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# RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

TANK INVESTIGATION OF THE EDO MODEL 142

HYDRO-SKI RESEARCH AIRPLANE

By John A. Ramsen, Kenneth L. Wadlin, and  
George R. Gray

Langley Aeronautical Laboratory  
Langley Field, Va.

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## RESEARCH MEMORANDUM

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## TANK INVESTIGATION OF THE EDO MODEL 142

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## SUMMARY

A tank investigation has been conducted of a  $\frac{1}{10}$ -size powered-dynamic model of the Edo model 142 hydro-ski research airplane. The results of tests of two configurations are presented: One included a large ski and a ski well; the other, a small ski without a well. Water take-offs would be possible with the available thrust for either configuration; however, the configuration with the large ski emerged sooner and had less resistance from ski emergence until take-off. Longitudinal stability and landing behavior in smooth water were satisfactory for both configurations. Some alteration to the design of the tail would be desirable in order to reduce the spray loads.

## INTRODUCTION

The NACA has been conducting an investigation of the use of retractable lifting surfaces, called hydro-skis, the purpose of which is to provide acceptable water landing and take-off characteristics for high-speed aircraft without compromising flight performance. (See reference 1.)

Results of model tests of the Grumman JRF-5 airplane equipped with tandem hydro-skis suitable for operation on snow and ice as well as on water were presented in reference 2 and results of full-scale tests of this configuration were given in reference 3. As a next step, the Edo Corporation presented a proposal to the Air Force for the construction of a research airplane which had take-off and landing speeds comparable to those of a modern high-speed fighter. This airplane also incorporated

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other characteristics of high-speed operational aircraft, such as jet propulsion and swept wings. The airplane was to be capable of operation from water, snow, and ice and for this purpose was fitted with a main ski, a tail ski, and wing-tip skids.

At the request of the U. S. Air Force, an investigation was conducted in Langley tank no. 2 in cooperation with the contractor to determine a hydrodynamically satisfactory configuration for this airplane.

This paper presents the results of tests of two configurations, either of which might be used for the full-scale airplane. One configuration included a large ski and a ski well; the other, a small ski without a well. These two configurations were selected after an investigation of the effects on the hydrodynamic characteristics of the various design parameters involved. These parameters included ski angle, vertical and horizontal location of the ski. Data from these preliminary tests were not of a nature to permit extensive generalizations on the properties of hydro-skis and therefore are not presented herein.

#### DESCRIPTION OF MODEL

A  $\frac{1}{10}$ -size powered-dynamic model of the proposed airplane was constructed at the Langley Laboratory for use in the tank investigation. The general arrangement of the model is shown in figure 1. Photographs of the model are shown in figure 2. The principal characteristics of the airplane are presented in table I.

Tests in the Langley 300 MPH 7- by 10-foot tunnel (reference 4) indicated that the stability of the original design would be improved by refairing the aft portion of the fuselage to reduce its curvature and by adding a thin plate extending aft of the sternpost. These changes were incorporated in the tank model (see figs. 1 and 2) and all results presented are for the model thus modified.

The model was equipped with movable ruddervators of scale dimensions. Scale-size versions of the wing slats and fences to be included in the full-scale airplane were installed on the model.

The original proposal included a relatively small main ski together with a well to permit retraction into the fuselage. In preliminary tests this configuration had more resistance than the thrust available for take-off with the proposed power plant. Elimination of the ski well reduced the resistance sufficiently to permit take-off with this ski. Since retraction into a well remained desirable aerodynamically, a larger main ski with a matching well geometrically similar to the original was

also tested. This ski provided greater lift and therefore reduced the load on the fuselage permitting take-off with the available thrust even with the well.

The lines of the large main ski, which is the ski shown in figures 1 and 2, are presented in figure 3. The lines, in general, were similar to those of the main ski used in the tests of reference 2 except that the dead rise was "washed out" toward the stern to provide a better fairing with the well when in the retracted position while the upper surface was refaired to eliminate the vertical sides. This ski had a loading of 365 pounds per square foot (full size). The small main ski which had a loading of 475 pounds per square foot (full size) was a 0.88-scale model of the large main ski shown in figure 3.

The location of the large main ski can be seen in figure 1. The small main ski was placed so that its pivot point (see fig. 3) would be in the same position in relation to the fuselage. Both skis were attached to the fuselage by the faired struts shown in figure 3. The skis were fixed in trim since they were to be fixed for water operation on the full-size airplane. For snow and ice operation they would be free to pivot about the pivot point shown.

The tail ski was a 0.42-scale model of the large main ski. The wing-tip skids are shown in figure 4.

Scale power for the model (3500 lb static thrust, full size) was supplied by a jet ducting system and an ejector (see fig. 5) operated by compressed air. The duct had to be split just aft of the entrance to permit insertion of the towing staff. This arrangement did not allow scale air inflow to be obtained. The tests of reference 5, however, indicated that the jet air inflow had only a slight effect on the hydrodynamic characteristics.

## APPARATUS AND PROCEDURE

### Take-Off Tests

General.- The test setup with the model floating at the test gross weight (7,850 lb, full size) is shown in figure 6. The model was free to trim about the center of gravity and free to rise but was restrained laterally and in roll and yaw. Trim is defined as the angle between the undisturbed water surface and the fuselage reference line.

The ruddervators were movable over a range of deflections from  $-30^{\circ}$  to  $+30^{\circ}$  measured perpendicular to the hinge line.

In these tests the tail ski and the wing-tip skids were kept in the retracted position. For the full-scale tests on water proposed by the Edo Corporation the tail ski would remain retracted while the vertical position of the tip skids would be programmed so that they would normally not be operated in a submerged position.

Compressed air for the jet unit was supplied through a hose which can be seen in figure 6. Before data were taken, tests were run to determine a suitable hose arrangement. An arrangement was found which, with normal operating pressure in the hose but with no air flow, gave no measurable effect on the trim and rise of the model.

Longitudinal stability.- The variation of trim with speed for several locations of the center of gravity and several ruddervator settings was determined during runs at an acceleration of 1.0 foot per second per second and with full power. The range of available center-of-gravity and ruddervator positions which would permit take-off without porpoising of greater than  $2^\circ$  oscillation in trim was determined from these runs.

In order to find the trim limits of stability the model was towed from the normal center of gravity ( $0.238\bar{c}$ , where  $\bar{c}$  is the mean aerodynamic chord) at constant speeds with full power. The trim was slowly increased or decreased by use of the ruddervators until porpoising began or maximum ruddervator deflection was reached.

Resistance.- The resistance tests were run at constant speeds with no power and with the model fixed in trim. The range of trims tested at each speed corresponded to the range of stable trims found in the stability tests at the normal center of gravity.

#### Landing Tests

Landing tests were made with the model balanced about the normal center of gravity ( $0.238\bar{c}$ ) and the ruddervators set to maintain the desired trim while in the air. The model was launched with no power as a free body with zero roll and yaw from the Langley tank no. 2 monorail in smooth water. The data were obtained by means of motion pictures and visual observations.

During the landing tests, the wing-tip skids were extended to provide additional lateral stability.

## RESULTS AND DISCUSSION

## Take-Off Tests

General.- Sequence photographs of a typical take-off run with the large-ski configuration are shown in figure 7. The model rose onto the skis between 20 and 30 miles per hour (full size). For the small ski configuration the emergence occurred between 30 and 40 miles per hour (full size).

Emergence instability, which had been present in the tests of reference 2, was not evident in this case. Instead there was a fairly smooth transition from the submerged to the planing stage.

No spray was observed to enter the duct at any speed. Spray on the tail surfaces near the fuselage was heavy just after emergence suggesting that some alteration to the tail design might be desirable.

Longitudinal stability.- Trim tracks for several ruddervator settings at the normal center of gravity are shown in figure 8. The curves indicate that emergence was less abrupt with the large-ski configuration though no emergence instability was encountered with either configuration. When using the large ski, trims were about  $1^{\circ}$  lower before the start of emergence and  $2^{\circ}$  to  $4^{\circ}$  lower in the planing stage after emergence. Trims at emergence were approximately the same.

The trim limits of stability at the normal center of gravity are presented in figure 9(a) for the two configurations. The upper limit above which porpoising occurred was found over a very short speed range for both configurations but appeared at lower speeds with the large ski. The porpoising was very mild and no lower branch of the upper limit was found.

The lower limit below which porpoising occurred was encountered at rather high trims just after emergence but quickly dropped to lower trims as the speed was increased. Lower-limit porpoising began at trims  $2^{\circ}$  to  $4^{\circ}$  lower with the large ski than with the small ski. The same ruddervator setting, however, normally gave several degrees less trim for the large ski than for the small ski over the range of speeds during which lower-limit porpoising occurred. The over-all effect on the range of stability is indicated in figure 9(b) which shows the center-of-gravity limits of stability determined at an acceleration of 1.0 foot per second per second. The lower limits for the two configurations were very similar, with the limit for the small ski being at a slightly higher ruddervator setting at the aft center-of-gravity locations.

No upper-limit porpoising was encountered at center-of-gravity locations forward of 32 percent mean aerodynamic chord over the range of available ruddervator deflections. The slight upper-limit porpoising that was found at farther aft locations occurred at the same settings for the two configurations. At the normal center of gravity ( $0.238\tau$ ) there was a ruddervator range of  $27.5^\circ$  for which no porpoising occurred.

Resistance.- Curves of total resistance and the corresponding trim and rise are shown in figure 10. The total resistance includes both the water resistance and the air drag of the complete model and is the envelope of minimum resistance obtained from fixed trim tests over the stable range of trims. A curve showing the estimated available thrust from the proposed power plant is also included in the figure. Excess thrust was available at all speeds so that take-off would be possible for either configuration.

The resistance for the two configurations was the same until a speed of about 35 miles per hour was reached. Above this speed the resistance of the configuration with the large ski was less than that with the small ski until just before take-off when the two were equal.

The curves showing the corresponding trims indicate that this reduction in resistance accompanied a reduction in trim attained by using the large ski. Trims with this configuration were lower than those with the small ski configuration for all speeds except those between 20 and 40 miles per hour during which emergence of both configurations onto the skis took place and those near take-off when the trims were the same. The rise for the large-ski configuration was greater at all speeds.

#### Landing Tests

Sequence photographs of a typical landing of the large-ski configuration in smooth water at  $10^\circ$  trim are presented in figure 11. The behavior of the model with either ski configuration was essentially the same. In both cases, the model held a nearly constant trim while planing on the ski for the major portion of the run. Just before submergence, the trim increased until the tail of the model entered the water. The model then trimmed down and the main ski submerged so that the model came to rest on the fuselage.

Some landings were also made at  $16^\circ$  trim with the large ski. In these landings the model trimmed down immediately upon contact with the water to essentially the same trim as attained in the landings at  $10^\circ$  trim. From this point the  $16^\circ$  landings followed the same pattern as the  $10^\circ$  landings.

The model was very stable longitudinally and in yaw and roll during the landing run.

#### CONCLUDING REMARKS

In a tank investigation of a  $\frac{1}{10}$ -size powered-dynamic model of the Edo model 142 hydro-ski research airplane, two configurations have been evaluated: One configuration included a large ski having a loading of 365 pounds per square foot with a well into which the ski might be retracted; the other configuration included a small ski having a loading of 475 pounds per square foot but did not include a well. The tests indicated the following results:

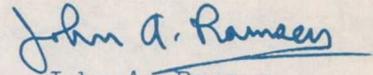
1. Water take-offs would be possible with the thrust available from the proposed power plant for either configuration. The configuration with the large ski emerged onto the ski at a lower speed and had less resistance from emergence to take-off.

2. Both configurations possessed adequate longitudinal stability for water operation with little difference between them.

3. Landing behavior in smooth water was satisfactory for both configurations.

4. Some alteration to the design of the tail would be desirable in order to reduce the spray loads.

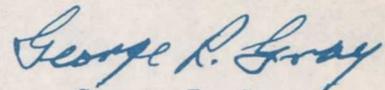
Langley Aeronautical Laboratory  
National Advisory Committee for Aeronautics  
Langley Field, Va.



John A. Ramsen  
Aeronautical Research Scientist

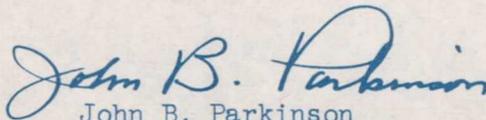


Kenneth L. Wadlin  
Aeronautical Research Scientist



George R. Gray  
Engineering Aide

Approved:



John B. Parkinson  
Chief of Hydrodynamics Division

mjw

## REFERENCES

1. Dawson, John R., and Wadlin, Kenneth L.: Preliminary Tank Tests of NACA Hydro-Skis for High-Speed Airplanes. NACA RM L7104, 1947.
2. Wadlin, Kenneth L., and Ramsen, John A.: Tank Investigation of the Grumman JRF-5 Airplane Fitted with Hydro-Skis Suitable for Operation on Water, Snow, and Ice. NACA RM L9K29, 1950.
3. Anon.: Summary Report on USAF Project MX-940. Rep. 2719, Edo Corp., April 5, 1949.
4. Riebe, John M., MacLeod, Richard G., and Moseley, William C., Jr.: Stability and Control Characteristics at Low Speed of a  $\frac{1}{5}$ -Scale Model of the Edo 142 Hydro-Ski Research Airplane. NACA RM SL51E10, U. S. Air Force, 1951.
5. Wadlin, Kenneth L., and Ramsen, John A.: Tank Spray Tests of a Jet-Powered Model Fitted with NACA Hydro-Skis. NACA RM L8B18, 1948.

TABLE I  
 CHARACTERISTICS OF FULL-SCALE HYDRO-SKI  
 RESEARCH AIRPLANE

## General:

Test gross weight, lb . . . . .	7,850
Engine type . . . . .	Westinghouse J-34
Rated thrust (static), lb . . . . .	3,500

## Principal areas:

Wing (total), sq ft . . . . .	182.25
Ailerons (each), sq ft . . . . .	9.82
Slats (each), sq ft . . . . .	5.14
Stabilizer, sq ft . . . . .	55.68
Ruddervators (each), sq ft . . . . .	8.00

## Principal dimensions:

## General -

Span (including tip floats), in. . . . .	345.0
Length, in. . . . .	508.5
Height, in. . . . .	123.0

## Wing -

Chord (parallel to airplane center line), in. . . . .	81.0
Aspect ratio . . . . .	4
Taper ratio . . . . .	1
Incidence, deg . . . . .	2.5
Dihedral, deg . . . . .	-2.0
Sweepback, deg . . . . .	35.0
Airfoil section (normal to leading edge) . . . . .	NACA 64 <sub>1</sub> -412

## Slats -

Type . . . . .	Fixed, external
Chord, in. . . . .	9.62
Span, in. . . . .	77.0

## Empennage -

Span (true), in. . . . .	201.0
Chord (true), in. . . . .	45.0
Incidence, deg . . . . .	1.0
Dihedral, deg . . . . .	45.0
Airfoil section . . . . .	NACA 64-009



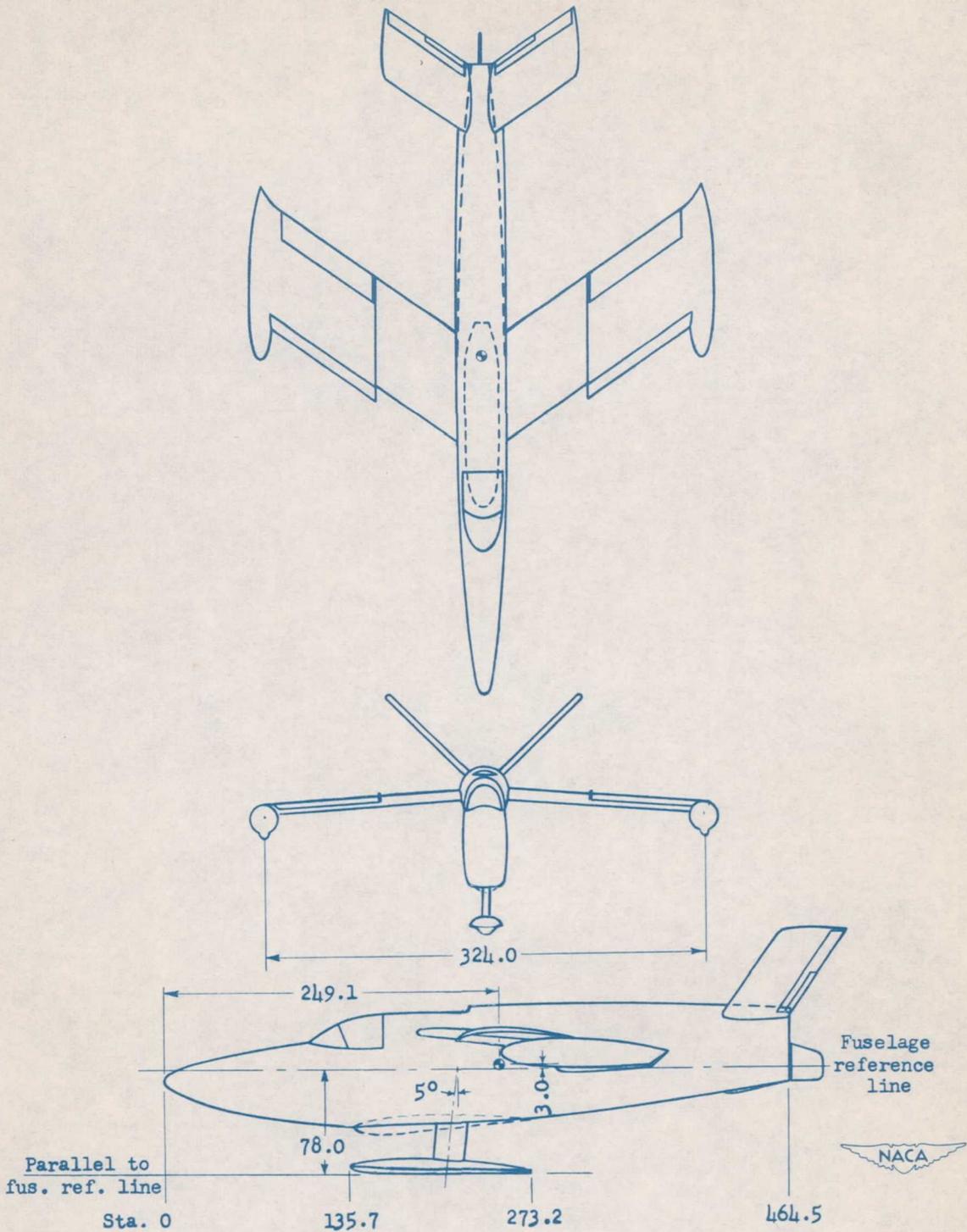


Figure 1.- General arrangement of  $\frac{1}{10}$  - size powered dynamic model of the Edo model 142 hydro-ski research airplane with the large ski installed. (Dimensions are inches, full size.)

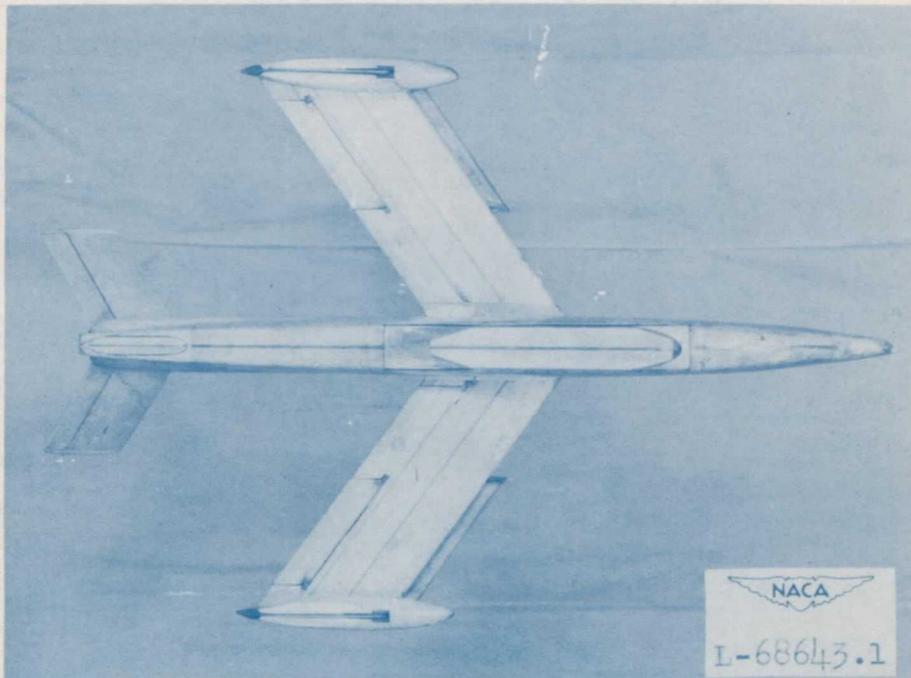
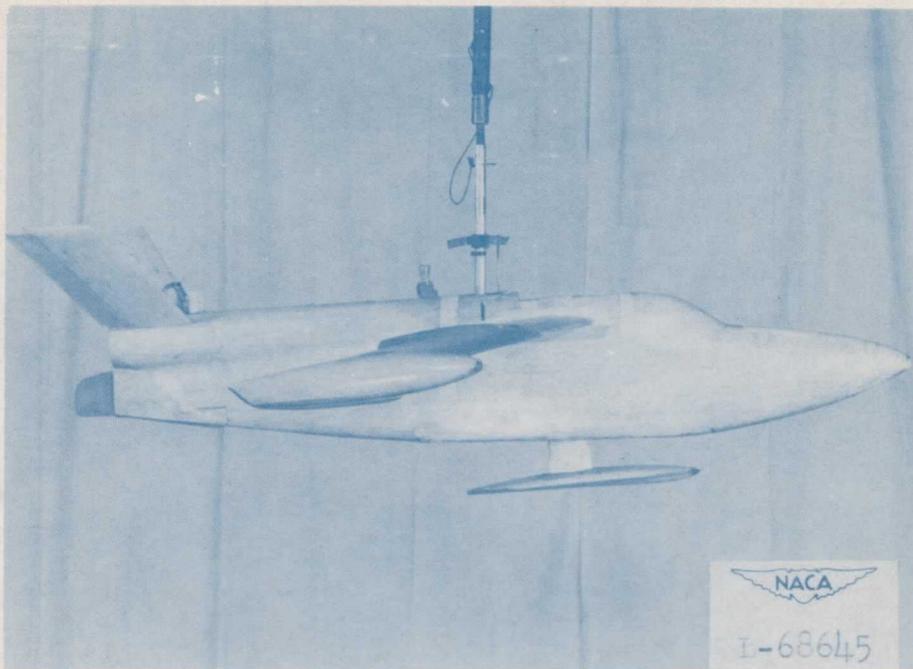


Figure 2.- Photographs of  $\frac{1}{10}$ -size model of the Edo model 142 hydro-ski research airplane with the large ski installed.

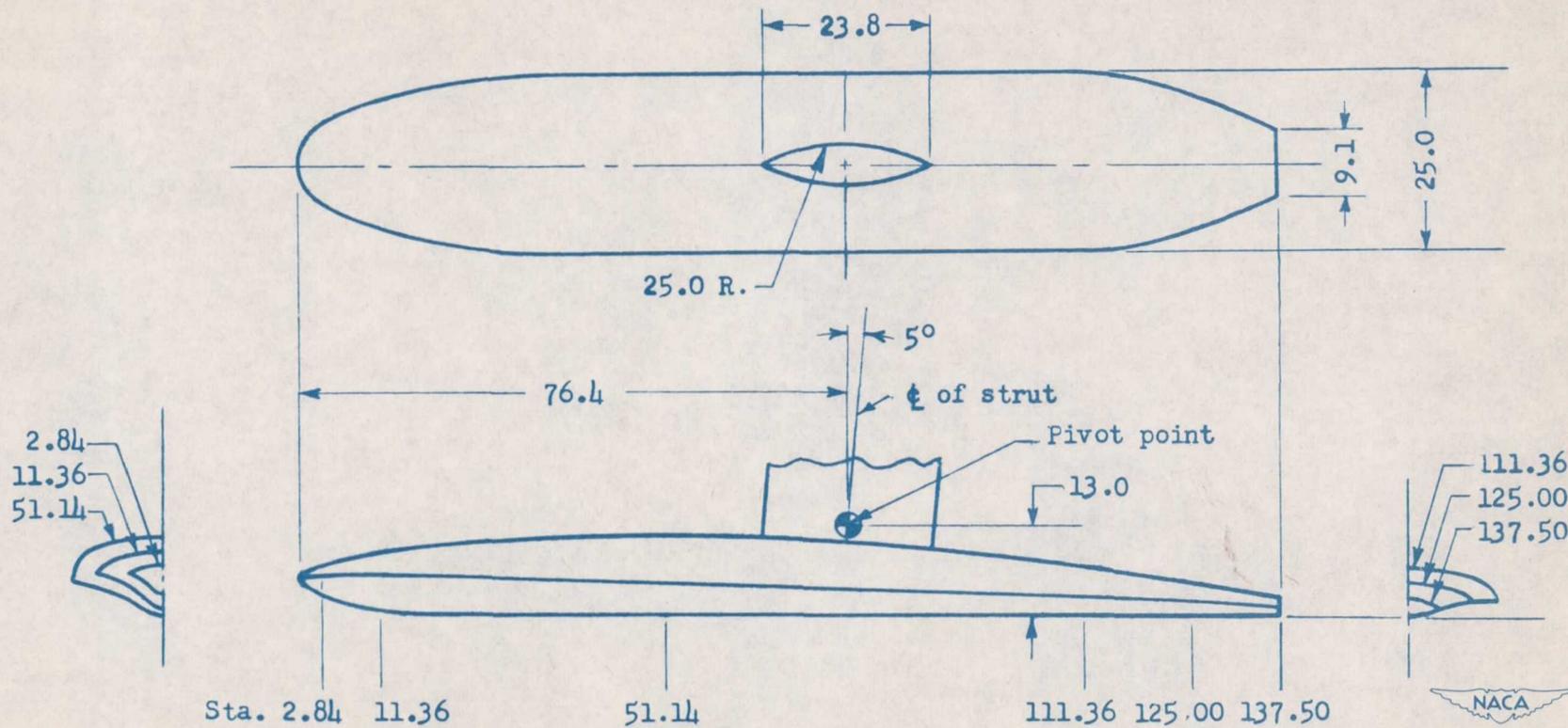


Figure 3.- Details of large main ski. (Dimensions are inches, full size.)

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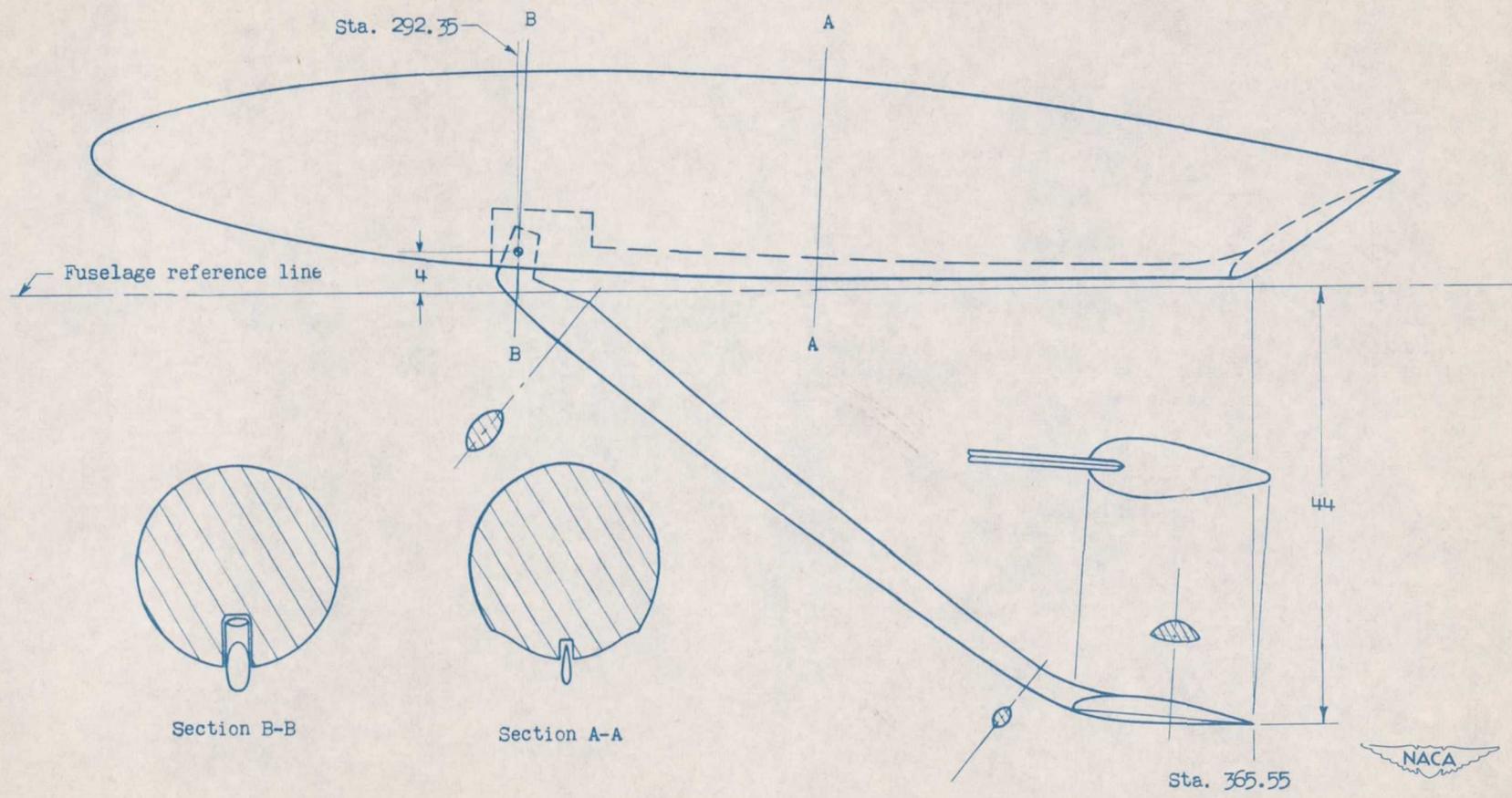


Figure 4.- Wing-tip skids. (Dimensions are in inches, full size.)



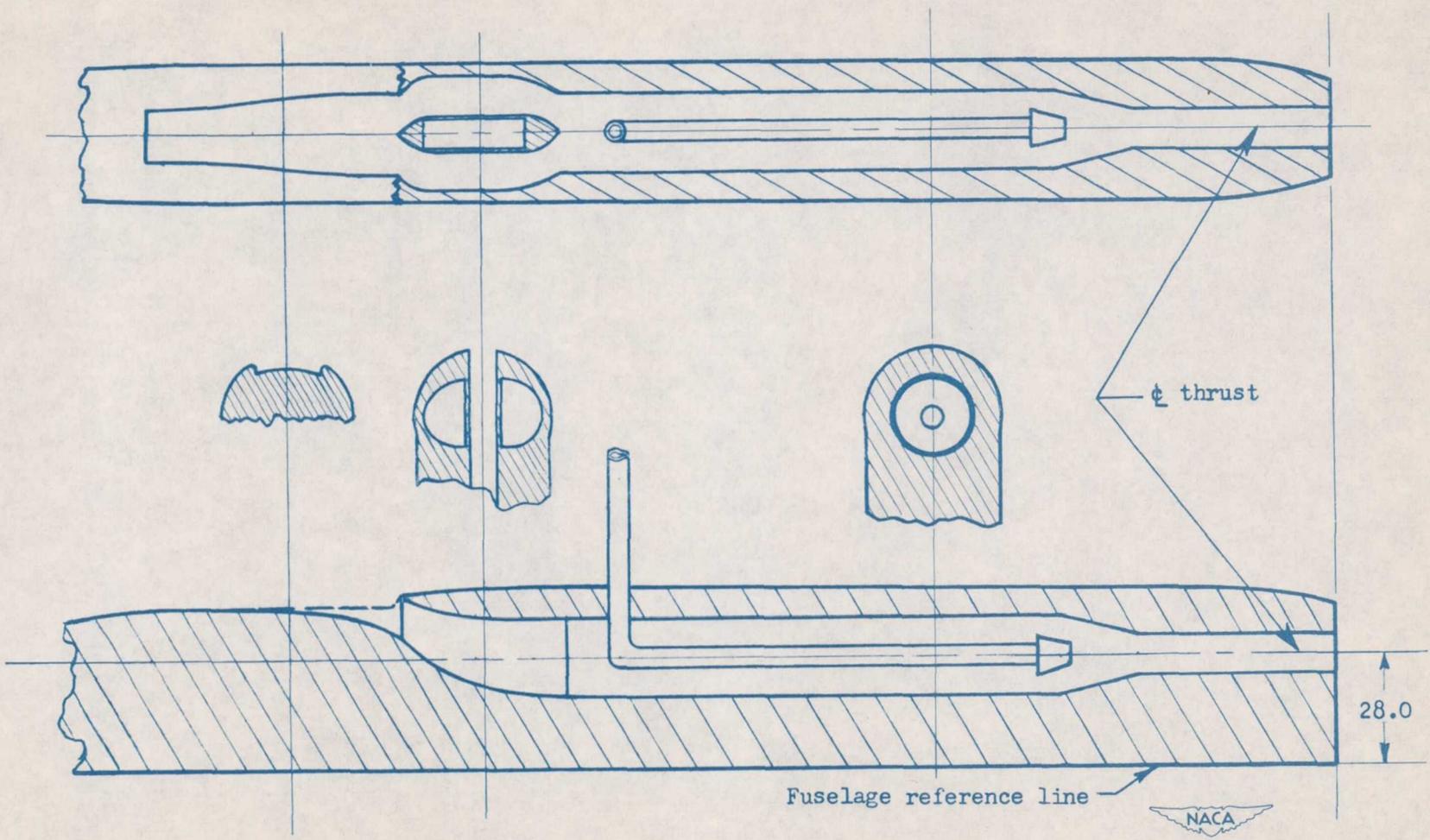
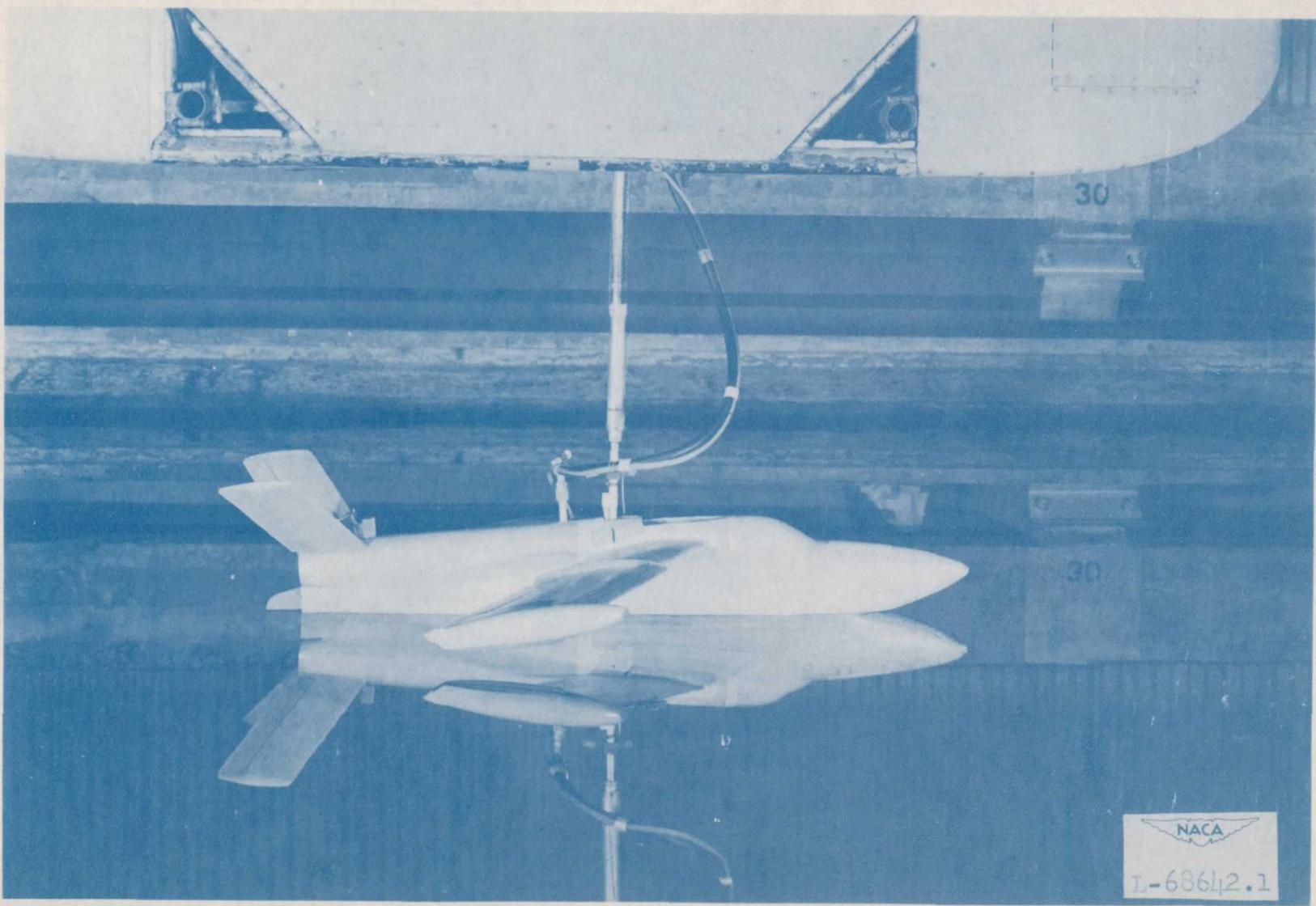


Figure 5.- Model jet unit. (Dimension is inches, full size.)

512

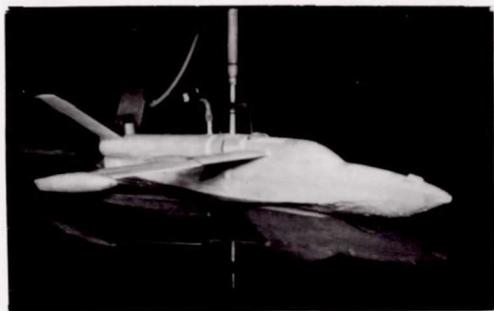
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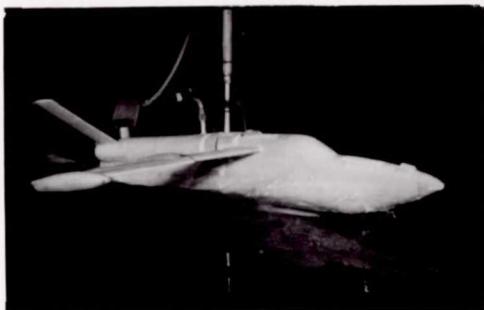


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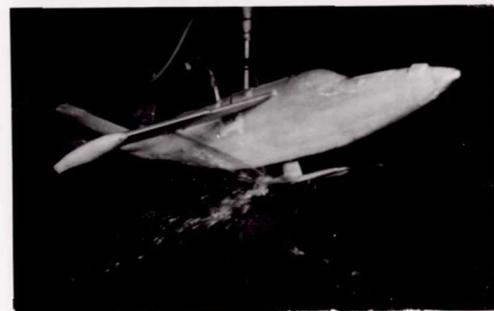
Figure 6.- Test setup showing model floating at normal gross weight.



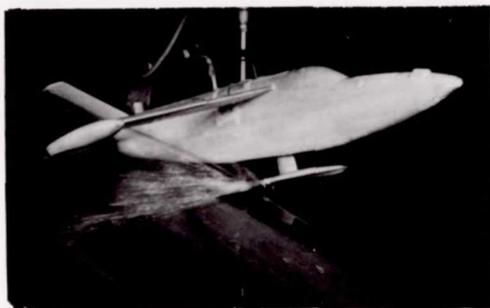
10 mph



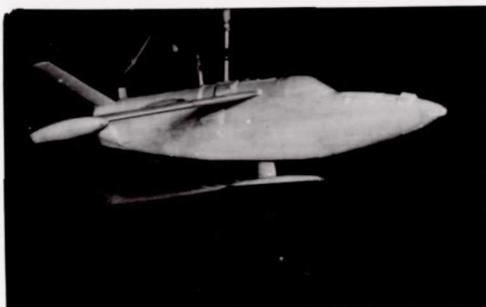
20 mph



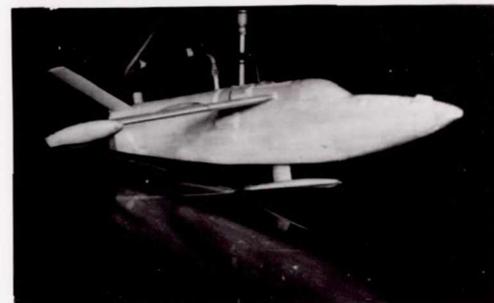
30 mph



50 mph



80 mph



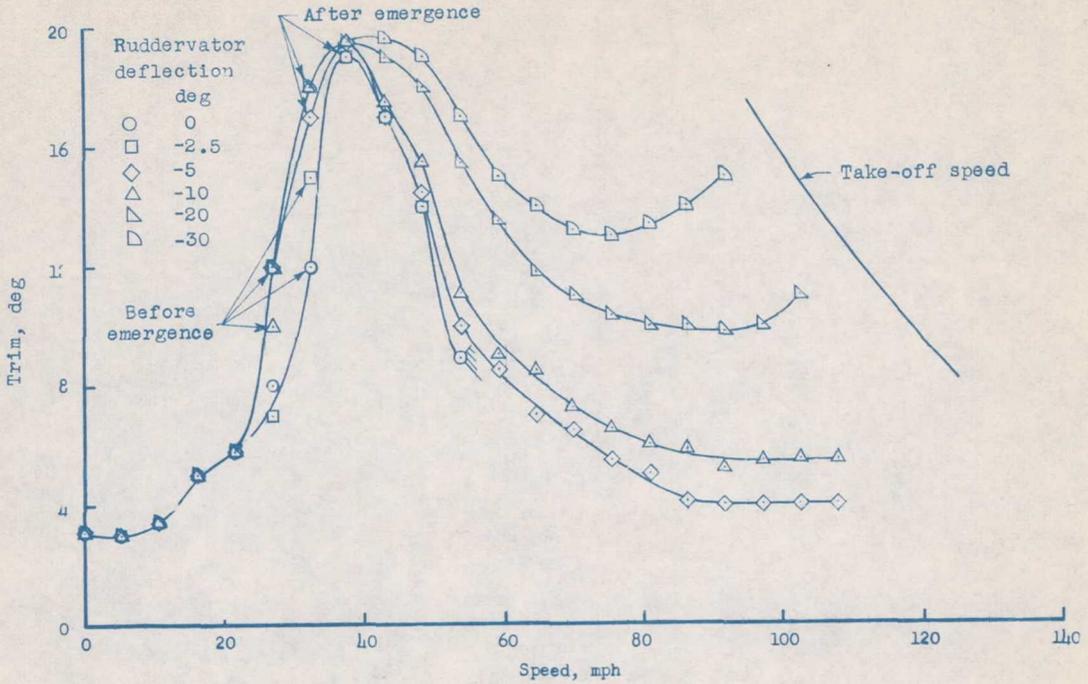
100 mph

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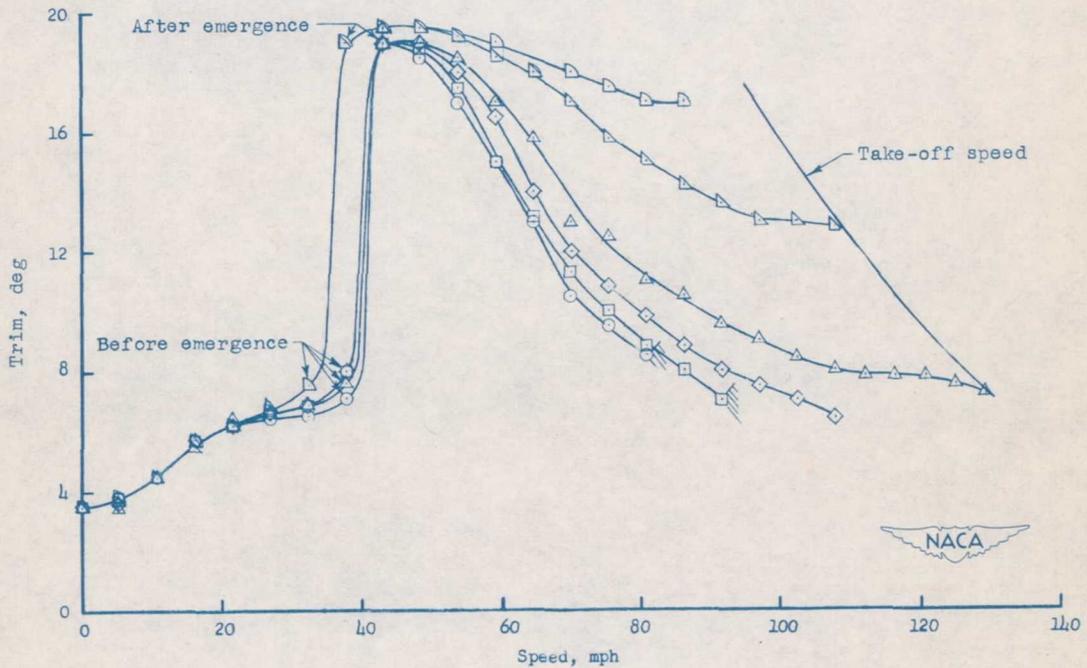


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Figure 7.- Sequence photographs of a typical take-off run for the large-ski configuration. (Speeds are full size.)

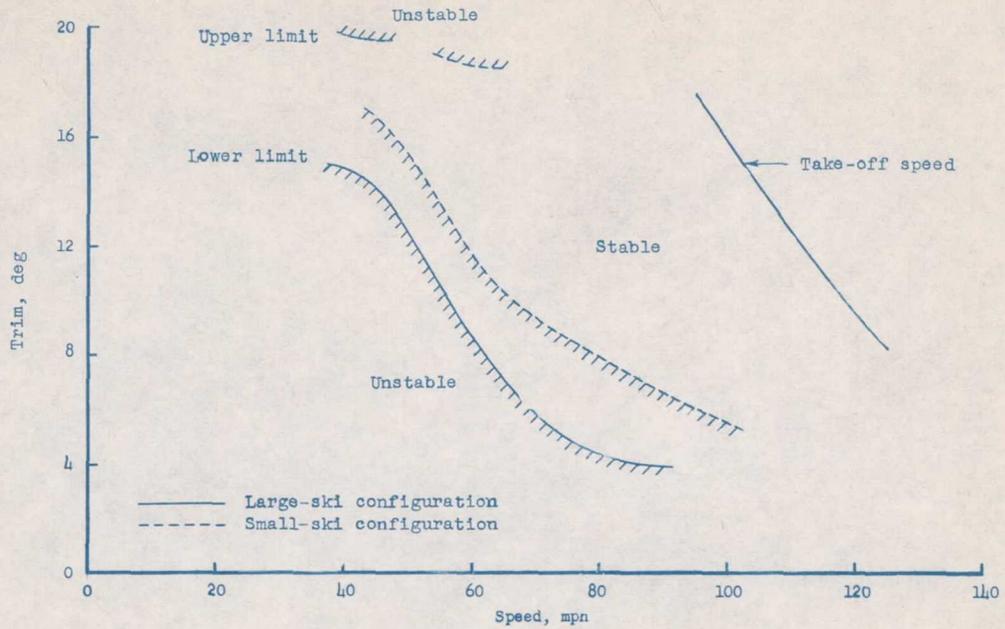


(a) Large-ski configuration.

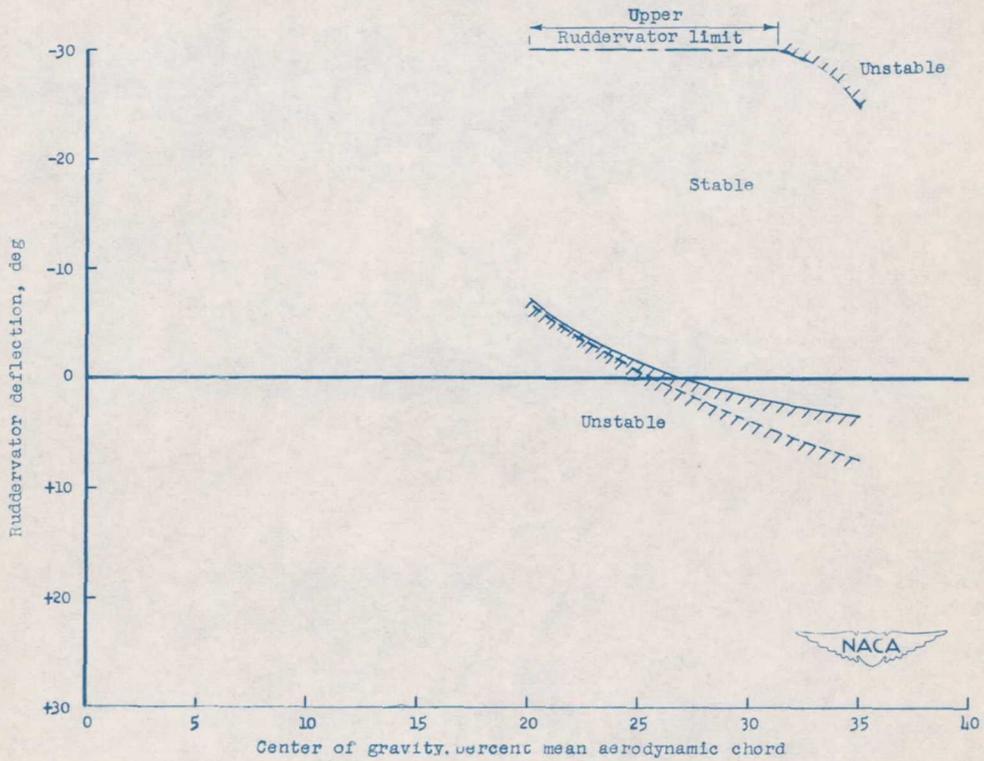


(b) Small-ski configuration.

Figure 8.- Variation of trim with speed for the airplane operating at the normal center of gravity. (Values are full size.)



(a) Trim limits of stability.



(b) Center-of-gravity limits of stability.

Figure 9.- Stability limits for the airplane. (Values are full size.)

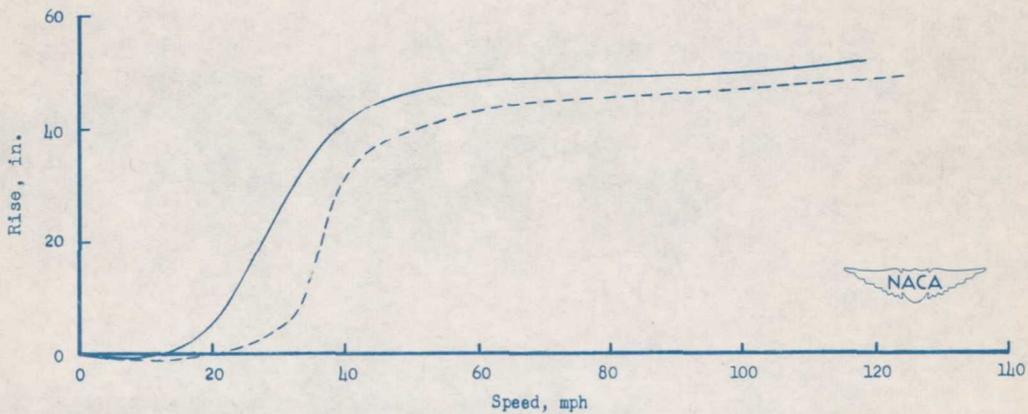
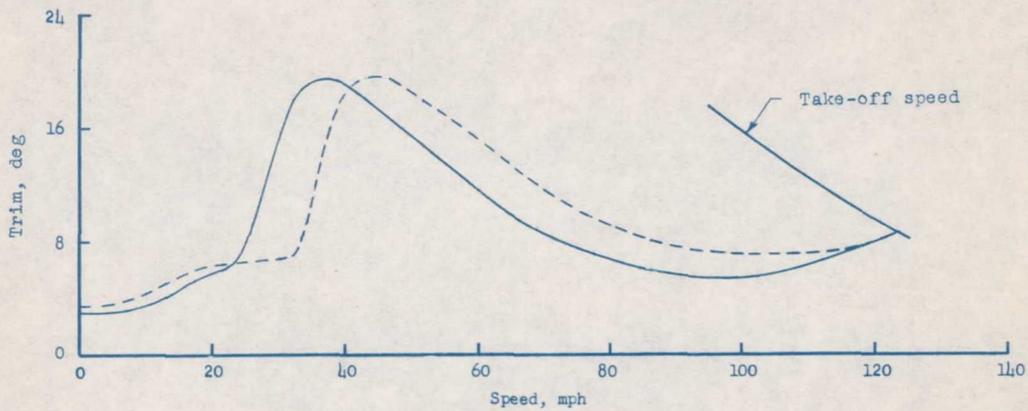
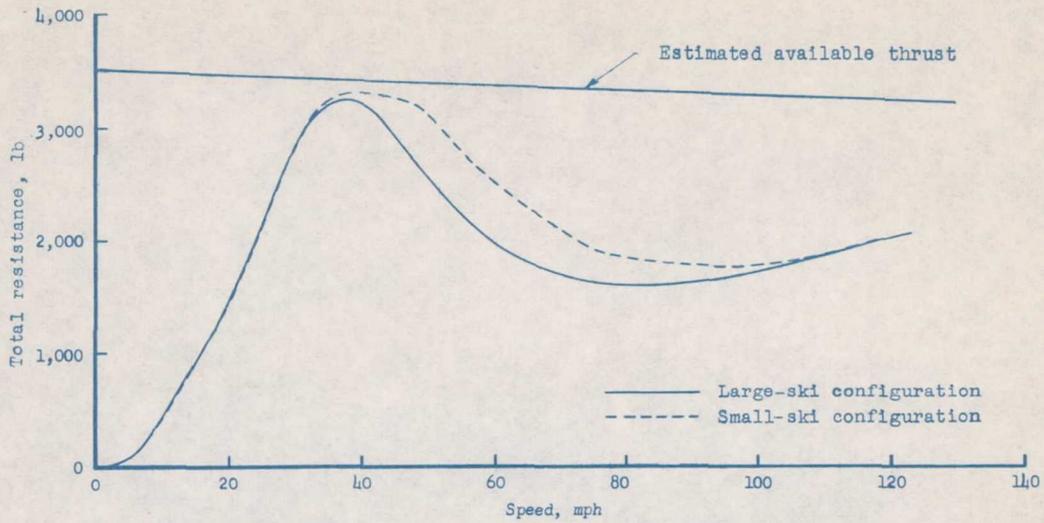
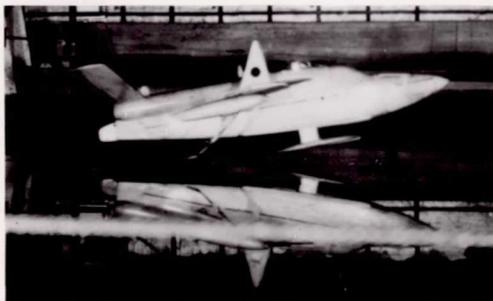
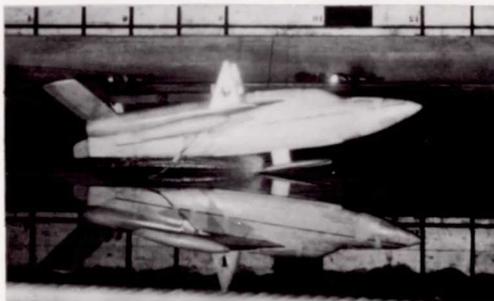


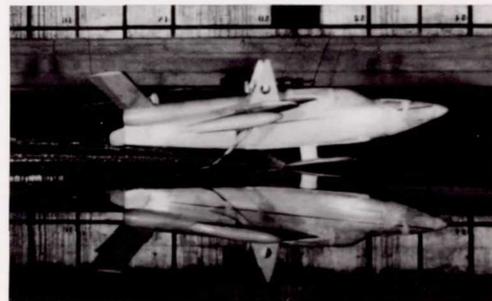
Figure 10.- Total resistance, trim, and rise for the airplane. (Values are full size.)



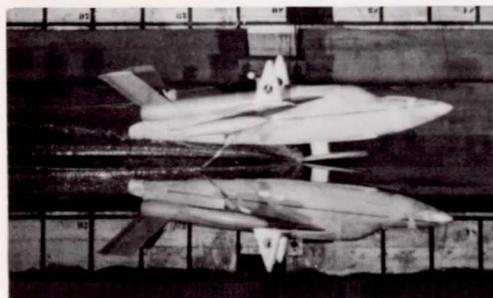
In flight



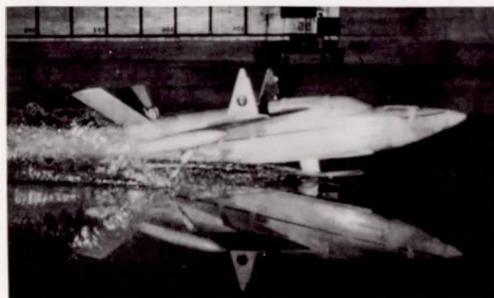
Just after contact



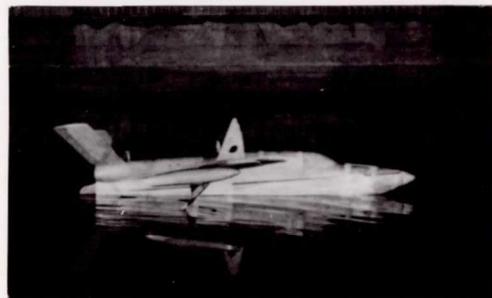
400 feet after contact



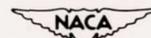
800 feet after contact



1300 feet after contact



1500 feet after contact



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Figure 11.- Sequence photographs of a typical landing run of the large-ski configuration in smooth water at  $10^{\circ}$  landing trim. (Distances are full size.)

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