NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT 923

EFFECT OF AFTERBODY LENGTH AND KEEL ANGLE ON MINIMUM DEPTH OF STEP FOR LANDING STABILITY AND ON TAKE-OFF STABILITY OF A FLYING BOAT

By **ROLAND E. OLSON** and **NORMAN S. LAND**

1949

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AERONAUTIC SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Abbreviation	Unit	Abbreviation
Length	l	meter	m	foot (or mile)	ft (or mi)
Time	t	second	s	second (or hour)	sec (or hr)
Force	F	weight of 1 kilogram	kg	weight of 1 pound	lb
Power	P	horsepower (metric)	----------	horsepower	hp
Speed	V	kilometers per hour meters per second	kph mps	miles per hour feet per second	mph fps

2. GENERAL SYMBOLS

W	Weight $=mg$
g	Standard acceleration of gravity $=9.80665$ m/s^2 or 32.1740 ft/sec^2
m	Mass $=\frac{W}{g}$
I	Moment of inertia $=mk^2$. (Indicate axis of radius of gyration k by proper subscript.)
μ	Coefficient of viscosity

ν	Kinematic viscosity
ρ	Density (mass per unit volume)
	Standard density of dry air, 0.12497 kg-m^{-4}-s^2 at 15° C and 760 mm; or 0.002378 lb-ft^{-4} sec^2
	Specific weight of "standard" air, 1.2255 kg/m^3 or 0.07651 lb/cu ft

3. AERODYNAMIC SYMBOLS

S	Area
S_w	Area of wing
G	Gap
b	Span
c	Chord
A	Aspect ratio, $\frac{b^2}{S}$
V	True air speed
q	Dynamic pressure, $\frac{1}{2}\rho V^2$
L	Lift, absolute coefficient $C_L=\frac{L}{qS}$
D	Drag, absolute coefficient $C_D=\frac{D}{qS}$
D_0	Profile drag, absolute coefficient $C_{D_0}=\frac{D_0}{qS}$
D_i	Induced drag, absolute coefficient $C_{D_i}=\frac{D_i}{qS}$
D_p	Parasite drag, absolute coefficient $C_{D_p}=\frac{D_p}{qS}$
C	Cross-wind force, absolute coefficient $C_C=\frac{C}{qS}$

i_w	Angle of setting of wings (relative to thrust line)
i_t	Angle of stabilizer setting (relative to thrust line)
Q	Resultant moment
Ω	Resultant angular velocity
R	Reynolds number, $\rho\frac{Vl}{\mu}$ where l is a linear dimension (e.g., for an airfoil of 1.0 ft chord, 100 mph, standard pressure at 15° C, the corresponding Reynolds number is 935,400; or for an airfoil of 1.0 m chord, 100 mps, the corresponding Reynolds number is 6,865,000)
α	Angle of attack
ϵ	Angle of downwash
α_0	Angle of attack, infinite aspect ratio
α_i	Angle of attack, induced
α_a	Angle of attack, absolute (measured from zero-lift position)
γ	Flight-path angle

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By ROLAND E. OLSON and NORMAN S. LAND

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REPORT 923

EFFECT OF AFTERBODY LENGTH AND KEEL ANGLE ON MINIMUM DEPTH OF STEP FOR LANDING STABILITY AND ON TAKE-OFF STABILITY OF A FLYING BOAT

By Roland E. Olson and Norman S. Land

SUMMARY

Tests were made to fill partly the need for information on the effect of afterbody dimensions on the hydrodynamic stability of a flying boat in smooth water. The dimensions investigated were depth of step, angle of afterbody keel, and length of afterbody. An analysis of the data showed that as either the afterbody length or keel angle was increased an accompanying increase in depth of step was required in order to maintain adequate landing stability. A comparison of models with differing afterbody lengths but with each having a depth of step which provides adequate landing stability revealed that there was no marked change in the take-off stability. A similar comparison for the models with differing keel angle showed that increases in keel angle resulted in a large increase in the angle of stable trim for take-off and some increase in the range of stable center-of-gravity location for take-off.

A large change in gross load had little effect on the landing stability.

The landing-test results have been reduced to an empirical formula giving the minimum depth of step in terms of afterbody length and keel angle. This formula is compared with results from other tank tests, and the correlation is fairly good. The formula thus becomes of use in preliminary design.

INTRODUCTION

The primary functions of the afterbody of a flying-boat hull are to provide the necessary buoyancy and dynamic lift at very low speeds while the airplane is on the water. At planing speeds, however, the presence of the afterbody generally is detrimental to the hydrodynamic performance, inasmuch as it introduces a region of instability which the forebody alone does not have and generally adds to the water resistance. Information available to guide designers in their choice of afterbody configurations for flying boats is generally inadequate. The effect of changes in dimensions of an afterbody on the resistance of the complete hull has been the subject of several reports, but the effect of these changes on take-off and landing stability has not been systematically investigated.

The purpose of the present report is to give the results of tests which were made in Langley tank no. 1 to determine the effects of afterbody length and keel angle on the take-off and landing stability of a dynamic model of a flying boat. Interest was focused on those afterbody configurations which resulted in stable landings inasmuch as landing stability is a primary concern in the design of a flying boat. Experience with models has shown that landing stability can generally be attained with a fixed afterbody length and keel angle if the depth of step is great enough. Accordingly, each afterbody in the present series (four lengths and four keel angles) was tested with several depths of step in order to determine the minimum depth necessary for adequate landing stability. Each of these afterbodies, with the depth of step required for adequate landing stability, was then tested to determine the take-off stability as judged by the available range of stable trim and the range of stable position of the center of gravity.

DESCRIPTION OF MODEL

The model used for this series of tests was a $\frac{1}{12}$-size unpowered dynamic model of a hypothetical flying boat with a design gross load of 160,000 pounds (91.8 lb, model size). A profile of the basic model, designated Langley tank model 134A, is shown in figure 1 and photographs of the model are shown as figure 2.

Four afterbodies of differing lengths and constant keel angle (fig. 3) and four afterbodies of differing keel angle and constant length (fig. 4) were tested. The afterbodies of the length series all had the same chine half-breadth at the same percentage of length from the step. Afterbodies of the keel-angle series were formed by rotating the basic afterbody about a horizontal transverse line passing through the intersection of the afterbody keel and the step. Changing afterbody keel by this method led to very short vertical sides on the afterbody with the highest keel angle. The models were designated as follows:

Designation	Afterbody keel angle (deg)	Afterbody length-beam ratio, L_a/b where $b=14.24$ in.
134A	6.2	2.61
134B	4.9	2.61
134C	7.5	2.61
134D	9.3	2.61
134E	6.2	3.11
134F	6.2	2.11
134G	6.2	1.61

Trim is the angle between the forebody keel and the horizontal.

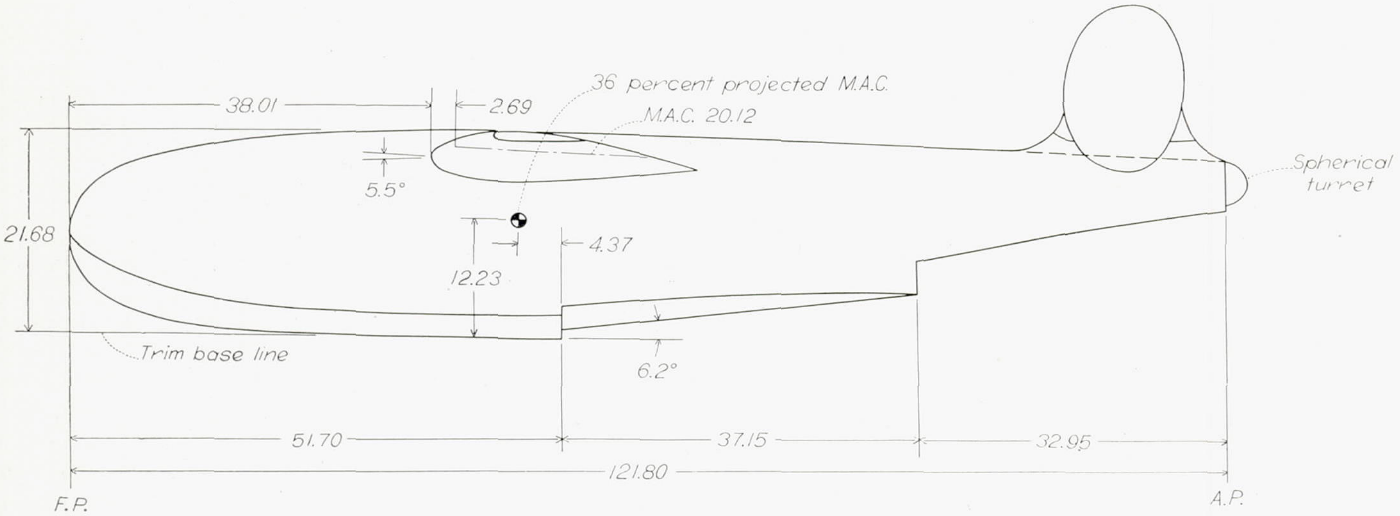
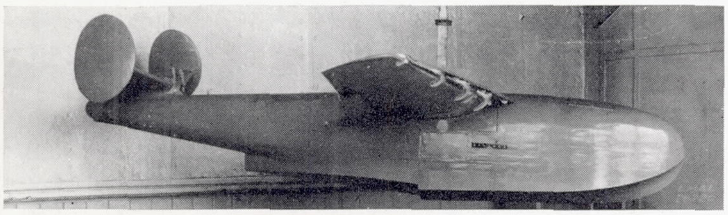
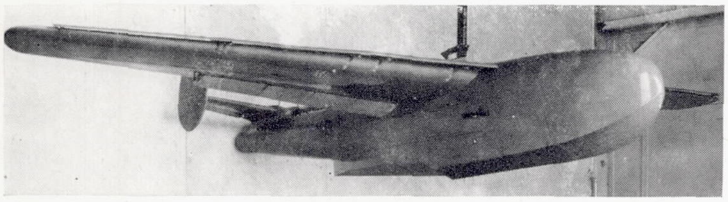


FIGURE 1.—Profile of Langley tank model 134A. (All dimensions are in inches.)

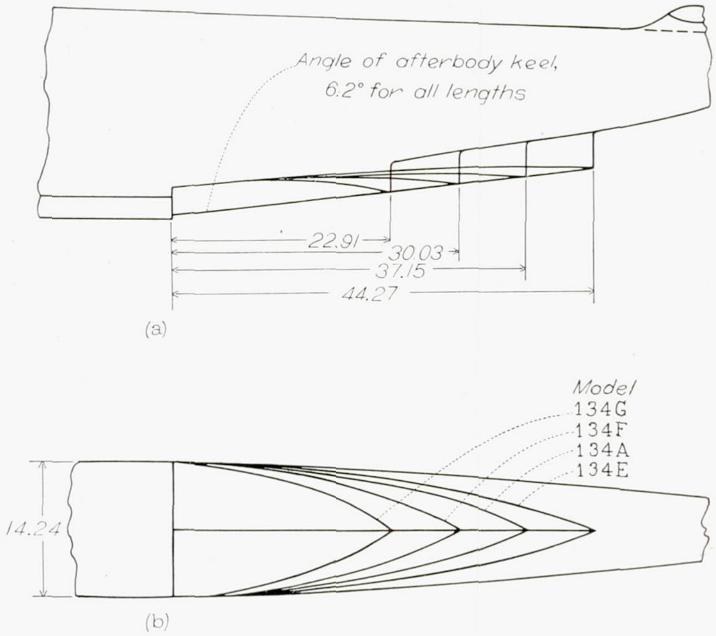


(a) Profile view.



(b) Three-quarter front view.

FIGURE 2.—Langley tank model 134A.



(a) Profile view.
(b) Bottom view.

FIGURE 3.—Afterbody length series. Langley tank model 134. (All dimensions are in inches.)

APPARATUS AND PROCEDURE

A general description of Langley tank no. 1 is included in reference 1. The towing gear, described in reference 2, was attached to the main towing carriage for these tests. The general test procedures are described in references 2 and 3. Landings were made by accelerating the towing carriage to a speed slightly above the take-off speed of the model, flying the model at the desired landing trim by means of the remotely controlled elevators, then decelerating the towing carriage at a constant rate (1 ft/sec^2), and allowing the model to land and to complete a landing run-out with no further manipulation of the elevators. The model, when flying, was at a height above the water such that the sternpost of the longest afterbody just touched the water at a trim of 14°. All the landings were made from this height. The trim and vertical positions of the model during landing were recorded by a stylus attached to the model that was in contact with a stationary piece of paper attached to the carriage.

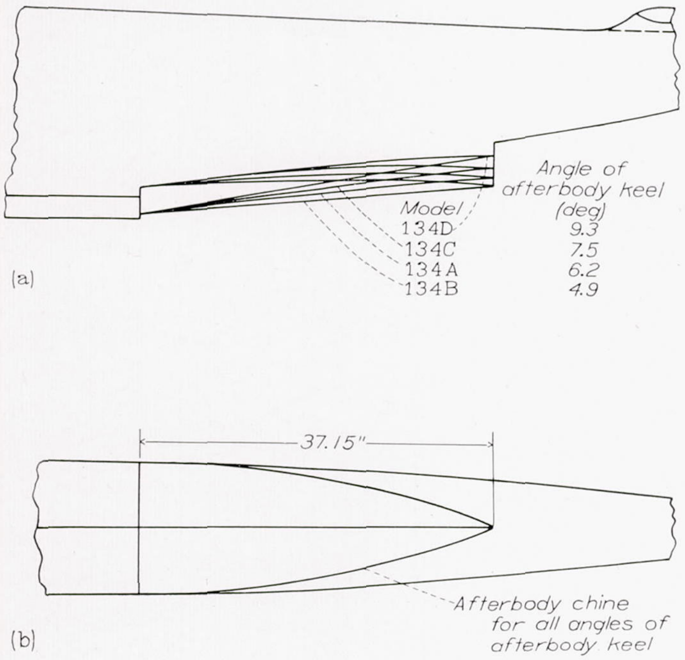
The first landing test of each afterbody was made with a depth of step of 7 percent of the maximum beam. The depth of step was then altered in the direction indicated by the landing characteristics so that marginal landing stability would be approached. For each modification, the trim limits of stability were determined as well as the landing characteristics. When a depth of step was attained which resulted in marginal landing characteristics, the limits of stable locations of the center of gravity were also determined. These limits were determined by making accelerated runs at a rate of 1 foot per second per second with various locations of the center of gravity and with the elevators neutral and full up.

All of the tests were made with a gross load of 91.8 pounds (160,000 lb, full-size) and a flap setting of 20° except where noted.

RESULTS AND DISCUSSION

LANDING STABILITY

In the operation of flying boats an instability, termed "skipping," is frequently encountered during landing. This instability occurs immediately after the initial landing contact and usually takes the form of an increase in trim with an accompanying leap from the water. After the subsequent return to the water, the cycle may be repeated several times, usually with diminishing amplitude as the forward speed decreases. The instability referred to is not due to rough water. The severity of such skipping is influenced by the attitude at initial contact with the water and sometimes is encountered only over a narrow range of contact trim. The severity of the skipping has been observed to be a function of those features of the hull bottom which affect the ventilation of the afterbody, such as depth of step or ventilation ducts at the step.



(a) Profile view.
(b) Bottom view.

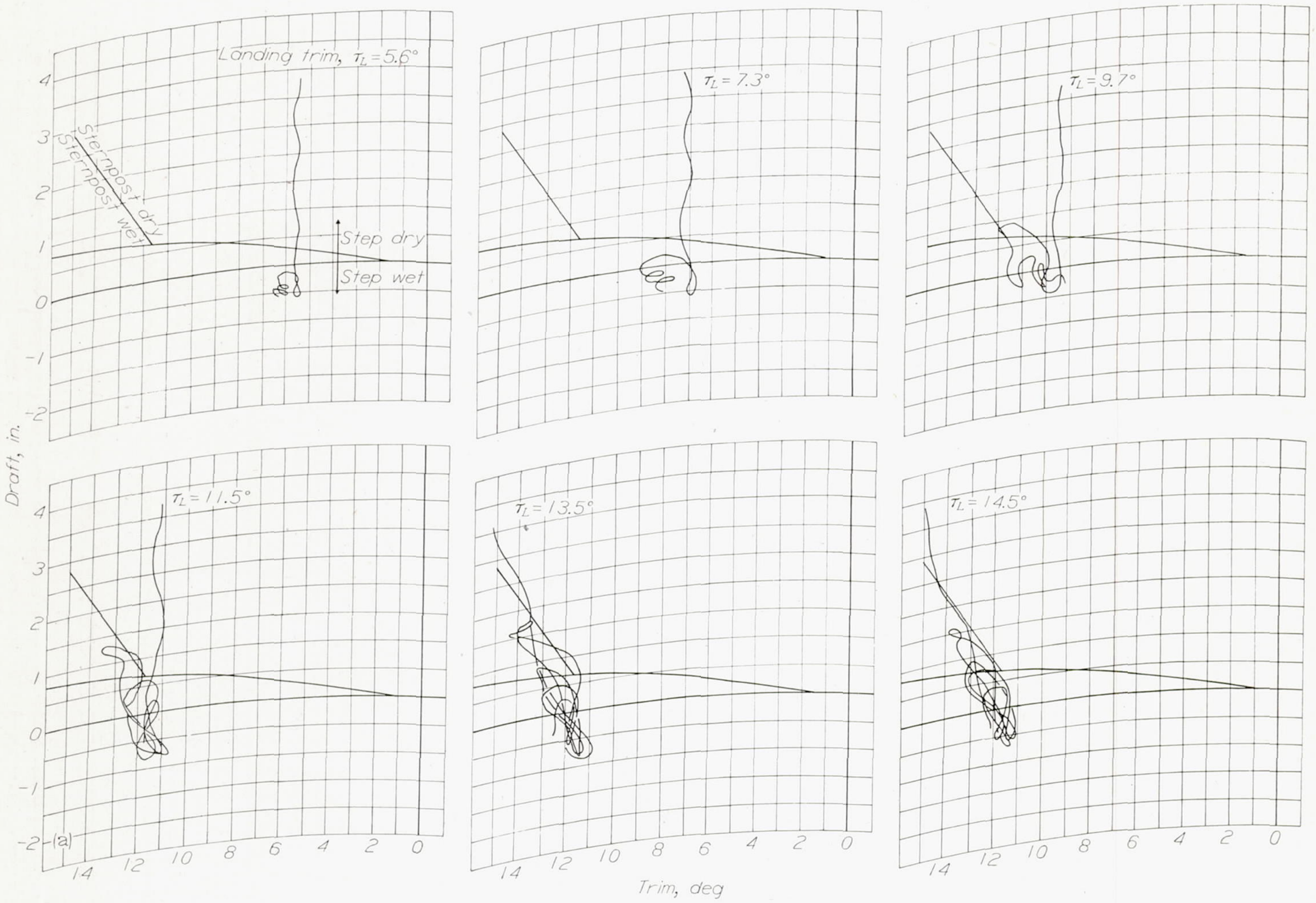
FIGURE 4.—Afterbody keel angle series. Langley tank model 134.

The landing characteristics of a flying boat may be regarded as undesirable if, subsequent to the initial contact made at reasonable attitude and speed, the airplane skips out of the water in such a manner that the pilot cannot maintain complete control. Such behavior may result in disastrously high vertical or angular accelerations when the airplane returns to the water. A large number of skips is undesirable because each successive cycle occurs at a lower forward speed and the pilot therefore has less chance of applying recovery forces through the use of aerodynamic controls. The height the airplane is thrown clear of the water, the attitude it reaches while clear of the water, and the range of initial contact trim over which skipping occurs are also factors that enter into an evaluation of the instability. In the present report, models with marginal landing stability are of primary interest and a comparison of the relative violence of motion of unstable models is of secondary importance.

Method of analysis.—A complete analysis of the landing behavior would require data in the form of time histories of the displacements, velocities, and accelerations. A record of the rise and trim of the model during a landing, with no regard for speed or time, however, is believed to be sufficient to enable quantitative comparisons of the behavior of different model configurations to be made and to determine the difference between models with acceptable and unacceptable landing stability. This type of record was made of every landing during the test. From these records the initial contact trim, the number of skipping cycles that occurred during each landing, and the values of trim and rise at the extremes of the largest cycle were determined.

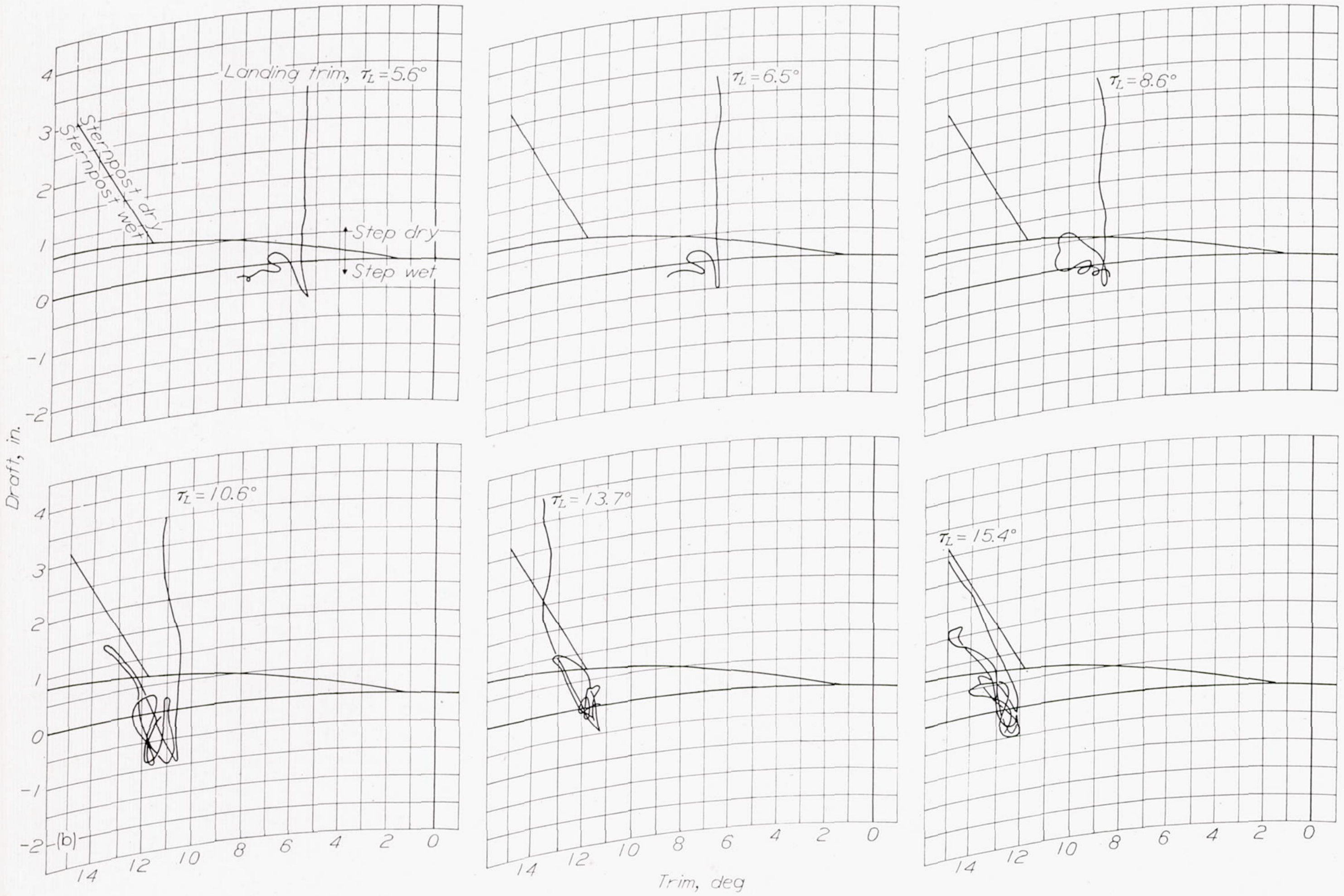
The data were analyzed in several ways. Comparisons of models were made on the basis of trim amplitudes, rise amplitudes, number of skipping cycles, combinations of trim and rise amplitudes, and a combination of the trim and rise amplitudes with the number of cycles and range of trim over which skipping occurred. All these methods of analysis showed the same trends of depth of step required for adequate stability with variations in afterbody length and keel angle. The data presented herein, however, are only those for initial contact trim and rise above the water surface for the greatest skipping cycle.

Typical landing records are reproduced in figure 5. Records of landings at several trims made with a model judged to be unstable are shown in figure 5 (a). Similar records made with the depth of step of the same model increased sufficiently to result in marginal landing stability are given in figure 5 (b) and records made with the step increased sufficiently to eliminate skipping almost entirely are given in figure 5 (c). A model was judged to be unstable if a landing at any trim resulted in a skipping cycle in which the main step of the hull cleared the free water surface by a distance equal to 5 percent of the beam and was judged to be stable if this clearance was less than 3 percent. A model having a behavior between these two boundaries was regarded as having marginal landing stability. Complete freedom from skipping is believed to be unnecessary. This evaluation of model stability appears to give results consistent with results of full-size seaplanes.



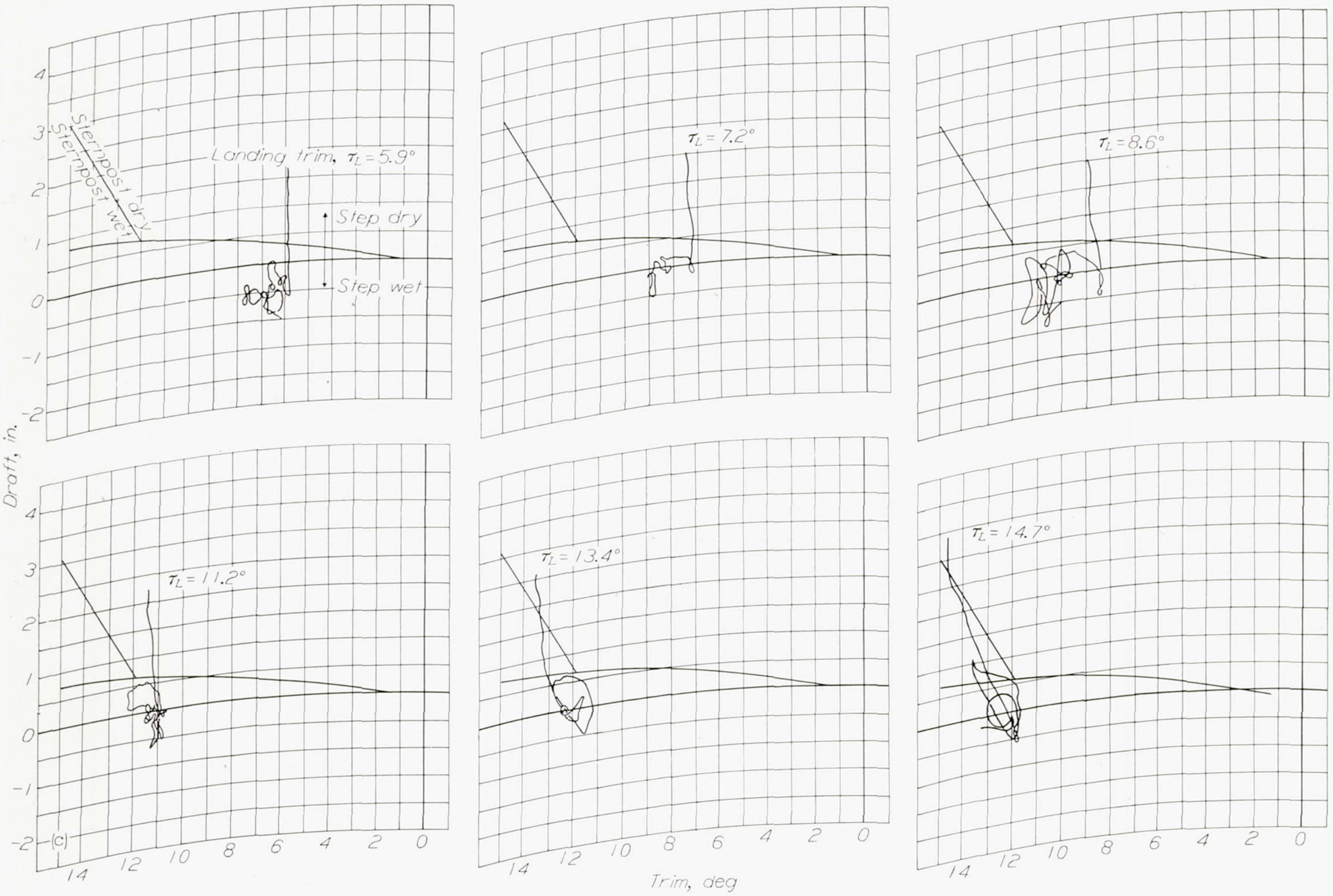
(a) Depth of step, 11 percent beam; unstable landing characteristics.

FIGURE 5.—Variation of trim and draft during landing. Langley tank model 134D.



(b) Depth of step, 13 percent beam; marginally stable landing characteristics.

FIGURE 5.—Continued.



(c) Depth of step, 14 percent beam; stable landing characteristics.

FIGURE 5.—Concluded.

Effect of depth of step.—The effect of depth of step on the landing stability of the model with one of the afterbodies is shown in figure 6. The curves shown in figures 6 to 8 are envelopes of the extreme values of rise above the water surface at the various landing trims, and actual test points are not given in order to avoid complication. The curves show a maximum-rise peak which occurs near the landing trim at which the afterbody keel is parallel to the free water surface. As the depth of step was increased, the landings became more stable. At a depth of step which resulted in marginal landing stability (13 percent beam) this peak is considerably reduced. With a depth of 14 percent the model was stable and no peak remained. This trend is characteristic of all the afterbodies tested.

Effect of angle of afterbody keel.—The effect on the landing behavior of changing the angle of afterbody keel but maintaining the same depth of step is illustrated in figure 7. As the keel angle is increased, the landing behavior changes from stable to very unstable. The peak of each curve tends to occur at a trim near the landing trim at which the afterbody keel is parallel to the free water surface.

Effect of length of afterbody.—The effect of changing the length of the afterbody but maintaining a constant depth of step on the landing behavior of the model is shown in figure 8. Increasing the length of the afterbody changed the landing characteristics of the model from marginal to very unstable. The trim at which the peaks of the curves occurred did not shift appreciably as the length of afterbody was changed.

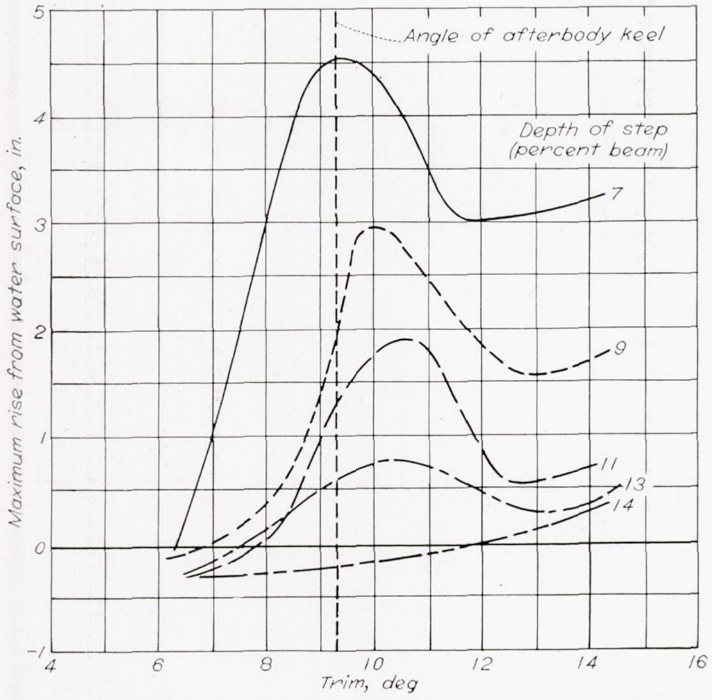


FIGURE 6.—Effect of depth of step on maximum rise during landing. Angle of afterbody keel, 9.3°; length of afterbody, 2.61 beams.

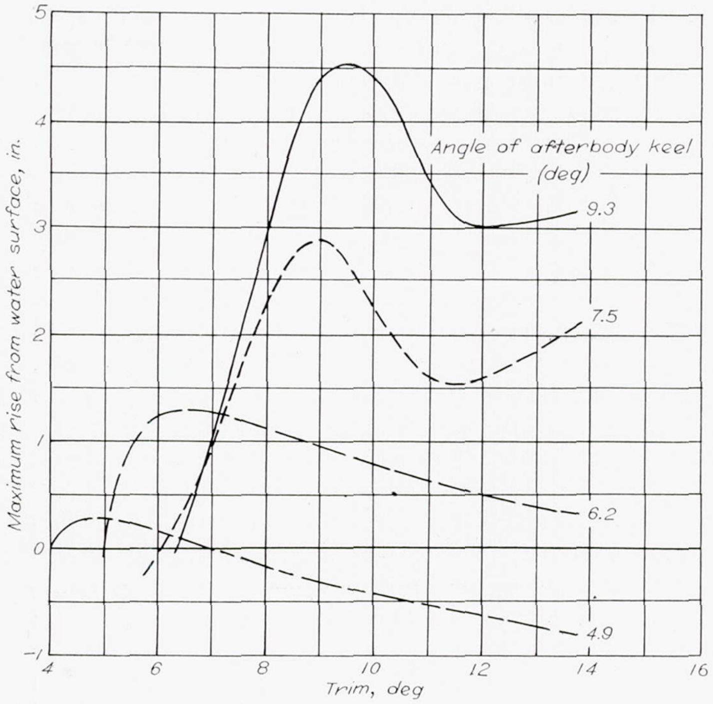


FIGURE 7.—Effect of angle of afterbody keel on maximum rise during landing. Length of afterbody, 2.61 beams; depth of step, 7 percent beam.

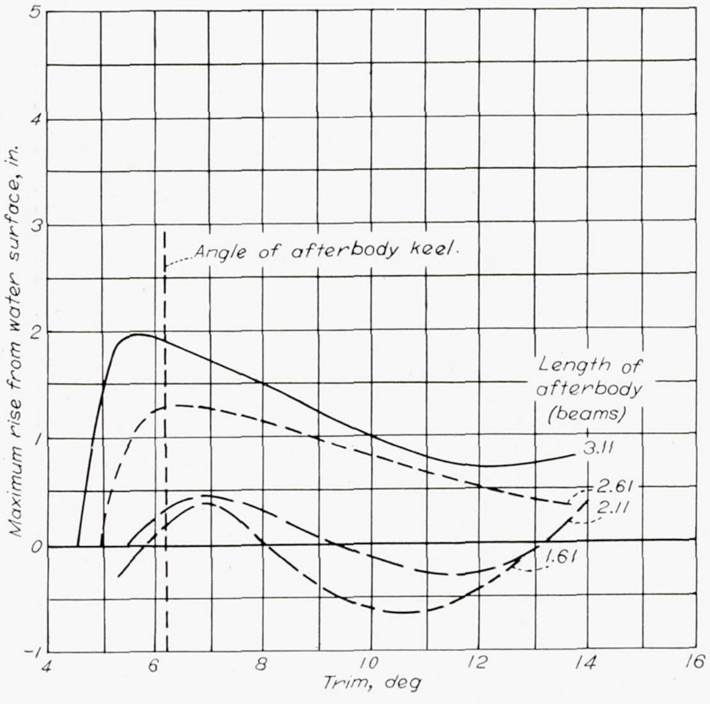


FIGURE 8.—Effect of length of afterbody on maximum rise during landing. Angle of afterbody keel, 6.2°; depth of step, 7 percent beam.

Optimum depth of step for various afterbodies.—The greatest rise observed during landings of the various models has been plotted against depth of step in figure 9. Each point appearing in figure 9 is not an actual test point but represents the worst behavior of a given model. The horizontal lines in figure 9 show the maximum rise above which the models were considered definitely unstable and a minimum rise below which the models were considered stable. Between these lines the landing stability was considered the minimum acceptable (marginal); and, therefore, the lines define the region of minimum acceptable depths of step. The depths of step at the limits of this region of marginal landing stability (shown in fig. 9) have been plotted against afterbody length and keel angle in figure 10. These data clearly show that a large increase in depth of step was required to maintain marginal landing stability as the afterbody length or keel angle was increased. The two curves shown for each case may be regarded as the envelopes of a region of depths of step which will insure marginal landing stability of this model. A greater depth of step results in stable landings but the unnecessarily deep step increases the hump resistance and the air drag. A smaller depth of step than the optimum leads to some landing instability and somewhat higher water resistance at high speeds but also leads to a lower air drag.

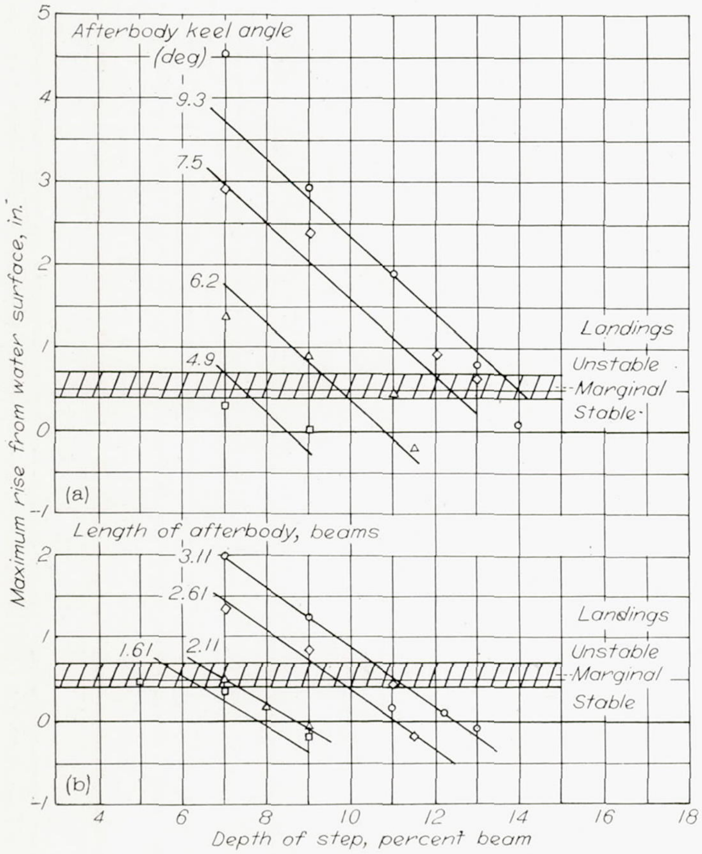
Effect of gross load.—The tests which were made to determine the optimum depths of step were all made at one gross load. In order to find the influence of gross load on the optimum depth of step, one model with marginal landing characteristics at the design load was tested over a wide variation of gross load. This range of loads is −19 percent to 25 percent of the design gross load. The extremes of the loading range correspond to gross load coefficients C_{Δ_0} of 0.70 and 1.08, respectively, where

$$C_{\Delta_0}=\frac{\Delta_0}{wb^3}$$

and

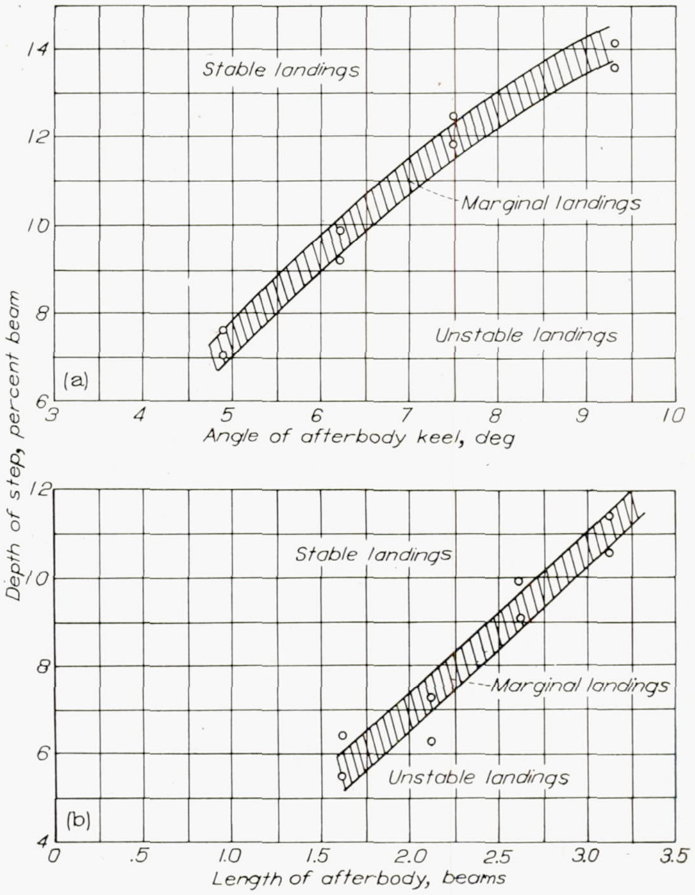
Δ_0 gross load, pounds
w specific weight of tank water (63.4 lb/cu ft)
b maximum beam of model (1.19 ft)

Typical records of the landings made at the extreme values of gross load are reproduced in figure 11. These records show that the change in landing behavior, which is slight over this range of loads, is no greater than that observed from runs made under supposedly the same conditions. With an optimum depth of step, selected as previously explained, the effect of load on the landing behavior of this model was small.



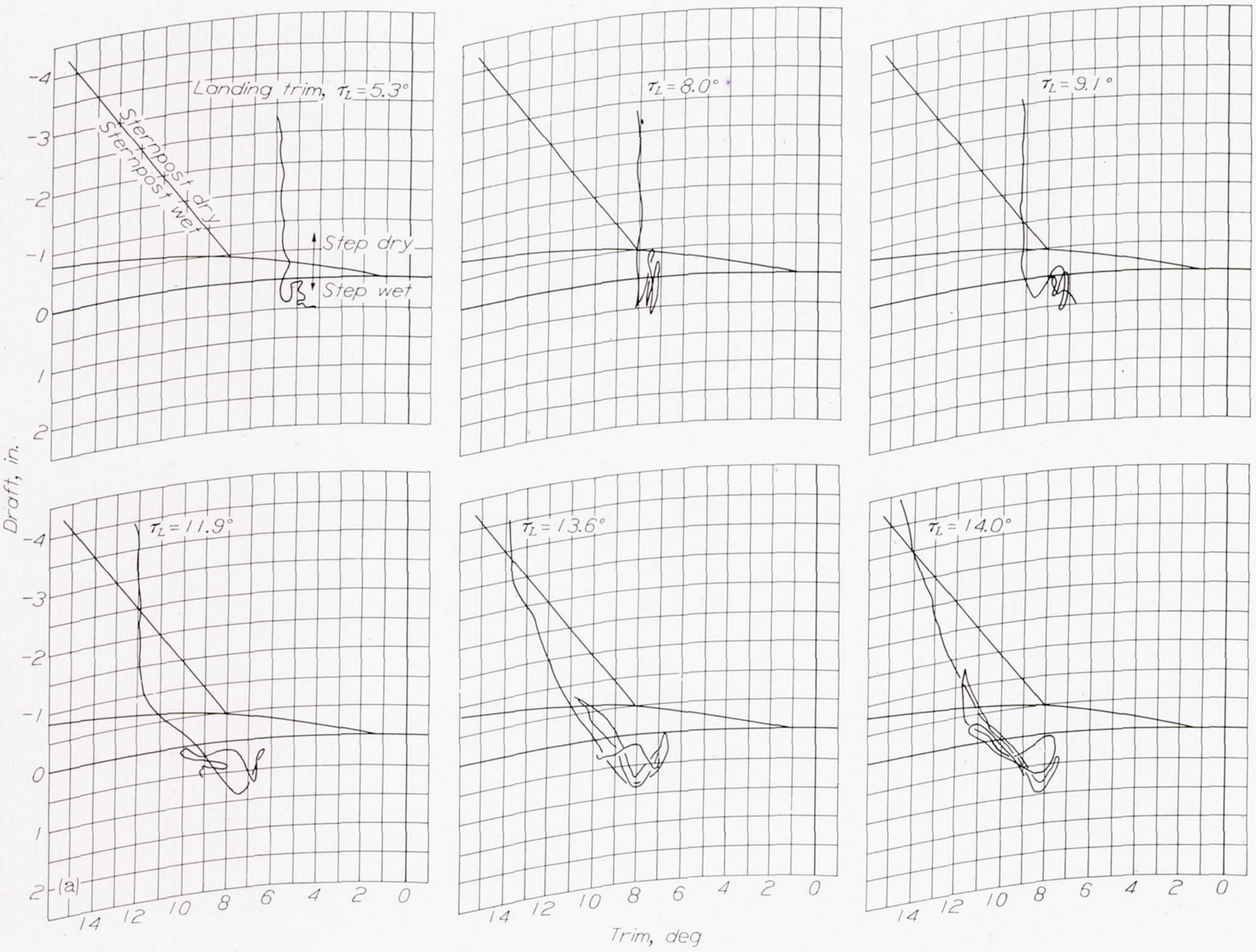
(a) Effect of angle of afterbody keel.
(b) Effect of length of afterbody.

FIGURE 9.—Effect of depth of step on maximum rise during landings made with models having various afterbody dimensions.



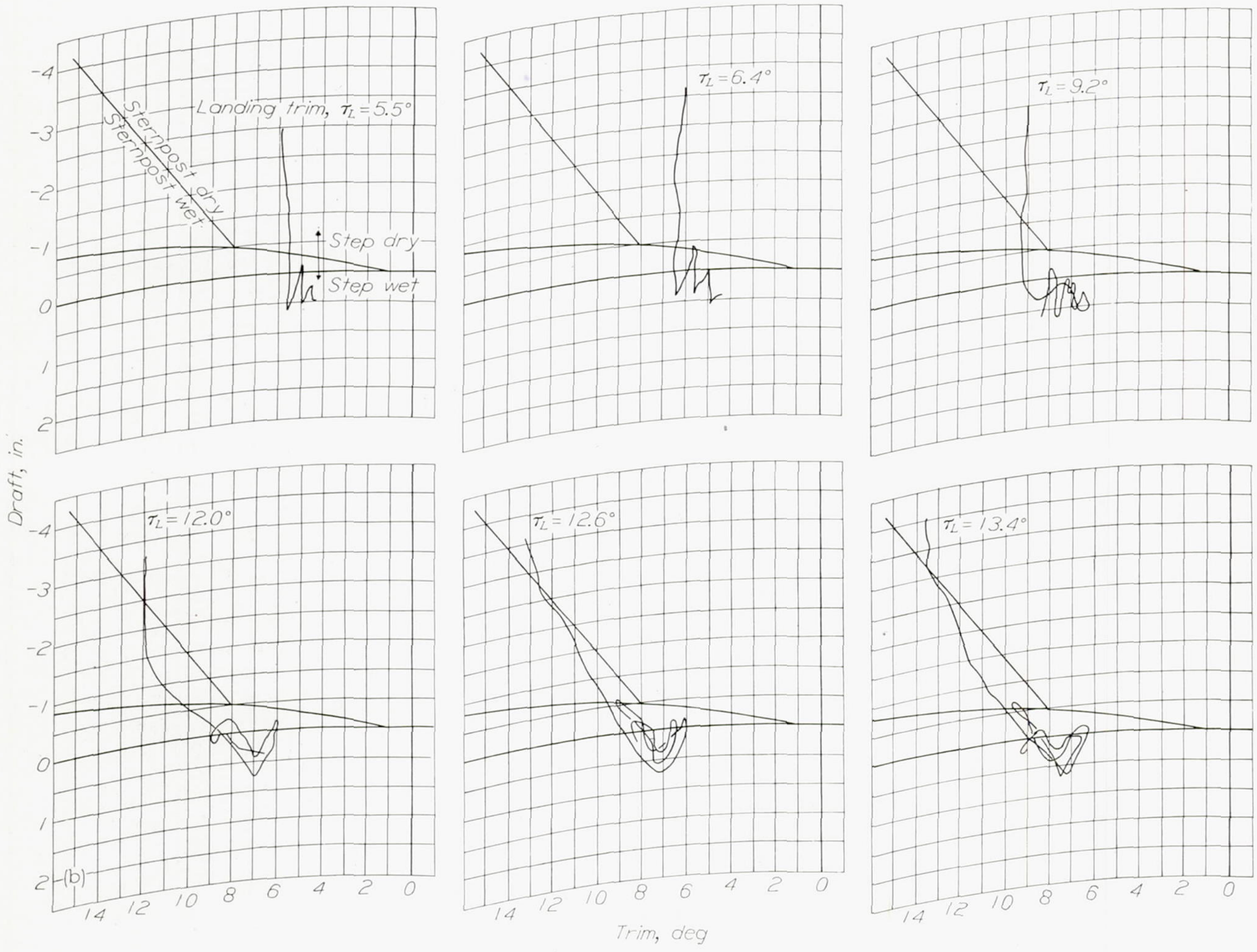
(a) Variation with angle of afterbody keel.
(b) Variation with length of afterbody.

FIGURE 10.—Depth of step required for landing stability.



(a) $\Delta_0=74.1$ pounds.

FIGURE 11.—Variation of trim and draft with load during landing. Langley tank model 134G.



(b) Δ_0=114.8 pounds.

FIGURE 11.—Concluded.

TAKE-OFF STABILITY

The take-off stability of a dynamic model may be determined, for the purpose of these tests, by the trim limits and the limits of stable locations of the center of gravity. The trim limits, obtained by methods described in reference 2, show the limits of the region of stable attitudes at speeds below the take-off speed—that is, the field of trim and speed within which the model must operate to avoid porpoising during take-off. A second method of determining the take-off stability is to locate the limits of the range of fore and aft center-of-gravity positions within which a stable take-off can be made. The method of obtaining these limits is discussed in references 2 and 3.

A comparison of the actual trim limits is not made herein but a cross plot is made of the part of them affected by the afterbody modifications, that is, the upper limits just below take-off speed (36 fps). A complete set of trim limits for one of the models tested is shown in figure 12. The lower trim limit was not affected by the changes in afterbody for all practical purposes. (See reference 4.) Figure 12 also shows a set of two trim tracks obtained from accelerated runs superimposed on the trim limits. These particular trim tracks were selected as typical of the behavior of a model at the limits of stable positions of the center of gravity.

Effect of angle of afterbody keel.—The effect on the take-off stability of changing the angle of afterbody keel and at the same time maintaining an optimum depth of step is shown in figures 13 (a) and 14 (a). Figure 13 (a) shows that just before take-off the upper trim limits rise to higher trims as the angle of afterbody keel and the step depth are increased in the preceding manner. This rise of the upper trim limits results in an increased range of stable trim because the lower trim limit of stability is determined by the forebody alone at these speeds.

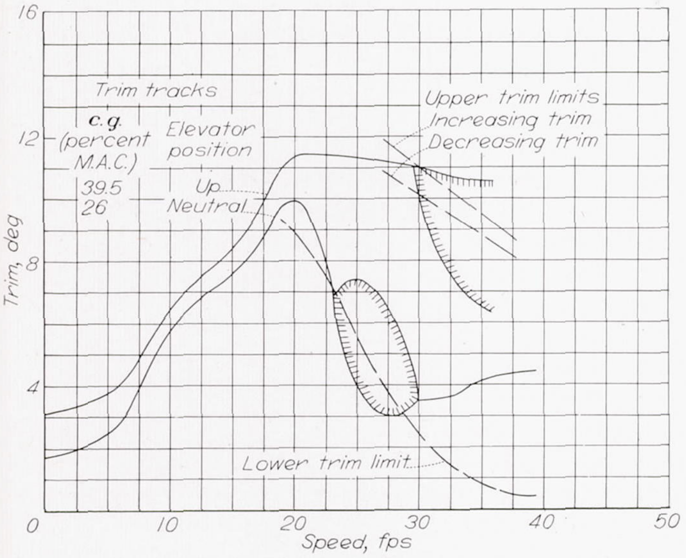


FIGURE 12.—Typical trim limits of stability and trim tracks at extreme locations of the center of gravity.

The range of stable position of the center of gravity for four models with differing keel angles is shown in figure 14 (a). These four models each had a depth of step near the optimum for landing stability. In general, a wider stability range is shown by the models with the greater afterbody keel angles. As might be expected, the increase in the range of stable position of the center of gravity principally is due to a change in the after limit inasmuch as changes in the dimensions of the afterbody generally do not have an appreciable effect on the forward limit.

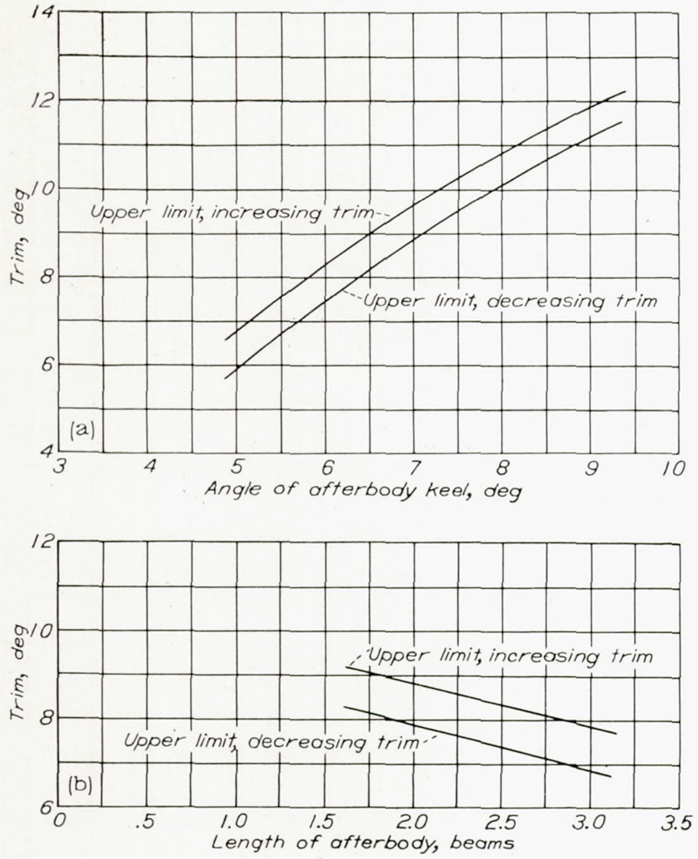
Increasing the angle of afterbody keel, with an accompanying increase in depth of step such as to maintain adequate landing stability, results in some increase in the range of take-off stability of the model.

Effect of length of afterbody.—Previous tests have shown that an increase in length of afterbody (constant depth of step) lowers the upper trim limits (reference 4); whereas an increase in depth of step (constant length of afterbody) raises the upper trim limits (reference 3). The effect of increasing the afterbody length and at the same time maintaining the optimum depth of step is shown in figure 13 (b), in which the upper trim limits are shown to be lowered slightly. The effect on the limits of stable positions of the center of gravity is shown to be quite small in figure 14 (b). If the length of afterbody is changed but the optimum depth of step is maintained, the take-off stability is seen to be relatively unchanged.

CONCLUSIONS

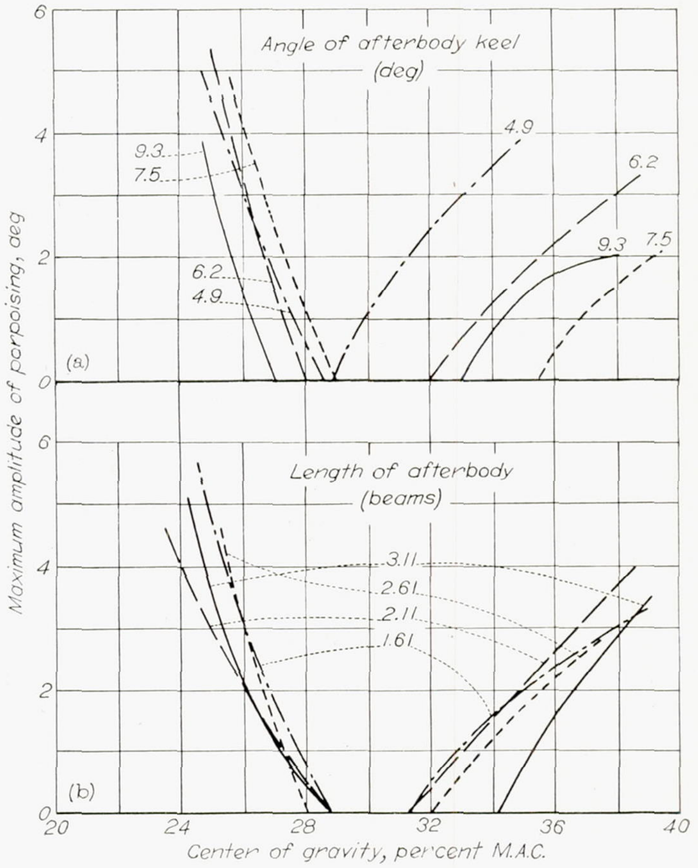
The results of tank tests made to determine the effects of afterbody length and keel angle on the take-off and landing stability of a dynamic model of a flying boat indicated the following conclusions:

1. An increase in length of afterbody required an accompanying increase in depth of step in order to maintain adequate landing stability.
2. Increasing the length of afterbody, and at the same time increasing the depth of step in such a manner as to maintain adequate landing stability, resulted in only a slight change in the take-off stability.
3. An increase in the angle of afterbody keel required an accompanying increase in depth of step in order to maintain adequate landing stability.



(a) Effect of angle of afterbody keel.
(b) Effect of length of afterbody.

FIGURE 13.—The effect of angle of afterbody keel and length of afterbody on the upper trim limits of stability at a speed just below take-off.



(a) Effect of angle of afterbody keel.
(b) Effect of length of afterbody.

FIGURE 14.—The effect of angle of afterbody keel and length of afterbody on the variation of maximum amplitude of porpoising with center-of-gravity location.

4. Increasing the angle of afterbody keel and at the same time increasing the depth of step in such a manner as to maintain adequate landing stability resulted in some increase in the take-off stability.

5. A variation in gross load larger than that likely to be encountered in practice had no appreciable effect on the landing stability of the model which was marginally stable at the design load.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., *November 13, 1947.*

APPENDIX

TENTATIVE AFTERBODY DESIGN FORMULA

The results of the tests are such that a simple empirical formula can be written which relates depth of step, length of afterbody, and angle of afterbody keel for marginal landing stability. This formula is compared with the results from tests of other models.

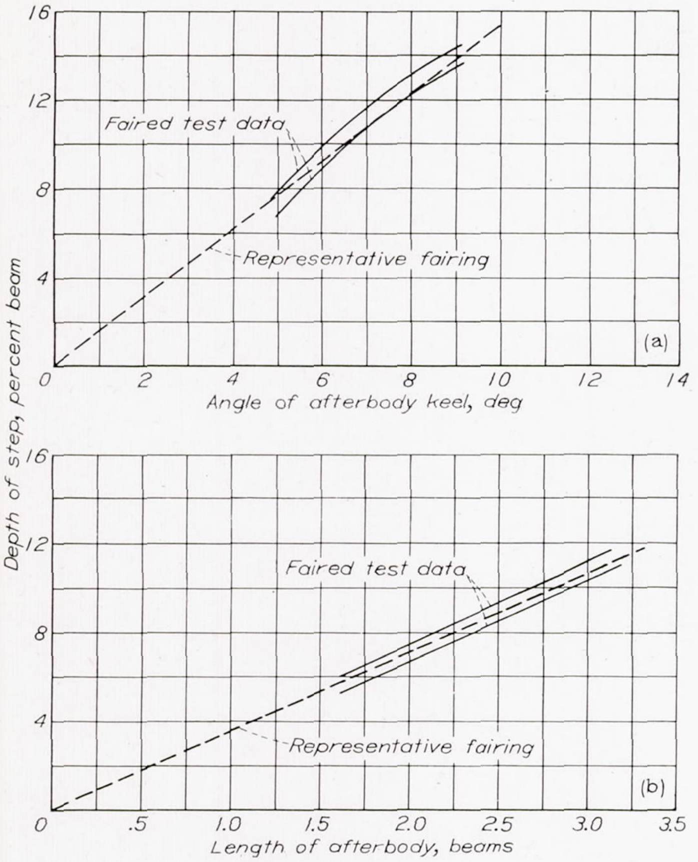
The required depth of step for various angles of afterbody keel and lengths of afterbody is shown in figure 10. These curves have been replotted in figure 15 and a single representative fairing has been made from the origin through the test curves which represents the test results with good accuracy (within 1 percent beam). These lines are drawn through the origin because zero keel angle or zero length of afterbody is assumed to be stable during landing and to require no step. Each of these lines, however, is only one of a family of lines which exists. The complete family of curves can be assumed to take the form shown in figure 16 in which the two curves of figure 15 have been combined and the family sketched in.

The following equation can be used to represent the family of lines in figure 16:

$$d=c\,\frac{L_a}{b}\,\alpha$$

where

d	depth of step, percent beam
L_a/b	length-beam ratio of afterbody
α	angle of afterbody keel, deg
c	constant



(a) Relationship between depth of step and keel angle.
(b) Relationship between depth of step and length of afterbody.

FIGURE 15.—Representative fairing for the test curves.

The constant c may be evaluated at the point where the two test series intersect; that is, where $\frac{L_a}{b}=2.61$, $\alpha=6.2°$, and $d=9.5$. Substituting the numerical value of the constant thus obtained gives

$$d=0.59\,\frac{L_a}{b}\,\alpha$$

Data from other dynamic models that have been tested in Langley tank no. 1 are compared with the preceding formula in figure 17. The correlation is fairly good and the formula is, therefore, suggested for use in preliminary design. Several factors, such as dead rise, step plan form, and plan form of afterbody, may be expected to influence the optimum depth of step as selected from the aforementioned simple formula. The model used for the tests had a transverse main step, an afterbody plan form terminating in a point at the second step, and both a forebody and afterbody with an angle of dead rise of 20°. The results shown in figure 17 for correlation with the present test data were obtained from models with angles of dead rise of 20° and 22½°, and transverse and 30° vee steps, but all had pointed afterbodies. The depth of step at the centroid was used for models with vee steps. These results are mostly from tests in which the landing stability was judged from records made of the landings.

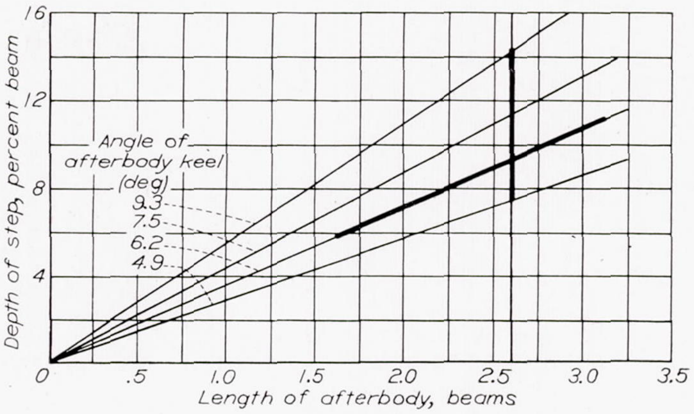


FIGURE 16.—Combined relationship among depth of step, length of afterbody, and angle of afterbody keel. (Heavy lines show range of test data.)

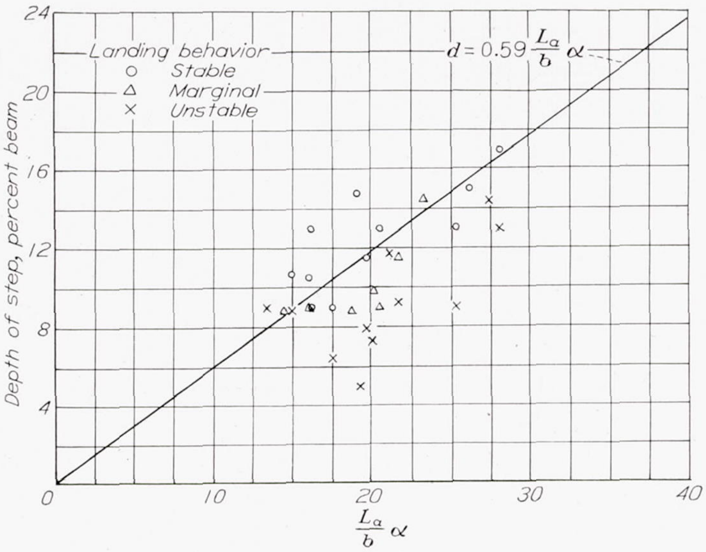


FIGURE 17.—Comparison of tentative afterbody design formula with data from several tank models.

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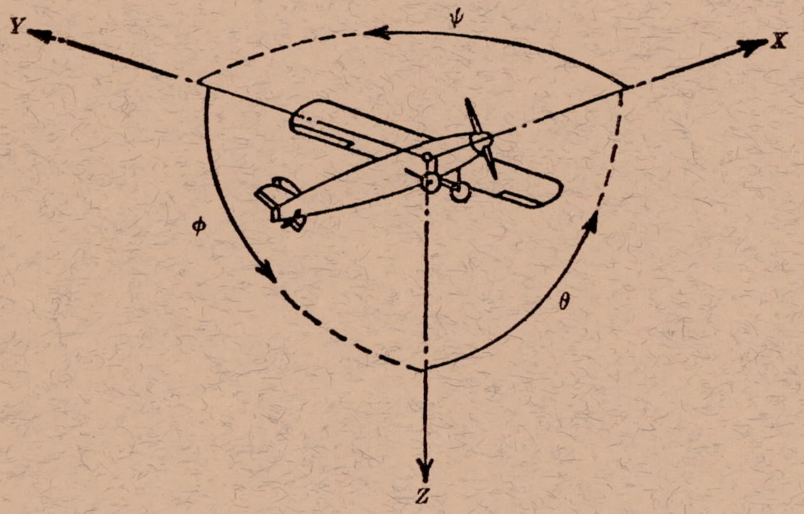

Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	X	X	Rolling	L	$Y \longrightarrow Z$	Roll	ϕ	u	p
Lateral	Y	Y	Pitching	M	$Z \longrightarrow X$	Pitch	θ	v	q
Normal	Z	Z	Yawing	N	$X \longrightarrow Y$	Yaw	ψ	w	r

Absolute coefficients of moment

$$C_l=\frac{L}{qbS} \quad C_m=\frac{M}{qcS} \quad C_n=\frac{N}{qbS}$$

(rolling) (pitching) (yawing)

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D	Diameter
p	Geometric pitch
p/D	Pitch ratio
V'	Inflow velocity
V_s	Slipstream velocity
T	Thrust, absolute coefficient $C_T=\frac{T}{\rho n^2 D^4}$
Q	Torque, absolute coefficient $C_Q=\frac{Q}{\rho n^2 D^5}$
P	Power, absolute coefficient $C_P=\frac{P}{\rho n^3 D^5}$
C_s	Speed-power coefficient $=\sqrt[5]{\frac{\rho V^5}{P n^2}}$
η	Efficiency
n	Revolutions per second, rps
Φ	Effective helix angle $=\tan^{-1}\left(\frac{V}{2\pi rn}\right)$

5. NUMERICAL RELATIONS

1 hp=76.04 kg-m/s=550 ft-lb/sec

1 metric horsepower=0.9863 hp

1 mph=0.4470 mps

1 mps=2.2369 mph

1 lb=0.4536 kg

1 kg=2.2046 lb

1 mi=1,609.35 m=5,280 ft

1 m=3.2808 ft