NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2929

EXPERIMENTAL INVESTIGATION OF THE EFFECT OF REAR-FUSELAGE SHAPE ON DITCHING BEHAVIOR

By Ellis E. McBride and Lloyd J. Fisher

Langley Aeronautical Laboratory
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SUMMARY

An experimental investigation was conducted to determine the effect of changes in shape of the rear fuselage of an airplane on ditching behavior. The basic fuselage used in the investigation was a streamline body of revolution. Variations in longitudinal curvature of the bottom of the fuselage were obtained by sweeping up or sweeping down the rear half of the center line. A change in rear-fuselage cross section was obtained by splitting the center line in the plan view. Most of the tests were made with a fuselage of fineness ratio 6, but some tests were made with a fuselage of fineness ratio 9 in order to determine the effect of a change in fuselage fineness ratio. The models were landed in calm water at the Langley tank no. 2 monorail at speeds of 30, 40, 50, and 60 feet per second.

The behavior of the models was recorded with a high-speed motion-picture camera. The motion-picture records were analyzed and the data obtained are presented as curves of speed, attitude, and center-of-gravity height plotted against time; in bar graphs; and in tabular form.

From the results of the investigation the following conclusions were drawn. At the lower landing speeds the flattened cross section is desirable except where there is no longitudinal curvature. At the higher landing speeds a rounded cross section should be used to avoid skipping. If the cross section is rounded a minimum amount of longitudinal curvature gives the best behavior. If the cross section is flattened a moderately curved profile is best. The fuselage with the higher fineness ratio is more moderate in behavior and will make the safer ditchings. At high landing speeds minimum longitudinal curvature and rounded cross sections are most desirable, and high longitudinal curvatures with flattened cross sections become very dangerous. At low landing speeds moderate longitudinal curvatures and moderately curved cross sections are most desirable.

INTRODUCTION

In specific ditching investigations, difficulty has been experienced in isolating the effects on ditching behavior of the various airplane parts. The previous work has, in general, been limited to determining the ditching behavior of specific airplanes, recommending the safest ditching procedure, and evaluating modifications to the airplane when necessary.

In a study of ditching behavior many design parameters must be considered, such as fuselage shape, wing and horizontal-tail location, engine placement and protuberances, and the strength of the under side of the airplane. The effect of rear-fuselage shape was chosen for this investigation because in a ditching the rear fuselage usually contacts the water first and the hydrodynamic forces developed on this part of the airplane largely determine the degree to which the other airplane parts enter the water and the damage done to the under side of the airplane.

The data given are intended to show the variation in ditching behavior that can be obtained by changes in fuselage shape and to aid the designer in selecting the fuselage shape which would give the most satisfactory ditching behavior should a choice present itself.

SYMBOLS

a	vertical distance of center of gravity above rear tip of fuselage, $l \sin(\theta + \tau)$, in.
h	height (vertical distance) of center of gravity above water, in.
$\frac{h}{a}$	skipping parameter
$\left(\frac{h}{L}\right)_{max}$	maximum ratio of height of center of gravity above water to over-all fuselage length
I	moment of inertia, slug-ft^2
L	over-all length of fuselage, in.
l	distance from center of gravity to rear tip of fuselage, in.
n	fineness ratio

S	wing area, sq ft
V	landing speed, fps
W	gross weight, lb
θ	angle between fuselage reference line and line running through center of gravity to rear tip of fuselage, deg
τ	attitude (angle between fuselage reference line and water surface), positive when nose is up, deg

APPARATUS AND PROCEDURE

Description of Model

Photographs of the basic model used in this investigation are shown in figure 1. A three-view drawing of the model is shown in figure 2. The model was constructed principally of balsa wood and was ballasted internally to obtain the desired weight and moments of inertia. The model had a wing span of $5\frac{1}{2}$ feet and a length of 4 feet. The center of gravity was located at 30 percent of the mean aerodynamic chord and 1.55 inches below the wing root chord.

The basic fuselage was a streamline body of revolution with the maximum width at 50 percent of the length and a fineness ratio of 6. The ordinates are given in table I. The configurations tested are shown in figure 3. By sweeping up the center line, the longitudinal curvature of the fuselage bottom was increased, and by sweeping down the center line, the longitudinal curvature of the bottom was decreased. By splitting the center line in the plan view, the cross section was flattened. The original radii of the basic body were used with all these changes in curvature.

The design requirements for the wing were that it produce enough lift to fly the fuselage onto the water at the desired landing speeds and that it remain clear of the water and have no hydrodynamic effect on the behavior of the model. The airfoil section at the root was NACA 23015 and at the tip NACA 23009. The wing had an area of 3.6 square feet and a taper ratio of 0.455 and was equipped with simple, half-span, 25-percent-chord flaps with a deflection range from 60° to -30° and with removable auxiliary flaps.

The NACA 0015 airfoil section was used for the tail surfaces to obtain the strength possible with a thick section. The horizontal tail had an area of 0.85 square foot and was equipped with elevators large enough to trim the model in stable flight at the desired attitude and landing speeds. The horizontal tail was mounted high on the vertical tail to keep it clear of the water. However, preliminary test runs showed that the behavior of some of the models was such that the horizontal tail was still heavily loaded by water. In order to minimize the effect of hydrodynamic forces on the tail, the tail assembly was attached to the fuselage by a weak strand of thread so that when it became loaded with water it would break away and not inhibit the movement of the fuselage. The lack of aerodynamic stability caused by knocking off the tail after the model contacted the water had no observable effect on the subsequent behavior of the model.

Some of the physical characteristics of the model are listed in table II and are converted to full-scale values for three general sizes of airplanes. The weight, wing area, wing loading, moments of inertia, and landing speeds of the test model were chosen so that they would scale up by Froude's law of dynamic similarity to reasonable values for these three general airplane types. These values may be converted in the same manner for any specific airplane which does not fit the three examples in table II.

Test Methods and Equipment

The model was launched at landing speeds of 30, 40, 50, and 60 feet per second by catapulting it from the Langley tank no. 2 monorail. The control surfaces were set so that the model did not yaw or change attitude appreciably in flight. The wing lift was varied by changing the wing-flap configuration so that the model was airborne at the desired landing speed. At the landing speed of 30 feet per second the main flaps were deflected 60° and the auxiliary flaps were attached. At 40 feet per second the auxiliary flaps were removed and the main flaps deflected 20°. At 50 feet per second the main flaps were at 0° and a full-span spoiler was added at the 25-percent-chord line. At 60 feet per second the same spoiler was used and the flaps were deflected -30°.

The behavior of the model was recorded with a motion-picture camera. The motion-picture records were analyzed to obtain time histories of speed, attitude, and center-of-gravity height of the model.

The model was launched at an attitude of 10°. This attitude is near the maximum lift angle for the wing and corresponds to the nose-high landing attitudes generally recommended for ditching. The reference line for all models is the center line of the basic streamline body.

RESULTS AND DISCUSSION

A summary of the results obtained with the various fuselage configurations is presented in table III. Typical time-history plots of speed, attitude, and center-of-gravity height are shown in figures 4 to 9 for the models of fineness ratio 6 and in figures 10 to 12 for the models of fineness ratio 9. These plots show the dynamic behavior of the model.

In a full-scale ditching, a large increase in attitude caused by suction on the rear of the fuselage is considered undesirable because if failure occurs and the suction is released the nose of the airplane will pitch downward violently, and a dive will probably result. Rapid changes in height during a ditching indicate that water loads are probably of sufficient magnitude to cause extensive damage to the fuselage and endanger its occupants. The length of run gives an indication of the severity of the longitudinal decelerations imposed upon the airplane and its occupants. Skipping, a motion in which the airplane leaves the water momentarily after landing, can also lead to loss of control, hazardous motions, and extensive damage upon recontact.

Behavior of the Models of Fineness Ratio 6

Model A.- The behavior of the basic configuration, model A, was very much the same at all the landing speeds, as shown in figure 4. Immediately after contact with the water the model pitched up to about 35° or 40°. This rapid increase in attitude was accompanied by very little change in the height of the center of gravity above the water. The model thus rotated about its center of gravity so that at the peak attitude the entire rear half of the fuselage was submerged. Such a large amount of fuselage submerged indicates that negative pressures were developed to pull it under. When the peak positive attitude was reached the model had slowed considerably; then the attitude decreased rapidly and the model actually attained a slightly negative attitude. The rest of the landing run was at very low speeds and involved only slight changes in attitude and height until the model came to rest.

The behavior of this model would be undesirable for airplanes with weak fuselage bottoms. Extensive bottom failure would suddenly release the suction forces on the rear fuselage and allow the nose of the airplane to pitch downward violently from a high angle, so that a dive would probably result. Should the bottom be strong enough to resist damage or be only slightly crumpled, this behavior would be satisfactory at all landing speeds, since the airplane would stick to the water with no tendency to skip.

Model B.- The behavior of model B, like that of the basic model, varied little with landing speed (fig. 5). The behavior of model B was similar to that of the basic model except that the maximum attitudes were about 10° lower than those attained by the basic model. Because of the minimum longitudinal curvature, model B contacted the water first on the tip of the fuselage; therefore the increase in attitude was delayed for about 0.15 second while the tip was sinking in.

The same restrictions regarding fuselage strength discussed for model A apply to model B. However, the lower maximum attitudes attained by model B make its behavior more desirable than that of model A.

Model C.- The behavior of model C also varied little with landing speed, but more increase in attitude than with models A and B was noted as landing speed increased. The behavior of model C is shown in figure 6. The maximum attitudes attained by model C were very high (53° at a landing speed of 60 feet per second), about 10° to 15° higher than the attitudes attained by the basic model. The peak attitudes were accompanied by only slight increases in height and the rear half of the fuselage was completely submerged. After the peak positive attitudes were reached, the attitude decreased to about 0°, whereas the attitude of model A decreased to about -10°. No other appreciable differences in the low-speed part of the run were noticed.

The extremely high attitudes attained by model C make it a less desirable shape than models A and B.

Model D.- The behavior of model D is shown in figure 7. The maximum attitudes attained (20° to 25°) varied little with landing speed and were considerably lower than the attitudes attained by the basic model. The initial peak in the height curve increased with increase in landing speed. The peak indicates a skipping tendency which was magnified by an increase in speed. At 30 feet per second the skipping tendency was not noticeable to the observer, but at 40 feet per second the skipping tendency was very apparent and the model almost cleared the water. When landed at 50 feet per second the model made one very severe skip and almost cleared the water a second time. At 60 feet per second the initial skip was so severe that the model sometimes fell back into the water out of control and hit the side of the tank. When the model did remain stable during the initial skip, a second and less severe skip followed, but the model was so far away from the camera and so much obscured by spray that the film could not be analyzed; hence, the termination of the plots in figure 7 after the initial skip.

Model D exhibited none of the sucking-down tendency so noticeable in the behavior of the basic model. The behavior of model D at 30 feet per second, and possibly at 40 feet per second, would be considered satisfactory; however, the skips which occur at 50 and 60 feet per second are very dangerous.

Model E.- The most significant motion in the behavior of model E (fig. 8) was the tripping action of the flat tail immediately after contact. The flat tip contacted the water and bounced out; a decrease in attitude resulted so that the model recontacted at a near-level attitude. This behavior caused a severe impact with the water and is considered a very dangerous motion. The model exhibited practically no tendency to increase its attitude, and at none of the speeds tested did it ever regain its 10° contact attitude. The attitude changes throughout the entire run were gradual and of small magnitude. At 30 and 40 feet per second there was no appreciable skipping tendency on second contact, but at 50 feet per second a definite peak occurred in the height plot and the model almost cleared the water. At 60 feet per second a comparatively mild, low-angle skip occurred. After recontacting the water a tendency to skip again was apparent, but the model did not completely clear the water.

Model E showed marked directional instability in that it never maintained a straight course during the landing run; it always turned either left or right. At 60 feet per second it would turn far enough to hit the side of the tank before the run could be completed; the premature termination of the plots in figure 8 indicates that the model struck the side of the tank.

The behavior of this model is considered unsatisfactory at all landing speeds because of the directional instability and the violent nose-down pitching immediately after contact. This pitching could be alleviated by a near-level landing attitude, but the high speeds generally associated with near-level landings would cause the airplane to skip from the water.

Model F.- The behavior of model F is shown in figure 9. The maximum attitudes (30° to 40°) attained by model F were much higher than the attitudes of model D, and the peaks of the height curve for model F were slightly higher than those for model D at corresponding speeds. Model F almost skipped at 40 feet per second, and at 50 feet per second it made a very bad skip and almost cleared the water a second time. At 60 feet per second the model skipped twice, and such a large amount of spray was sent up upon recontact after the first skip that the plots in figure 9 were terminated there.

The behavior of this model, like that of model D, would be satisfactory at landing speeds of 30 and 40 feet per second but the skipping which occurs at 50 and 60 feet per second is dangerous. The higher attitudes attained by this model make its behavior less desirable than that of model D.

Behavior of the Models of Fineness Ratio 9

Model G.- The behavior of model G is shown in figure 10. The maximum attitudes attained were lower than those of model A, the similar configuration of fineness ratio 6. The peaks of the height plots show more variation with speed and at the higher landing speeds the peaks are higher than those of model A. The lengths of run were longer and more tendency to skip was observed with model G than with model A.

The behavior of this model is satisfactory at the landing speeds of 30 and 40 feet per second. There is nothing particularly violent about the behavior at 50 and 60 feet per second, but there is a strong tendency for the model to skip at 60 feet per second though it never completely clears the water.

Model H.- The behavior of model H is shown in figure 11. The maximum attitudes were much the same as those of model B, the similar configuration of fineness ratio 6. The peaks of the height plots were higher, the lengths of run were longer, and a stronger tendency to skip was noticed, especially at the higher landing speeds, with model H than with model B. There was little difference in the behavior of models H and G. Model H had slightly less tendency to skip than model G, and the maximum attitudes attained by model H were slightly lower than those of model G. There was nothing violent about the behavior of this model, and, like model G, it is considered satisfactory except for the borderline skipping tendency at the landing speed of 60 feet per second.

Model J.- The behavior of model J is shown in figure 12. The maximum attitudes were lower, the lengths of run longer, the height peaks higher, and the tendency to skip more pronounced than with model C. There was little difference in the behavior of models J and G. The higher attitudes attained by model J make its behavior less desirable than that of models G and H.

Comparison of Behavior

Figure 13 compares the maximum peaks (exclusive of the 10° contact attitude) of the attitude curves of figures 4 to 12. Figure 14 compares the values of $\left(\frac{h}{L}\right)_{max}$ and figure 15 compares the lengths of runs for all the configurations tested. A comparison of the skipping tendencies of the models is shown in figure 16. The height and attitude plots do not by themselves give a readily interpretable measure of the skipping tendency of the models. A variety of expressions involving functions of height and attitude have been examined in a search for one which indicates the occurrence of skipping and at the same time gives some measure of the tendency to skip as observed in the tests. The expression h/a plotted in figure 16 meets these requirements for all the present tests, as well as for a number of model tests of specific airplane configurations. When the ratio h/a (fig. 17) is greater than unity skipping occurs, and when it is less than unity the model does not skip. As the values of h/a approach unity the tendency to skip is apparent in the motion pictures of the model tests, and as the values of h/a increase beyond unity a corresponding increase in the severity of the skipping is found.

Effect of changes in longitudinal curvature.- The summary plot of maximum attitudes (fig. 13) shows that an increase in longitudinal curvature increased the maximum attitudes attained by the models with both the cross sections tested. No noticeable effect on $\left(\frac{h}{L}\right)_{max}$ and the length of run was obtained by changing the longitudinal curvature (figs. 14 and 15).

If the cross section is circular a minimum amount of longitudinal curvature gives the best behavior. If the cross section is flattened a moderately curved profile is best.

Effect of flattening the cross section.- Figure 13 shows that the models having the flattened cross section did not reach the high maximum attitude attained by the models with the circular cross section. This reduction in maximum attitude was greatest for the models having the minimum longitudinal curvature.

Flattening the cross section eliminated or reduced the suction effects that were so noticeable with the models having the circular cross section. Therefore, the models with the flattened cross section made longer runs.

Figure 16 shows that a dangerous skipping tendency was introduced by flattening the cross section. This skipping tendency was increased by increasing the longitudinal curvature or by increasing the landing speed. At the lower landing speeds the flattened cross section is desirable except where there is no longitudinal curvature. At the higher landing speeds a circular cross section should be used to avoid skipping.

Effect of fuselage fineness ratio.- In general, the runs were longer, the values of $\left(\frac{h}{L}\right)_{max}$ greater, the attitudes lower, and the tendency to skip greater for models of fineness ratio 9 than for similar configurations of fineness ratio 6. The increase in fineness ratio reduced the sucking-down tendency and the effect of changes in longitudinal curvature was minimized with reference, in particular, to the maximum attitudes attained. Consequently, the higher fineness ratio is considered more moderate in behavior and will make the safer ditchings.

Effect of landing speed.- Increasing the landing speed had little effect on the behavior of the models with the circular cross section. The only noticeable effect was that, in general, increases in landing speed slightly increased the maximum attitude angles. This was untrue only for the basic model (model A), which had a higher maximum attitude when landed at 30 feet per second than when landed at 40 or 50 feet per second. For the models having the flattened cross section, the maximum attitudes were also increased slightly with an increase in speed but the biggest effect of an increase in speed was to magnify greatly the tendency to skip.

If high landing speeds are necessary, minimum longitudinal curvature and circular cross sections are most desirable, and high longitudinal curvatures with flattened cross sections become very dangerous. At the lower landing speeds, moderate longitudinal curvatures and moderately curved cross sections are most desirable.

CONCLUSIONS

As a result of an experimental investigation of the effect of rear-fuselage shape on ditching behavior, the following conclusions were drawn:

1. Flattening the cross section decreased the maximum attitudes attained, decreased the possibility of negative pressures' sucking the rear fuselage under, introduced a skipping tendency, and increased the length of run. At the lower landing speeds the flattened cross section is desirable except where there is no longitudinal curvature of the fuselage bottom. At the higher landing speeds a rounded cross section should be used to avoid skipping.

2. Increasing the longitudinal curvature of the fuselage bottom increased the maximum attitude angles attained, and, with the cross section flattened, increased the tendency to skip. If the cross section is rounded a minimum amount of longitudinal curvature gives the best behavior. If the cross section is flattened a moderately curved profile is best.

3. Increasing the fineness ratio of the fuselage increased the length of run, increased the maximum center-of-gravity height, increased the skipping tendency, decreased the maximum attitudes attained, and

decreased the possibility of negative pressures. The fuselage with the higher fineness ratio is more moderate in behavior and will make the safer ditchings.

4. Increasing the landing speed, in general, slightly increased the maximum attitudes attained, and, with the cross section flattened, magnified the tendency to skip. If high landing speeds are necessary, minimum longitudinal curvature and rounded cross sections are most desirable and high longitudinal curvatures with flattened cross sections become very dangerous. At the lower landing speeds, moderate longitudinal curvatures and moderately curved cross sections are most desirable.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 18, 1953.

TABLE I

FUSELAGE ORDINATES

Fuselage station, in.	Radius, in.		Deviation from fuselage reference line, in.				
			Swept-up center line		Swept-down center line		Split center line
	n = 6	n = 9	n = 6	n = 9	n = 6	n = 9	n = 6
0	0	0	0	0	0	0	0
.5	.85	.57	0	0	0	0	0
1	1.16	.77	0	0	0	0	0
2	1.60	1.08	0	0	0	0	0
3	1.93	1.29	0	0	0	0	0
4	2.21	1.47	0	0	0	0	0
6	2.65	1.77	0	0	0	0	0
8	2.88	1.92	0	0	0	0	0
10	3.25	2.17	0	0	0	0	0
12	3.46	2.31	0	0	0	0	0
16	3.77	2.52	0	0	0	0	0
20	3.94	2.63	0	0	0	0	0
24	4.00	2.67	0	0	0	0	0
28	3.88	2.59	.12	.08	-.12	-.08	±.06
32	3.54	2.36	.46	.31	-.46	-.31	±.23
36	2.94	1.96	1.06	.71	-1.06	-.71	±.53
40	2.06	1.37	1.94	1.29	-1.94	-1.29	±.97
42	1.57	1.05	2.43	1.62	-2.43	-1.62	±1.215
44	1.06	.71	2.94	1.96	-2.94	-1.96	±1.47
46	.54	.36	3.46	2.31	-3.46	-2.31	±1.73
47	.27	.18	3.73	2.48	-3.73	-2.48	±1.865
48	0	0	4.00	2.67	-4.00	-2.67	±2.00

TABLE II

CONVERSION OF MODEL TEST RESULTS TO FULL-SCALE APPLICATION

Physical characteristics	Test model	Test model assumed to be -		
		$\frac{1}{10}$ - scale fighter	$\frac{1}{15}$ - scale transport	$\frac{1}{20}$ - scale bomber
Gross weight, W, lb	12.5	12,500	42,000	100,000
Wing area, S, sq ft	3.6	360	810	1,440
Wing loading, W/S, lb/sq ft	3.47	34.7	52	69.5
Moments of inertia, slug-ft^2:				
I_X (roll)	0.2157	21,570	163,286	690,131
I_Y (pitch)	0.2157	21,570	163,286	690,131
I_Z (yaw)	0.3882	38,820	293,914	1,242,236
Landing speed, V	30 fps	---------	---------	80 knots
	40 fps	---------	92 knots	106 knots
	50 fps	94 knots	115 knots	132 knots
	60 fps	112 knots	138 knots	---------

TABLE III

SUMMARY OF RESULTS OBTAINED WITH THE VARIOUS MODELS

Model configuration			Landing speed, fps	Maximum trim, deg	$\left(\frac{h}{L}\right)_{max}$	Length of skip, fuselage lengths	Duration of skip, sec	Length of run, fuselage lengths
Designation	Center-line deviation	Fineness ratio, n						
A	None	6	30	38.5	0.133	---	----	3.5
			40	34.0	.170	---	----	5.1
			50	35.0	.175	---	----	5.4
			60	42.0	.185	---	----	6.1
B	Swept down	6	30	25.0	.108	---	----	5.0
			40	27.0	.145	---	----	6.0
			50	30.0	.150	---	----	5.8
			60	32.0	.170	---	----	7.0
C	Swept up	6	30	44.0	.152	---	----	3.6
			40	48.0	.163	---	----	4.1
			50	49.5	.158	---	----	4.7
			60	53.0	.180	---	----	4.8
D	Straight and split	6	30	19.5	.175	---	----	7.0
			40	24.0	.238	---	----	9.3
			50	24.5	.297	2.5	0.29	13.2
			60	24.0	.400	5.9	.55	----
E	Swept down and split	6	30	2.5	.110	---	----	7.3
			40	6.0	.150	---	----	11.0
			50	7.5	.187	---	----	11.6
			60	8.5	.215	1.7	.16	----
F	Swept up and split	6	30	32.0	.172	---	----	4.7
			40	38.0	.240	---	----	7.2
			50	42.0	.343	2.1	.33	10.0
			60	43.0	.425	4.3	.53	----
G	None	9	30	21.0	.058	---	----	5.2
			40	32.0	.163	---	----	5.8
			50	33.5	.248	---	----	9.5
			60	34.0	.265	1.5	.18	11.5
H	Swept down	9	40	24.0	.149	---	----	6.3
			50	28.0	.219	---	----	7.4
			60	31.0	.251	---	----	9.1
J	Swept up	9	30	34.0	.109	---	----	4.0
			40	34.5	.169	---	----	5.7
			50	38.0	.197	---	----	7.4
			60	41.5	.242	---	----	11.3

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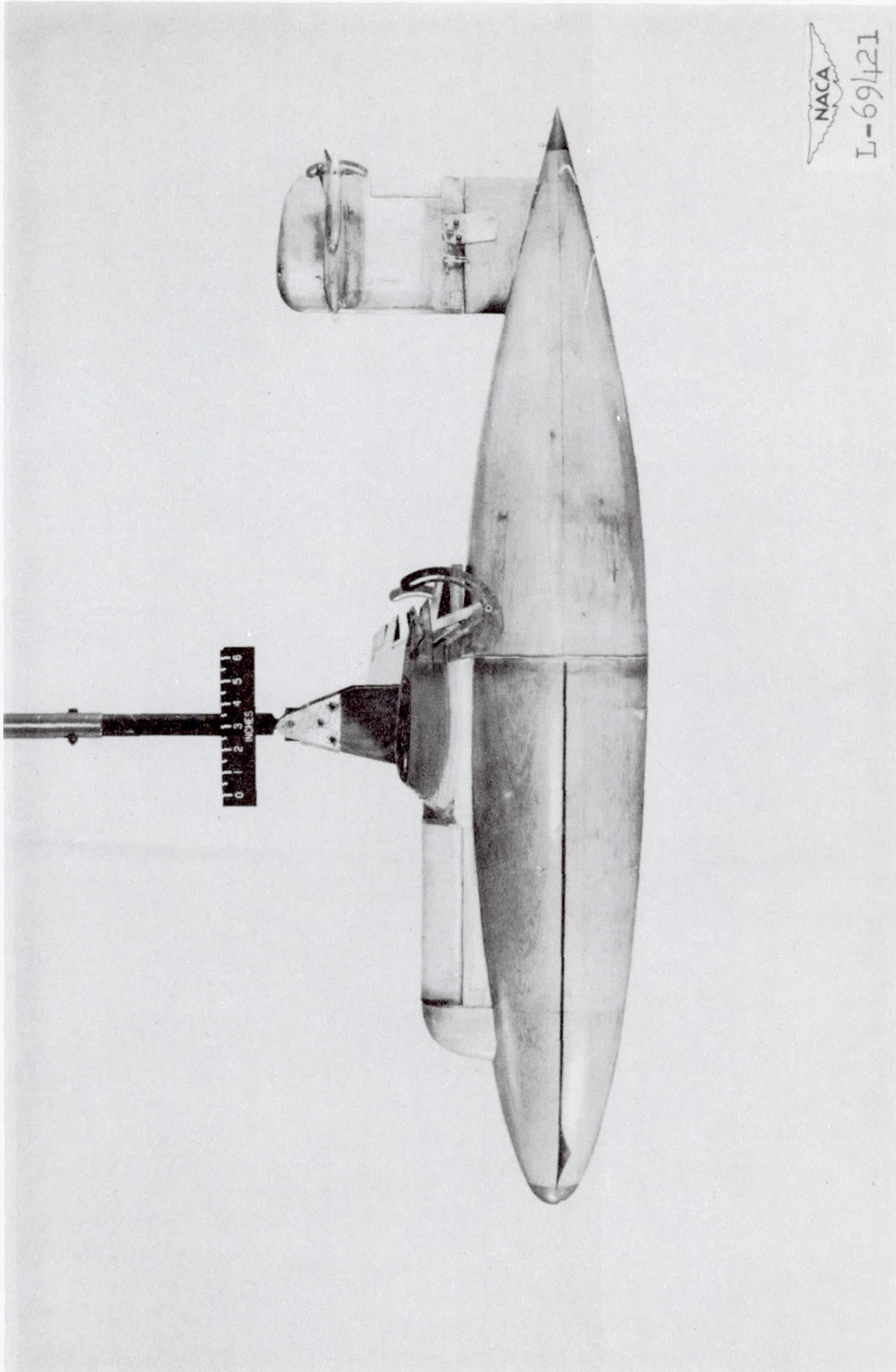
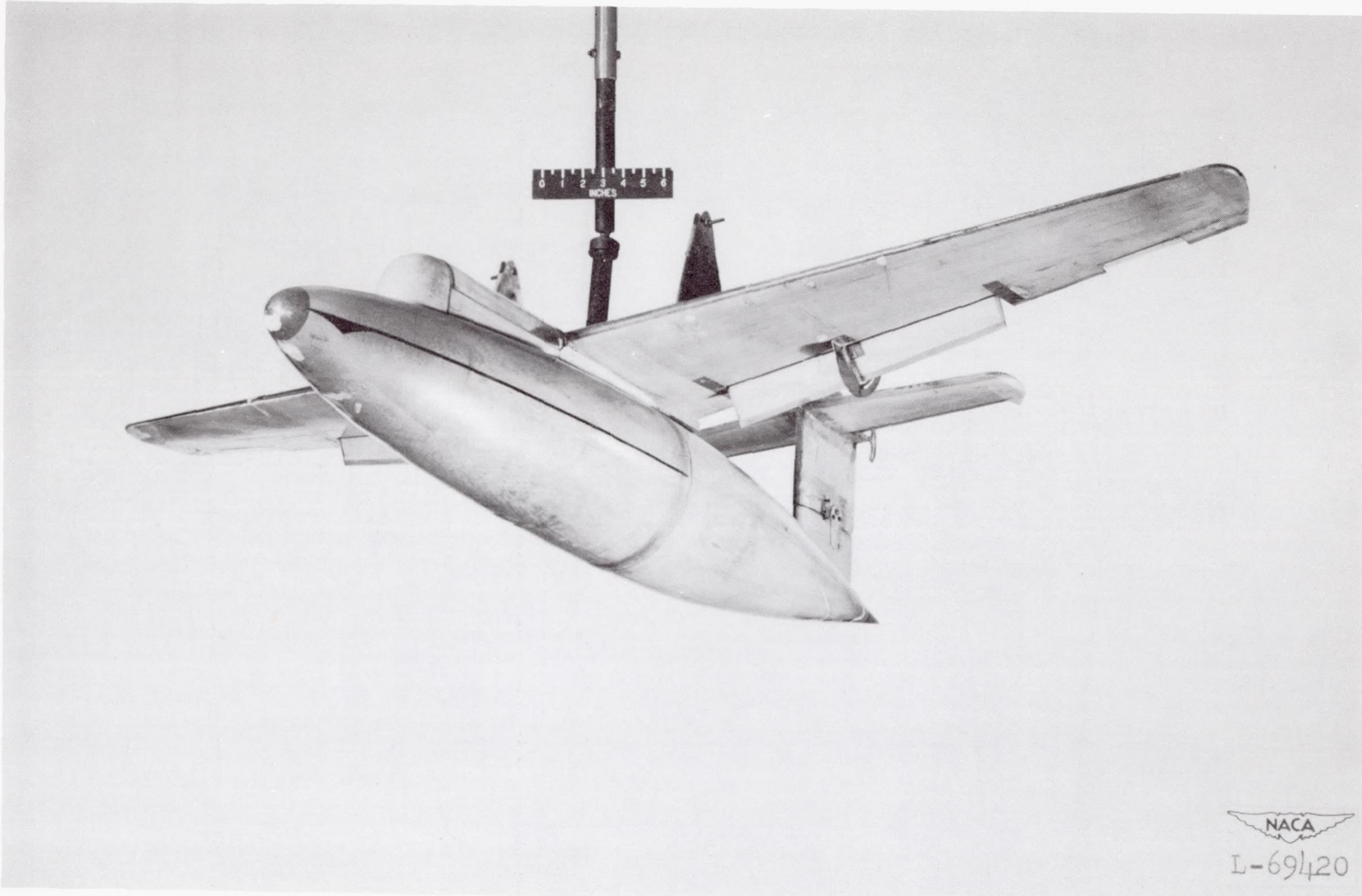
(a) Front view.

Figure 1.- The model of fineness ratio 6 in the basic configuration.



(b) Profile view.

Figure 1.- Continued.



(c) Three-quarter bottom view.

Figure 1.- Concluded.

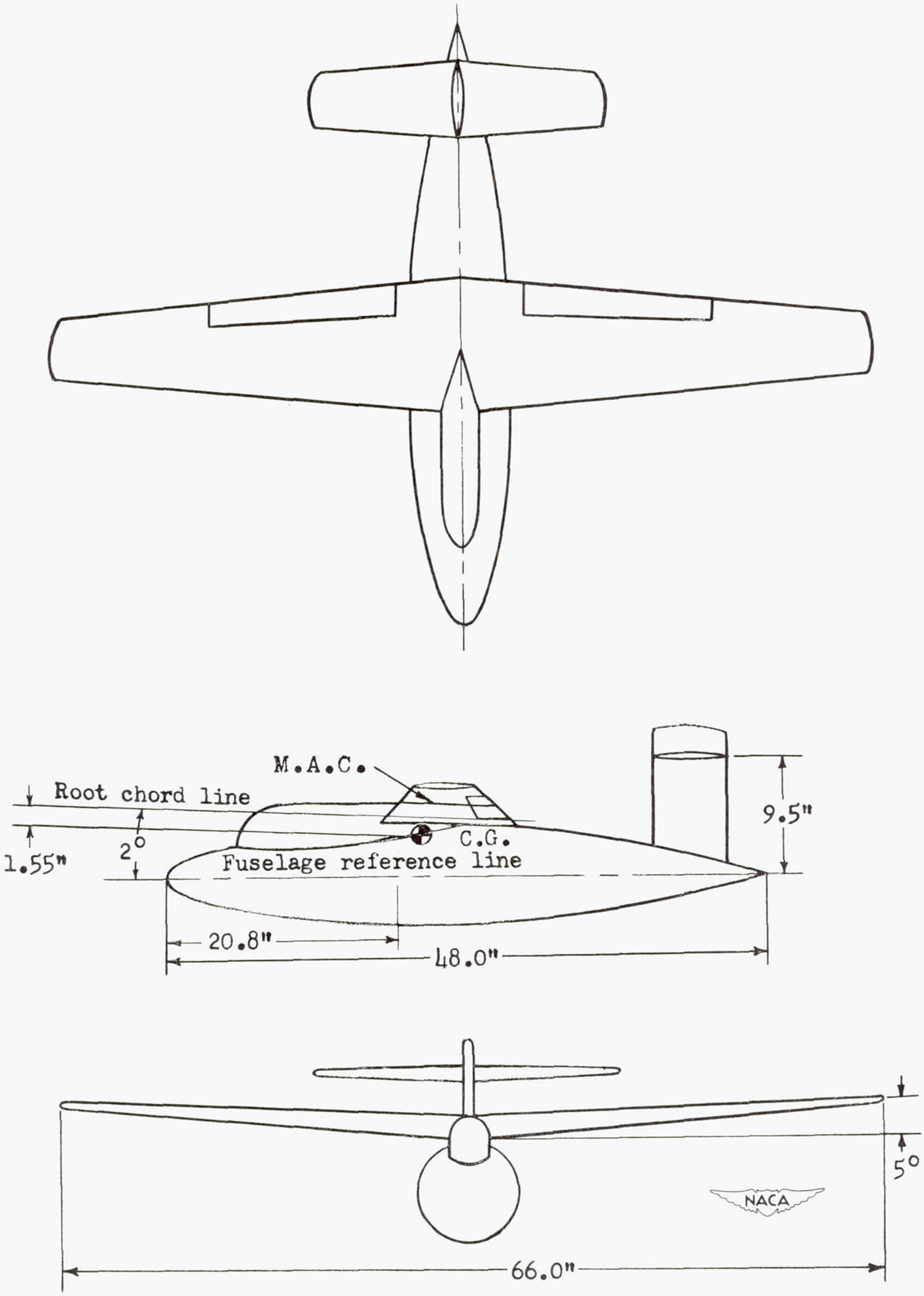


Figure 2.- Three-view drawing of the basic model (fineness ratio 6).

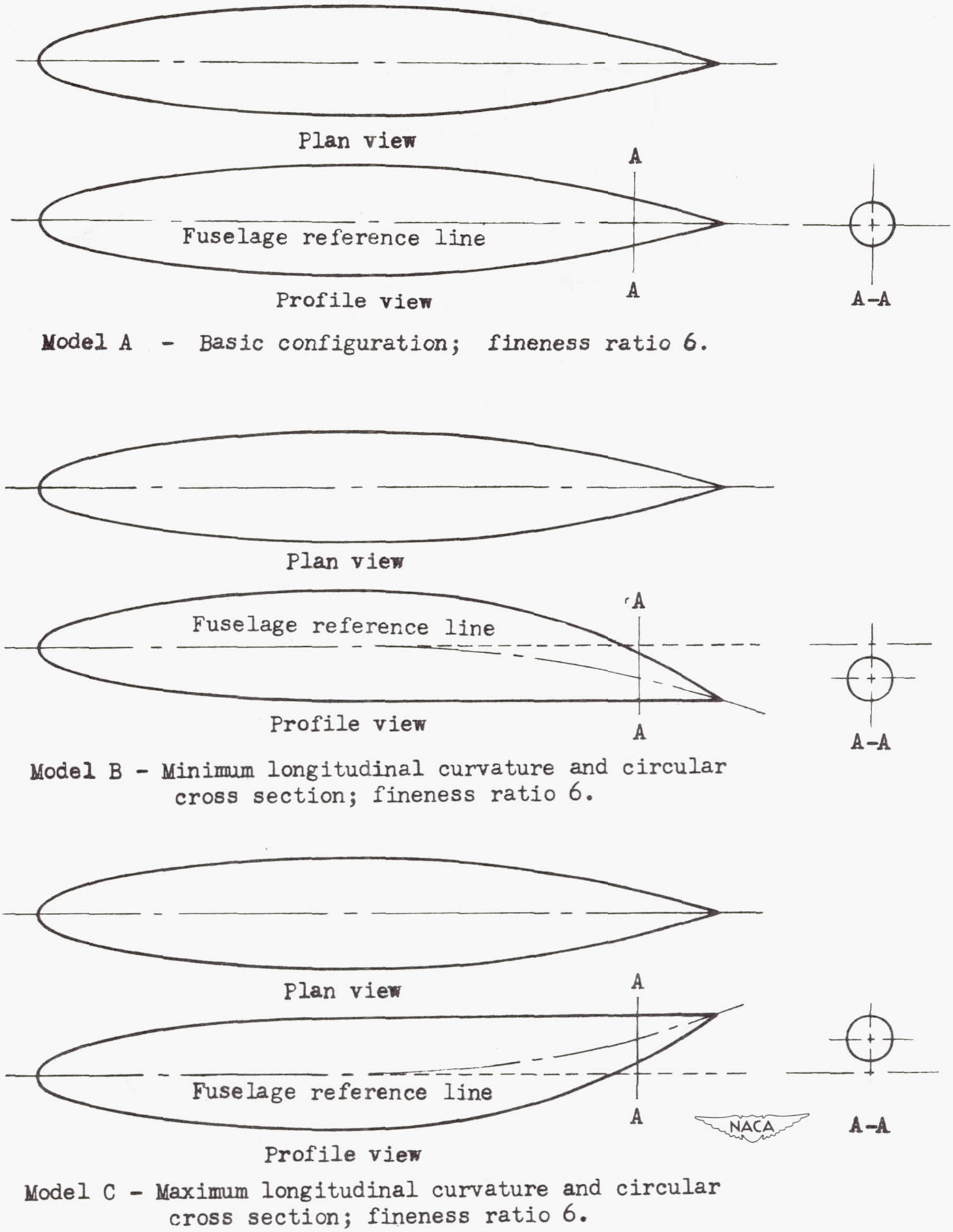
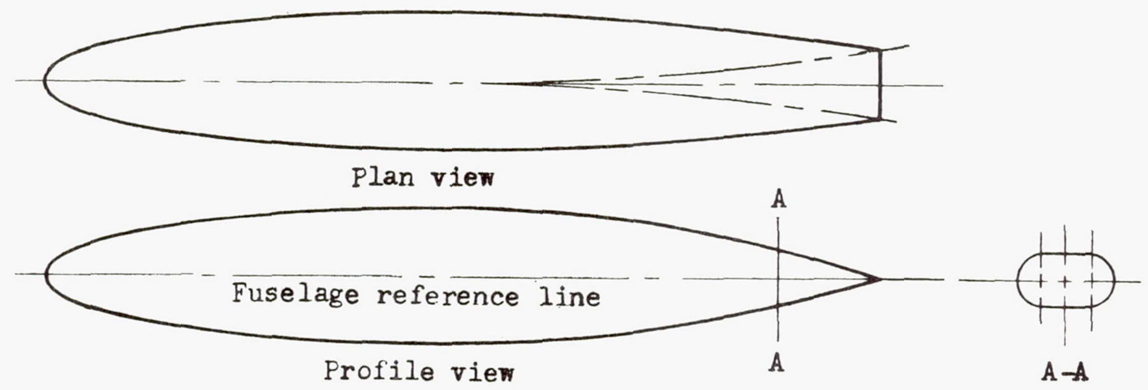
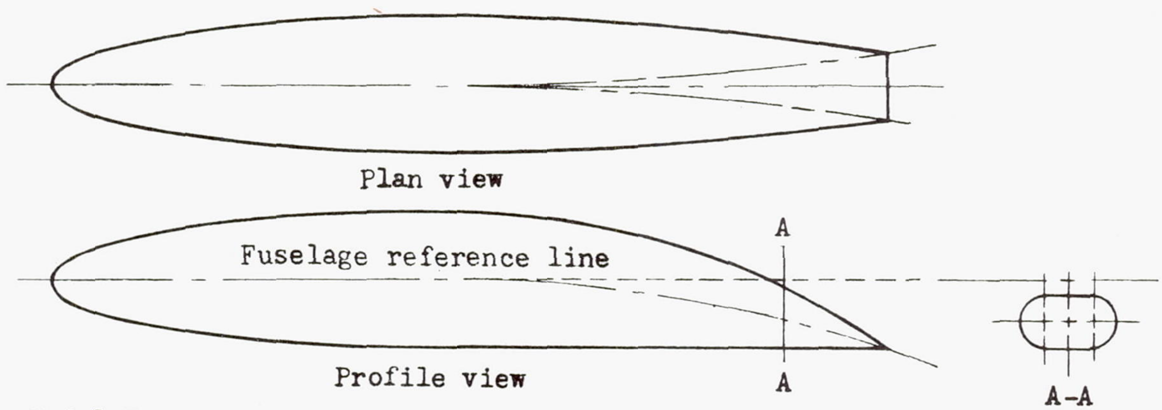


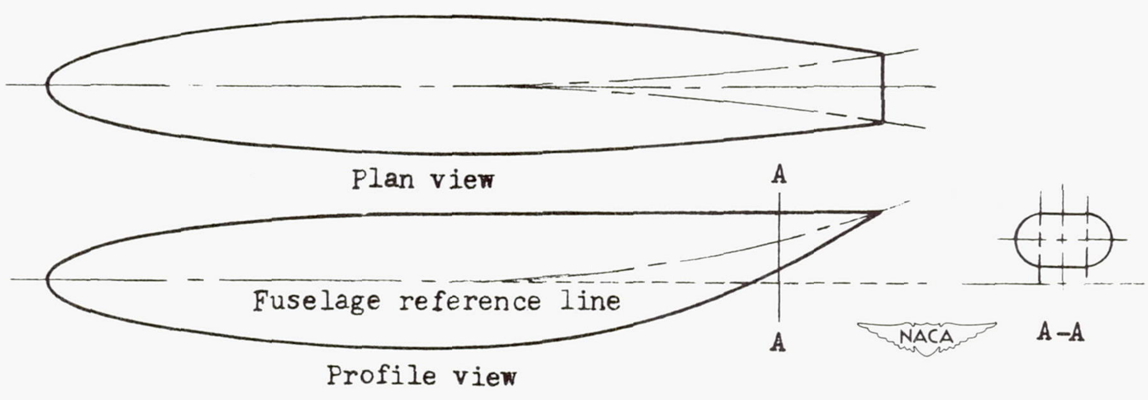
Figure 3.- Models tested in the investigation.



Model D - Basic longitudinal curvature and flattened cross section; fineness ratio 6.

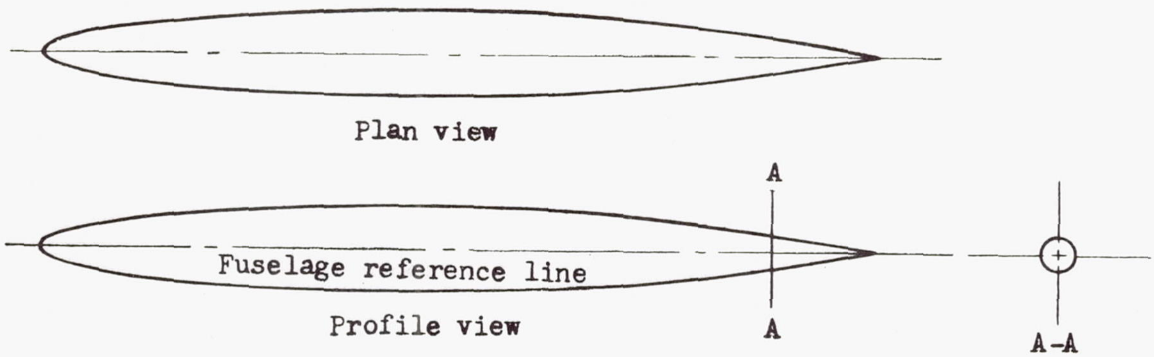


Model E - Minimum longitudinal curvature and flattened cross section; fineness ratio 6.

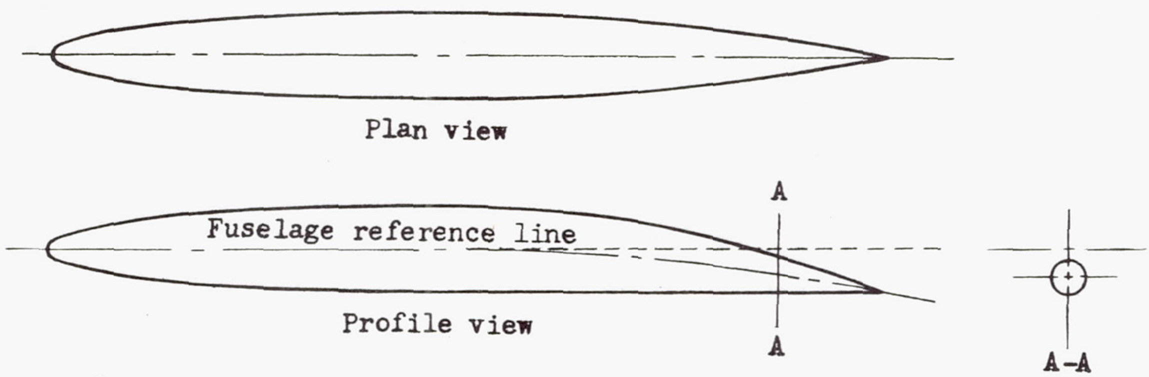


Model F - Maximum longitudinal curvature and flattened cross section; fineness ratio 6.

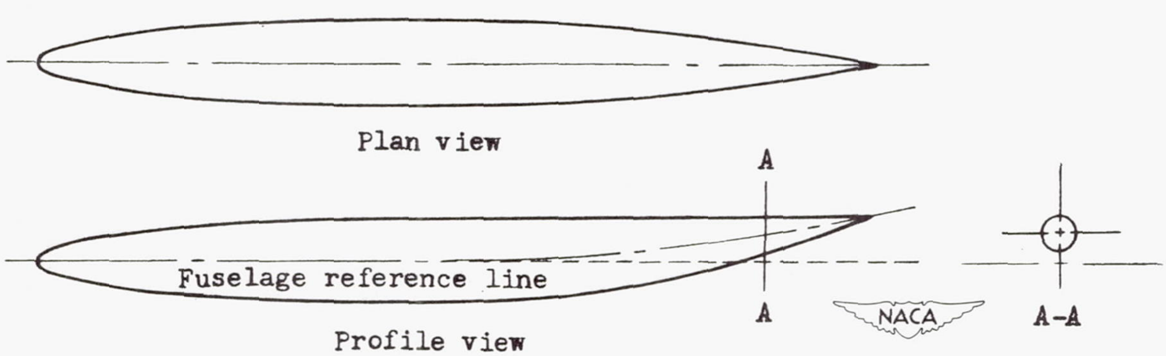
Figure 3.- Continued.



Model G - Basic configuration; fineness ratio 9.



Model H - Minimum longitudinal curvature and circular cross section; fineness ratio 9.



Model J - Maximum longitudinal curvature and circular cross section; fineness ratio 9.

Figure 3.- Concluded.

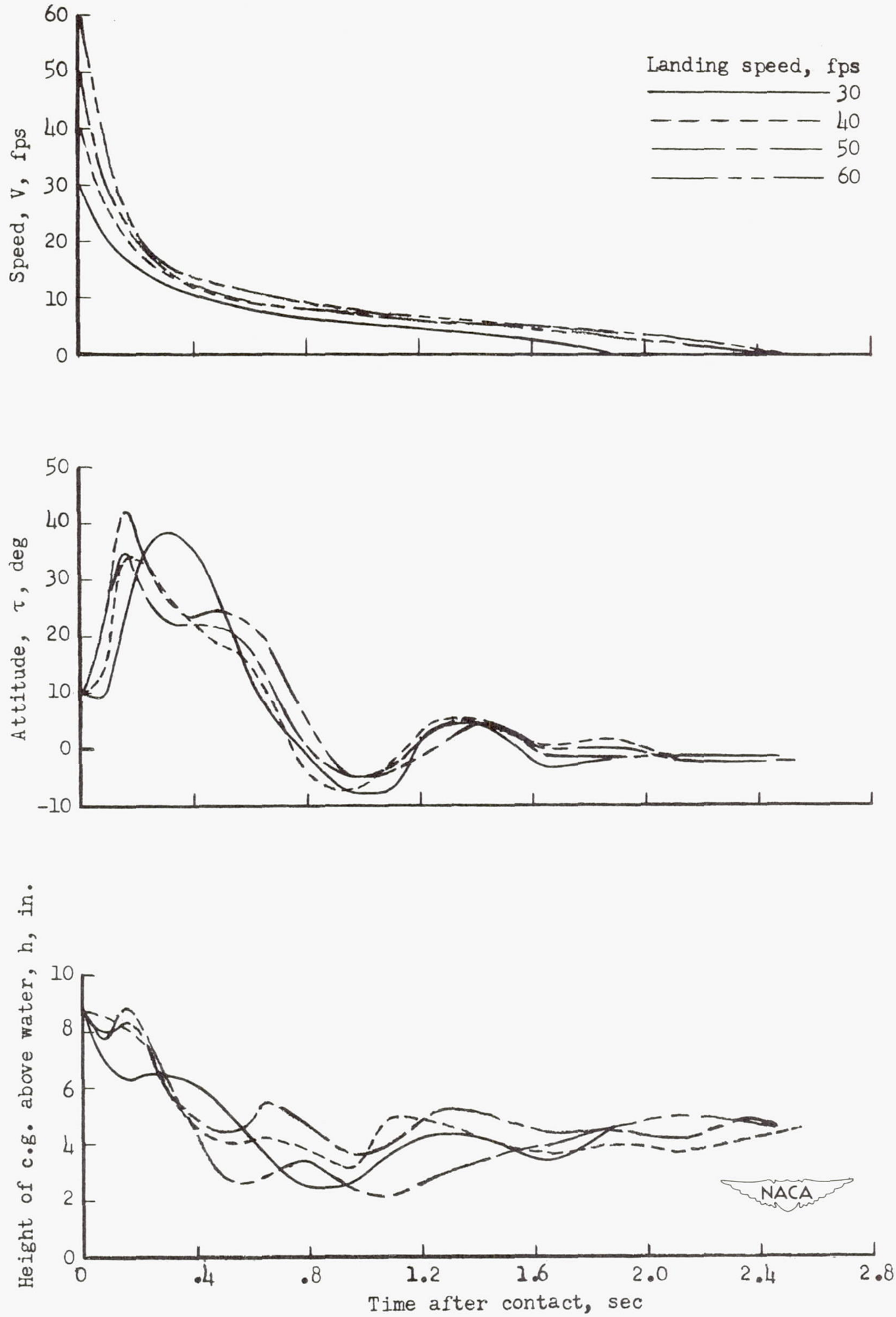


Figure 4.- Speed, attitude, and height time histories for model A.

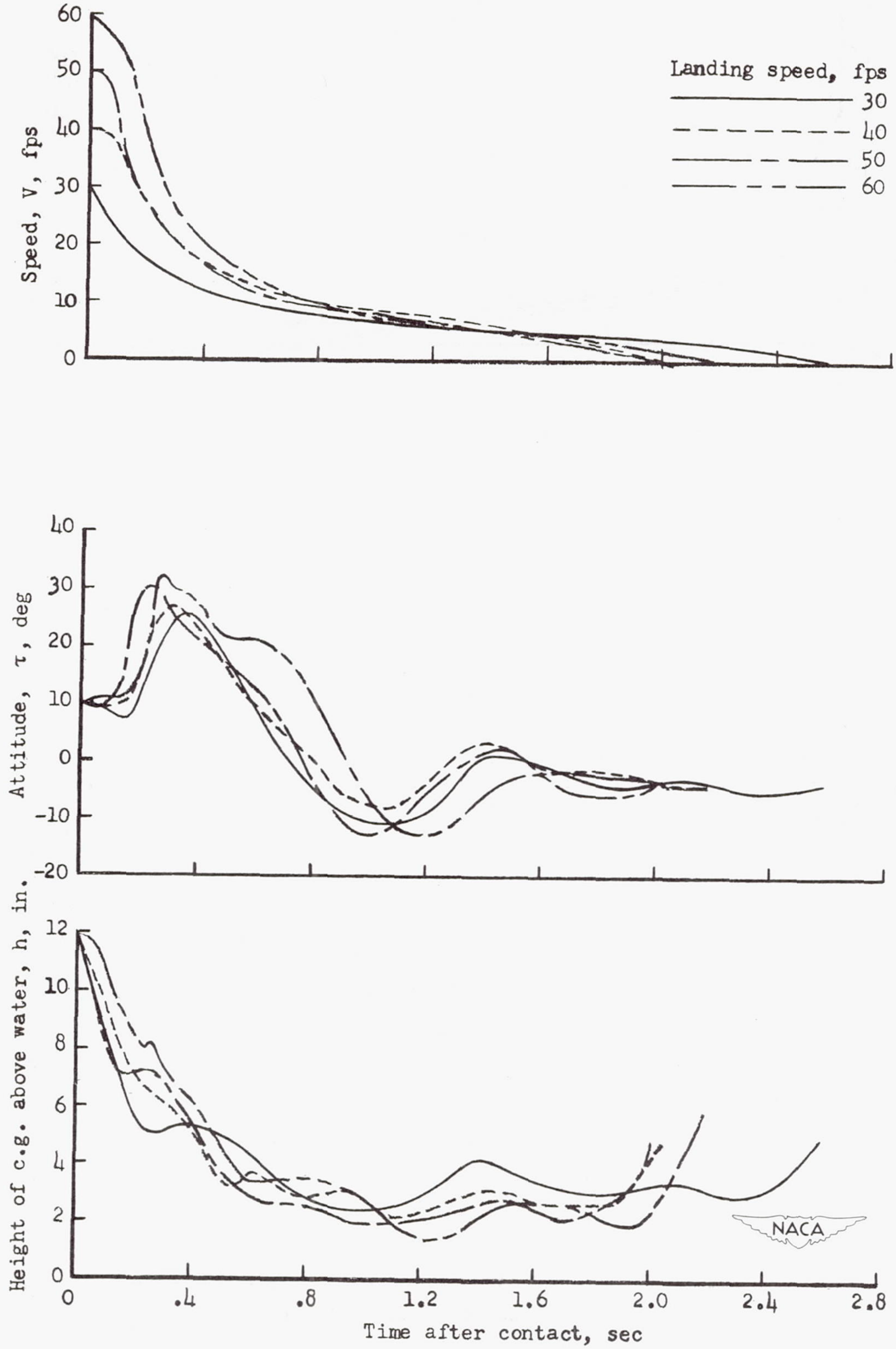


Figure 5.- Speed, attitude, and height time histories for model B.

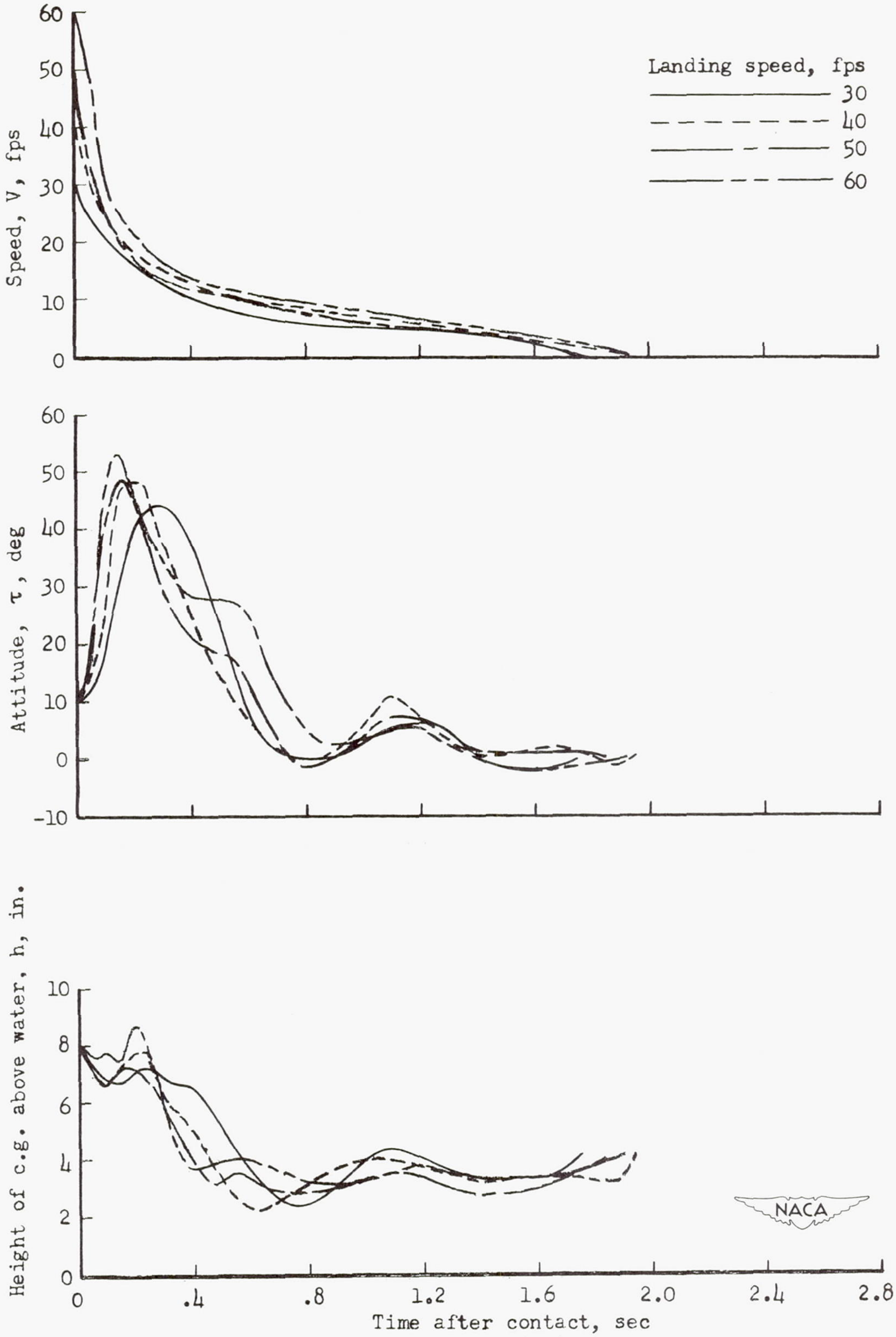


Figure 6.- Speed, attitude, and height time histories for model C.

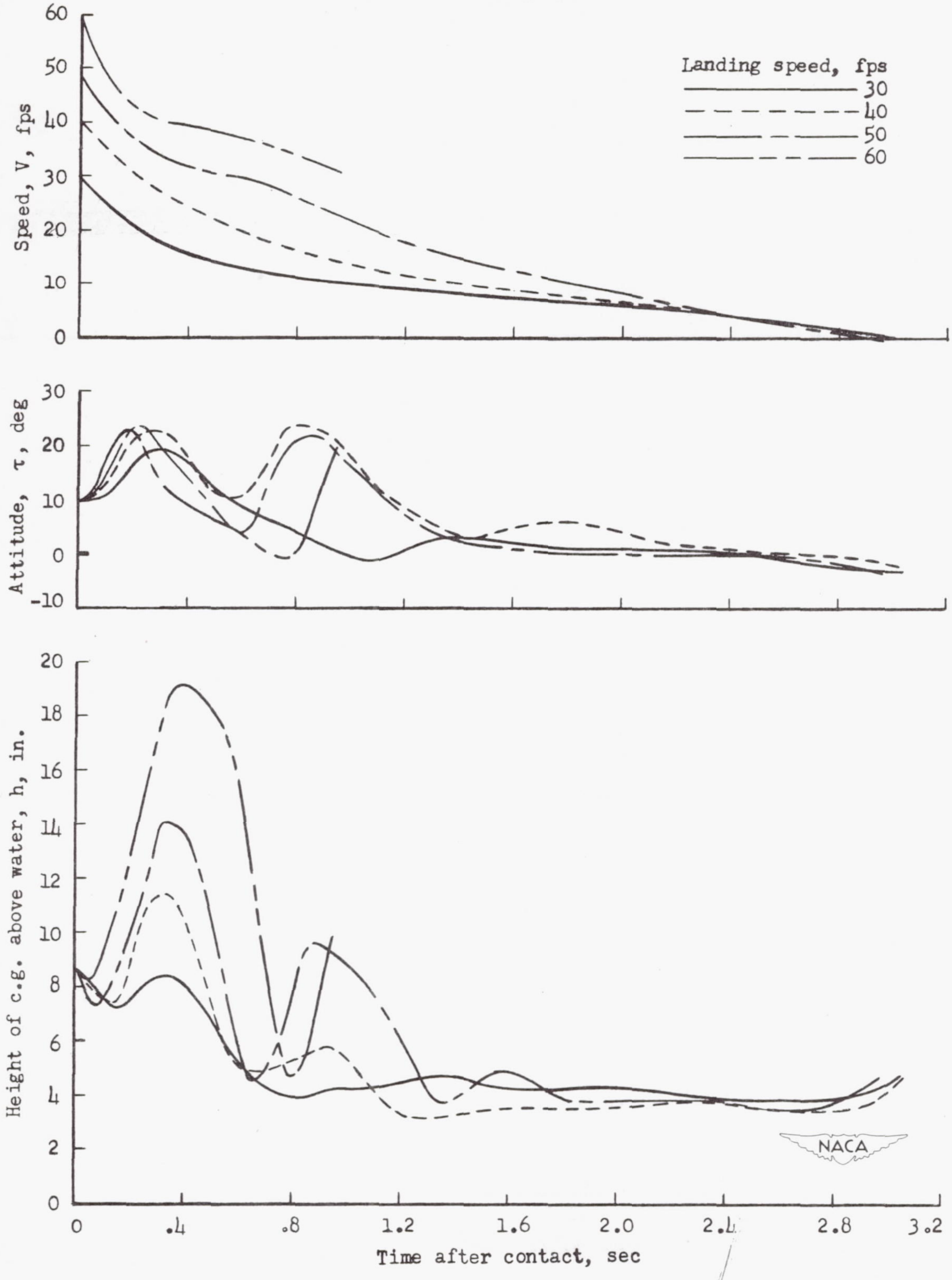


Figure 7.- Speed, attitude, and height time histories for model D.

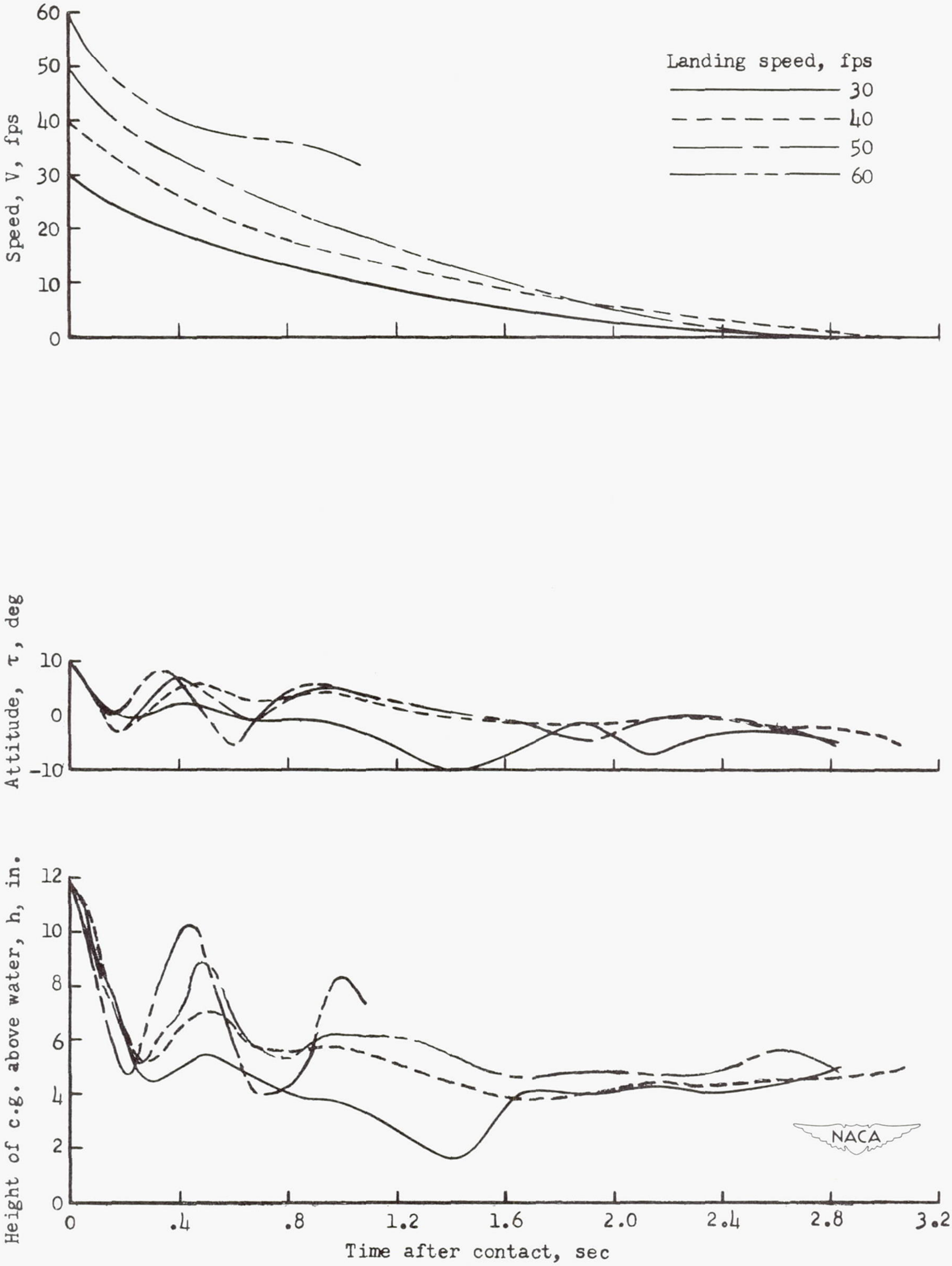


Figure 8.- Speed, attitude, and height time histories for model E.

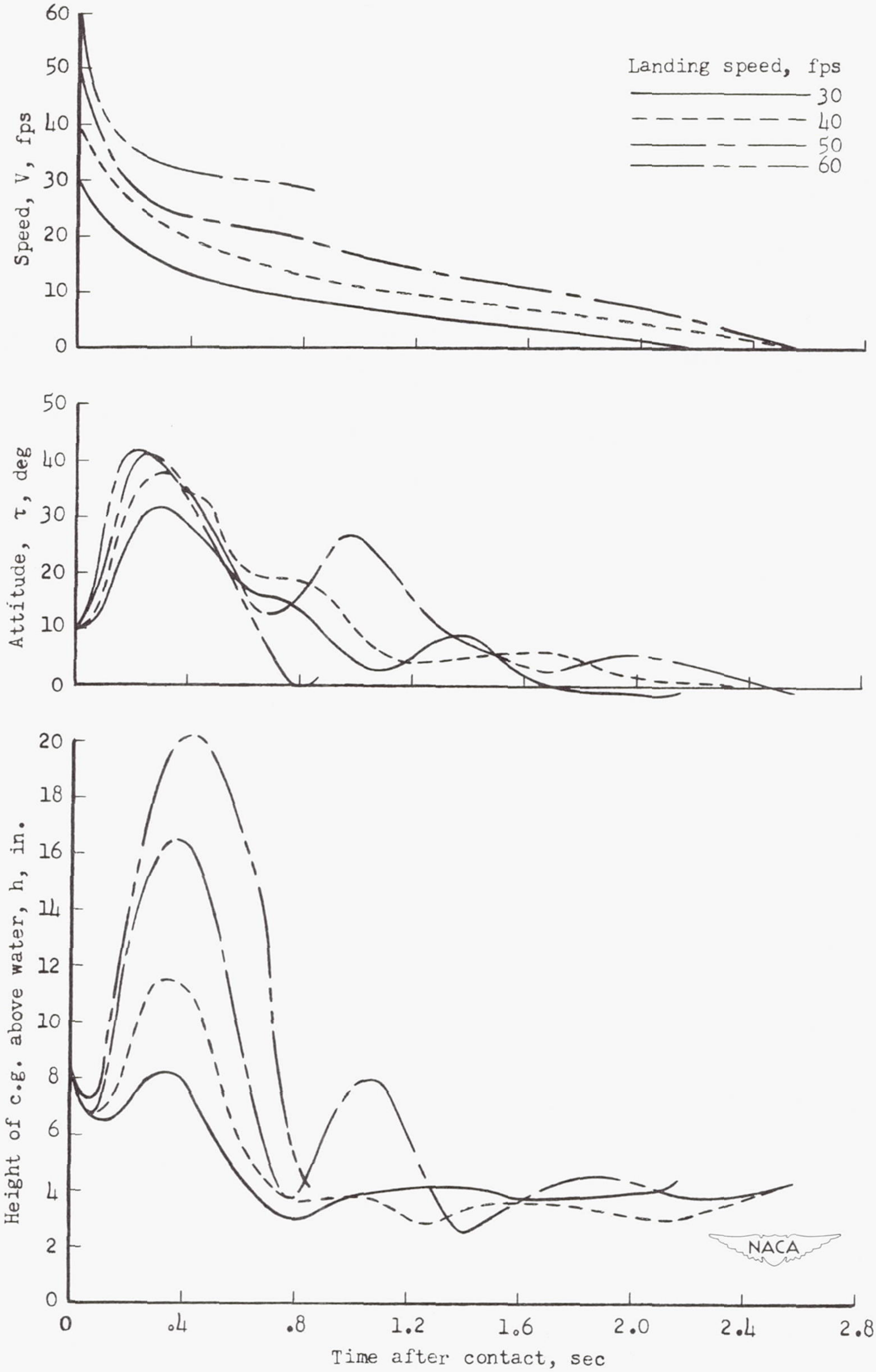


Figure 9.- Speed, attitude, and height time histories for model F.

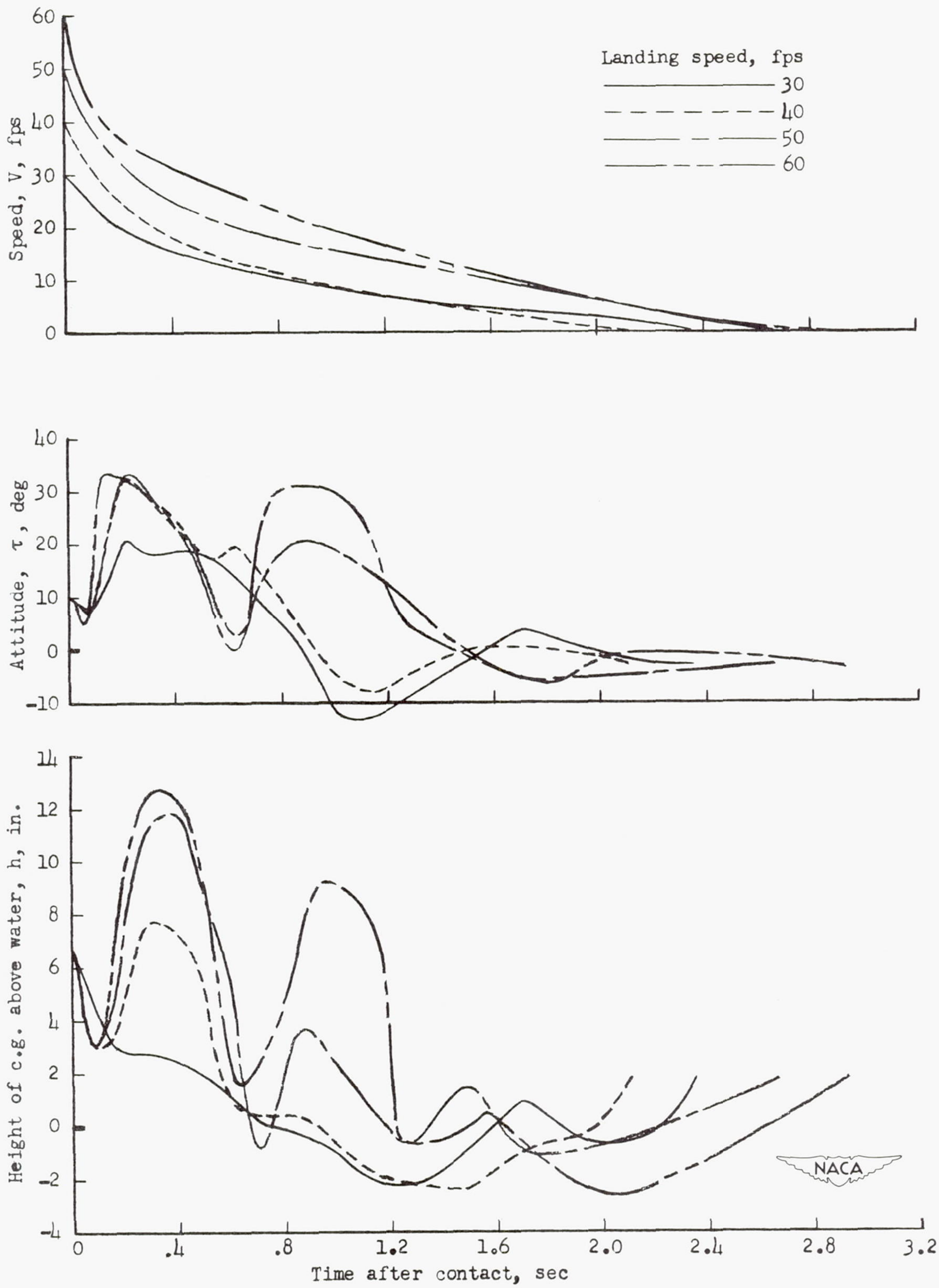


Figure 10.- Speed, attitude, and height time histories for model G.

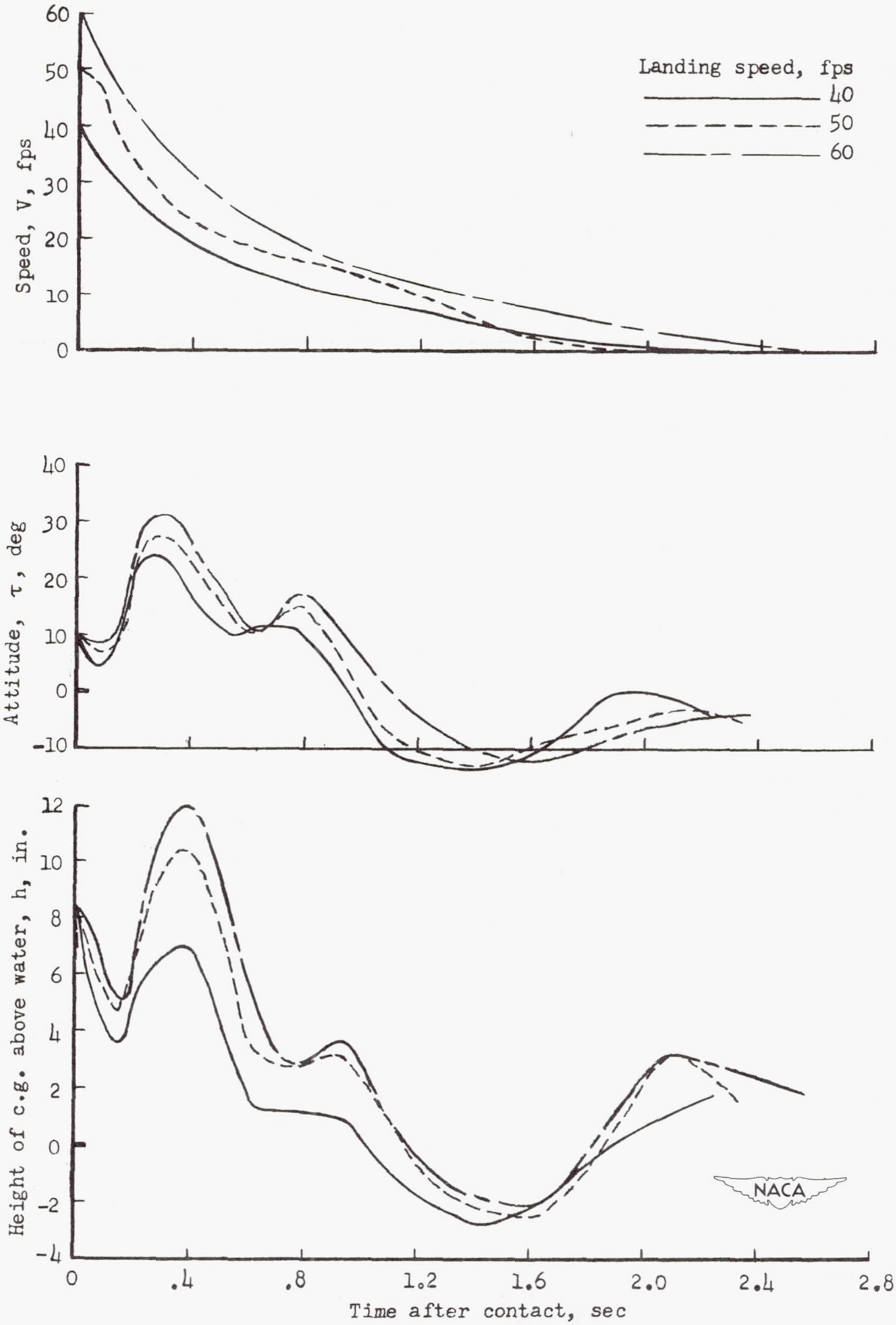


Figure 11.- Speed, attitude, and height time histories for model H.

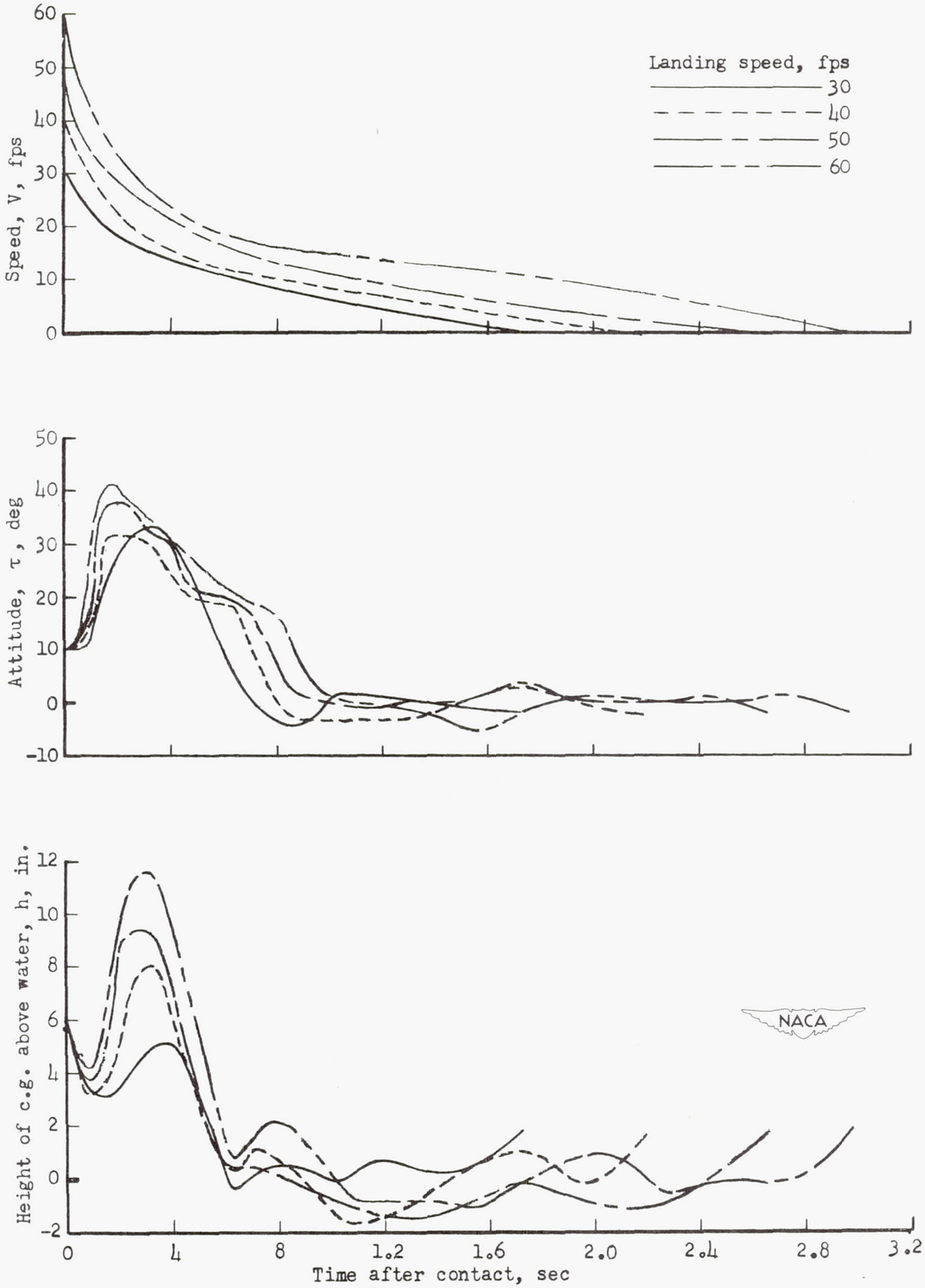


Figure 12.- Speed, attitude, and height time histories for model J.

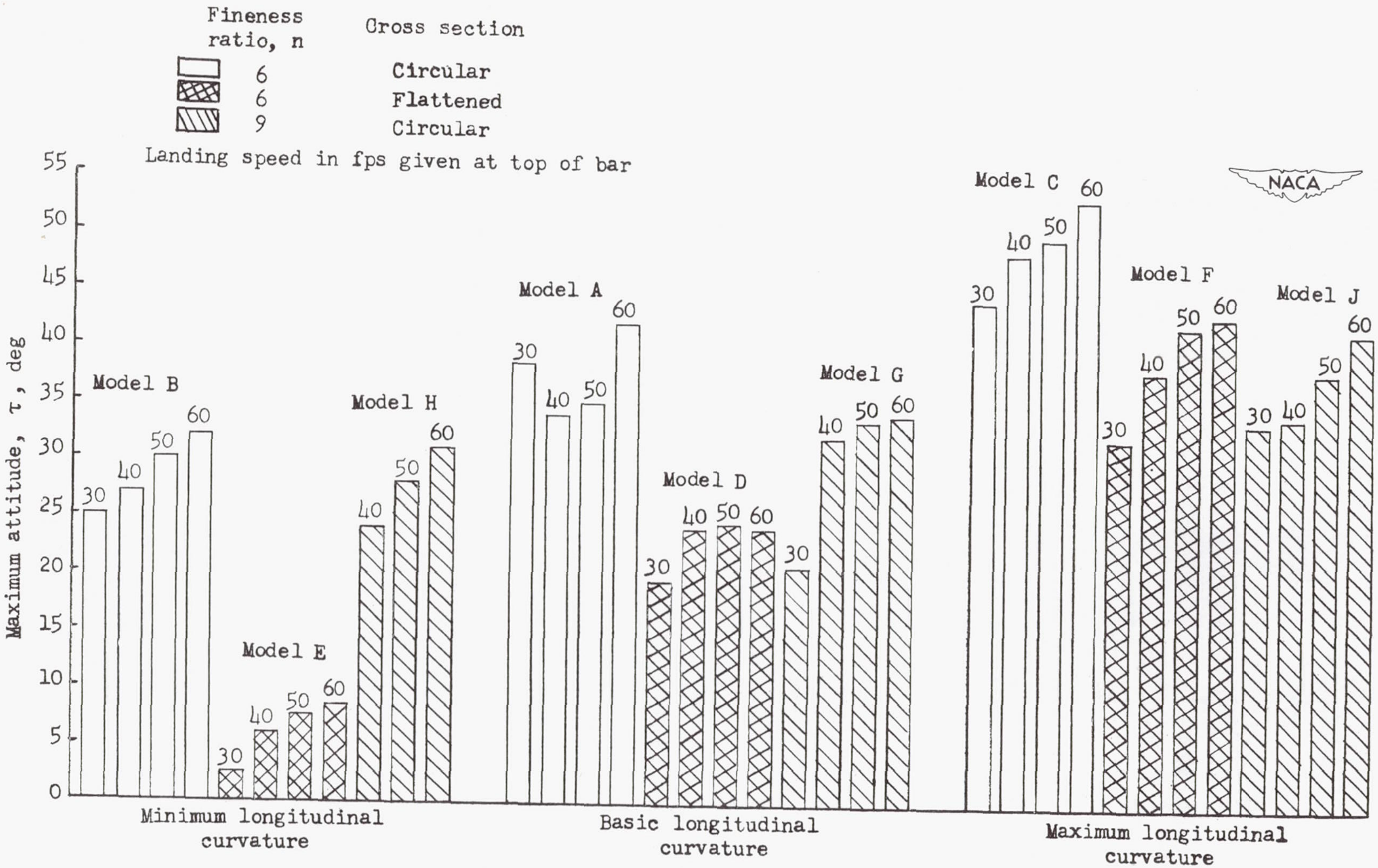


Figure 13.- Effect of rear-fuselage curvature changes on maximum attitude.

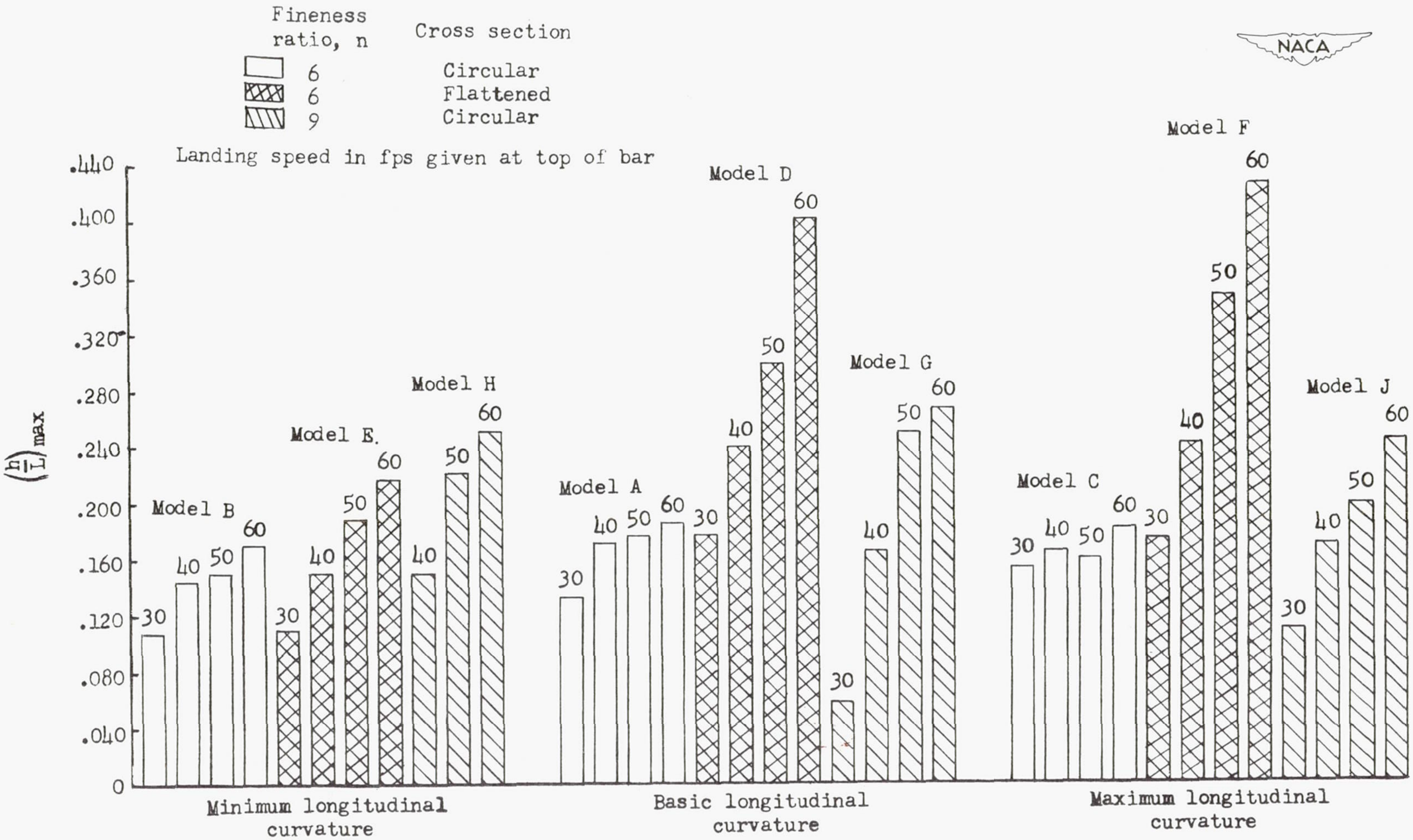


Figure 14.- Effect of rear-fuselage curvature changes on $\left(\frac{h}{L}\right)_{max}$

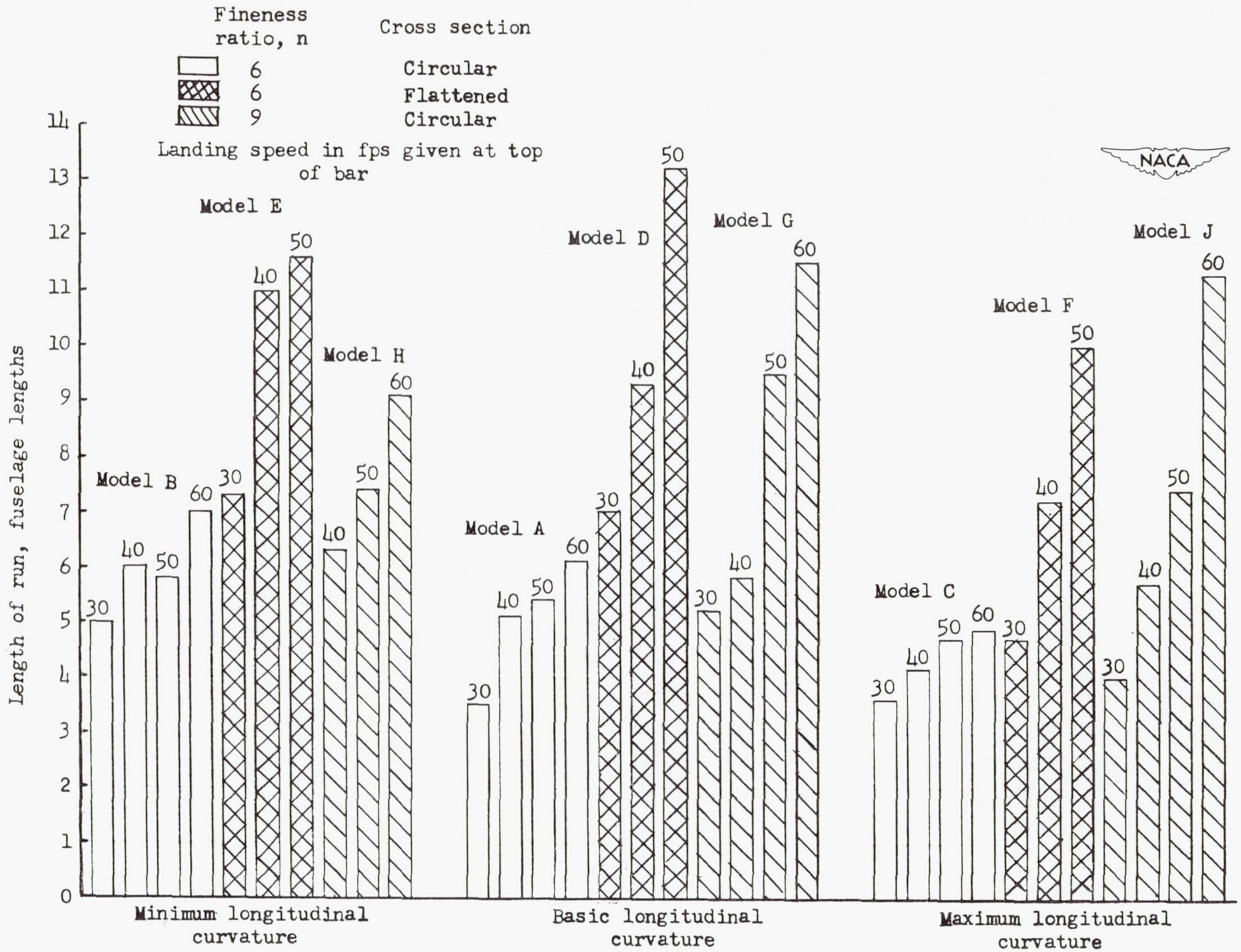


Figure 15.- Effect of rear-fuselage curvature changes on length of run.

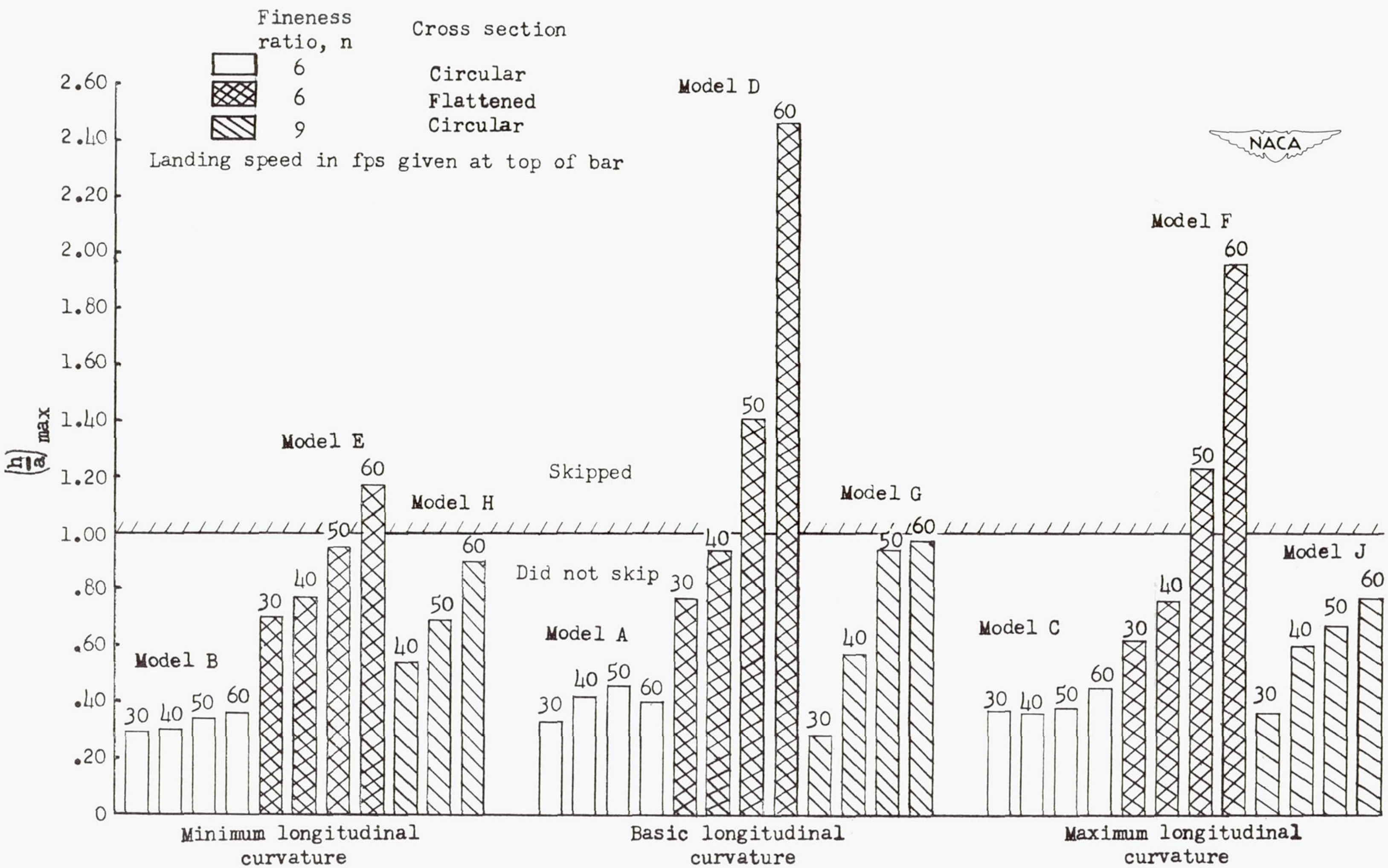


Figure 16.- Effect of rear-fuselage curvature changes on skipping tendency.

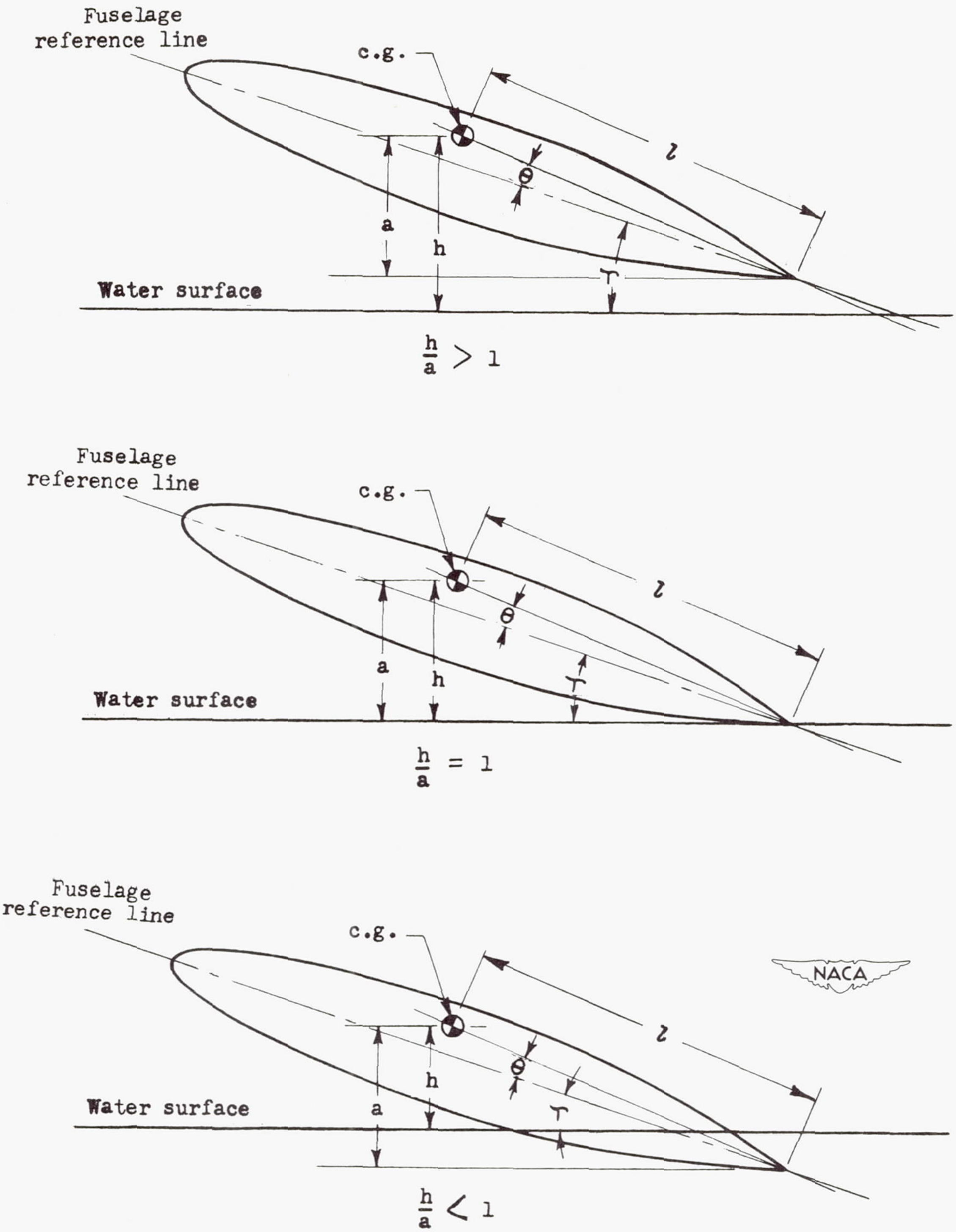


Figure 17.- Terms used to compare skipping tendency.

NACA-Langley - 4-28-53 - 1000