TECHNICAL MEMORANDUMS

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No. 676

TOWING TESTS OF MODELS AS AN AID IN THE DESIGN OF SEAPLANES

By P. Schröder

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I. INTRODUCTION

The seaplane, both before and during its take-off run, is a water craft. As such, it must have a sufficient displacement and must fulfill the well-known requirements of longitudinal and transverse stability while afloat, just as any ship. But in addition to these it must attain a speed which is altogether beyond the capacity of most water craft. This presents no difficulty if there is available an extraordinarily large propelling power, as is usually the case with small float seaplanes. If, however, we are concerned with a very large aircraft, one which is intended for long-distance flights, we must lift from the water, when taking off, just as heavy a load as possible. It might easily happen that the seaplane could carry its designed load if it were once in the air, but that it could not reach take-off speed on the water. The problem then arises: What form of float is best suited to carry a relatively heavy load to a high speed with a given propelling power? This problem has been studied ever since there have been seaplanes by the comparison of the take-off performance of seaplanes which have been built and by towing models in experimental model basins. As a result of this work, there are available to-day a number of proven designs.

Nevertheless, in the design of a seaplane, one always meets anew the problem of determining the suitable float. For it should be noted that the successful take-off of a proven seaplane is not dependent solely on the floats. If the float of a successful seaplane is assembled with another wing cell and power plant it may fail to take off,

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*"Der Modellschleppversuch als Hilfsmittel beim Entwurf eines Seeflugzeuges." Werft-Reederei-Hafen, August 22, 1930, pp. 349-354. Paper presented at the Ninth Meeting of the Gesellschaft der Freunde und Förderer der Hamburgischen Schiffbau-Versuchsanstalt, June 11, 1930.

even with the same power loading. Moreover, the identical float assembled with the same wing cell and power plant may have entirely different take-off characteristics, according to the specifications under which the assembly is made.

These facts have not yet received the consideration which they deserve in the study of the take-off phenomena of seaplanes. In part this is because the results of tests are as a rule not made available for publication. The most serious obstacle, however, is presented by the practical difficulties encountered in carrying out tests in such a manner that they make it possible to perceive the effects of changes in the design of the airplane on the take-off performance.

So far, the difficulties mentioned have been avoided in the following manner. To begin with, the design of the airplane, including the float system, was prepared by reference to successful prototypes. Then, the float system was tested in an experimental model basin, and in these tests the model was subjected to the conditions which would be imposed upon it by the proposed wing cell and power plant. If the results of the towing tests were unsatisfactory, the form of the float was changed according to judgment until satisfactory results were obtained. This method of itself makes it impracticable to attempt changes in the design because the scope of the experimental work for each new seaplane would thereby become infinite.

The procedure described gives good service when it is a question of obtaining a quick decision concerning a specific design. It probably will be necessary to resort to this method in the future for the same purpose. However, it is not suited to the further advancement of our task, which is to obtain the best take-off performance for the floats of large seaplanes. While being tested, the float system must be subjected to the requirements of a specific airplane design, consequently, such tests do not permit general conclusions regarding the float system under test. It is not possible, on the basis of such tests, to predict how the float system would behave when assembled with another wing cell or power plant. It is not even possible to predict the effect of a small change in the original design on the take-off performance.

Hence, it was necessary to develop a method of research which would make it possible to conduct the tests in such a manner that they would be independent of the requirements of a special airplane design. Such tests could be made before the completion of the work of designing the aircraft and would then be just as much an aid to the airplane designer in the design of the seaplane as would the aerodynamic model tests, which no designer to-day would forego.

The making and evaluation of a towing test of a seaplane float system, which answers the requirements just mentioned, is the subject of my present remarks. The experimental data presented have been taken from the tests of the transoceanic airplane designed by Dr. Rumpler, which were made by the H.S.V.A. only a short while ago.

II. THE MAKING OF THE MODEL TESTS AND THE PRESENTATION OF THE RESULTS

Because of practical difficulties in obtaining measurements, we cannot simulate the accelerated take-off run. Instead we select a number of definite speeds and tow the model at each with constant speed. The model must be towed at each speed at several trim angles because the resistance in general depends very much on the angle of trim. Besides the speed and angle of trim, the lift which is developed by the water must also be prescribed. Then only does the question of resistance have a single meaning. As the load which must be carried by the water is strongly influenced by the wing cell and power plant, even for a given definite flying weight, runs must be made at different loads for each speed and trim.

In each case, besides the resistance, the trimming moment necessary to produce the trim angle must be measured. In the later computations these moment measurements form the point of departure for the determination of the trim position which the float system would assume under a given aircraft.

Figure 1 shows in graphic form a part of the schedule of test runs for the study of the Rumpler model. In this manner the model is towed at all odd angles of trim up to 11°. For each of the parallel abscissas indicated, we ob-

tain a resistance curve and a moment curve which correspond to a given trim angle and a prescribed load.

For example, Figure 2 shows the results of the resistance measurements for a trim angle of $\alpha = 5^\circ$.

An example of the moment measurements is shown in Figure 3. The reference axis for the moments shown is the transverse axis through the point at which the center of gravity is to be, according to the first design of the airplane.

The first presentation of the results is derived directly from the practice in making towing tests. We can easily derive from these curves those resistance and moment curves which correspond to a given speed and a prescribed angle of trim for any arbitrary change in the lift.

In Figure 4 we have the resistances, in Figure 5 the moments in the new presentation, measured at $\alpha = 1^\circ$.

The results are placed at the disposal of the airplane designer, in this form two curve sheets for each trim angle investigated. These experimental data include all the properties of the float system which we need for the investigation of the take-off with any power plant and wing cellule.

III. THE APPLICATION OF THE TEST RESULTS IN THE DESIGN OF THE AIRPLANE

1. The Influence of the Wing Cell and Power Plant on the Take-Off Performance

For any form of float system, even the best imaginable, there are limits to the take-off performance which is obtainable, fixed by the wing loading G/F and the power loading G/N of the aircraft. In these, G is the gross weight, F the wing area, and N the engine horsepower. However, in the investigation of the take-off, G, F, and N are to be considered as constant because they principally determine the flight characteristics. Furthermore, the wing form selected must be determined from the aerodynamic standpoint alone.

The arrangement of the wing cell and power plant relative to the float system can influence the take-off resistance very much. The question of which arrangement would give the best take-off performances which are possible with the prescribed float system can be determined by means of such towing tests as have just been described. It is in this sense that model tests with the float system are to be regarded as an aid in the designing of the seaplane.

The effect of the wing cell and power plant on the float system can be expressed as a lifting force and a moment. Changes in arrangement which will change this force and this moment without impairing the flight performance are:

(a) Changing the distance from the step to the vertical through the center of gravity of the seaplane. This can be done without changing the form of the float system by shifting the float system longitudinally relative to the wing cell or by shifting equipment and cargo longitudinally.

(b) Changing the distance H from the center of gravity to the line of thrust of the propellers. This can be done practically by moving equipment and cargo vertically or by moving the shafts.

(c) Changing the angles of inclination σ of the wing chord to the C.W.L. (designed water line).

(d) Changing the angle of inclination ζ of the propeller shafts to the C.W.L.

Methods (a) and (b) are the most effective. They determine the trimming moment applied to the float system and thereby the trim positions which occur during the take-off. Methods (c) and (d) mainly change the lifting force. They have little influence on the moment.

In order to obtain that arrangement which will lead to the most favorable take-off resistance which is possible with the float system being considered, and taking into account all of the secondary requirements, the following method seems most suitable: For some arrangement which is practicable, and which seems plausible when compared with proven constructions, the take-off performance is determined from the tests. Then each of methods (a), (b),

(c), and (d) is tried to determine in which direction a change must be made to improve the performance of the first design. Only when none of the practicable arrangements leads to satisfactory results is the float system under consideration to be rejected as unsuitable for the proposed aircraft, and a change in the form of the float system to be considered.

In this the fundamental requirement is that the form of the float system shall be derived primarily from the hydrodynamic point of view. In assembling it with the wing cell and power plant it is necessary to insure by a suitable arrangement that the float system is working under conditions that approach as closely as possible those under which it has its minimum water resistance.

Besides the changes in arrangement which influence the conditions under which the float system must work, we have in the altitude controls an additional important aid for influencing the take-off of a seaplane. The greater the speed which has been reached, the greater the limits within which one can influence the trim by pulling up or nosing down with the elevators. Consequently, if at high speeds the position of equilibrium free to trim is unfavorable, the float system can be brought into a favorable position by using the elevators.

From this we derive the following divisions for the investigation of the take-off characteristics of a proposed seaplane:

1) The most favorable resistance curve which can be obtained in the free-to-trim condition by changes in arrangement is derived. The elevator has little effect at low speeds and this curve is decisive for the first part of the take-off.

2) The resistance in the free-to-trim condition during the second part of the take-off will generally exceed the most favorable resistance of the float system by a considerable amount. Information as to the elevator movement which is required to bring the float system into its best attitude is to be obtained from the tests. The best attitude which can be attained by suitable elevator movements is decisive for the course of the resistance curve during the second part of the take-off.

In the past we have been obliged to leave to the pilot the task of determining this requirement for each seaplane by making a number of trial take-offs. This is a thankless task, as the requirement changes with every change in the loading and the distribution of this load in the aircraft. Furthermore, with heavily loaded seaplanes it is not without danger, for with unsuitable trims, which have a high resistance, other inconveniences are involved. The float system shows a tendency to pitch and to leave the water (porpoise). In addition, the spray becomes heavier the farther the float system departs from its most favorable trim. This can be very disagreeable in connection with the propeller. The greater the total weight of the seaplane becomes, the more important it is to avoid such dangers as far as possible by resorting to model tests.

2. The Determination of the Resistance Curve for the Take-Off Free to Trim

The working of a definite example is much more instructive than a purely abstract discussion, so we will now imagine that we have been given the problem of carrying out the study of the take-off characteristics of the design for a transoceanic airplane proposed by Dr. Rumpler on the basis of model towing tests. In accordance with the considerations just discussed the first step is to determine the resistance for take-off free to trim under the conditions of the proposed design. According to this design it is specified that:

$$G = 115{,}000 \text{ kg} \quad (253{,}530 \text{ lb.})$$

$$F = 1{,}000 \text{ m}^2 \quad (10{,}764 \text{ sq.ft.})$$

$$\sigma = 2.5^\circ$$

$$\zeta = 4^\circ$$

$$H = 1.14 \text{ m} \quad (3.74 \text{ ft.})$$

Static thrust of propellers ca. 23,500 kg (51,809 lb.) decreasing to about 16,900 kg (37,258 lb.) at 150 km/h (93.2 mi./hr.). The center of gravity is 2.9 m (9.51 ft.) forward of the step and 4.75 m (15.58 ft.) above the designed water line (C.W.L.).

The model is 1/16 full size. The displacement of the model at rest is therefore

$$D = G \lambda^{-3} = 28.08 \text{ kg} \quad (61.91 \text{ lb.}) \tag{1}$$

in which $\lambda = 16$ denotes the model scale. The model speed v corresponds to the airplane speed V.

$$v = V \lambda^{-1/2} \tag{2}$$

The towing-carriage speed of 10 m/s (32.8 ft./sec.) under these conditions suffices to simulate a speed of 144 km/h (89.5 mi./hr.) of the airplane. The weight on the water a, which must be supported by the water at any speed of the model v, is derived from:

$$a = D - e \tag{3}$$

In this, e is the air lift supplied by the wing cell and power plant reduced to model scale

$$e = E \lambda^{-3} \tag{4}$$

E consists of the wing lift E_f and a contribution E_t which is derived from the thrust of the propellers:

$$E = E_f + E_t \tag{5}$$

The wing lift E_f is calculated from

$$E_f = c_a \, q \, F, \tag{6}$$

in which

$$q = \frac{1}{2} \rho \, v^2 = \frac{1}{16} v^2 \text{ kg m}^{-2} \tag{7}$$

The lift coefficient c_a is given in the polar diagram (fig. 6) as a function of the angle of attack of the wing chord. This is the result of aerodynamic model tests. In addition to the value of the lift coefficient c_a, which we need to begin with, we also obtain the drag coefficient c_w for the air resistance of the seaplane. The angle of the wing δ is

$$\delta = \alpha + \sigma \tag{8}$$

According to the specifications of the design, a wing angle

of 8.5° corresponds to a trim angle of 6°. The part of the lift derived from the propellers E_t, is

$$E_t = S \sin \eta \tag{9}$$

as a result of the inclination of the propeller axis at an angle η to the horizontal. The angle η is accordingly,

$$\eta = \alpha + \zeta \tag{10}$$

In this case η is always 4° greater than the angle of trim. Compared to E_f, E_t is of secondary importance but generally is not so small as to be negligible.

The results of this computation we can see in Figure 7. The scale of abscissa in this case is set off proportional to the squares. By this means we get a straight line for the weight on the water at each trim angle. Consequently, we need to carry out the calculation for only two speeds at each trim angle.

We now determine the resistances and moments for $\alpha = 1°$. With the weight on the water now known we can take the resistances and moments which correspond to $\alpha = 1°$ from Figures 4 and 5.

In this manner similar resistance and moment curves are obtained for each trim angle investigated. These curves fulfill the simultaneous requirement that at every point

$$A + E = G; \tag{11}$$

that is, the weight on the water and the lift from the proposed cellule and propeller thrust always total the gross weight. Figures 8 and 9 give us these curves for the transoceanic flying boat of Dr. Rumpler.

The next problem is to determine the trim angles which the seaplane will assume during the take-off. These are dependent upon the moment loads M_o which the float system receives from wings and tail and from propellers. This constraining moment M_o consists mainly of two parts

$$M_o = M_l + M_t \tag{12}$$

Of these M_l is the part derived from the aerodynamic

forces and M_t that from the power plant. M_l is determined by aerodynamic measurements and in this case it may be considered as known, just as is the polar diagram of the wings. M_t is computed from

$$M_t = S\,H,$$

in which it must be remembered that S is dependent upon the speed. For the model the imposed moment is then

$$m_o = M_o\,\lambda^{-4} \qquad (14)$$

The moment m_o thus computed is shown in our example as the curve m_o of Figure 9. The moments m arising from the action of the water are drawn positive when they lift the bow; the constraining moment m_o is drawn as positive when it depresses the bow, so that positions of equilibrium are indicated by

$$m + m_o = 0 \qquad (15)$$

Therefore, the various points at which the curve m_o intersects the curves α = constant are such points of equilibrium. In Figure 9 we can now read the various changes in trim angle which may be expected in a take-off free to trim under the conditions of the design. Figure 10 shows this curve.

With this knowledge of the changes in trim we are in a position to determine the corresponding resistance curve in Figure 8. With this the first step of our problem is solved. We see at once that left free to trim the seaplane has a much greater resistance at high speeds than at trims of from 3° to 5°.

3. The Resistance Curves with Elevator Control (at Fixed Trims)

The next problem is the determination of the resistance curves in the second part of the take-off when the seaplane is pulled up to a fixed trim. We will, as an example, consider trimming to $\alpha = 5°$. This is the most favorable trim for the design under consideration.

First we must determine by computation whether the

elevator can hold the seaplane at $\alpha = 5^\circ$. A simple aerodynamic computation leads to the moment curve m' seen in Figure 9. The differences between m_o and m' are the computed maximum moments which the proposed control surfaces can produce. It can be seen that the control surfaces can hold the seaplane at $\alpha = 5^\circ$ if it has once reached this trim. The ordinates m_5, etc., show the moments which are necessary for this purpose at each speed. Now, let n_o = the distance of the center of pressure of the control surfaces from the axis of moments, and k_5 = the force on the control surfaces, both reduced to the scale of the model. n_o is known from the design and k_5 is computed from

$$k_5 \ n_o = m_5 \tag{16}$$

The load which must be carried on the water is increased by the amount k_5 so that the new weight on the water a_5 is given by

$$a_5 = a + k_5 \tag{17}$$

With the new weight on the water, the resistance curve which corresponds to the weight a_5 is determined in the manner already indicated. The result of this computation is shown in Figure 8. The resistance curve for a take-off at a fixed trim of $\alpha = 3^\circ$ is found by the same method. The change in the moments is so small that it may be neglected.

4. Take-Off Time and Take-Off Run

The data now obtained make it possible to compute the take-off time and run for the proposed design. Frankly, at present, several factors must be neglected in making this computation, so that the result can claim only approximate accuracy. The H.S.V.A. is investigating the effect of these neglected factors, but the study is not yet completed.

We first compute the total water resistance according to Froude's law and are aware that the results are somewhat too great. The error cannot be very large because all practical float forms, when planing, rise so far that only a small fraction of the surface is wet by the water. The results of this computation are seen in Figure 11.

To the water resistance thus computed, the air resistance

$$L = (c_w + c_{ws})\ q\ F \tag{18}$$

is to be added. The drag coefficient c_w is taken from the polar diagram. The data regarding c_{ws}, which includes the so-called "parasite drag," are also derived from aerodynamic tests.

The difference between the sum of the resistances and the propeller thrust is available for accelerating the seaplane. If the reciprocal of this difference is denoted by r, an elementary principle of dynamics gives the formula for take-off time t and length of take-off run s,

$$t = \frac{G}{g} \int_0^{V_s} r\ dV, \qquad s = \frac{G}{2g} \int_0^{V_s^2} r\ d(V^2) \tag{19}$$

The integral can easily be solved graphically. In our case,

$$t = 70 \text{ sec.} \quad \text{and} \quad s = 1{,}430 \text{ m } (4{,}690 \text{ ft.})$$

for a take-off in which the seaplane is left free to trim until it reaches 70 km/h (43.5 mi./hr.), and then is held at 5°.

5. An Example of the Investigation of Changes in Design

We have reached the objective of our investigation of the design under consideration, and are now confronted by the question whether still better performances can be obtained from the float system. The next step of a complete investigation of the take-off, according to our discussion, is the trial of all four changes in design (III-1-a,b,c,d) which may be used for the purpose. To consider all four cases would lead to tiresome repetition. Accordingly, I would like to limit myself, for purposes of illustration, to describing in detail only the investigation of the effect of a change in the position of the center of gravity.

We will assume that as a result of a change in the distribution of the cargo, the center of gravity is moved aft 800 mm (31.5 in.). Since its original position was also our axis of moments, this shift means a stern-heavy

moment for the model of

$$m_s = 28.08 \times 0.8 : 16 = 1.404 \text{ m kg (10.155 lb.ft.)} \quad (20)$$

The previously computed moment m_0, is decreased by this amount as seen in Figure 9. The curve of the new trim angles is obtained from this figure and is shown in Figure 10. The corresponding resistance curve for a take-off free to trim is found in Figure 8.

For high speeds, a change in the position of the center of gravity is of no importance since we are then able to assume any trim by means of the elevators. Under these circumstances, a change in the angle of the wings relative to the C.W.L. is effective. As σ increases, the wings lift a greater part of the gross weight; consequently, the water resistance decreases. The investigation requires a repetition of the whole process of analysis. Figure 12 shows the results for an increase in the angle of the wings from $\sigma = 2.5^\circ$ to $\sigma = 4.5^\circ$. The expected reduction in water resistance is obtained, but the greater part of the gain is lost because of increased air resistance. We must not conclude that the investigation was fruitless, however. In this case the original design already lay very near to the most favorable proportions. That fact was determined by the investigation.

IV. CLOSING REMARKS

The take-off which we have just discussed referred to a take-off without wind and at a prescribed gross weight. It is easily possible to compute the take-off for any other desired gross weight from the experimental results previously discussed and according to the method of evaluation presented and also to take account of the wind. At this time I can only mention this fact.

Even if it is decided to make essential changes in the wing cell or power plant an estimation of the take-off performance is still possible without its being necessary to make new test runs. Such radical changes are, for example, the choice of another wing profile, another wing area, or the fitting of more powerful engines.

The cost of such a comprehensive investigation is nat-

urally greater than that of the customary simpler procedure. But if we keep in mind that the value of the entire seaplane depends on its ability to take off, because there can be no flight without take-off, and also consider that the cost of a giant seaplane runs into millions of marks, the cost of the research is fully justified. If we undertake a complete investigation of a float system, as is here recommended, we are assured that we will be protected against disagreeable surprises, which will cause much greater expense, if they are first encountered on the finished seaplane, than a complete model test would cost.

A shortened test which is limited to the runs absolutely necessary for the consideration of a given take-off condition and which neglects the determination of the other properties of the float system does not offer this protection to the same extent. Experience has already shown that in the region of maximum resistance, two different resistances may occur. The more stingily the research program is laid out, the more easily does the more unfavorable case escape observation.

A more reliable way of preventing a costly increase in the scope of the tests lies in the solution of the following research problem: Let the resistance w_1 and the trimming moment m_1 of a high-speed flying boat with a load a_1 be measured at a speed v_1. The resistance w_2 and moment m_2 for the same flying boat with a load a_2 are to be computed from these results for a corresponding speed. The H.S.V.A. has done this and will report soon on the solution of this problem.*

In conclusion, I express to Dr. Rumpler my best thanks, because he has so kindly agreed to the publication of the experimental data which I have given and thereby has enabled me to enliven the presentation with actual test results.

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*Schröder, P.: Determination of Resistance and Trimming moment of Planing Water Craft. T.M. No. 619, N.A.C.A., 1931.

DISCUSSION

In the discussion of the preceding paper, Oberbaurat, Dr. Ing. Weitbrecht, Berlin, remarked: "I can only congratulate the H.S.V.A. and Dr. Schröder on this work which they have described here. My questions do not relate to the results of the tests but to the methods used.

"Question 1.- Aside from the various loadings of the seaplane in the initial condition, the variables in the investigation are:

(a) speed
(b) moment
(c) trim

In the work under discussion the speed and trim were chosen as the constant quantities in the test. In our opinion it is simpler not to change the speed and moment within one test and to plot trim angles as functions of the moment. I believe the consideration of the possibility of affecting the speed by means of the elevators or by changes in weight distribution is made simpler. Naturally, this is conditioned upon the fitting of a trim-controlled lift. (One which simulates the wing lift, varying with the angle of attack of the wing.- Translator.)

"Question 2.- Is there any hesitation at attempting the quantitative measurements of accelerated runs if dynamically similar models are used? An obstacle to carrying out these tests up to now has been the difficulty of taking care of the change in wing lift on the model corresponding to changing trim angles. This problem has already been solved by us and I believe also by others, so that in this respect there need be no further hesitation.

"Question 3.- Are there any figures which compare the time of take-off and take-off run computed according to equation (19) for model and full size?"

Mr. Diemer (Engineer), Friedrichshafen, remarked as follows: "I would like to add to the presentation by Dr. Schröder a point which he has not referred to in this discussion of the balance of forces and moments on the aircraft while taking off. This is the moment which is developed by the air stream of the propeller on the flying surfaces. The lift of the wings is more or less strongly

affected by the slipstream according to the relative positions of propeller and wings as is also the induced angle of attack over that area of the wings which is swept by the slipstream. Because of this, the direction of the wake behind the wing is also changed and likewise, the direction of the blast on the control surfaces, and their moments. It is further changed by the increase in air speed in the slipstream as compared to the flying speed. This moment developed by the effect of the slipstream on the wings and control surfaces is greater than the moment of the thrust about the center of gravity of the system and consequently cannot be neglected in working up the results of towing tests. Unfortunately, the designer is in a difficult position because at present this moment generally cannot be calculated and can be estimated only very approximately from wind-tunnel tests. Consequently, this circumstance causes an undesirable uncertainty in the application of tank tests to large seaplanes.

"With regard to the question raised by the previous speaker concerning the agreement between the take-off performance obtained by analysis of towing tests and the take-off performance of actual airplanes, I might refer to the results on the flying boat Dornier Wal, the model of which was towed last year at various trim angles in the manner described by the lecturer. The computation of the model tests for a gross load of 6,200 kg (13,669 lb.) gave a take-off time of 27 seconds, while the actual measured take-off time was about 23 seconds, showing a relatively good agreement."

Mr. H. Herrmann (Engineer), Bremen, made the following remarks: "The lecturer has shown us how much further research methods have developed at the Hamburg tank in the last few years. He even goes so far as to work out directions for the pilot to follow during take-off. Of course, as a pilot one can abide by such directions to a certain extent. But there are many considerations against it. According to experience, the trim angle is measured too large on small models, and consequently an important piece of fundamental data is wrong. We have no measure whatever of the magnitude of this error. Consequently, it appears most advisable to check the whole procedure again by take-off tests."

In his conclusion, Dr. Schröder replied: "Oberbaurat Dr. Weitbrecht has expressed the opinion that it would be better to bring in the trim moment as the independent vari-

able instead of the trim angle. This procedure is, of course, to be preferred when we are concerned with testing a definite seaplane design, for which we know accurately the moments produced by the wings and power plant. But Engineer Diemer has also pointed out that these very moments are very difficult to determine. I can only agree with him. This circumstance has been settled in my mind with the decision to choose the angle at will and to measure the moments. In this manner, the measurements themselves remain free from unreliable assumptions regarding the magnitude of the external moments which are introduced. In the working up of the results on the drawing board, according to my method, one can determine the effect of any desired moment. One can obtain the same result if one runs at fixed, prescribed moments, but cannot rely upon a definite variation of moment with speed and trim in carrying out the tests. Hence, the advantage which the choice of the moments as the independent variable should give is lost. But, if one must carry out an investigation of the same extent in both cases, I believe it more advantageous to fix the angle. In addition one must always be careful to carry out model tests with different forms of floats in such a manner that they are comparable with one another. Comparison at equal trim angles is directly apparent. It is not at equal moments.

"The trim-controlled lift of the float is an advantage only if one is investigating a specific design. In complete investigations of the float system, which are intended to give information concerning the take-off performance of any aircraft which may be equipped with the float system being studied, the measurements in general must not be subjected to the requirements of a particular aircraft, as I have established thoroughly in my lecture.

"For carrying out the measurements in accelerated runs, all instruments must record automatically and work without lag. As yet we have no such instruments. Furthermore, the value of measurements in accelerated runs should not be over-estimated. The manner in which the accelerating force varies with the speed is unknown before the run and consequently must be selected arbitrarily. In my opinion, a necessity for busying ourselves with the new difficulties which are found in this does not arise until it appears that in actual fact accelerations produce serious changes in the resistance of planing water craft. The investigation of this question by special tests is truly much to be desired.

"The further checking of the results of model tests by take-off measurements made on actual aircraft, as Engineer Herrmann has just pointed out, is certainly necessary. The earlier measurements of take-off time, unfortunately, could not be drawn upon for this purpose, since the method of research and evaluation which has just been presented has been developed but recently."

Translation by
The Staff, N.A.C.A. Tank.

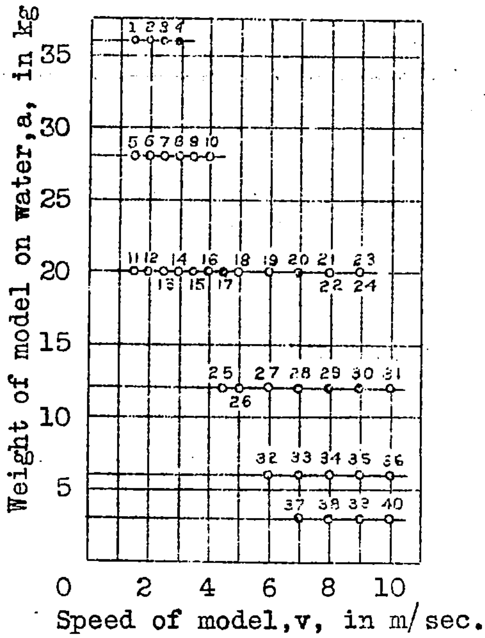


Fig.1 Program of test runs for model 802 at a fixed trim of $\alpha = 1^{\circ}$

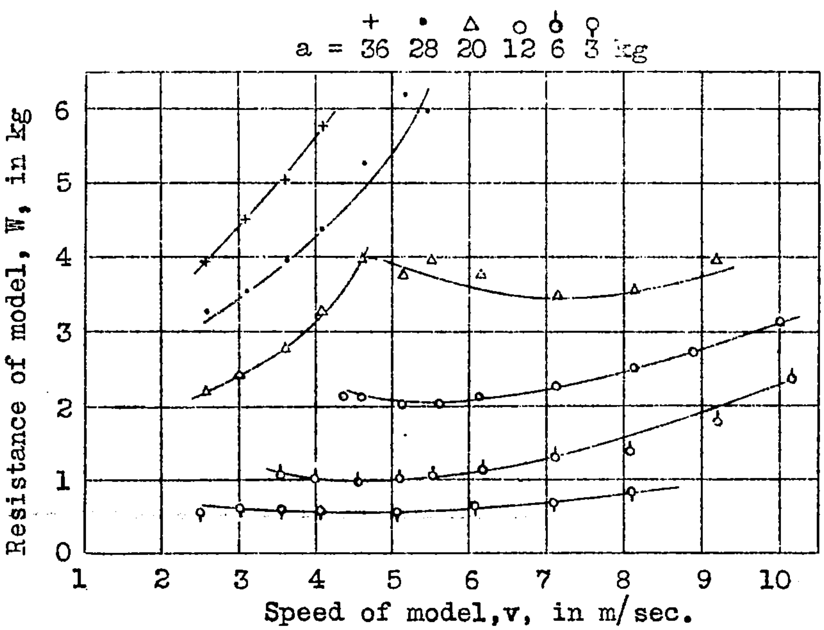


Fig.2 Model 802. Displacement of twin floats, D = 28.08 kg. λ =16. Resistance curves at trim, $\alpha = 5^{\circ}$ for various weights on water, a.

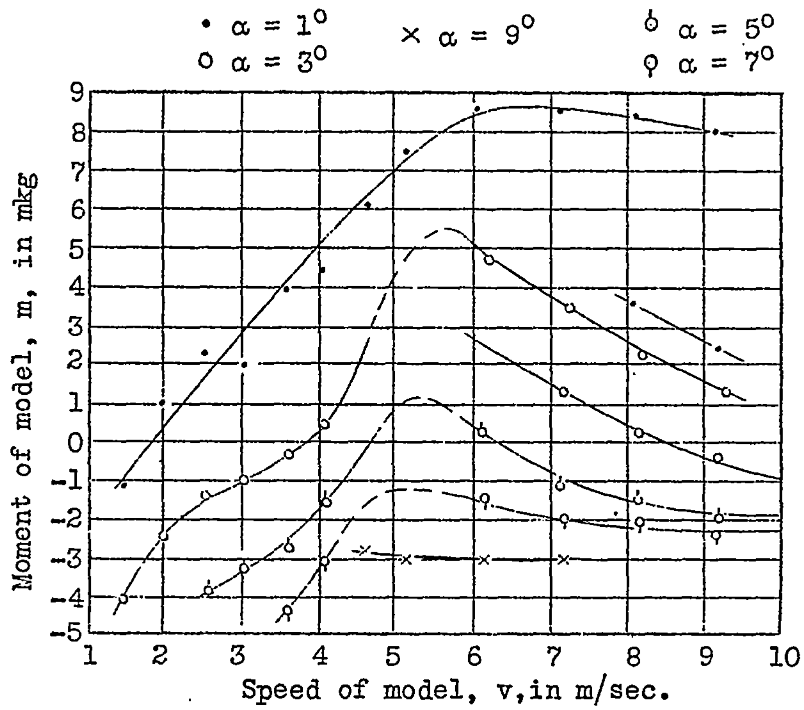


Fig.3 Model 802. Displacement of twin floats, D = 28.08 kg. λ = 16 . Moment curves at weight on water, a = 20 kg for various trim angles α .

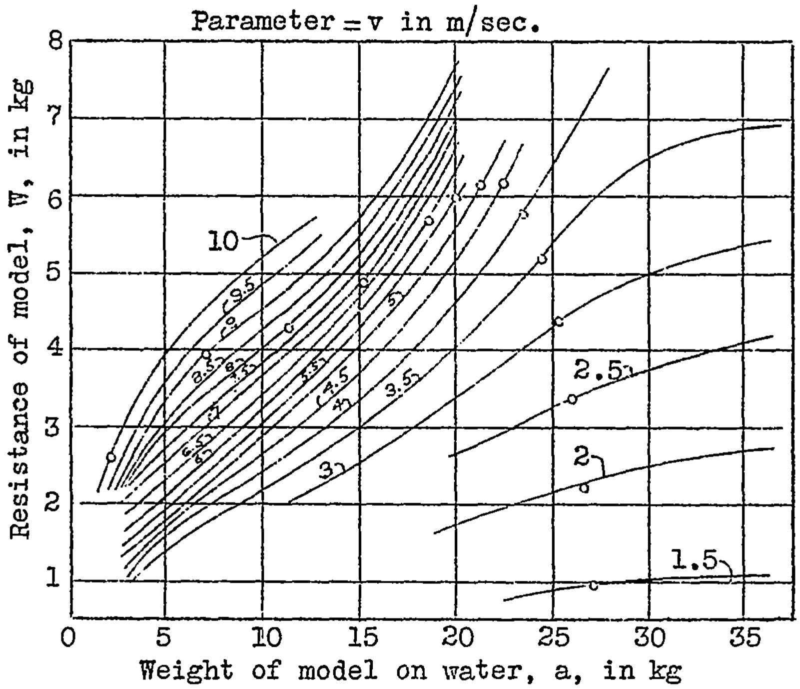


Fig.4 Model 802. Displacement of twin floats, D = 28.08 kg , λ = 16 . Curves of resistance, W, at trim of α = 1° for various weights on water, a .

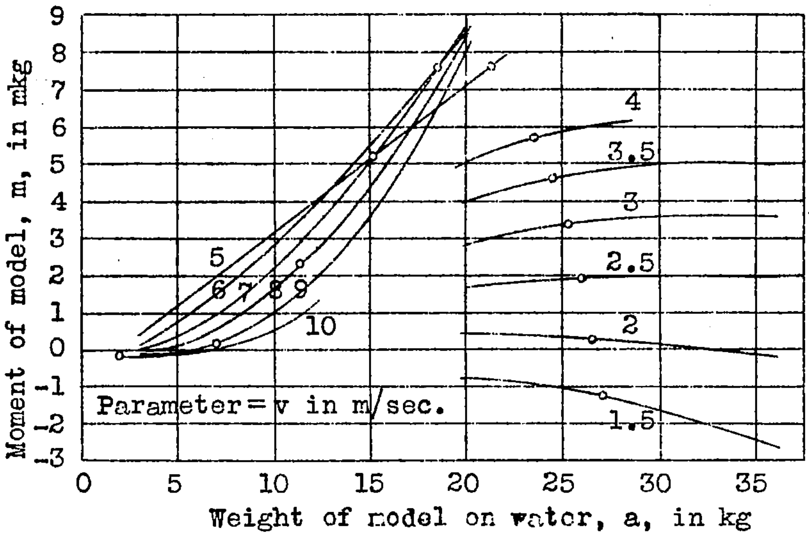


Fig.5 Model 802. Displacement of twin floats, D = 28.08 kg. $\lambda = 16$. Curves of moment, m, at trim of $\alpha = 1^{\circ}$ for various weights on water, a.

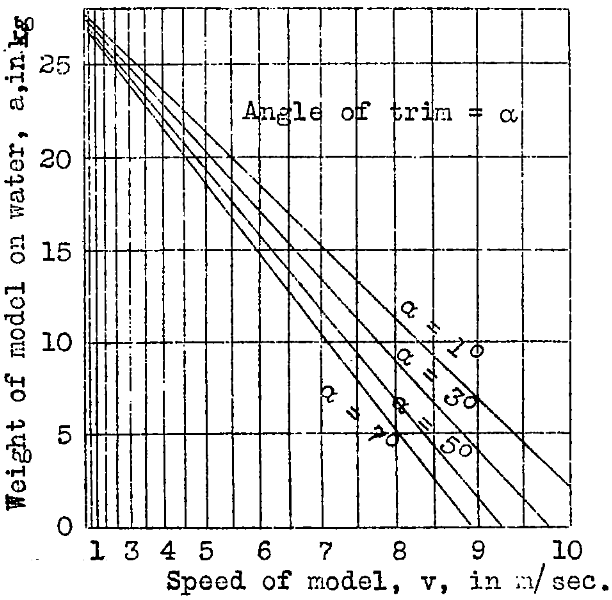
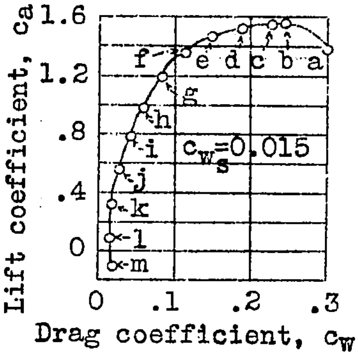


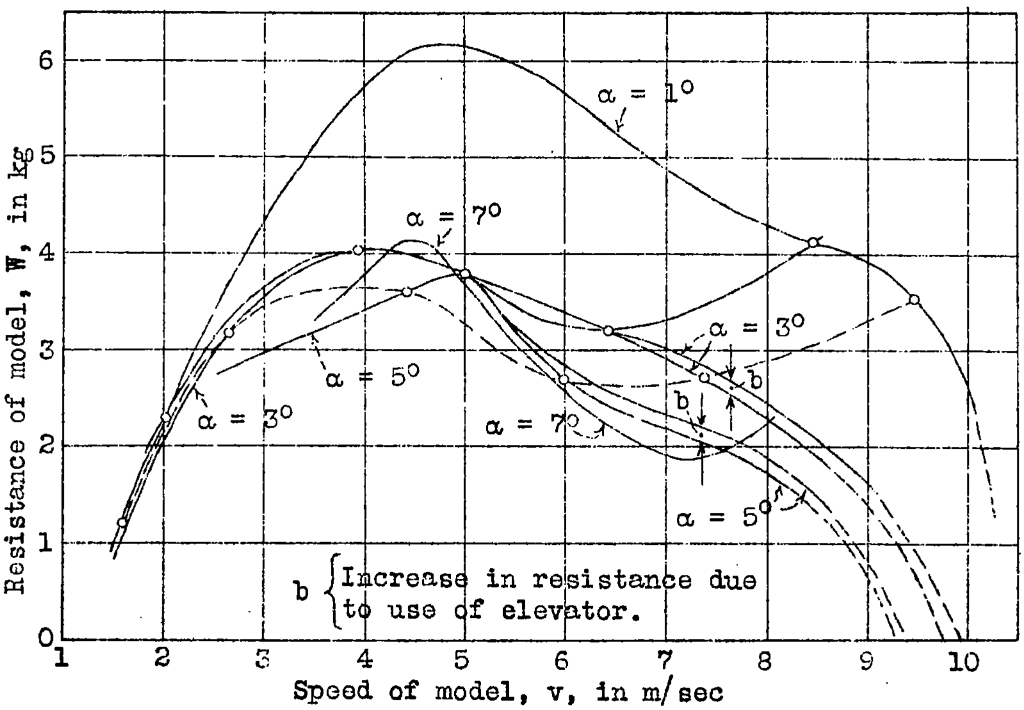
Fig.7 Rumpler transoceanic flying boat. $\lambda = 16$. Weight of model on water, a, at $\delta = 2.5^{\circ}$ and $\zeta = 4^{\circ}$ for various speeds, v, and trims, α.



a, 20.5 = δ
b, 18.4
c, 17.4
d, 14.4
e, 11.5
f, 8.5
g, 5.6
h, 2.6

i, -0.3
j, -3.2
k, -6.1
l, -9.0
m, -12.0

Fig. 6 Polar curve for Rumpler transoceanic flying boat.

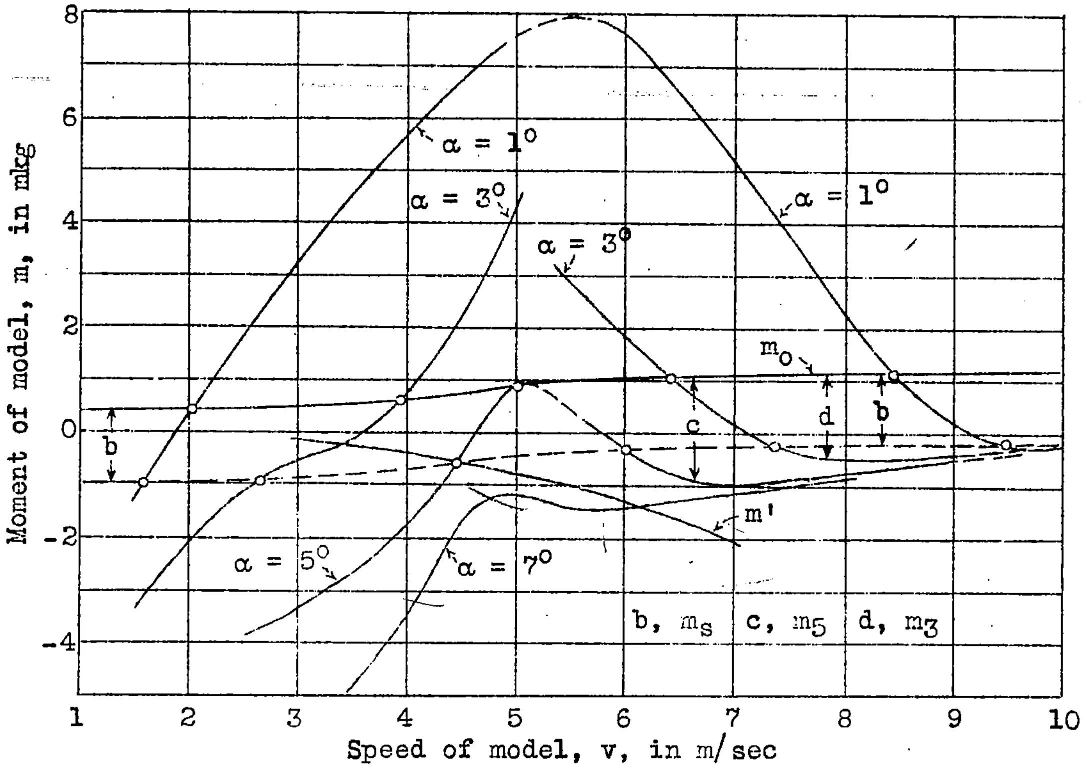


——— Curves of resistance, W, at fixed trim angles, α, for the weight on water, a, indicated in Fig. 7

o ——— Resistance for take off free to trim.

o – – – Resistance for take off free to trim after the center of gravity has been shifted.

Fig. 8 Rumpler transoceanic flying boat. Curves of resistance of model, W, at various speeds, v, for conditions indicated.

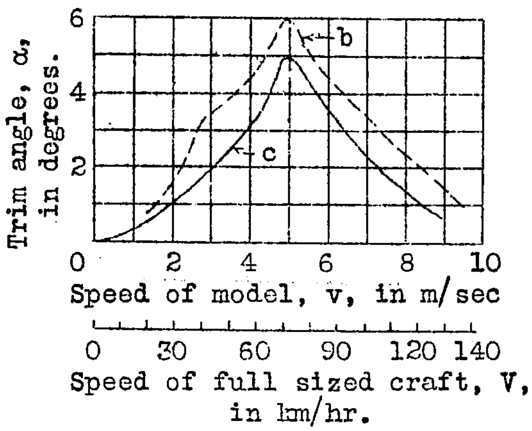


——— Curves of moment, m, at fixed trim angles, α, for the weights on water, a, indicated in Fig. 7

o——— Constraining moment free to trim.

o- - - - Constraining moment free to trim after the center of gravity has been shifted.

Fig. 9 Rumpler transoceanic flying boat. Curves of moment of model, m, at various speeds, v, for conditions indicated.



b, After shifting center of gravity aft.

c, Original design.

Fig. 10 Rumpler transoceanic flying boat. Trim angle, α, running free to trim, at various speeds.

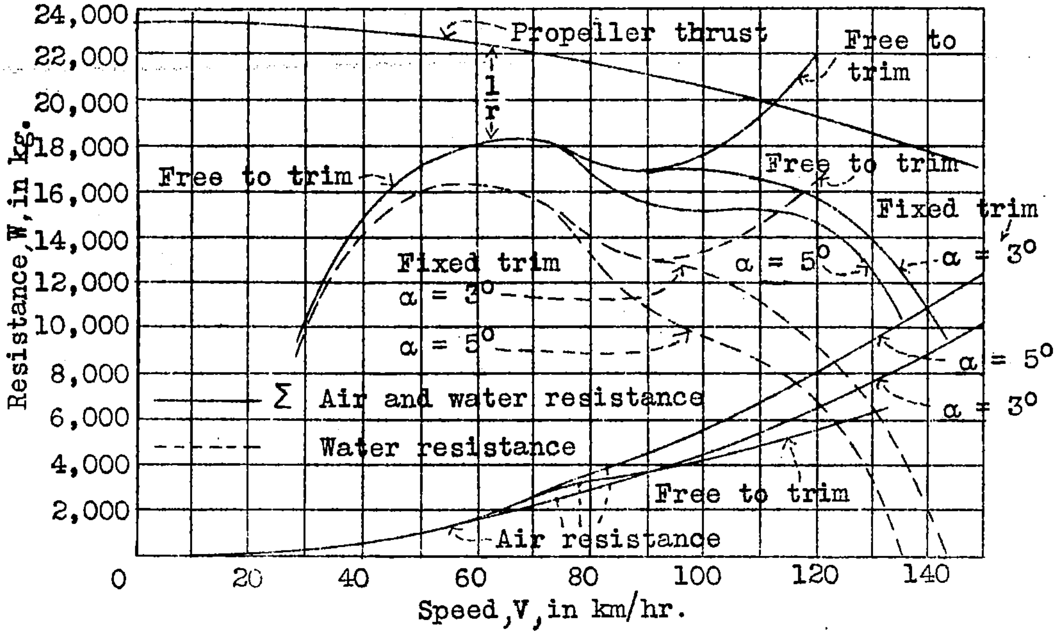


Fig. 11 Rumpler transoceanic flyingboat. Resistances of full sized craft at various speeds and under various conditions indicated.

—— Center of gravity 2.1 m forward of the step, σ = 4.5 °
--- Center of gravity 2.9m forward of the step, σ = 2.5 °

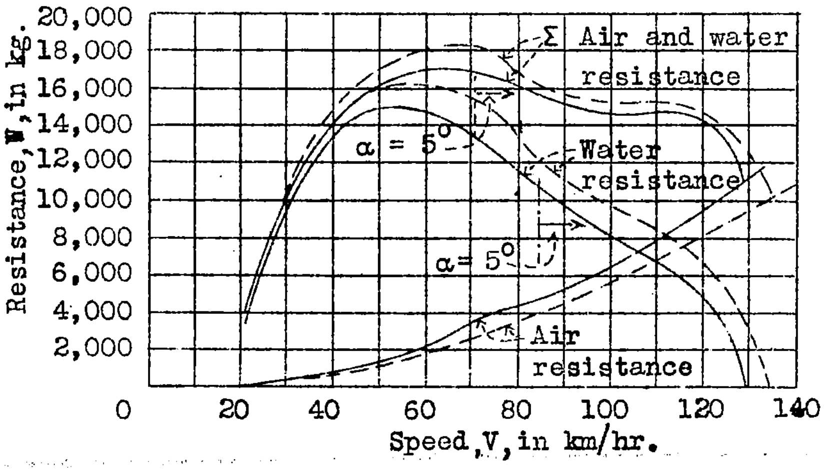


Fig. 12 Rumpler transoceanic flyingboat. The effect of a change in the design on the take-off resistance.