REPORT No. 242

CHARACTERISTICS OF A TWIN-FLOAT SEAPLANE DURING TAKE-OFF

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SUMMARY

At the request of the Bureau of Aeronautics, Navy Department, an investigation has been made, by the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics, of the planing and get-away characteristics of three representative types of seaplanes, namely: Single float, boat, and twin float. The experiments carried out on the single float (Reference 1) and boat (Reference 2) types have been reported on previously. This report covers the investigation conducted on the twin-float seaplane, the DT–2, and includes, as an appendix, a brief summary of the results obtained on all three tests.

The fundamental take-off characteristics of the DT–2 seaplane (twin float) are similar to those of the N–9H (single float) and the F–5L (boat type). At low water speeds, 20 to 25 M. P. H., the seaplane trims by the stern and has a high resistance. Above these speeds the longitudinal control becomes increasingly effective until, with a gross load of 6,000 pounds, it is possible to get away at angles of attack of 8 to 14 degrees with corresponding speeds of 56 to 46 M.P.H. It was further determined that an increase in the load caused little if any change in the water speed at which the maximum angle and resistance occurred, but that it did produce an increase in the maximum angle.

INTRODUCTION

The use of twin floats has been mainly restricted to racing and torpedo-carrying seaplanes. The float characteristics of the former, beyond stability and aerodynamic resistance, are of small consequence as an abundance of reserve power is available for getting off. Since the requirement of the torpedo seaplane is to get off with a maximum load, it was selected as being the most representative of twin-float types to test. The difference in the type and size of the seaplane proper would probably affect the over-all take-off performance to a greater extent than would the use of twin floats in place of a single float. It is therefore expected that the difference between the single and twin float results is more of a type than a float effect. The tests have been conducted mainly to acquaint the designer and those who test model floats with the actual conditions arising from the beginning of the take-off[1] to the get-away.[2] The report also contains information which is interesting and valuable to pilots.

METHODS AND APPARATUS

The seaplane used was the Douglas torpedo plane, the DT–2.[3] The floats and fabric were in fairly good condition, but the engine was in need of an overhaul and the propeller used held it down to 1,550 R. P. M. at the get-away.

As in the tests on the other types of seaplanes, four control methods, covering practically all the possible control variations, were used, namely: Free, forward, back, and normal. The control forward and control back methods are self-explanatory, but the other two may need

[1] Take-off as used herein is the period on the water from the time of the opening of the throttle until the seaplane leaves the water.
[2] Get-away as used herein is the act of leaving the water.
[3] See Appendix 1.

some further description. In the control-free method the pilot allows the elevators to float but maintains enough control to prevent excessive oscillations and at the same time maintains proper lateral balance and directional control by means of the ailerons and rudder. The piloting was done entirely by Mr. Paul King, of the laboratory staff, so that all the normal take-offs should be quite similar. The following is his description of the normal take-off:

"The take-off of this seaplane, light, was very easy. At the opening of the throttle the control column was pulled well back. As the seaplane gained in speed the control column was eased foward slightly past neutral, thus allowing it to get on the step. At a speed of approximately 55 M. P. H. a slight backward pressure was exerted on the control column, enabling the seaplane to fly off the water. It was unnecessary to pull the DT-2 off. With the heavier loading the procedure differed but slightly. To get it upon the step it was necessary to throw the seaplane by pushing the control column smartly forward just past neutral. After getting upon the step the column was returned to neutral and held there until sufficient speed was attained; then by a sharp backward pull the seaplane left the water. In several instances, with the heavy load, as the DT-2 was thrown upon the step there was a tendency for it to porpoise. This was stopped by pulling the control column backward as the seaplane pitched forward, and pushing forward as it reared backward. At no time was it necessary to rock the seaplane to get upon the step, nor was the stabilizer setting changed, it being set at all times for level flying at cruising speed."

To facilitate the testing, the runs to obtain the effect of these control variations were made with a gross light load (6,000 pounds). To ascertain the effect of different loadings and to obtain the full-load conditions one take-off was made with a load of 6,800 pounds and one with a load of 7,500 pounds. The loading was obtained by filling the distance fuel tanks with water and attaching them in place of the torpedo.

Continuous synchronized records of the air speed, water speed, and planing angle were obtained from the beginning to the end of the take-off.

The air speed was measured by means of a Baden double-Venturi head mounted on a boom extending a chord length ahead of the wings, and an N. A. C. A. air-speed recorder. (Reference 3.)

The water speed was measured by a Pitot tube, extended through a breather hole, and connected to an instrument similar in principle to the air-speed recorder. The tube was attached so that it could be lowered into place after the seaplane was launched. A comparison of runs with and without the Pitot tube lowered showed that its resistance was negligible. A calibration of the attachment on a water-speed course showed the indicated water speed to be slightly high at low speeds. The necessary correction has been applied to the curves.

The planing angle was obtained by means of a vane mounted on a boom a chord length ahead of the wings, and free to align itself along the relative wind. Integral with the vane was a variable resistance so connected with a recording galvanometer (Reference 4) in a Wheatstone bridge circuit that any deflection of the vane was recorded by the galvanometer. A calibration to obtain the true angle, which differs from the indicated by the "upwash" angle, was made by mounting a gun camera parallel to the Y-axis of the seaplane so as to take pictures of the horizon during a take-off. These pictures gave the inclination of the seaplane to the horizontal, and therefore the planing angle, at the same time that a record was taken of the indicated angle. The calibration thus obtained was extended to cover all the flights by asssuming that the variation is a function of the angle of attack only.

PRECISION

The estimated precision is as follows:

Air speed	±1 M. P. H.
Water speed	±1 M. P. H.
Angles	±1°.
Time synchronization	±0.5 sec.

DISCUSSION OF RESULTS

The take-off may be divided into three stages—plowing, transition, and planing, where the term "transition" is used to denote the period during which the float is climbing out of the water from the condition where the lift is almost entirely buoyant (plowing) to where it becomes dynamic (planing). These stages are ordinarily well defined by the slope of the velocity curves and the change of trim. However, on the light load runs the resistance is practically constant throughout so that it is difficult to pick out the boundaries from the velocity curves, but they have been established approximately from the angle curves and are noted as "rising to step" and "planing on step."

The results are given in curve form in Figures 1 to 17. Figures 1 to 15 show curves of the original take-offs and Figures 16 and 17 are derived from them.

The take-off by the control-free method, which allows the seaplane to trim naturally, is shown in Figures 1 to 3. In these figures it will be noted that the slopes of the water-speed curves are nearly constant up to a water speed of approximately 37 M. P. H., where they commence to flatten out, indicating an increase in resistance. The curves also establish the fact that the normal planing angle of this seaplane is about 4°. The seaplane appears to pass through the transition stage quickly and without any tendency to oscillate, but once on the step it oscillates steadily until water speeds of 40 M. P. H. are reached, beyond which the seaplane becomes more stable. This characteristic is particularly noticeable in Figure 3, which shows the results of a run made on water with a glassy surface. The increased stability at high speeds is unusual because oscillations or even porpoising are quite apt to occur at the higher speeds, particularly when light float loadings are used. (Reference 5.) While the control-free method will allow a take-off on the DT–2, it is objectionable because control is needed to damp oscillations when they occur.

It seems worth stating at this time that the above-mentioned increase in resistance at high speeds was characteristic of the boat-type seaplane, the F–5L, but not of the single-float seaplane, the N–9H. The N–9H type of float is similar to those used on the DT–2 except that the former has a V bottom with a 7½° slope while the latter have 15° V bottoms. The interference effects of the floats are not appreciable when planing, since the bow wave is small, so that part of the difference in resistance between the single and double float types at high planing speeds is due to the difference in the angles of the V bottoms.

Figures 4 and 5 show the records of take-offs made by holding the elevators down (control forward). The curves are quite similar to those of the control-free method except that this method has largely eliminated the trimming aft during the transition stage. This effect would be reduced by a larger load because the float moments would be increased. Here again the slope of the water-speed curves is nearly constant up to 37 M. P. H., where it flattens out, and here also planing oscillations are very evident, being even more pronounced than with the control-free method. A run taken on smooth water (fig. 5) shows especially noticeable oscillations in which the period is constant at 1¼ seconds and the amplitude is 3°. As shown here, the attempt to hold the nose of a seaplane lower than its natural trim seems to produce oscillations which may lead to severe porpoising. In a normal take-off it is quite usual for a pilot to ease forward on the control, after planing is started, to allow the seaplane to pick up speed. This usually gives the desired results, but on the DT–2 it would intensify the oscillating tendency, which is detrimental to the life of the seaplane.

Figures 6, 7, and 8 show runs made with the elevators held up throughout. The trimming effectiveness of this control is manifested by the increased transition stage angles and the greatly increased planing angles over those obtained with free control. As is shown by a comparison of the slopes of the water-speed curves of the different methods, these high planing angles (10° or more) are detrimental in that they increase the resistance at low planing speeds. The characteristic qualities of more or less steady planing on rippled water (fig. 6) and oscillatory planing on smooth water (figs. 7 and 8) show that the stability is neither noticeably improved nor harmed by this control.

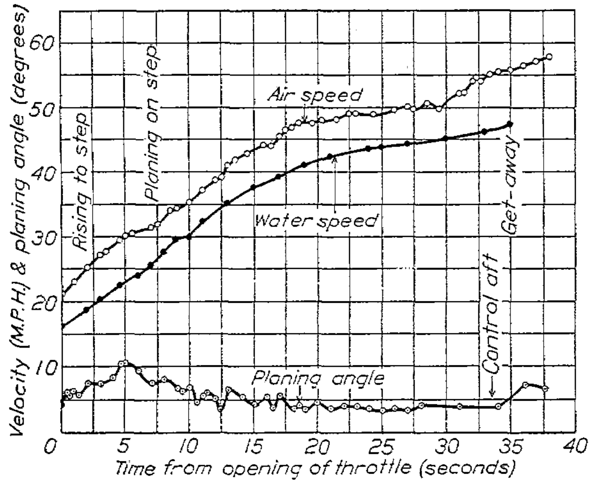

FIG. 1.—Method: Control free. Weight, 6,000 pounds. Rippled water

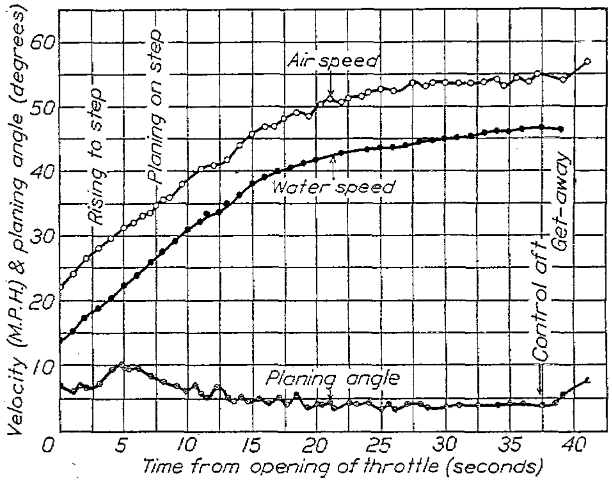

FIG. 2.—Method: Control free. Weight, 6,000 pounds. Rippled water

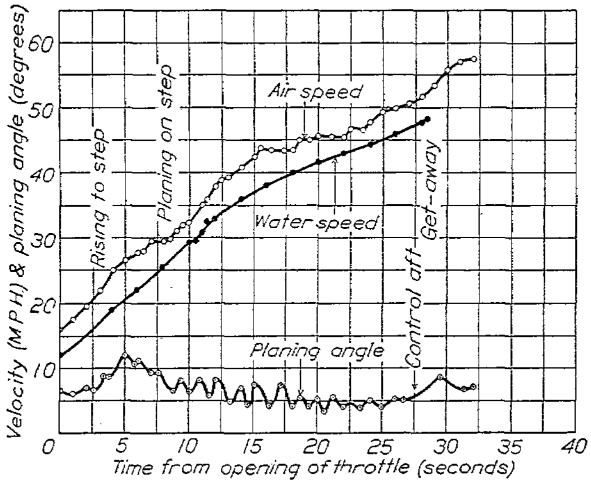

FIG. 3.—Method: Control free. Weight, 6,000 pounds. Smooth water

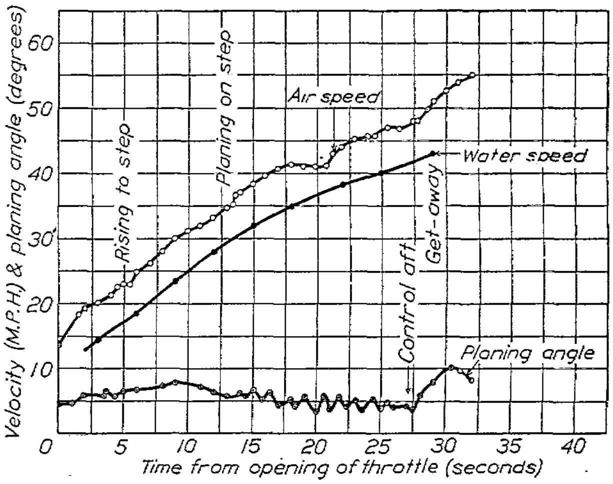

FIG. 4.—Method: Control forward. Weight, 6,000 pounds. Rippled water

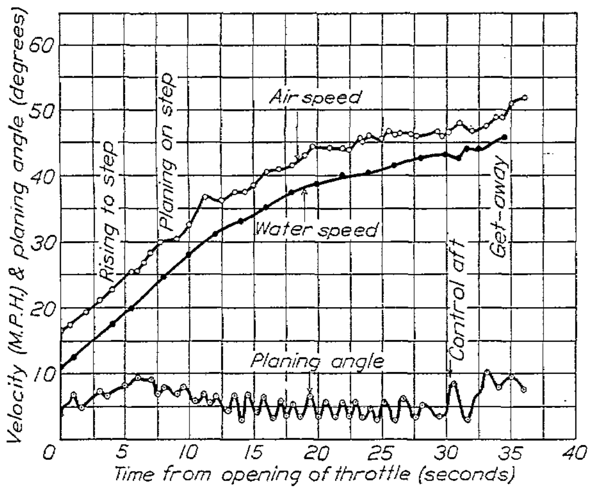

FIG. 5.—Method: Control forward. Weight, 6,000 pounds. Smooth water

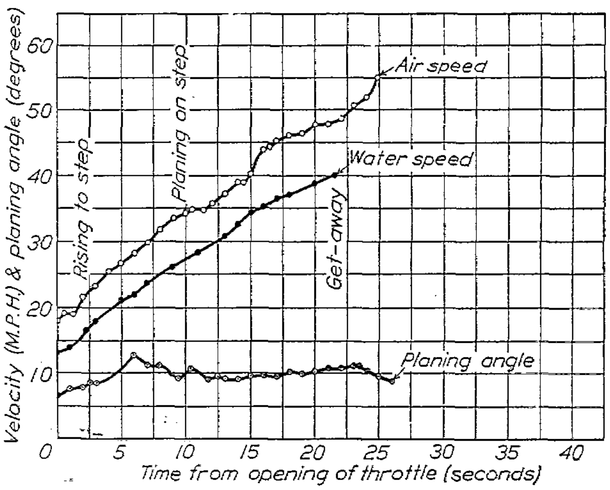

FIG. 6.—Method: Control back. Weight, 6,000 pounds. Rippled water

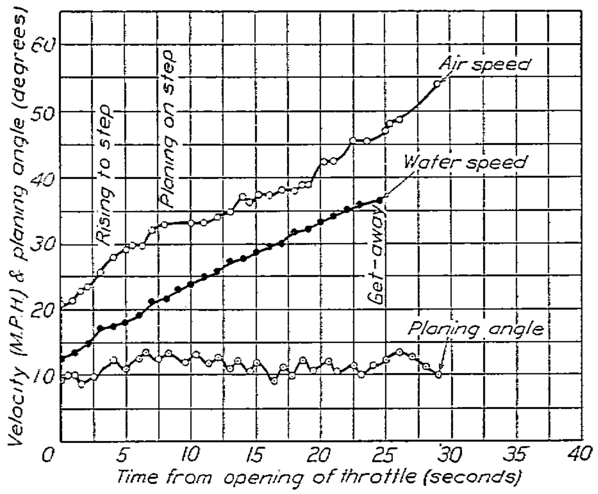

FIG. 7.—Method: Control back. Weight, 6,000 pounds. Smooth water

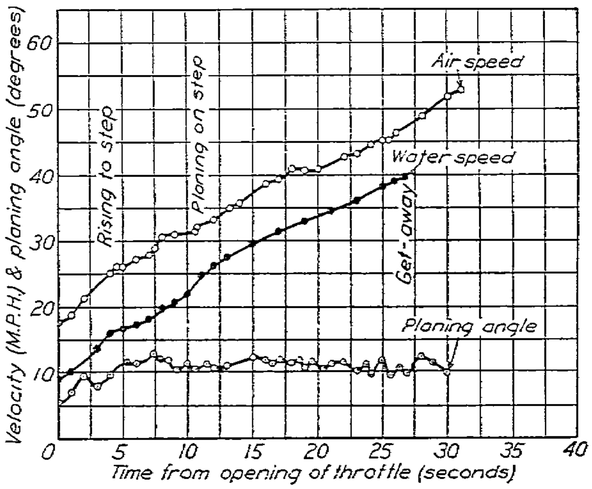

FIG. 8.—Method: Control back. Weight, 6,000 pounds. Smooth water

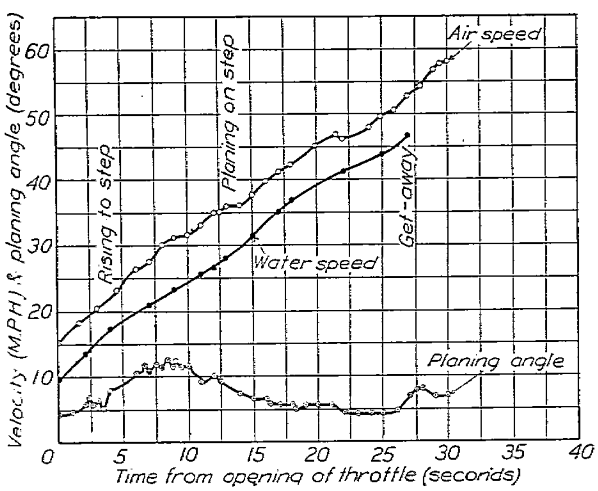

FIG. 9.—Method: Normal. Weight, 6,000 pounds. Rippled water

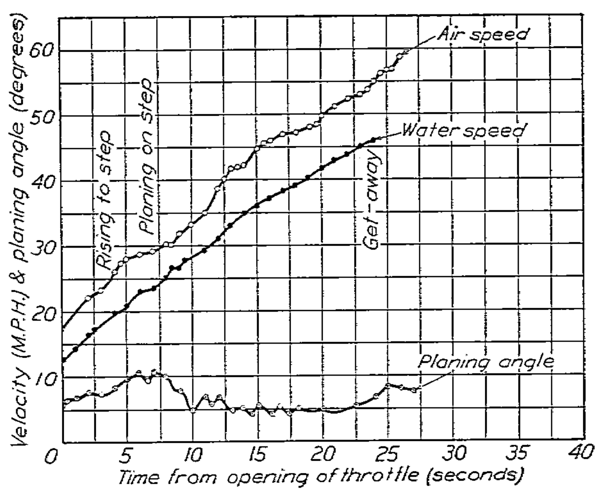

FIG. 10.—Method: Normal. Weight, 6,000 pounds. Rippled water

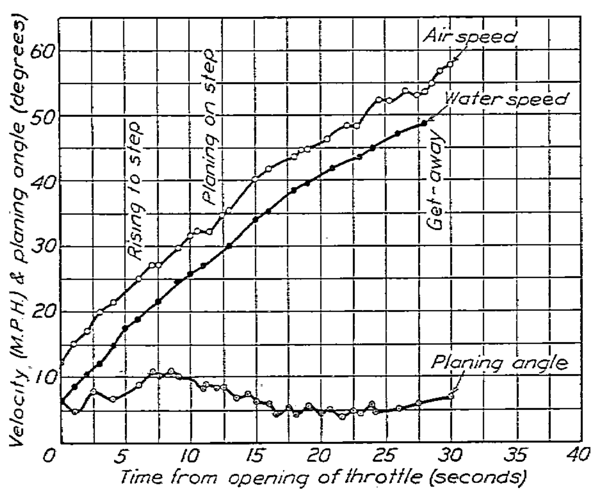

FIG. 11.—Method: Normal. Weight, 6,000 pounds. Smooth water

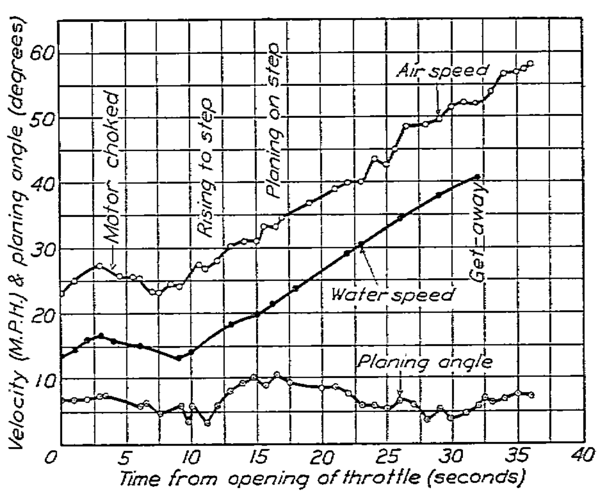

FIG. 12.—Method: Normal. Weight, 6,000 pounds. Rippled water

Figures 9 to 15 show take-offs made in the pilot's usual manner. The planing oscillations are not as pronounced in these runs, and it is quite probable that they were somewhat broken up by control opposing oscillation. Figure 12 shows a run in which the engine choked up at 3 seconds and picked up again at 9 seconds. The oscillations at 10 seconds were probably started by the sudden application of thrust. In the down wind run (fig. 13) considerable air speed was needed to maintain directional control while turning, so that by the time the seaplane

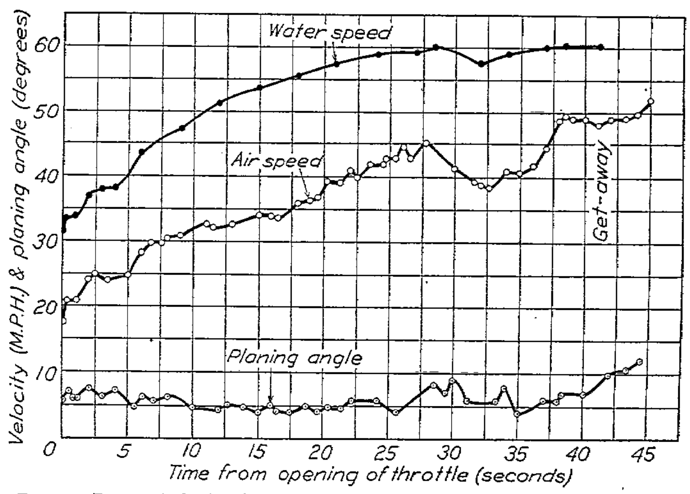

FIG. 13.—Down wind. Method: Normal. Weight, 6,000 pounds. Rippled water

was actually headed down wind it was already on the step. At 28 seconds a region of higher wind velocity was encountered which was detrimental to the lift and allowed the seaplane to settle, thus increasing the resistance enough to lower the water speed.

Figures 14 and 15 show runs made with a gross load of 6,800 and 7,500 pounds, respectively. Compared to the curves of the light load runs, these are more characteristic of the take-off of a normally loaded seaplane. The velocity increase or acceleration is large while plowing, small

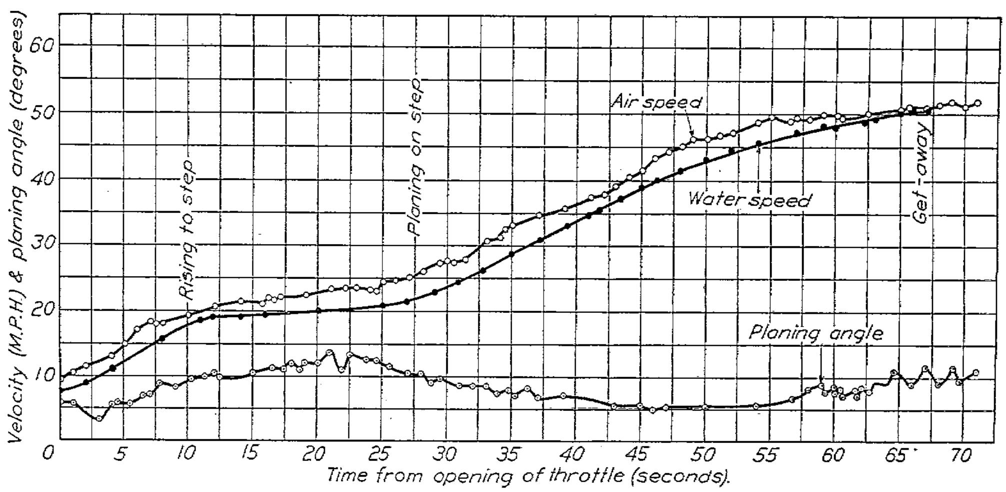

FIG. 14.—Method: Normal. Weight, 6,800 pounds. Smooth water

while changing from plowing to planing, and again large while planing, indicating, respectively small, large, and small resistance. The transition stage starts at about 19 M. P. H., but the velocity of its ending varies somewhat with load as does also the maximum angle, which is 8° to 10° higher than the normal planing angle. With the 6,800-pound load the planing condition is reached at 21 M.P.H., but with 7,500 pounds the planing does not appear to start until 25 M.P.H. As seen here, the increase in loading does not materially affect the speed at the beginning of the transition stage, but does appear to delay the start of the planing stage. Control effectiveness is desired when planing commences, as it is then that objectionable oscillations are apt to occur, but this small variation in velocity at the start of planing would affect the control available only slightly. In comparing the runs of different loads it is seen that while two or three seconds are required to get through the transition stage with a light load, 12½ seconds are required for the 6,800-pound load, and 23 seconds for the 7,500-pound load. As in the light-load runs, the slope of the water-speed curve decreases at high planing speeds, thus showing

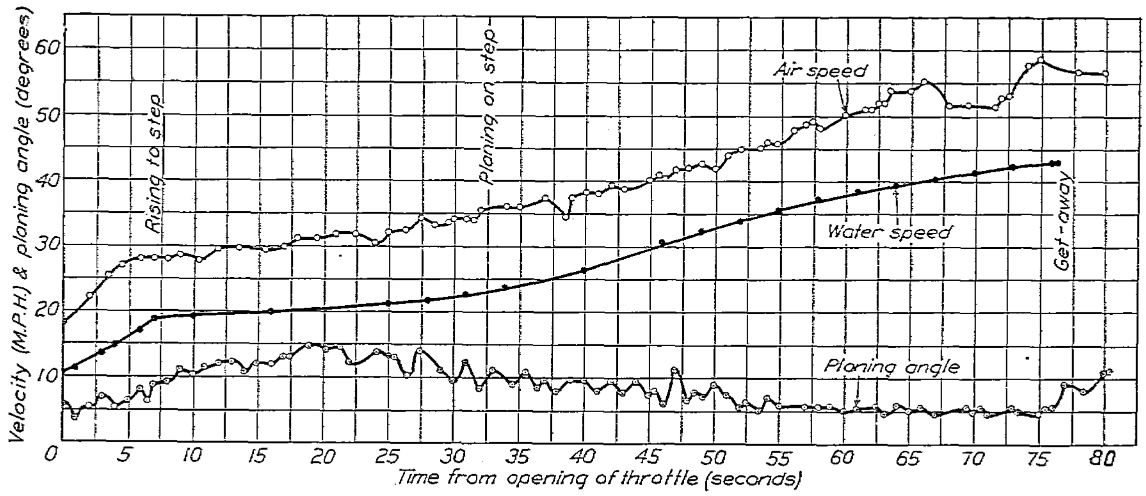

FIG. 15.—Method: Normal. Weight, 7,500 pounds. Rippled water

the same tendency toward increase in resistance. At 35 M. P. H. the normal planing angle of 5° is attained.

While planing at lower velocities with the 7,500-pound load there is considerable oscillation, which it is believed was not entirely due to the method of control. As this was found to be true also of the light-load runs, it appears reasonable to assume that the DT–2 is slightly unstable while planing below velocities of 40 M. P. H., whether lightly or heavily loaded. Some

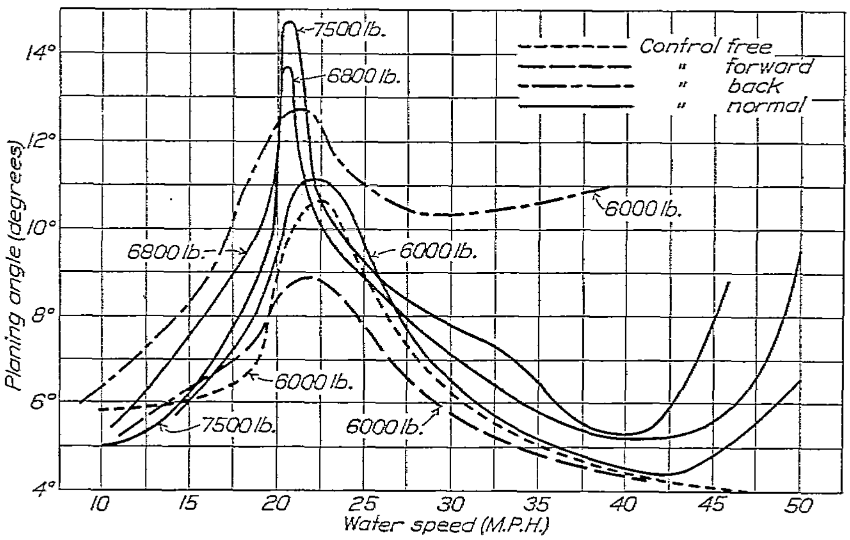

FIG. 16.—Variation in planing angle with water speed

trouble was experienced in bringing the nose up to a get-away angle with the 6,800-pound load. Since this difficulty was not experienced with the 7,500-pound load, the smooth water surface, which it is known often hinders planing, must have been mainly responsible for it.

The relation of the attitude of the seaplane to water speed when subject to various longitudinal controls and different loadings is plotted in Figure 16. The effect of the longitudinal control on a lightly loaded DT–2 during a take-off is such that the transition angle can be varied from 9° to 13° as desired. With a full load the trimming moments of the floats overcome those of the control to such an extent that the trimming range at this time would probably be decreased to less than 2 degrees. (Reference 1.) In the take-offs with increased load the maximum transition angle becomes larger, and it is recorded as occurring at a water speed which is 1 M. P. H. greater than that which occurred at the same angle with light load. However, the error in the measurement of velocity and synchronization may be this amount so it is reasonable to assume that they occur at practically the same velocity. The speed, at which maximum angle and maximum resistance are attained, with change of loading is characteristic of the float. The shape and angles of the forebody are probably the dominating factors. (Reference 6.) The enlargement of the angular control range with increasing velocity is shown by the divergence of the curves of control forward and control back. The proximity of the curve of control forward to that of the control free at high speeds shows that the positive restoring moment of the floats is such that very little trimming by the head can be secured.

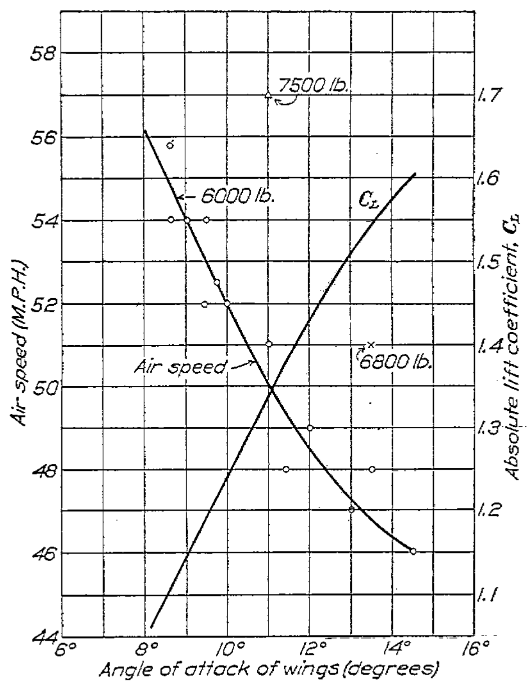

FIG. 17.—Velocity and lift coefficient at various get-away angles

In Figure 17 are plotted the angles of attack of the wing at various get-away speeds. The lift coefficient curve, C_L, as obtained from the angle-velocity curve, is also given. The error caused by ground effect has not been considered. The DT–2 will get away light through an angular range of 8° to 14° at corresponding velocities of 56 to 46 M. P. H., or through about 22 per cent of the speed range.

CONCLUSIONS

The DT–2 will oscillate steadily at low planing speeds with free control. The oscillations are amplified when planing on smooth water and when the elevators are held down but these can be damped by control opposing the oscillations. At high planing speeds the DT–2 is more stable, caused no doubt by the damping effect of the V-bottom.

The total resistance increases with increase of planing velocities above 37 M. P. H. The sharpness of the included angle of the V-bottom, which has a 15° slope, is believed to be responsible for this.

With the light float loading (63.3 lb./inch of beam), the stability of the DT–2 is as good as with heavier loadings and it has no tendency to porpoise at high speeds. Light loadings are often objectionable because planing and porpoising occur early, i.e., at an air speed which is too low to provide effective control. On the DT–2, however, light loading is not objectionable, for while the need for control when planing starts comes at a slightly lower velocity, the effectiveness of the control is better because the trimming moments of the floats are less.

The seaplane will trim by the stern until an angle is reached that gives the required dynamic lift. The relation between the loading and this maximum planing angle is approximately linear.

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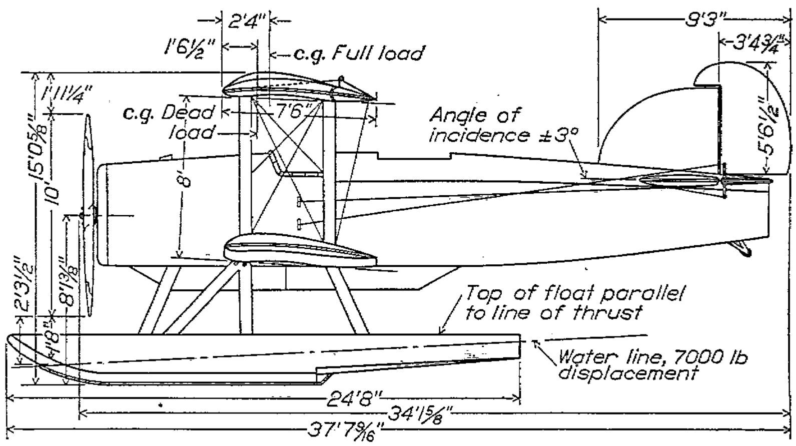
APPENDIX NO. 1

CHARACTERISTICS OF THE DT-2 SEAPLANE

Type	Twin float tractor biplane.
Wing area	707 square feet.
Angle of incidence of wings	3°.
Angle of incidence of pontoon	0°.
Weight, as tested	6,000 to 7,500 pounds.
Engine	Liberty, 370 HP. at 1,500 R. P. M.
Wing loading	8.5 to 10.6 pounds per square foot.
Power loading	16.2 to 20 pounds per HP.
Span	50 feet.
Float tread	10 feet.
Wing section	U. S. A. 27.



APPENDIX NO. 2

COMPARISON OF THE TAKE-OFF CHARACTERISTICS OF THE THREE TYPES OF SEAPLANES

The general take-off characteristics of the three types of seaplanes are repeated here. Because of the variable conditions only the most obvious qualities attributable to the different types are emphasized. For instance the stability characteristics of a float are as dependent on the air, thrust, and weight forces as upon the water forces. It is not permissible then to say that the stability of one type as indicated by one example is superior to that of another unless this representative shows qualities which are known from other sources to be characteristic. It is desired, of course, to get off the water quickly and easily. To do this the seaplane's resistance must be small or its power large, while it must plane stably and trim easily.

Table I is a recapitulation of the results obtained in the tests of the three types of seaplanes. The data tabulated therein are taken directly from the results of the individual tests or from U. S. Navy charts of characteristics, with the exception of the float loadings. The first float loading given, $\frac{\text{total weight}}{\text{beam}}$, is only a relative term, as at any but zero velocity the wings carry some of the weight. The float loading at peak angle was obtained by subtracting the weight supported by the wings at peak angle from the total weight and using this value in the expression $\frac{\text{weight}}{\text{beam}}$. The load supported by the wings was computed from the get-away C_L curves given in each report.

A study of the original take-off curves of all three shows that water with a smooth surface offers more resistance, especially at the transition stage, than does a rougher surface.

As mentioned before, it is not permissible to consider the stability characteristics of one seaplane as being typical. However, these tests bear out the generally accepted axiom that the flatter the bottom the greater the tendency toward planing instability. On smooth water, at low planing speeds, the N–9H with a 7½° float was slightly unstable, the DT–2 with a 15° float had steady oscillations, while the F–5L with a 20° V bottom had damped oscillations. The stability of the DT–2 is considerably improved at the higher planing speeds while that of the others does not change. The planing stability of all three is improved on water with a roughened surface. This means that model float testing without the employment of a wave-making apparatus is simulating the worst conditions, as regards stability and resistance.

An idea of the controllability of the three seaplanes is gained by recording the approximate range through which the seaplane can be trimmed. The F–5L has a 6° range at high planing speeds, which is an indication that the float can be trimmed through a sufficient range to get away as desired. However, this trimming can not be done quickly nor easily, so that it is especially difficult to get the F–5L off on smooth water. The section abaft the steps is probably a liability in this case because if it is not sharply inclined upward it hinders trimming. The inefficient tail surfaces are also a factor in the poor controllability of the F–5L.

The control methods used to take-off vary greatly with different pilots and are the subject of many discussions. By "rocking," as used in the table, is meant the periodic up-and-down movement of the elevators. By "flipping" is meant pulling the elevators up quickly and attempting to hold the position attained, then easing the elevators down and repeating the process. It is rather general practice to "rock" a seaplane slightly to get it on the step. As is seen in the table, little or no control is necessary to take off, except to trim to a get-away angle. In general it can be said that the best or worst control aids or hinders but little until the get-away, when proper control is usually necessary to bring the seaplane to a flying angle.

TABLE I

Seaplane Type Class	N-9H Single float Training	DT-2 Twin float Torpedo	DT-2 Twin float Torpedo	F-5L Boat Patrol
CHARACTERISTICS				
Weight (pounds)	2,970	7,500	6,000	13,700
Wing area (square feet)	496	707	707	1,397
Wing loading (pounds per square foot)	6.0	10.6	8.5	9.8
Horsepower	150	370	370	720
Power loading (pounds per horsepower)	19.8	20.0	16.2	19.0
Float beam (inches)	41.5	47.5	47.5	120
Float loading (pounds per inch of beam)	71.5	79.0	63.3	114
Vee at step, slope (degrees)	7½	15	15	20
TAKE-OFF PERFORMANCE				
Take-off time, average (seconds)	20	75	25	45
Time in transition stage (seconds)	5	23	3	5
Angle of attack at get-away (degrees)	8–16	----------	8–14.5	11–19
Get-away speeds (M. P. H.)	41–53	----------	45–56	51–58
Ratio $\sim \frac{\text{Get-away speed range}}{\text{Flight speed range}}$	0.40	----------	0.22	0.25
[illegible]	4	5	5	6
[illegible]	12	15	12	13
[illegible]	[a] 1,100	2,340	1,930	3,425
[illegible]	45	54.5	42.8	85.5
Trimming angles:				
Plowing	3.5–4.5	----------	5–6	----------
Transition	10.5–12	----------	9–13	12–13
Planing (low speed)	5.5–8.5	----------	5.5–10.5	5–9
Planing (high speed)	4–12	----------	4–11	4–12

[a] Angle assumed when planing free at high speeds.

Seaplane Type Class	N-9H Single float Training	DT-2 Twin float Torpedo Weight 7,500 lb.	DT-2 Twin float Torpedo Weight 6,000 lb.	F-5L Boat Patrol
STABILITY				
Smooth water:				
Plowing and transition	Stable			Stable.
Planing (low speed)	Slightly unstable			Damped oscillations.
Planing (high speed)	do			Do.
Rippled water:				
Plowing and transition	Small oscillations	Stable	Stable	Stable.
Planing (low speed)	Damped oscillations	Damped oscillations	Damped oscillations	Do.
Planing (high speed)	Stable	Stable	Stable	Do.
CONTROLLABILITY				
Trimming ability at get-away:				
Smooth water	Good	Poor	Good	Very poor.
Rippled water	do	Good	do	Fair.
CONTROL NECESSARY				
Smooth water:				
To start to rise	None	None	None	None.
To start planing	Forward or slight flipping.	Quick forward	do	Do.
While planing	None	None	do	Do.
To get-away	Slightly aft	Aft or slight flipping	Slightly aft	Steady flipping to strenuous rocking.
Rippled water:				
To start to rise	None	None	None	None.
To start planing	do	Quick forward	do	Do.
While planing	do	None	do	Do.
To get-away	Slightly aft	Aft	Slightly aft	Aft to steady flipping.