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RESEARCH MEMORANDUM

HYDRODYNAMIC DIRECTIONAL BEHAVIOR OF A SWEPT PLANING-TAIL HULL

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

A qualitative investigation of the low-speed directional behavior of a swept planing-tail hull was made in the Langley tank no. 2 in still water and still air with the use of a free self-propelled model. The configuration was directionally unstable over a range of low speed. It was, however, directionally controllable at all speeds by use of the rudder and elevator. Several modifications that were investigated did not improve the controllability.

INTRODUCTION

The general hydrodynamic characteristics of an aerodynamically refined, swept planing-tail hull were investigated in the Langley tank no. 2 and the results published in reference 1. Directional instability, which is found to some degree in most conventional hulls (reference 2), was noticed in the low-speed region during the towing tests (reference 1). The severity of the instability could not be determined in the tests of reference 1 since the model was restrained in yaw, and yawing motion was limited to that allowed by the elasticity of the system.

A qualitative investigation of the directional control and stability characteristics of this unconventional hull design has been made. This evaluation was obtained by operating the model in a free self-propelled condition in still water and still air at speeds up to approximately 50 percent of take-off speed. The various types of directional behavior which were encountered, and the control available by the use of the rudder and fixed-elevator settings are given in this paper. Brief investigations of the effects of several modifications also are given.

DESCRIPTION OF MODEL

A powered dynamic model of a swept-hull configuration, designated Langley tank model 237-6SB, was used for the directional-stability tests. A description of the model is found in reference 1. The general arrangement and hull lines are shown in figures 1 and 2, respectively.

The $\frac{1}{16}$ - scale model represented an assumed flying boat of 65,000 pounds gross weight with a wing loading of 35.6 pounds per square foot and a power loading of 14.8 pounds per horsepower. Tip floats, which were $\frac{1}{16}$ - scale models of those on the XPBB-1 flying boat, were installed as shown in figure 1. A rudder was installed which had an area of 44.1 square feet, full size. The rudder was actuated through a range of deflection from 30° right to 30° left by a quick-acting pneumatic motor.

Several modifications (fig. 3) were made in an attempt to improve the directional stability characteristics of the model. A triangular metal plate 0.03 inch thick, designated skeg A and having an area of 10.4 percent of the fin area, was fastened on the underside of the tail boom in the plane of symmetry (fig. 3(a)). A second skeg of less depth and an area of 6.2 percent of the fin area, designated skeg B, was similarly located (fig. 3(b)). Another modification consisted of small chine strips of triangular cross section glued to each side of the tail boom along most of its length, (fig. 3(c)).

APPARATUS AND PROCEDURE

The directional behavior was investigated with a free-model gear attached beneath the main towing carriage (fig. 4). This gear consisted of a framework and pulley system that allowed the model to be tracked by the tow, lift, power, and pneumatic lines.

The thrust was balanced between the two propellers to give zero yawing moment with the model suspended in the air at rest. The model was accelerated on the water, without thrust, to a constant speed by the tow line. Power was then applied and adjusted to render the model self-propelled. All lines were slacked during the test run.

Directional stability characteristics were investigated over a range of speed coefficient C_V from approximately 1.0 to 5.0. Speed coefficient is defined as

$$C_V = \frac{V}{\sqrt{gb}}$$

where

V model speed, feet per second

g acceleration due to gravity, feet per second per second

b maximum beam of model, feet

The tests were made with the center of gravity located at 30 percent mean aerodynamic chord $\bar{c}$ and with fixed elevator deflections from 20° to -30°. The modifications were tested with a fixed elevator deflection of 20°. The type of stability which existed at any speed and elevator position was determined from observations of the motions of the model with the rudder in neutral position. If the model was directionally stable with the rudder neutral, the degree of stability was determined by the amount of rudder deflection required to change heading. The response to rudder control for all types of stability was rated by the pilot in arbitrary ratings of controllability.

RESULTS AND DISCUSSION

The general types of directional stability are defined, for this particular investigation, by the motion of the model after being disturbed from a trimmed state about the orthogonal fixed axes.

Positive stability: The model held heading with neutral rudder. Rudder deflections of about 5° or more were required to change heading.

Neutral stability: The model tended to hold heading with neutral rudder. Only very small rudder deflections (less than 2°) were required to change heading.

Negative stability: The model did not hold heading with neutral rudder.

Oscillating stability: The model oscillated in yaw between relatively fixed yaw angles with neutral rudder.

The regions in which these types of directional stability were observed with the basic model are shown in figure 5. The model did not hold heading at any elevator deflection tested for speed coefficients from 2.6 to 3.0. Oscillating stability was observed in a range of speed coefficient from approximately 3.0 to about 4.6 at all elevator settings. Neutral stability was encountered after the tail boom was clear of the forebody roach at a speed coefficient of approximately 4.5. The regions that were uncontrollable with full rudder deflection are indicated on the plot.

In the speed-coefficient range for negative stability, the forebody roach rose vertically near the step point, impinging on the sides of the hull and the boom as sketched in figure 6. At zero yaw the flow was evenly divided and there was no marked tendency to yaw. At small angles of yaw the flow was greater on the side of the hull in the direction of the yaw and the yaw increased. A stable condition was reached when the yaw increased to such an angle that the roach cleared the hull.

In the speed-coefficient range for oscillating stability, the forebody roach cleared the sides of the hull and impinged only on the boom as sketched in figure 7. In this range, the direction of flow at the top of the roach moved the boom sideways, so that the angle of yaw was increased. The direction of the flow between the roach and the bow wave was such as to return the boom to the roach, and the angle of yaw was decreased. As a result, the boom oscillated between the bow wave and the roach or between the bow waves across the roach at a frequency of about 3 cycles per second.

At speed coefficients below which the roach was formed and above which the roach cleared the boom, the model had neutral stability, indicating that the forebody itself had little effect on the behavior described. At the higher speed coefficients where the tip floats were clear and the model could heel, it tended to yaw in the direction of heel but the yaw was easily controlled by small deflections of the rudder. This effect of heel was not considered in defining the upper range of neutral stability in figure 5.

The directional controllability of the model in response to the rudder was observed and rated by the pilot as follows:

0	no directional control
1	marginal directional control
2	fair directional control
3	good directional control

A plot of the directional controllability against speed coefficient is given in figure 8. The model was controllable with the up-elevator deflections in a range of speed coefficient from approximately 1.0 to 3.3. The directional control with up-elevators decreased rapidly with speed coefficient in the oscillating stability region. The model was uncontrollable with down-elevator deflections in a range of speed coefficient from approximately 2.7 to 3.0 where it continually changed heading. The directional control with down-elevator deflections changed abruptly as the region of oscillating stability was entered at a speed coefficient of approximately 3.0 and became good. This control decreased until a speed coefficient of approximately 4.0 was reached, where the control began to improve again as the speed at which the tail boom came clear of the water was approached.

From these results, it appears that, by properly trimming the model with the elevators within the speed regions where directional instability occurred, directional control can be maintained by the use of the rudder in still water and still air.

The effects of skegs and tail-boom chine strips on the controllability of the model with 20° elevator deflection are shown in figure 9. A plot for 20° elevator deflection for the basic model is also included for comparison in figure 9.

The unsatisfactory controllability rating of the configuration with skeg A for the entire speed range tested is believed due to the positive stability of this skeg. Skeg B produced the same effects as skeg A but to a lesser degree, as shown in figure 9.

The controllability rating of the model with chine strips installed along the tail boom was unsatisfactory between speed coefficients of approximately 2.6 to 4.0. The chine strips appeared effective in reducing the flow of the forebody roach over the tail, but it was observed that this model was more unstable than the basic configuration. Brief tests with 64 percent additional rudder area indicated a slight improvement of controllability but no effect on stability was apparent.

CONCLUSIONS

An investigation of the directional behavior of a powered dynamic model of the swept-hull flying boat indicated the following conclusions:

1. The configuration was directionally unstable over a range of speed coefficient from 2.6 to about 4.6 and neutrally stable below and above this range. It was, however, directionally controllable at all speeds by use of the rudder and elevator.

2. The controllability at a fixed elevator deflection was marginal or unsatisfactory and was not greatly improved by skegs or chine strips.

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REFERENCES

1. McKann, Robert E., Coffee, Claude W., and Arabian, Donald D.: Hydrodynamic Characteristics of a Swept Planing-Tail Hull. NACA RM L9D15, 1949.

2. Locke, F. W. S., Jr.: Some Yawing Tests of a $\frac{1}{30}$-Scale Model of the Hull of the XPB2M-1 Flying Boat. NACA ARR 3G06, 1943.

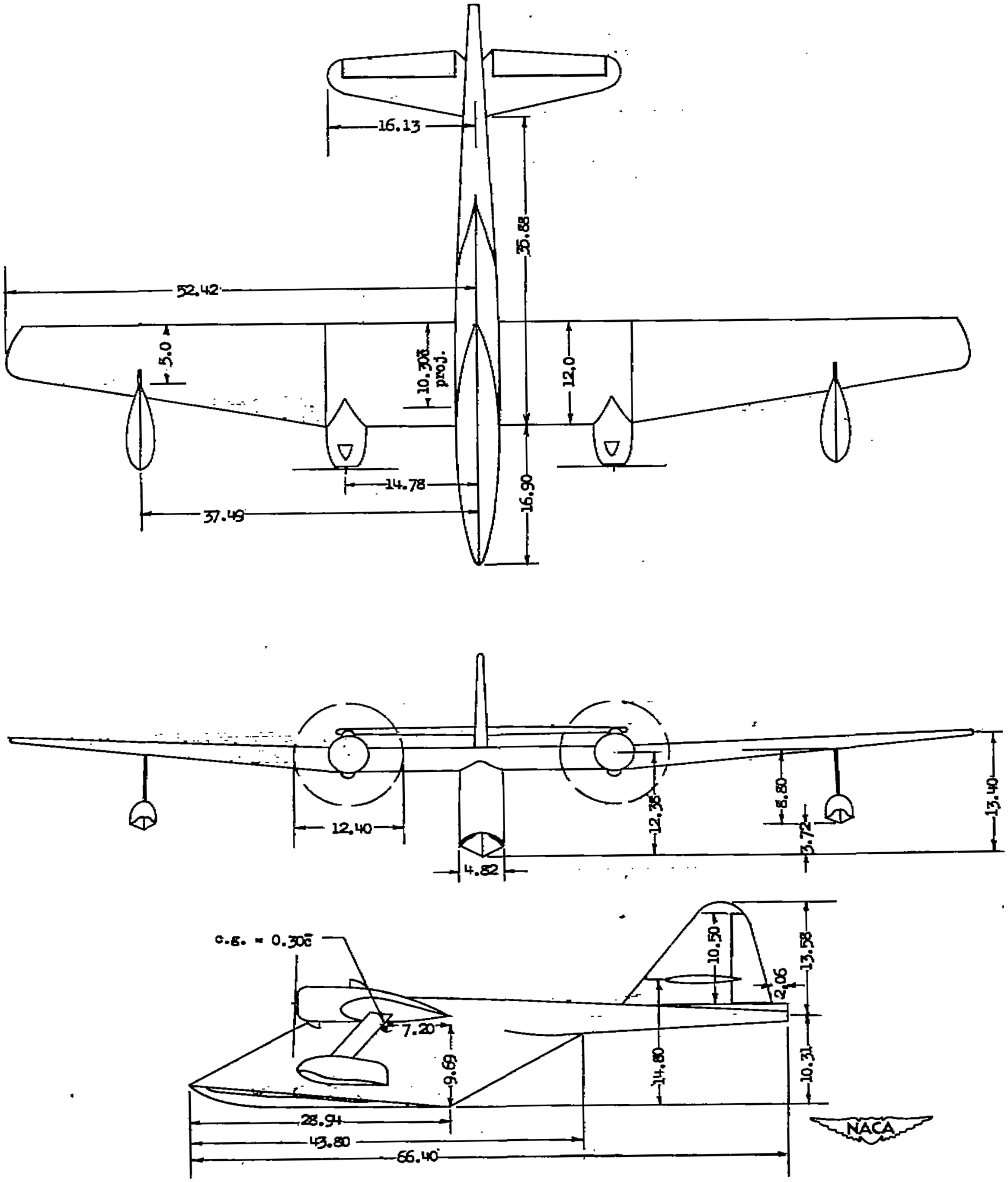

Figure 1.- General arrangement of Langley tank model 237-6SB.
(All dimensions are in inches.)

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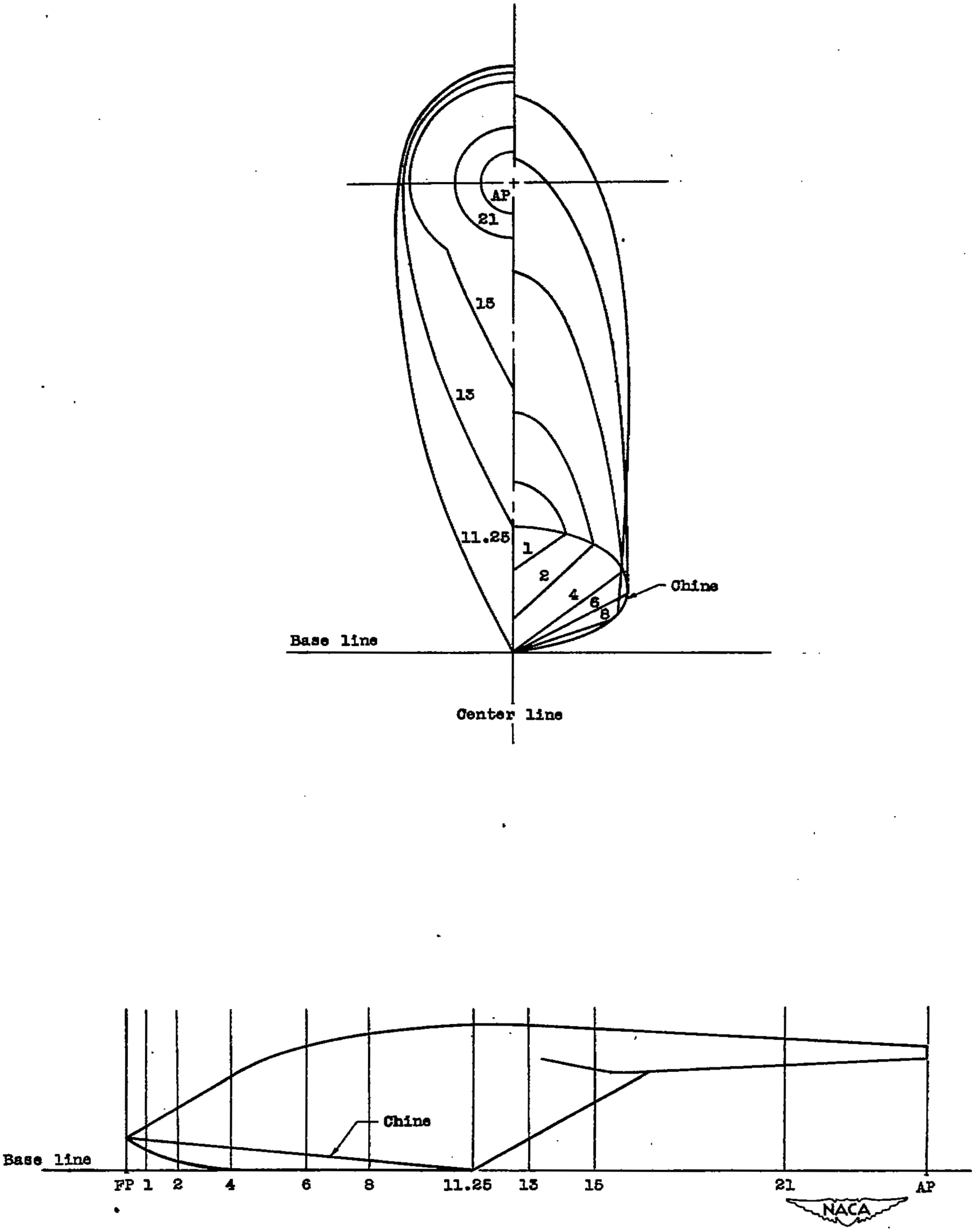
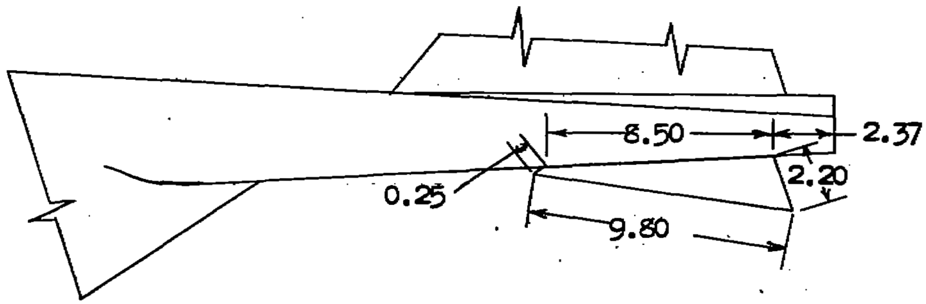
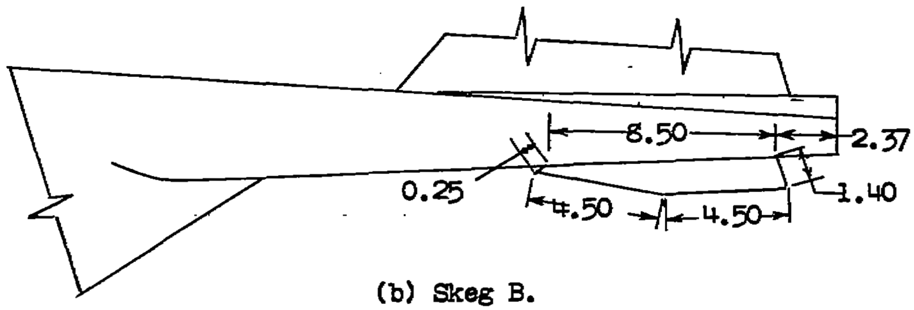


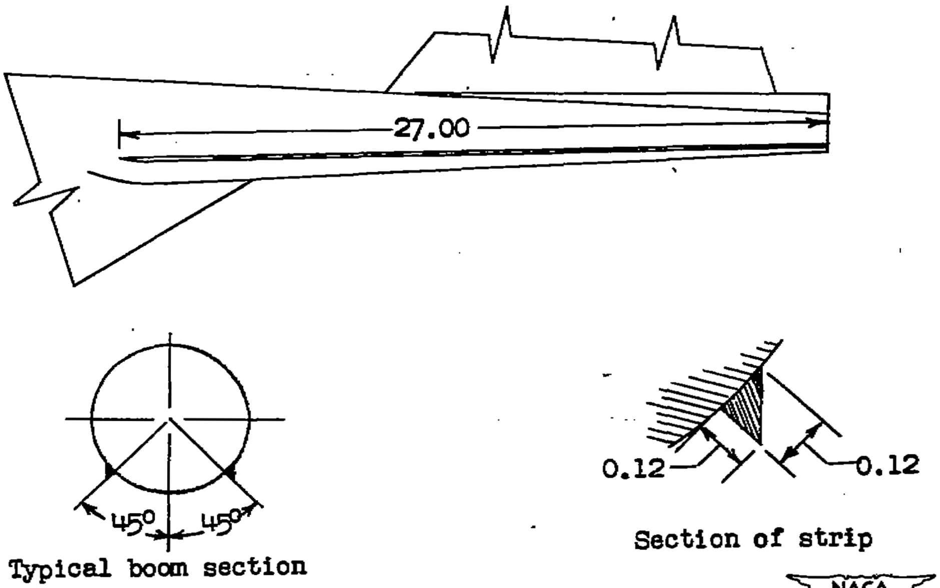
Figure 2.- Hull lines of Langley tank model 237-6SB.



(a) Skeg A.



(b) Skeg B.



(c) Chine strips.

Figure 3.- Modifications to Langley tank model 237-6SB. (All dimensions are in inches.)

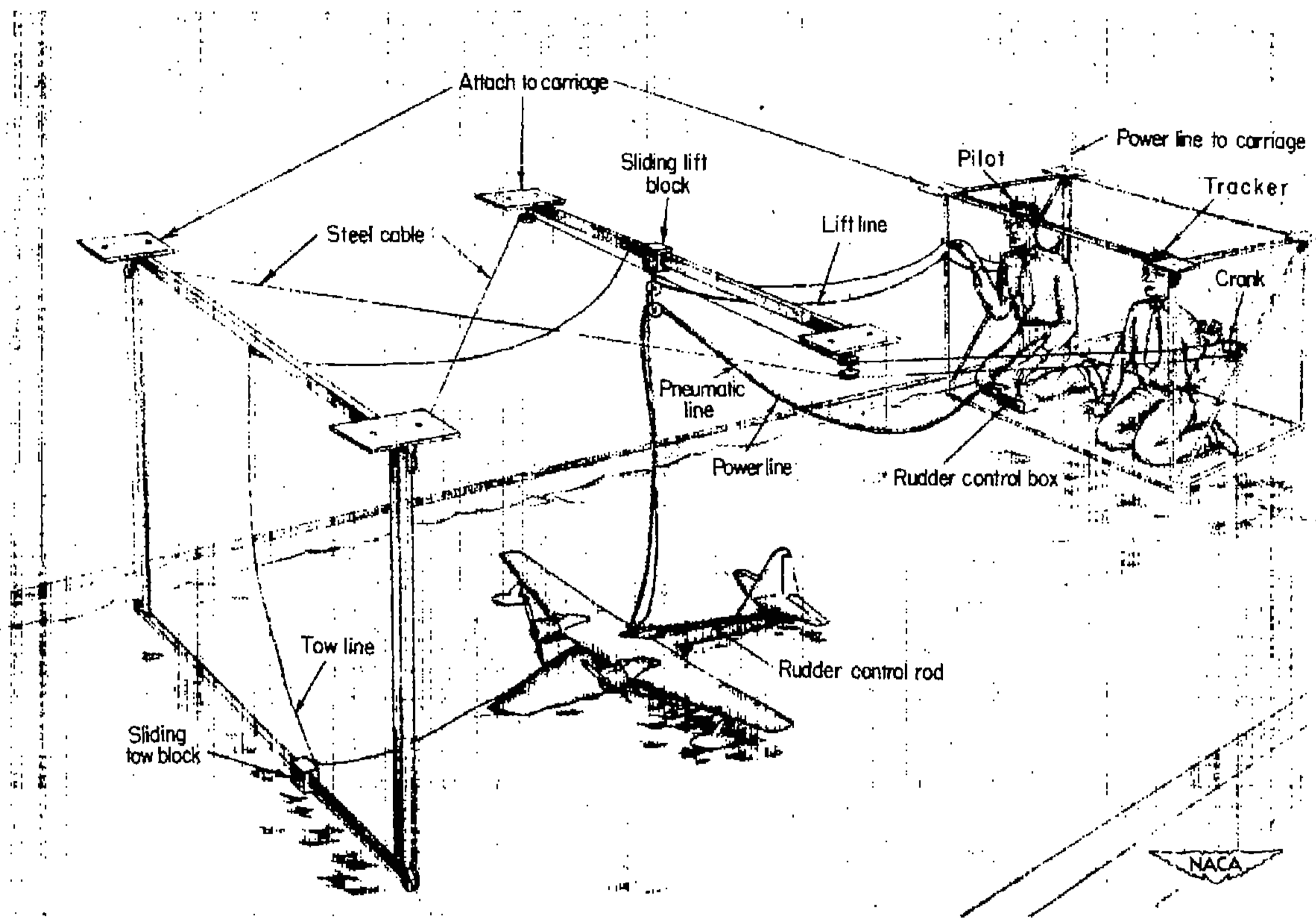


Figure 4.- Free-model testing gear.

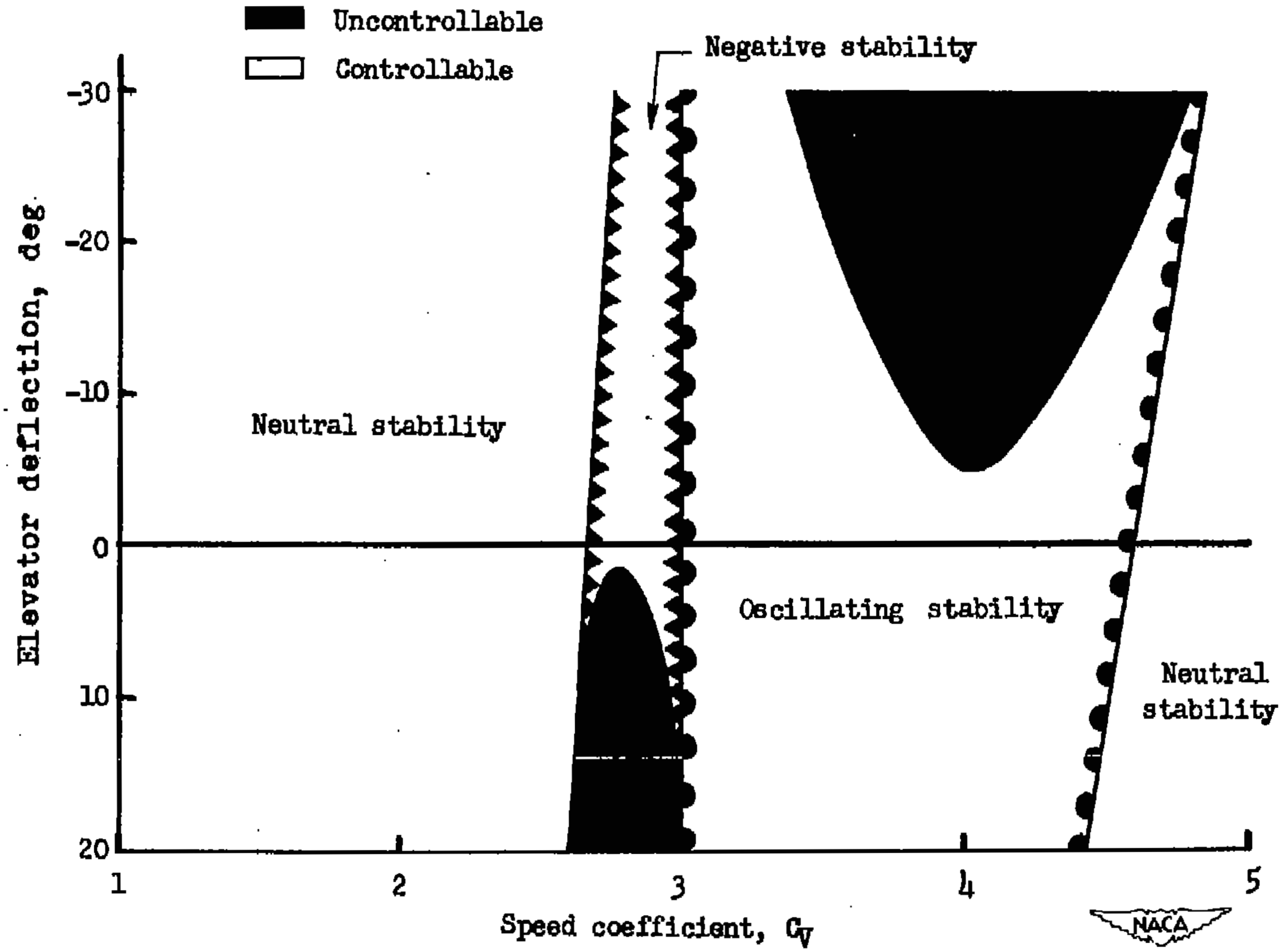


Figure 5.- Regions of directional stability for the basic model.

Figure 6.- General flow associated with negative stability for speed coefficients from 2.6 to 3.0.

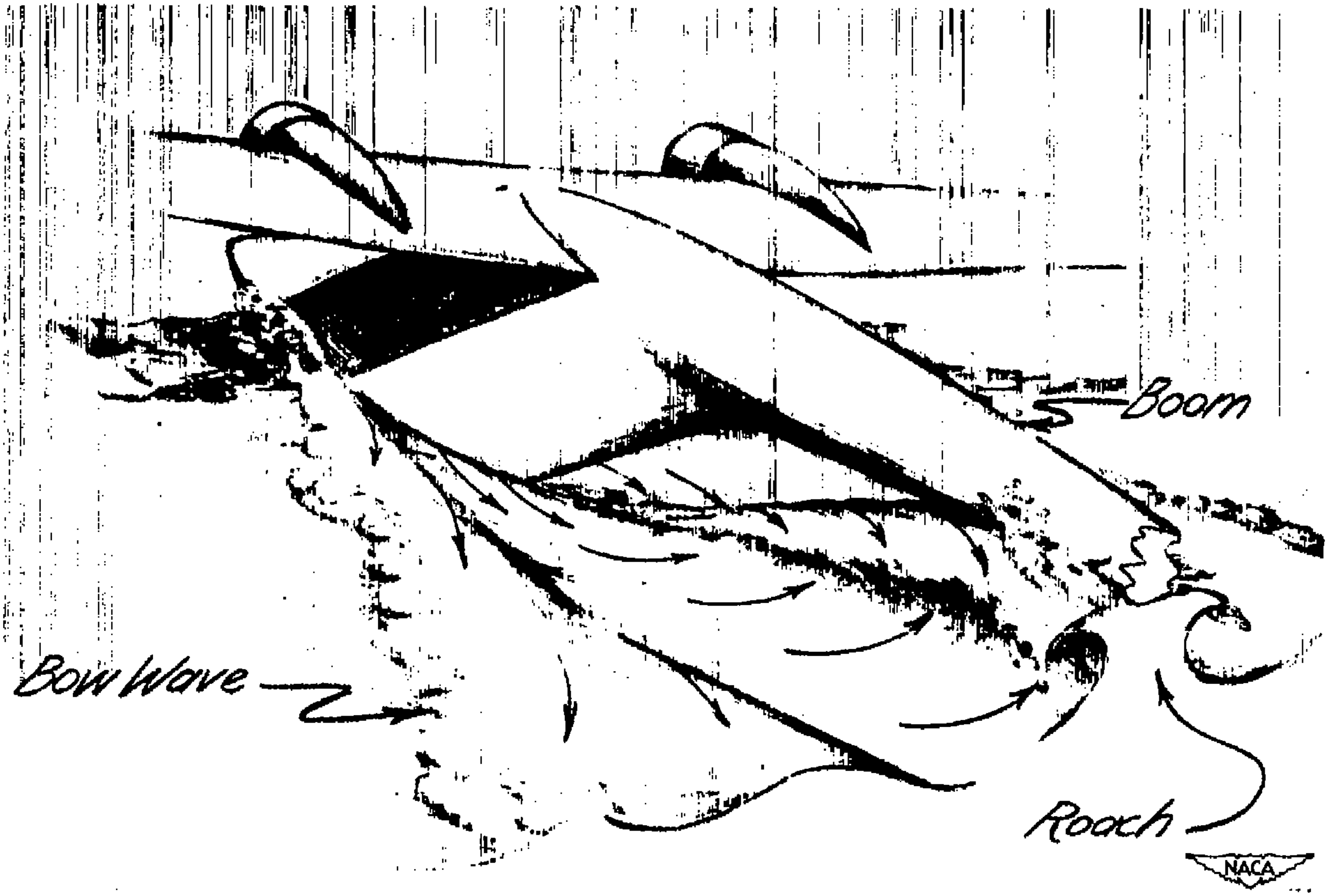


Figure 7.- General flow associated with oscillatory stability for speed coefficients from 3.0 to 4.6.

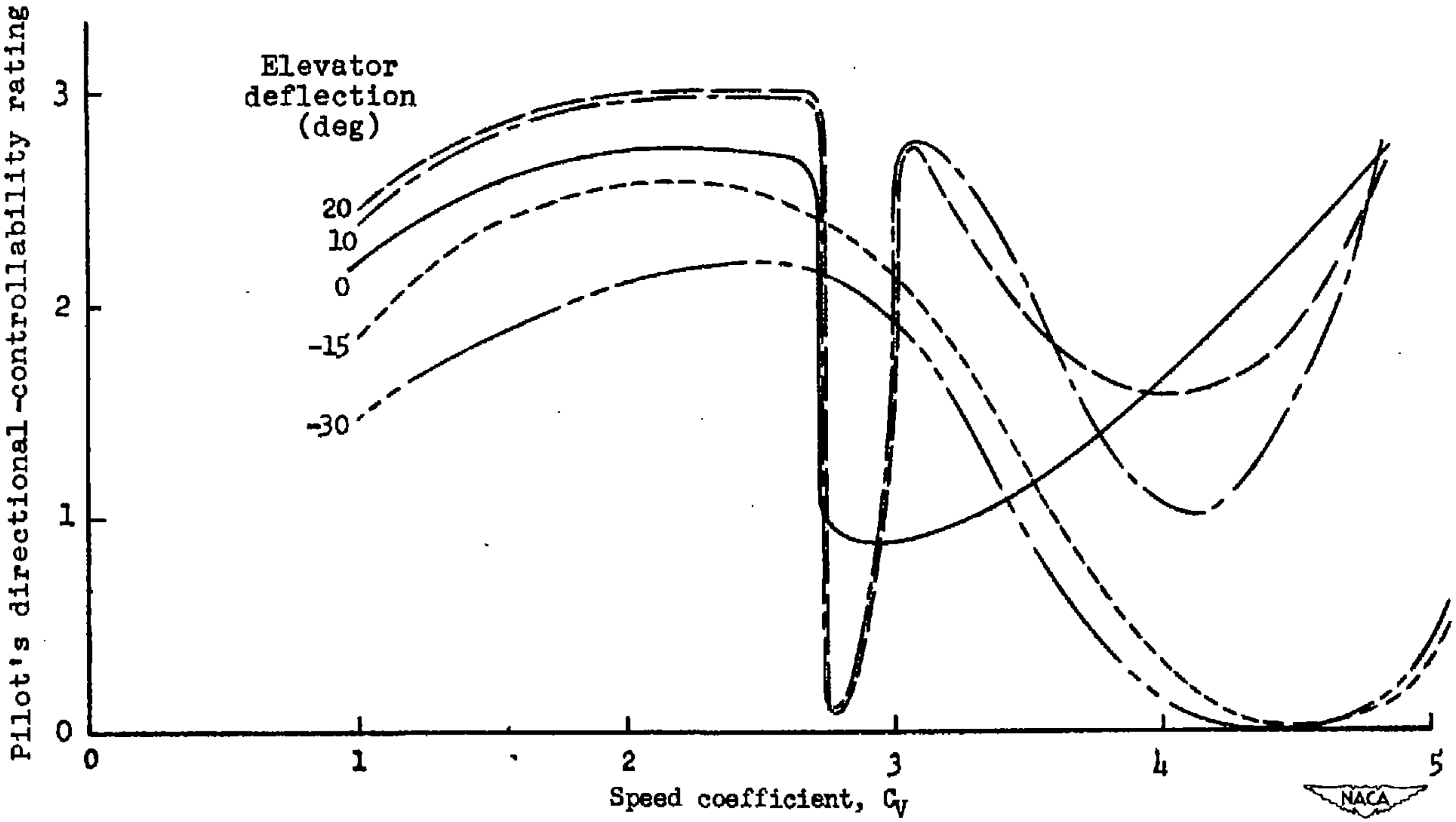


Figure 8.- Variation of low-speed directional controllability with elevator deflection for the basic model. Rudder deflection, ±30°.

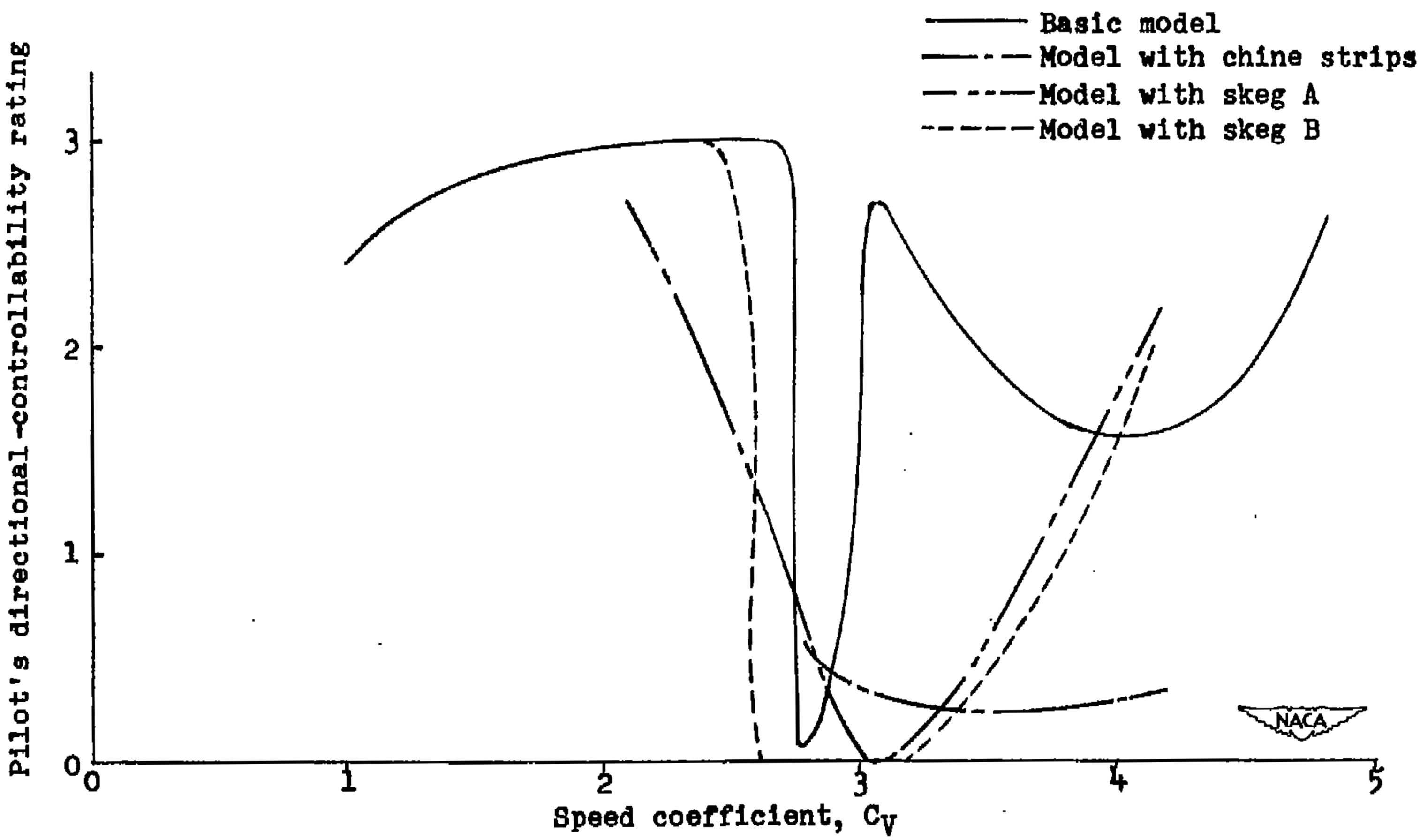


Figure 9.- Effect of chines and skegs on low-speed directional controllability. Elevator deflection, 20°; rudder deflection, ±30°.

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