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REPORT No. 209

CHARACTERISTICS OF A SINGLE FLOAT SEAPLANE DURING TAKE-OFF

By J. W. CROWLEY, Jr., and K. M. RONAN

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AERONAUTICAL SYMBOLS.

1. FUNDAMENTAL AND DERIVED UNITS.

	Symbol.	Metric.		English.	
		Unit.	Symbol.	Unit.	Symbol.
Length	l	meter	m.	foot (or mile)	ft. (or mi.).
Time	t	second	sec.	second (or hour)	sec. (or hr.).
Force	F	weight of one kilogram	kg.	weight of one pound	lb.
Power	P	kg.m/sec		horsepower	HP
Speed		m/sec	m. p. s.	mi/hr	M. P. H.

2. GENERAL SYMBOLS, ETC.

Weight, $W=mg$.

Standard acceleration of gravity, $g=9.806\text{m/sec.}^2=32.172\text{ft/sec.}^2$

Mass, $m=\frac{W}{g}$

Density (mass per unit volume), ρ

Standard density of dry air, 0.1247 (kg.-m.-sec.) at 15.6°C. and 760 mm. = 0.00237 (lb.-ft.-sec.)

Specific weight of "standard" air, 1.223 kg/m.^{3} = 0.07635 lb/ft.^{3}

Moment of inertia, mk^2 (indicate axis of the radius of gyration, k, by proper subscript).

Area, S; wing area, S_w, etc.

Gap, G

Span, b; chord length, c.

Aspect ratio $= b/c$

Distance from $c.\ g.$ to elevator hinge, f.

Coefficient of viscosity, μ.

3. AERODYNAMICAL SYMBOLS.

True airspeed, V

Dynamic (or impact) pressure, $q=\frac{1}{2}\rho V^2$

Lift, L; absolute coefficient $C_L=\frac{L}{qS}$

Drag, D; absolute coefficient $C_D=\frac{D}{qS}$.

Cross-wind force, C; absolute coefficient $C_C=\frac{C}{qS}$.

Resultant force, R

(Note that these coefficients are twice as large as the old coefficients L_c, D_c.)

Angle of setting of wings (relative to thrust line), i_w

Angle of stabilizer setting with reference to thrust line i_t

Dihedral angle, γ

Reynolds Number $=\rho\frac{Vl}{\mu}$, where l is a linear dimension.

e. g., for a model airfoil 3 in. chord, 100 mi/hr., normal pressure, 0°C: 255,000 and at 15.6°C, 230,000;

or for a model of 10 cm. chord, 40 m/sec., corresponding numbers are 299,000 and 270,000.

Center of pressure coefficient (ratio of distance of C. P. from leading edge to chord length), C_p.

Angle of stabilizer setting with reference to lower wing. $(i_t - i_w)=\beta$

Angle of attack, α

Angle of downwash, ϵ

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By J. W. CROWLEY, Jr., and K. M. RONAN
Langley Memorial Aeronautical Laboratory

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SUMMARY

At the request of the Bureau of Aeronautics, Navy Department, the National Advisory Committee for Aeronautics at Langley Field is investigating the planing and get-away characteristics of an N–9H, a DT–2, and an F–5L, as representing, respectively, a single float, a double float, and a boat type of seaplane. This report covers the investigation conducted on the N–9H. The results show that a single float seaplane trims aft in taking off. Until a planing condition is reached the angle of attack is about 15° and is only slightly affected by the controls. When planing it seeks a lower angle, but is controllable through a widening range, until at the take-off it is possible to obtain angles of 8° to 15° with corresponding speeds of 53 to 41 M. P. H. or about 40 per cent of the speed range. The point of greatest resistance occurs at about the highest angle or a pontoon planing angle of 9½° and at a water speed of 24 M. P. H.

INTRODUCTION

Due to the scarcity of full-scale data the float designer is handicapped, as there is little basis for determining which of the results obtained by model tests similate most clearly the full-scale planing characteristics. The Bureau of Aeronautics decided that planing tests in which synchronized, continuous records of waterspeed, airspeed, and planing angles would show enough fundamental characteristics to somewhat alleviate this condition.

The seaplane used, the N–9H, while practically obsolete, has the present standard type of pontoon and its characteristics no doubt are quite representative of its class. Its small reserve power fitted well with the purpose of the test, as it served to emphasize the vital points.

The report includes a description of the methods and apparatus used, a discussion of the results obtained, and the conclusions drawn. It permits the engineer to apply intelligently the results of model tests and should also be of assistance to the pilot in studying the characteristics of his seaplane.

REFERENCES

1. H. C. Richardson. Airplane and Seaplane Engineering. Bureau of Aeronautics Technical Note No. 59.
2. E. S. Goodwin. Seaplanes Taking Off and Alighting. Reports and Memoranda No. 784.
3. G. S. Baker. Experiments with Models of Seaplane Floats. Reports and Memoranda Nos. 165, 166, 187, and 188.
4. G. S. Baker. Some Notes on Floats for Seaplanes of the Single Float Type. Reports and Memoranda No. 437.

METHODS AND APPARATUS

The tests were made in the basin of the Hampton Roads Naval Air Station on a service type N–9H, under fairly good flying conditions. Synchronized records of airspeed, waterspeed, and angle of attack were taken of various methods of take-off.

The engine was in good condition, turning up 1,475 R. P. M. while taking off. The seaplane was well rigged and its fabric was taut, but it was "loggy" both in maneuvering on the water and in the air. This was probably caused by its heavily loaded condition, due to absorption of water.[1]

[1] Appendix No. 1.

The day was almost ideal for this test. The water was calm, its surface being glassy on the first two or three runs and slightly rippled on the remaining. There was a 5-mile wind blowing and the airspeed records indicate that it was slightly gusty. It is thought that the presence of a sea wall on the windward side amplified this gustiness.

The airspeed was recorded on an N. A. C. A. recording airspeed meter,[2] which was connected to a swiveling Pitot static head.

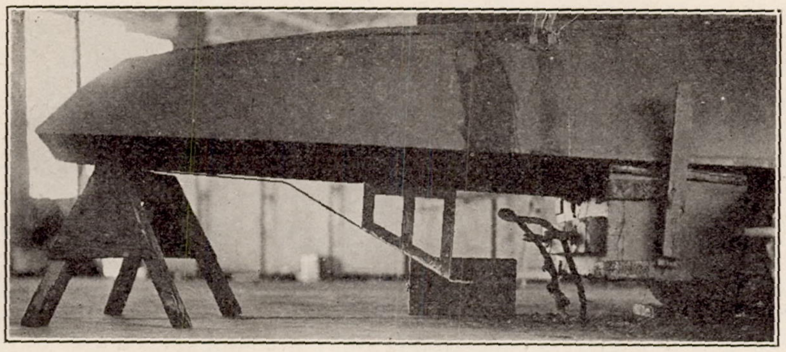


FIG. 1.—Waterspeed pressure nozzle attachment

The waterspeed was recorded on a similar instrument except that the capsule had a heavier diaphragm. This was connected to a pressure nozzle attached to the bottom of the pontoon aft of the step (fig. 1). A calibration of this apparatus over a speed course showed that at low speeds the indicated waterspeed was slightly less than the true. The curves are corrected for this.

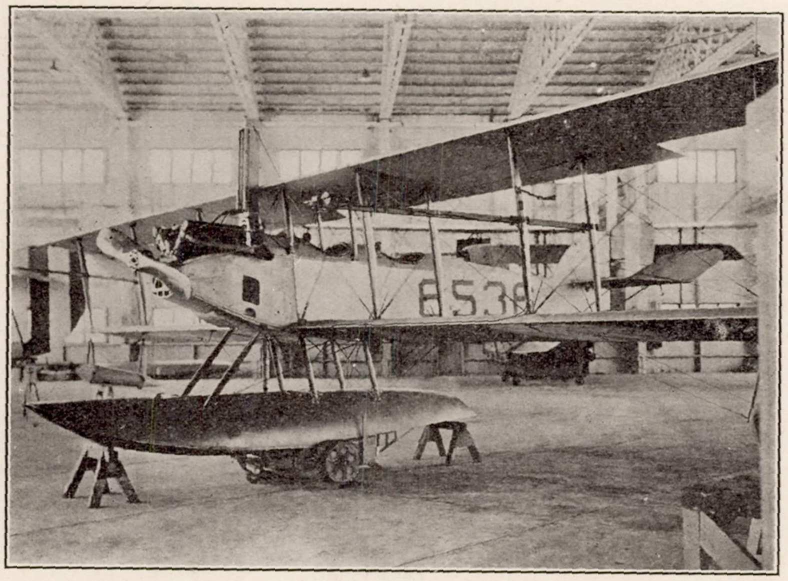


FIG. 2.—N-9H ready for planing test. Angle of attack controller vane in the foreground

An interesting condition was observed on the calibration trials. An unstable speed range was found between 15 and 27 M. P. H., within which a constant waterspeed could not be maintained.

The angle of attack was measured by the N. A. C. A. angle of attack recorder.[3] The controller vane was mounted on an outrigger, 5 feet in front and on a line midway between the wings (fig. 2). To check this recorder, a sliding pointer was attached to a center section

[2] N. A. C. A. Technical Note No. 64, 1921.

[3] N. A. C. A. Technical Note No. 156, 1923.

strut, so that the observer could line it up with a point on the nose of the seaplane and the horizon. The position of this pointer was recorded on an N. A. C. A. control position recorder.[4] The angle of attack thus obtained closely agreed with that found by the angle of attack recorder, with the exception, that in the last method the observer could not follow the smaller oscillations, so that a faired record was obtained.

In order to cover the range of take-off speeds and angles, four different control methods were used. These were normal control, control held back, control free, and control held forward. On the first or normal method the pilot was requested to take off in his usual manner. This consisted in rocking to get on the step, nosing slightly forward to assist in gaining speed while planing, and then pulling the nose slowly up until the seaplane took off. In the second method the control was held back to its extreme position throughout the run. The third method consisted in letting the longitudinal control be free to assume any position, but guiding it to keep from oscillating. In the last method the control was held as far forward as the pilot thought would allow a take-off.

PRECISION

The estimated precision of the factors obtained are:

Airspeed	±1 M. P. H.
Waterspeed	±1.5 M. P. H.
Angle of attack	±1°
Time	±0.5 sec.

Below 20 M. P. H. the interpolation becomes increasingly difficult and the above values would be slightly increased.

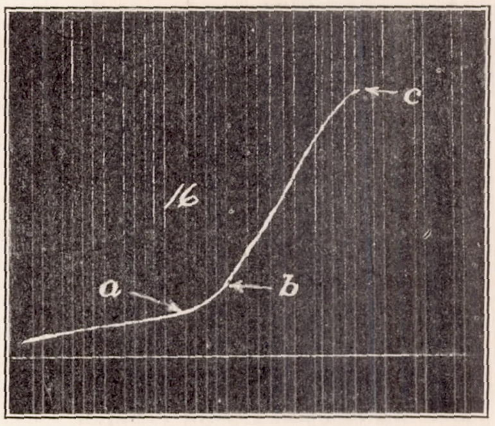


FIG. 3.—Recorded waterspeed pressure curves
RUN 16
a—First change in slope.
b—Second change in slope.
c—Take-off.

RESULTS

The results of the test are given in Figures 4 to 23. Figures 4 to 19 are grouped according to methods of take-off, the run number referring to the order of making them. Figures 21 to 23 are summations of the originals.

In each run the waterspeed, airspeed, and angle of attack are plotted on a time basis. As the angle of incidence of the wings is +4° and of the pontoon is −2½°, the planing angle of the pontoon is 6½° less than the angle of attack. The conditions "rising to step," "planing on step," and "take-off" are indicated. These occur at a point on the waterspeed curve where there is a definite change in the slope (fig. 3), and is also similarly marked on the angle of attack curve. It is assumed that the first change of slope occurring at a waterspeed of about 24 M. P. H. and an angle of attack of about 14° determines the place where the seaplane first definitely starts to rise toward a planing condition. The second change occurring at about 27 M. P. H. and at an angle of attack of 10½° to 12½° is the start of the planing stage. The take-off is at the end of the waterspeed record, and varies with the angle of attack from 41 M. P. H. at 15½° to 53 M. P. H. at 8°.

The curves of the control free method are shown in Figures 4 to 7. It is noticeable that the range of slope of the velocity curve is small and it has no abrupt changes. Curve No. 4 was taken on very smooth water which delayed getting on the step and taking off and the pilot assisted in both cases. In this particular run it will be noted that before the planing

[4] N. A. C. A. Technical Note No. 154, 1923.

condition is reached the velocity curves have a much smaller slope than in any of the other runs. This indicates that smooth glassy water offers the greatest impediment to rising on the step. The angle of attack curve shows that the seaplane was very stable until planing, when an unstable oscillation appeared. The runs plotted in Figures 5 to 7 were made on slightly rippled water and, contrary to that shown in Figure 4, have oscillations until planing, when they are highly damped. It appears that under favorable conditions the seaplane supplies its own rocking motion to get on the step.

Figures 8 and 9 show the effects of holding the control forward. It delays but does not prevent the trimming aft. Practically the same planing angle is obtained as with the control free. The slope of the velocity curve approaches zero abruptly at the point of rising to the step, which indicates an appreciable hump in the resistance curve. This method of control damps the natural rocking until planing, when small oscillations are induced.

The results of holding the control back are given in Figures 10 to 13. The slopes of the velocity curves are quite similar except in Figure 11. The latter indicates that the pilot was able to hold a high angle after starting to plane which has decreased he slope, indicating an increased resistance. In this run the angle was brought up to abou 17°, probably aided by a wave, and a take-off was made, but the angle could not be held and the seaplane settled back. In this method, as in the preceding, the larger rocking oscillations are damped out at first, leaving smaller ones, the latter being particularly noticeable in Figure 12. Planing oscillations are also set up. Figure 10 shows the presence of a highly damped planing oscillation.

The normal method of control gives the results shown in Figures 14 to 19. As is to be expected where a personal factor is present, the shape of the velocity curves are not similar. The angle of attack curves, however, have a general similarity showing that the pilot followed a set procedure. Oscillations are so broken up by the control movements that they are of no definite period. This shows that the pilot did not rock the seaplane in phase with its natural oscillations and therefore lost the assistance of this inherent asset. The cross-wind and down-wind take-offs are interesting variations. The steepest slope on the velocity curves occurs on the cross-wind take-off where an acceleration of $1/9g$ occurs while planing. The down-wind curves show that the waterspeed is the dominating factor in a take-off until the planing condition is reached. This is shown by the fact that although the airspeed is low, the first two stages are passed through at about the same waterspeed as in the previous runs. This fact is further shown by a curve of waterspeed against airspeed, where for the "rising to step" condition the slope of the curve is 1:7, i. e., an increase of 1 M. P. H. water speed is equivalent to 7 M. P. H. increase of airspeed, while for the "planing" condition the slope is 1:1.

Figure 20 shows the variation in angle of attack with waterspeed by the different control methods. These curves are faired from all the points obtained on each method. They are quite similar in shape until the planing condition is reached, when the control becomes more effective. The normal control curve has a hump at about 21 M. P. H., which is caused by rocking the seaplane. The peaks of these curves represent the critical point in the take-off. They occur at a place on the velocity curves where the slope is very small and where an increase of about 3 M. P. H. (three-fortieths of the total range of waterspeed) takes one-fifth of the total time. If the seaplane gets past this point it has plenty of reserve power to take off.

Figure 21 shows the angle of attack at the different stages obtained by the different methods of control. This gives additional information on the effect of control.

Figure 22 gives the time consumed for each stage by the different methods. In the first stage the free control is best. The control makes little difference during the second stage. The normal being slightly the longest, however, indicates that the forced rocking by interfering with, rather than assisting, the natural tendency, has been disadvantageous. The normal method is the quickest for the planing stage. The time gained over the other methods is undoubtedly due to nosing the seaplane down and decreasing the resistance.

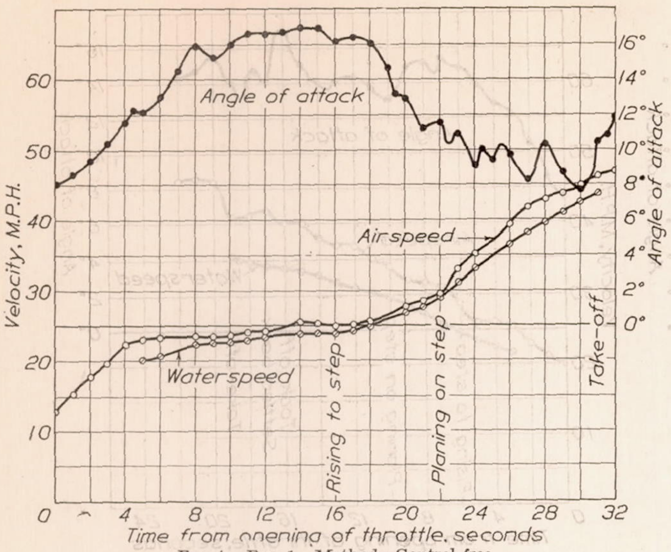


FIG. 4.—Run 1. Method—Control free
(NOTE.—The seaplane needed assistance to get on step, and was pulled off)

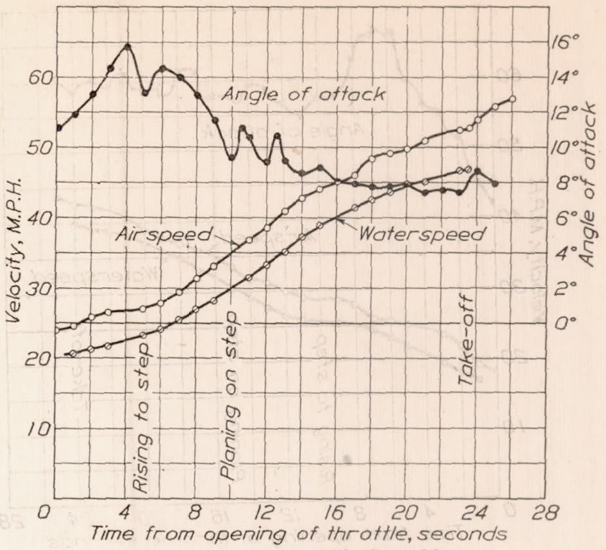


FIG. 5.—Run 7. Method—Control free

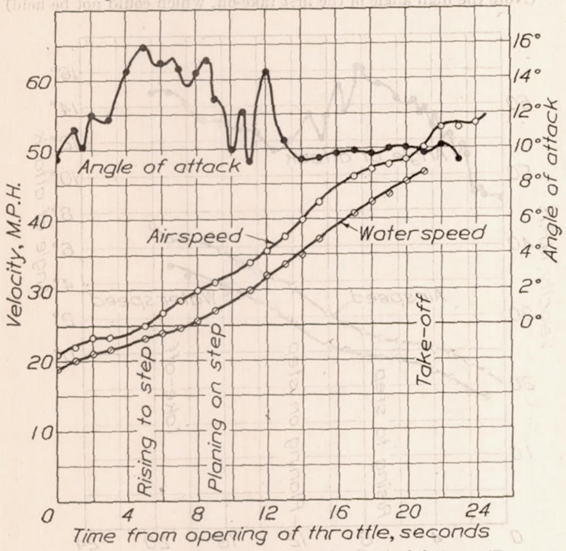


FIG. 6.—Run 10. Method—Control free
(NOTE.—Pilot assisted seaplane in getting on step by rocking slightly)

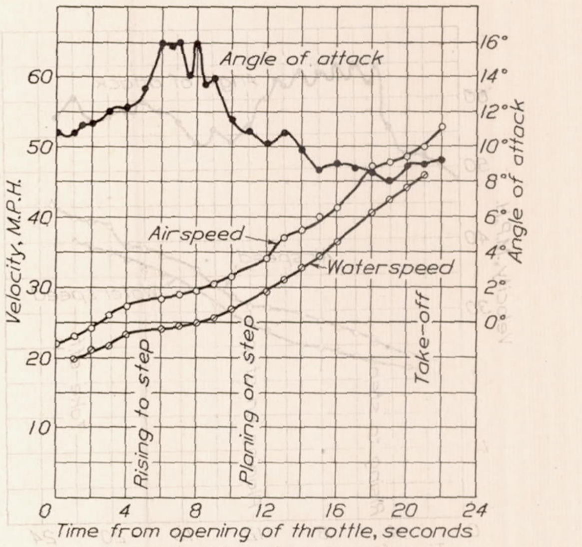


FIG. 7.—Run 14. Method—Control free

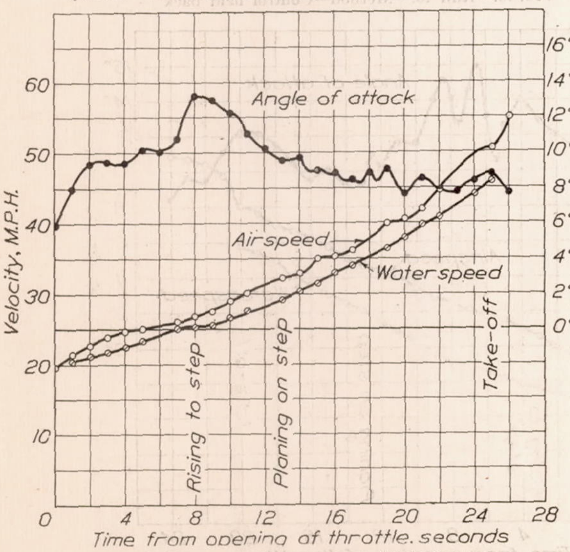


FIG. 8.—Run 4. Method—Control held forward
(NOTE.—Pilot had to let control back in order to get on step)

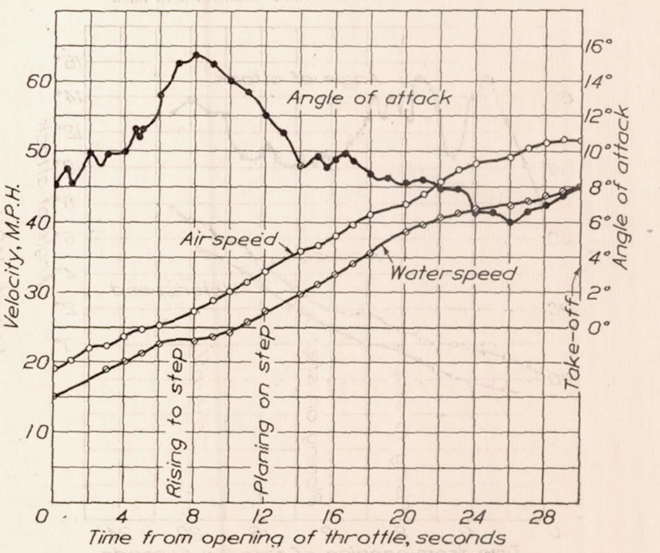


FIG. 9.—Run 12. Method—Control held half forward
(NOTE.—The control was pulled back slightly in order to take-off)

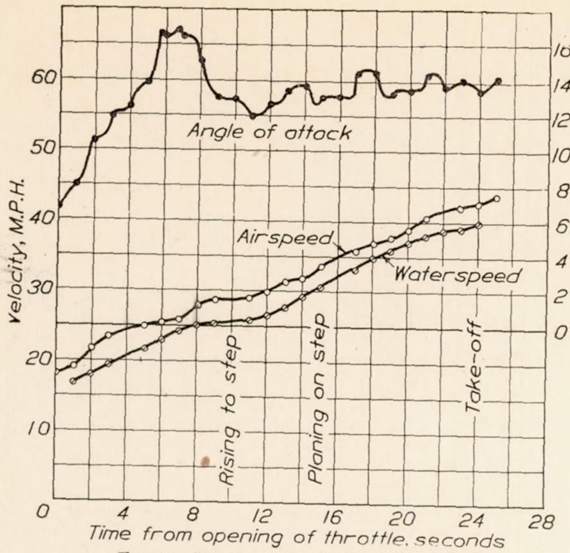


FIG. 10.—Run 3. Method—Control held back

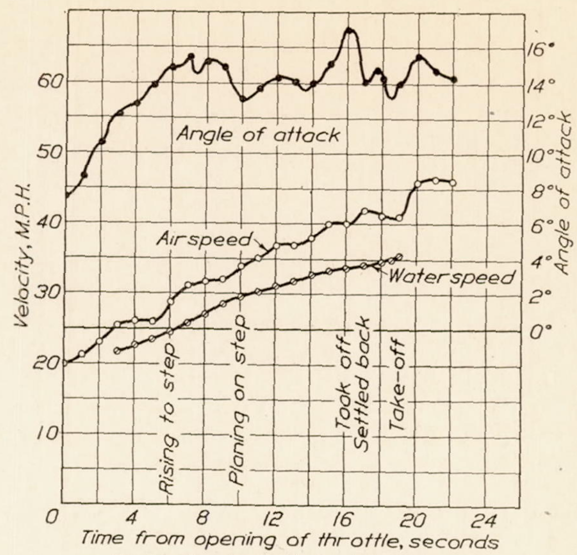


FIG. 11.—Run 5. Method—Control held back
(Note the high angle of the first take-off, which could not be held)

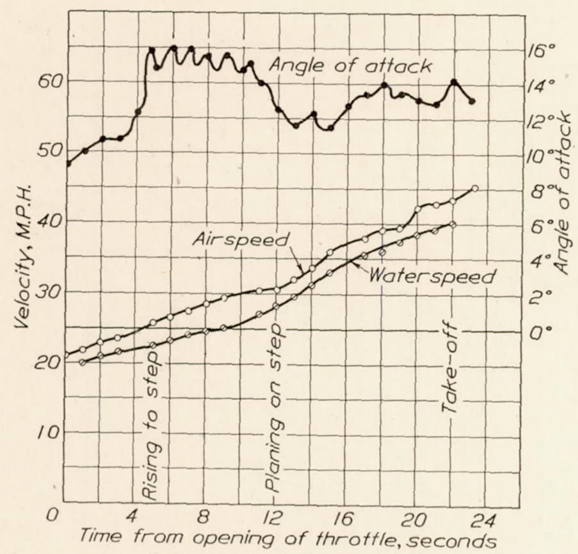


FIG. 12.—Run 9. Method—Control held back

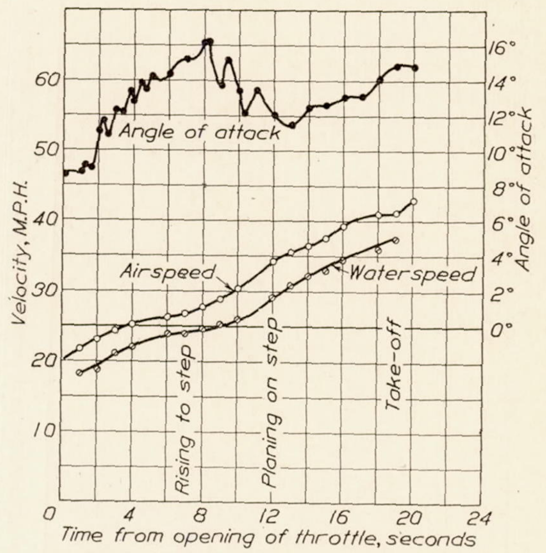


FIG. 13.—Run 13. Method—Control held back

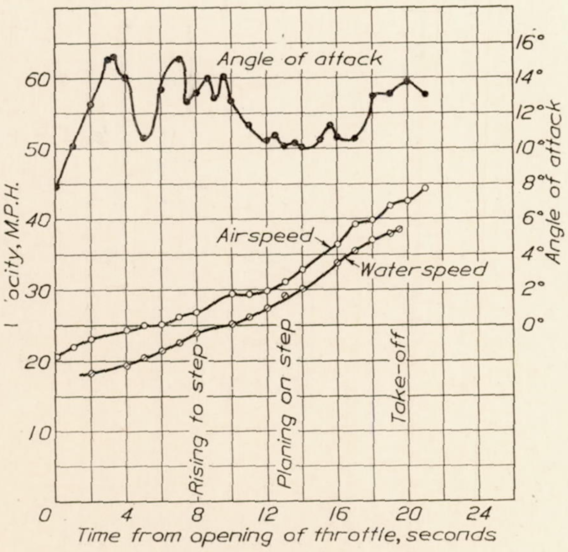


FIG. 14.—Run 2. Method—Normal

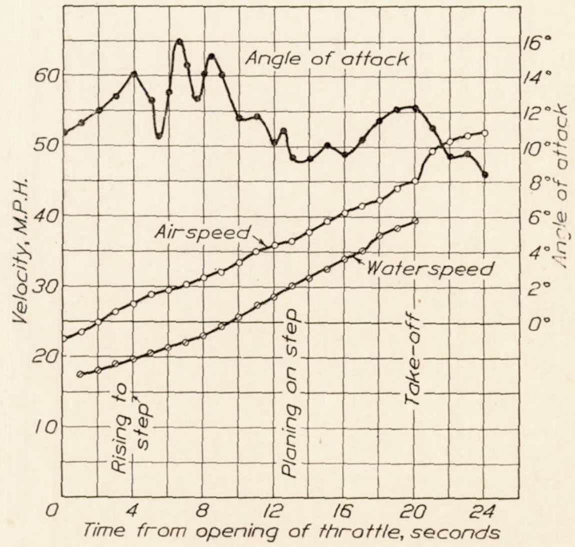


FIG. 15.—Run 6. Method—Normal

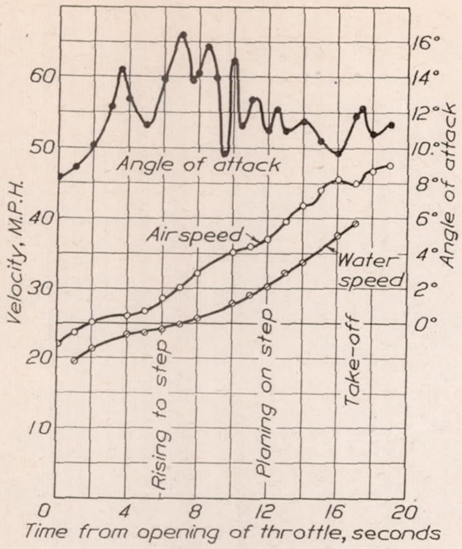


FIG. 16.—Run 11. Method—Normal

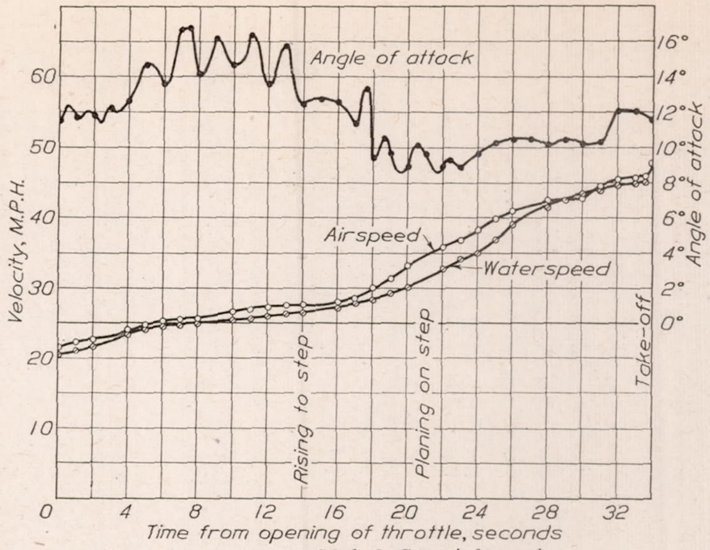


FIG. 18.—Run 16. Method—Crosswind normal

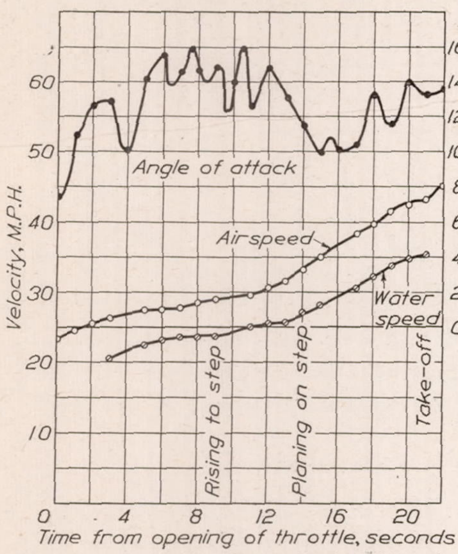


FIG. 17.—Run 15. Method—Normal

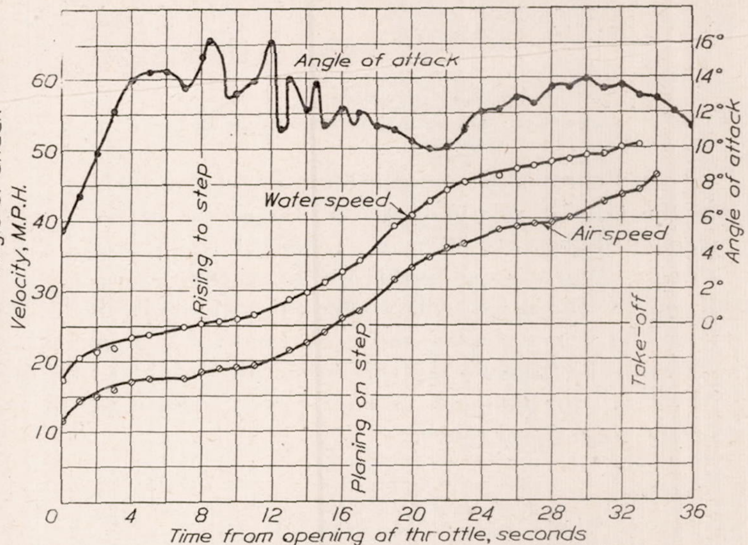


FIG. 19.—Run 8. Method—Downward normal

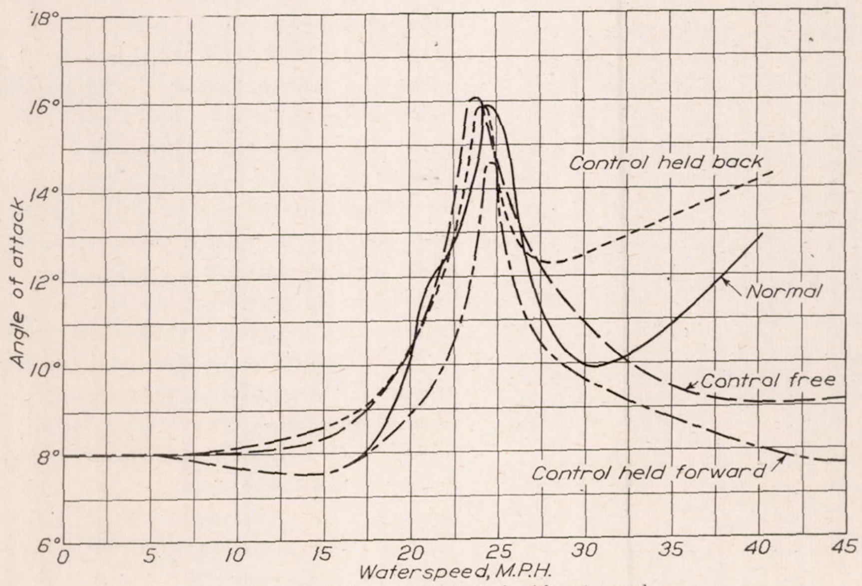


FIG. 20.—Variation in angle of attack with waterspeed

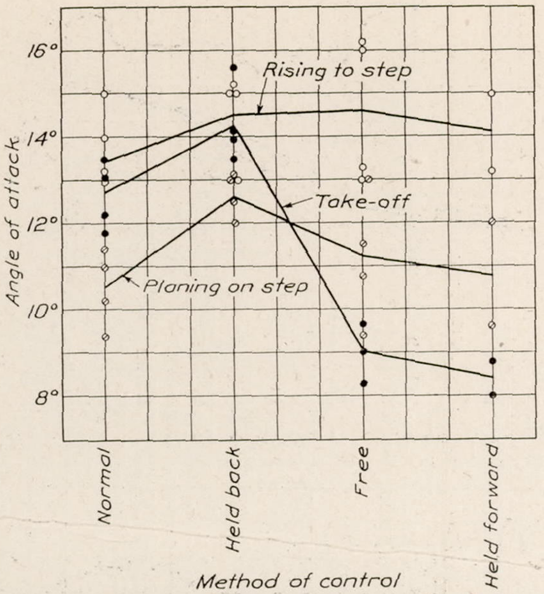


FIG. 21.—Angle of attack for each stage by different take-off methods

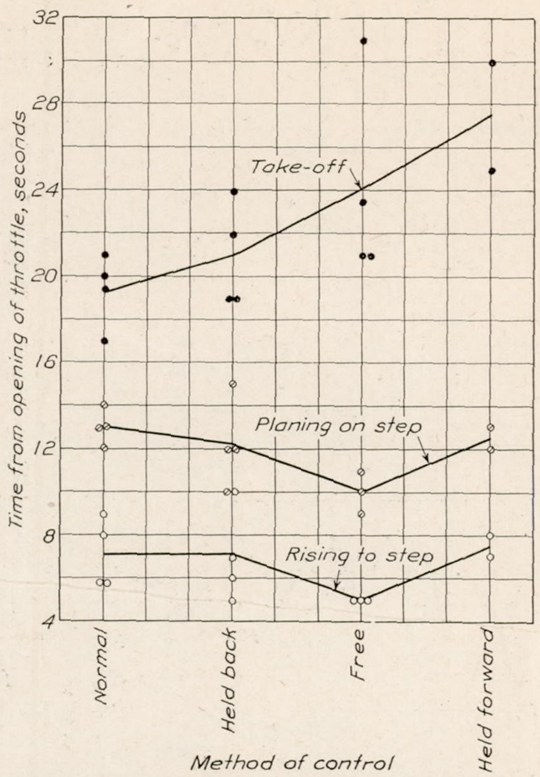


FIG. 22.—Time used for each stage by different take-off methods

In Figure 23 the airspeed and angle of attack at the take-off are plotted. As far as the lift is concerned the take-off is a level flight condition, though somewhat in error due to ground interference. The absolute lift coefficient, C_L, is derived from the velocity curve and is also plotted in Figure 23. The range of take-off speeds is here shown to be from 41 M. P. H. to 53 M. P. H. As the top speed of this seaplane is about 75 M. P. H., the range of take-off speeds is cut down by planing resistance to about 40 per cent of the total speed range.

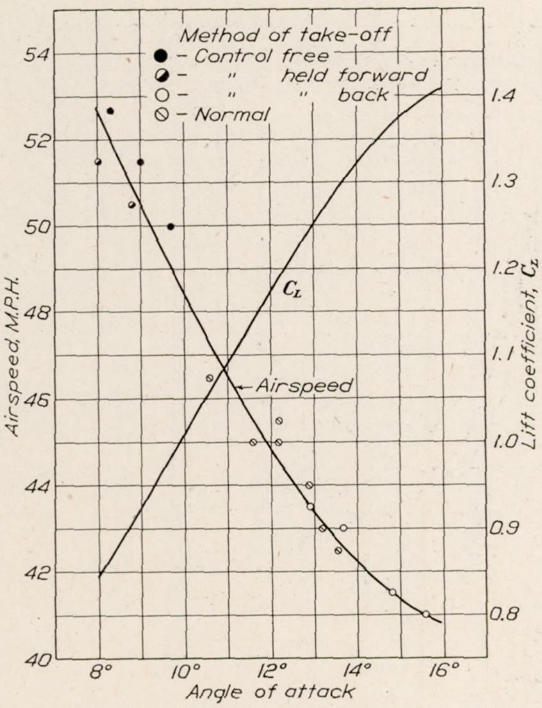


FIG. 23.—Velocity and lift coefficient at various angles of take-off

CONCLUSIONS

The test has served to bring out clearly the critical point in the take-off. It occurs close to the point spoken of as "rising to step" at a pontoon planing angle of about 9½° and a waterspeed of 24 M. P. H. At this point the waterspeed is the dominating factor, the lifting effect of waterspeed and airspeed being in ratio of 7:1. At this point also very smooth water offers a hindrance which can be overcome by rocking, especially if the pilot combines his efforts with those of the seaplane. The amount of control before planing is slight, its effect mainly having an influence on the oscillations. It is found that the seaplane will accelerate faster when planing if it is nosed down slightly.

These results show the need for further investigation of the fundamental characteristics of a pontoon when ploughing and planing through the water. As the pontoon has a high angle at the critical speed the relation between fore and aft setting of the seaplane on the pontoon and the angle between the pontoon and the x-axis of the seaplane must have an important bearing on the performance and should be known.

APPENDIX NO. 1

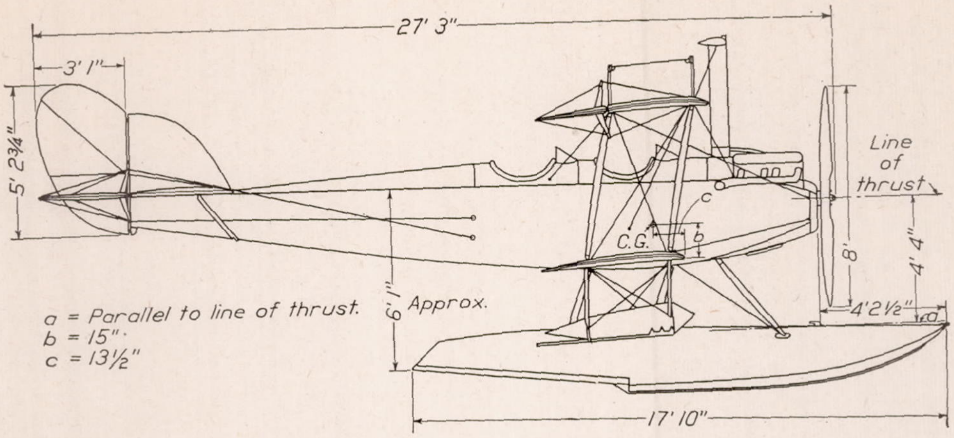


FIG. 24.—N-9H seaplane

CHARACTERISTICS OF THE N-9H SEAPLANE

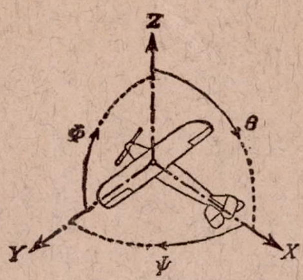
Type	Single-pontoon tractor biplane.
Wing area	496 square feet.
Angle of incidence of wings	4 degrees.
Weight, as tested	2,970 pounds.
Engine	Hispano-Suiza I, 150 horsepower at 1,475 revolutions per minute.
Wing loading	6.00 pounds/square foot.
Power loading	19.8 pounds/brake horsepower.
Center of gravity location	13½ inches aft and 15 inches above leading edge of lower wing, and 10¾ inches forward of step.
Propeller	8 feet diameter.

Markings: Buffalo Airplane Corporation 2, H-S, SE5 80-60, 3 feet by 4 feet 3 inches, RH, CP 42547

Pontoon	17 feet 10 inches in length.
Angle of incidence[5]	−2½ degrees.
Step	11 feet 8 inches from bow.
Markings	Burgess float, 19–2523.

[5] Refers to angle between x-axis of the seaplane and upper surface of pontoon.

○



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

$$C_l = \frac{L}{q b S} \quad C_m = \frac{M}{q c S} \quad C_n = \frac{N}{q f S}$$

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

4. PROPELLER SYMBOLS.

Diameter, D

Pitch (a) Aerodynamic pitch, p_a

(b) Effective pitch, p_e

(c) Mean geometric pitch, p_g

(d) Virtual pitch, p_v

(e) Standard pitch, p_s

Pitch ratio, p/D

Inflow velocity, V'

Slipstream velocity, V_s

Thrust, T

Torque, Q

Power, P

(If "coefficients" are introduced all units used must be consistent.)

Efficiency $\eta = T\,V/P$

Revolutions per sec., n; per min., N

Effective helix angle $\Phi = \tan^{-1}\left(\frac{V}{2\pi r n}\right)$

5. NUMERICAL RELATIONS.

1 HP = 76.04 kg. m/sec. = 550 lb. ft/sec.

1 kg. m/sec. = 0.01315 HP

1 mi/hr. = 0.44704 m/sec.

1 m/sec. = 2.23693 mi/hr.

1 lb. = 0.45359 kg.

1 kg. = 2.20462 lb.

1 mi. = 1609.35 m. = 5280 ft.

1 m. = 3.28083 ft.