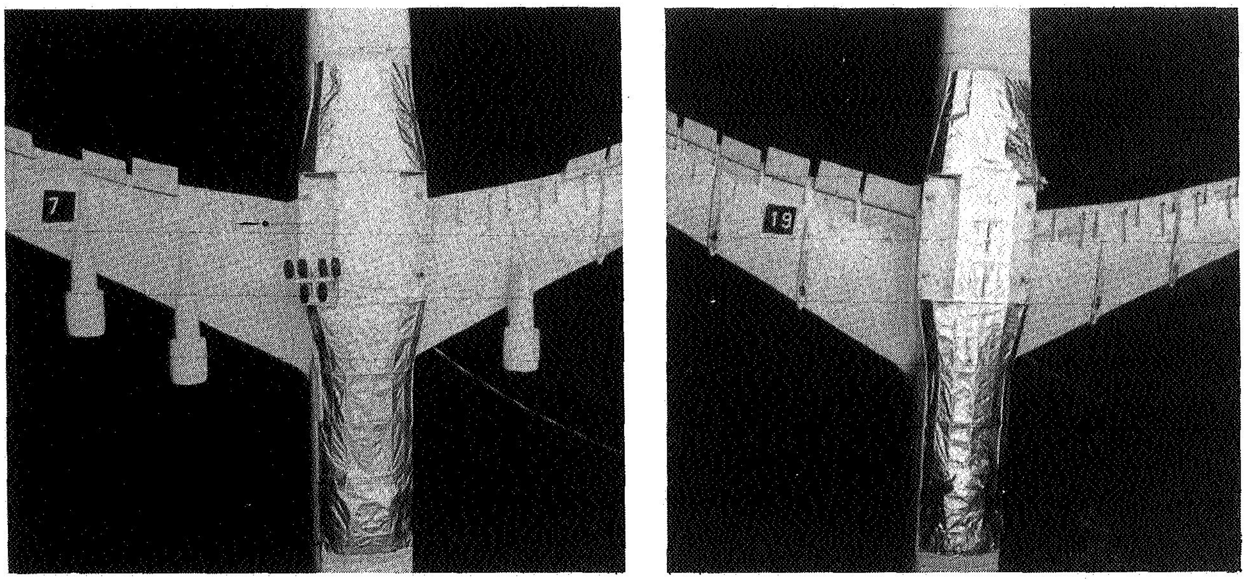


L-71-7134

(c) Landing attitude, $9\frac{1}{2}^{\circ}$; speed, 68 m/sec (132 knots); water surface, calm.

(d) Landing attitude, $9\frac{1}{2}^{\circ}$; speed, 68 m/sec (132 knots); water surface, rough.

Figure 41.- Continued.

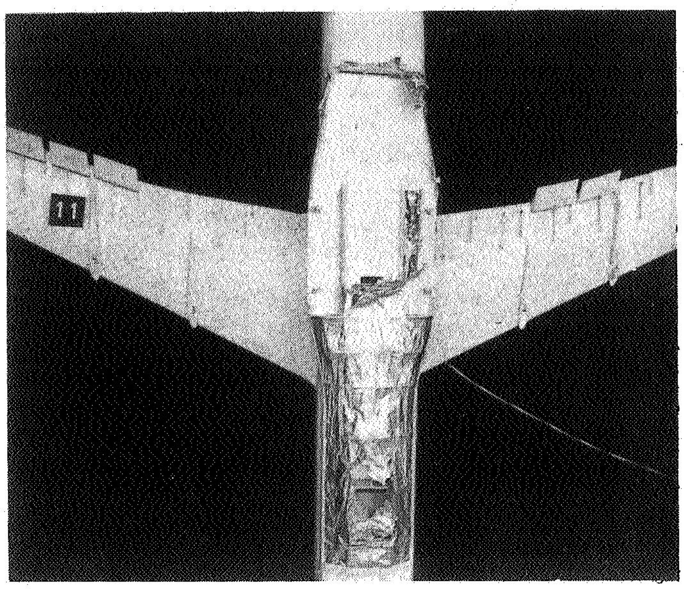


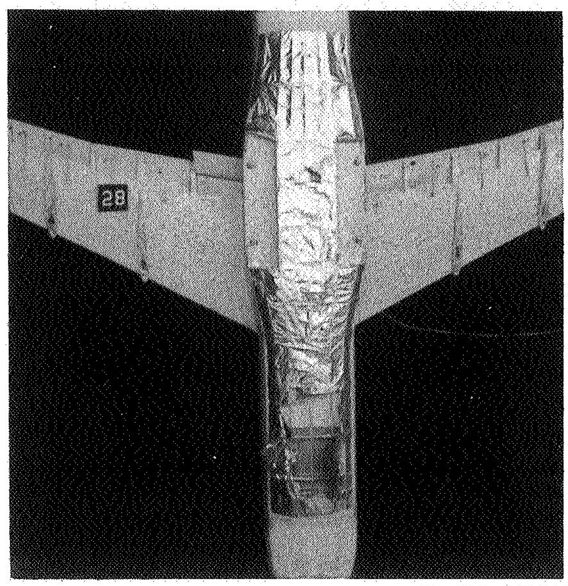
L-71-7135

(e) Landing attitude, 7°; speed, 71 m/sec (137 knots); water surface, calm.

(f) Landing attitude, 7°; speed, 71 m/sec (137 knots); water surface, rough.

Figure 41.- Continued.



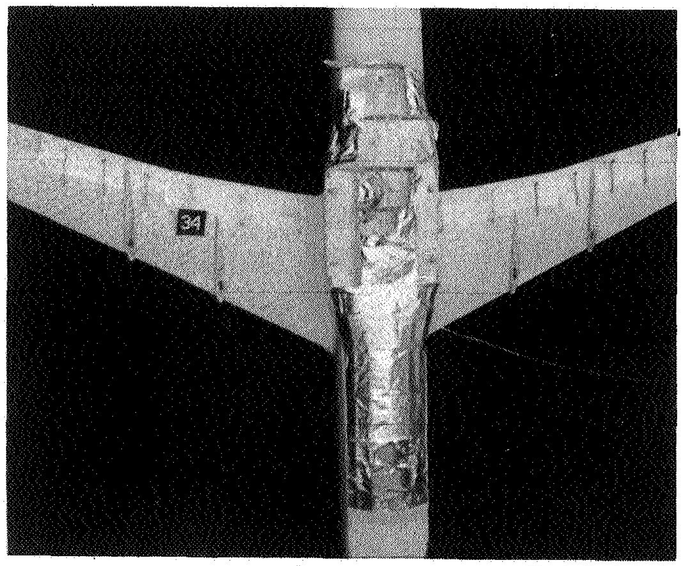


L-71-7136

(g) Landing attitude, 4^{o}; speed, 79 m/sec (153 knots); water surface, calm.

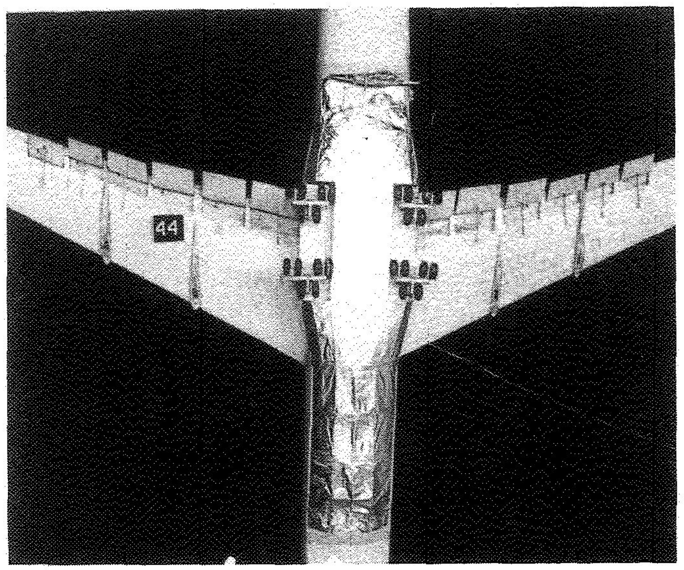
(h) Landing attitude, 4^{o}; speed, 79 m/sec (153 knots); water surface, rough.

Figure 41.- Concluded.

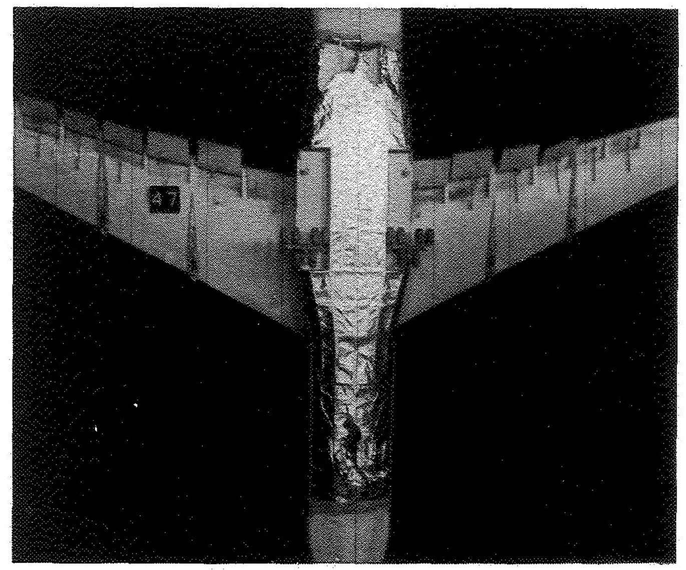


L-71-7137

Figure 42.- Photograph of typical damage for ditchings in calm water with nose gear retracted and the main gear fully extended. Landing attitude, 7°; flaps, 0°; speed, 91 m/sec (176 knots). All values are full scale.



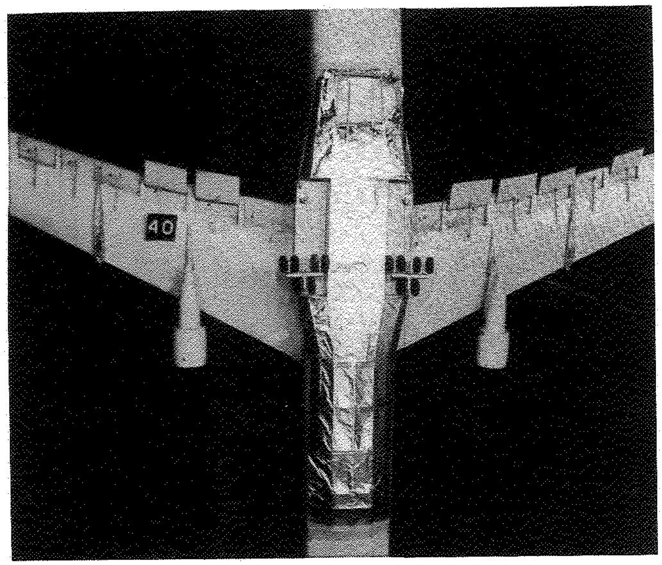
(a) Landing attitude 12°; speed, 65 m/sec (126 knots); water surface, calm.



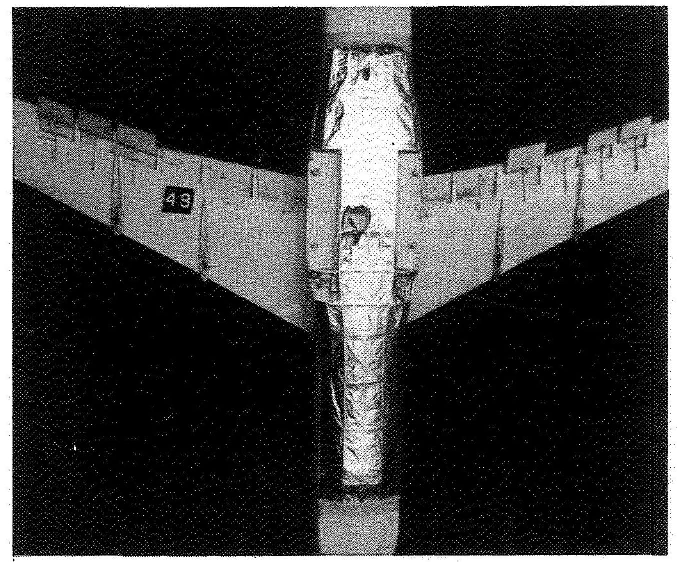
L-71-7138

(b) Landing attitude, 12°; speed, 65 m/sec (126 knots); water surface, rough.

Figure 43.- Photographs of typical damage for ditchings with nose gear retracted; main gear, kneeling; and flaps down 40°. All values are full scale.



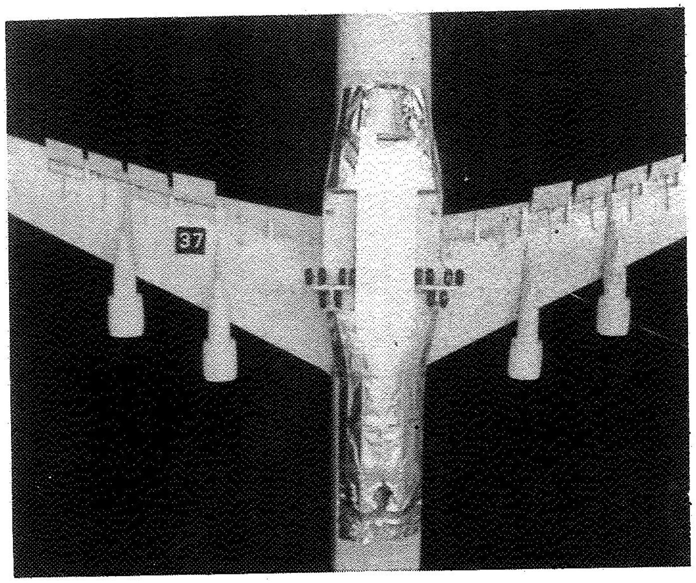
(c) Landing attitude, $9\frac{1}{2}^{\circ}$; speed, 68 m/sec (132 knots); water surface, calm.



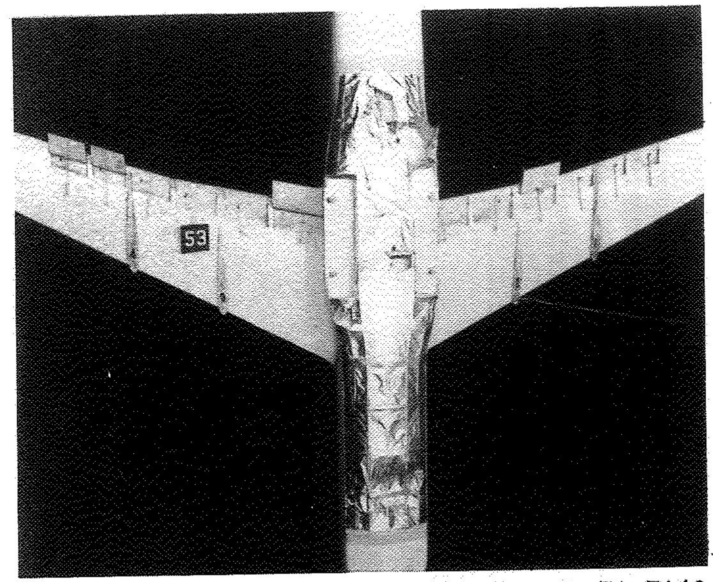
L-71-7139

(d) Landing attitude, $9\frac{1}{2}^{\circ}$; speed, 68 m/sec (132 knots); water surface, rough.

Figure 43.- Continued.



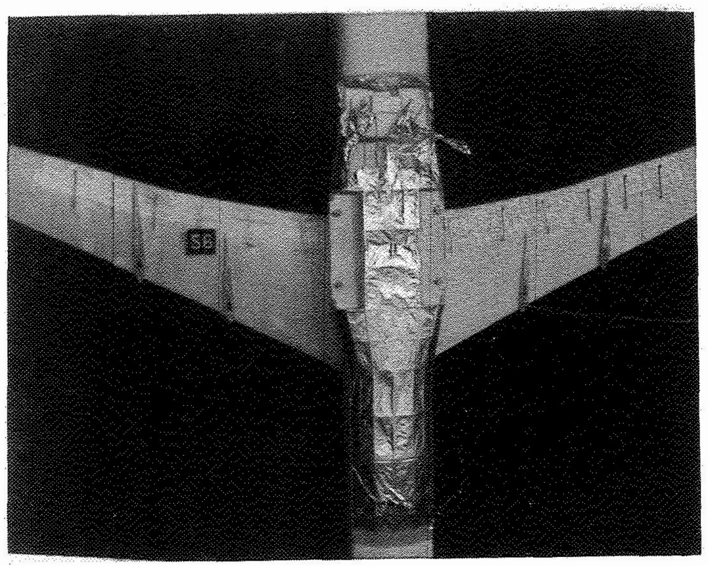
(e) Landing attitude, 7°; speed, 71 m/sec (137 knots); water surface, calm.

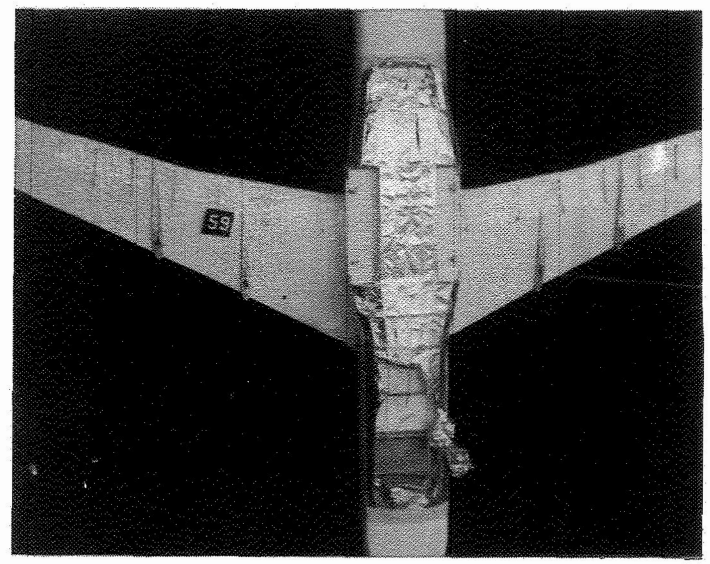


L-71-7140

(f) Landing attitude, 7°; speed, 71 m/sec (137 knots); water surface, rough.

Figure 43.- Concluded.





L-71-7141

(a) Landing attitude, 7°; speed, 71 m/sec (137 knots). (b) Landing attitude, 4°; speed, 79 m/sec (153 knots).

Figure 44.- Photographs of typical damage for ditchings with nose gear retracted and main gear in kneeling position. Vertical velocity, 2.7 m/sec (9 ft/sec); flaps, 40°; water surface, calm. All values are full scale.

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The tests were made with a 1/30-scale dynamic model ditched at various landing attitudes, flap settings, and fuselage configurations in both calm- and rough-water conditions.

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