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THE ESTIMATION OF MAXIMUM LOAD CAPACITY OF SEAPLANES AND FLYING BOATS

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SUMMARY

It is shown that the relation between the gross load W and the time for take-off t of seaplanes and flying boats is of the form

$$W_m = W + K \frac{\mathrm{b \cdot hp}}{t}$$

Where W_m is the maximum possible load corresponding to infinite value of t, b·hp is the total brake horsepower and K is a constant. Data from four tests give K=140.

This equation supplies a method of calculating time for take-off with any load, or vice versa, when the time for one load is known.

INTRODUCTION

The maximum load that can be taken into the air by a seaplane or flying boat is a matter of general interest and, in some cases, of considerable importance. It may be obtained either by calculation or by direct experiment. However, the calculation requires model basin data not always available, while the direct determination with gradually increased loads is often out of the question, due to the time and expense involved. Consequently, very little data are available on the ability of seaplanes to take off with heavy loads. This paper is concerned with the study of take-off data and the development of a simple method for the estimation of maximum load.

GRAPHICAL SOLUTION FOR MAXIMUM LOAD

Observed times for take-off with a progressive increase in gross weight are given in Table I. These data are for a typical flying boat fitted with two engines developing 540 b·hp each, according to calibration tests. The conventional plot of take-off time against gross weight is given in Figure 1.

A test was also made on another flying boat substantially identical with the above except that it was fitted with two calibrated engines developing 620 b·hp each, and the time for take-off was found to be 30 seconds with a gross load of 17,184 pounds. This point is also plotted on Figure 1. The question then arises as to what is the maximum load that can be taken off with the second flying boat. It is obvious that the plotting method used in Figure 1 is unsatisfactory for this purpose.

A study of the various methods of plotting indicates that the use of the reciprocal of the time for take-off

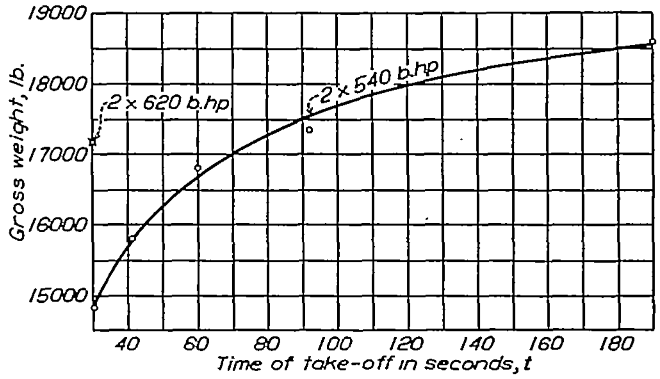

FIGURE 1.—Observed time for take-off of flying boats

should give a curve intercepting the weight axis at the limiting weight and that the use of power loading in-

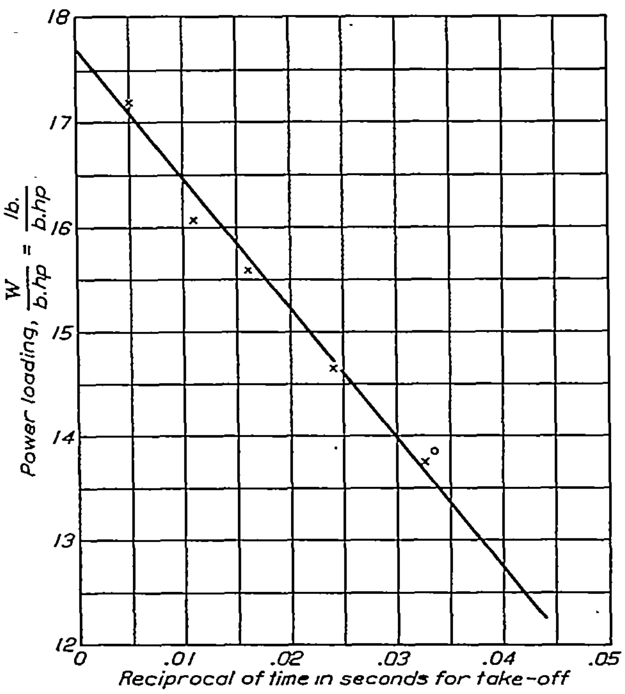

FIGURE 2.—Take-off curve for flying boats

stead of weight would make the plot more general. When plotted in this manner, as in Figure 2, the data from Table I lie on or very near to a straight line as does the single point from the second test. If this relation is general it supplies a very simple method of determining the maximum load from a single take-off since the straight line is represented by an equation of the form

$$\left(\frac{W_m}{\text{b. hp}}\right)=\left(\frac{W}{\text{b. hp}}\right)+\frac{K}{t} \tag{1}$$

Where t is the time in seconds for take-off with the power loading $\left(\frac{W}{\text{b. hp}}\right)$, $\left(\frac{W_m}{\text{b. hp}}\right)$ is the power loading for the maximum load that can be taken off and K, the slope of the line, is a load constant.

The maximum possible load would be

$$W_m=\text{b. hp}\times\left(\frac{W_m}{\text{b. hp}}\right) \tag{2}$$

DETERMINATION OF LOAD CONSTANT K

Table II contains take-off data for two flying boats. Table III contains take-off data for the short "Singapore I" as given in Tables I and II of Reports and Memoranda No. 1411 of the British Aeronautical Research Committee. (Reference 1.) All of these data are plotted on Figure 3, and the points are found to lie on lines of the same slope giving $K=140$. This slope differs slightly from that obtained from a single set of test data in Figure 2, where K would appear to be about 125. The tests on the "Singapore," Table III, if taken alone would indicate a value of about 150

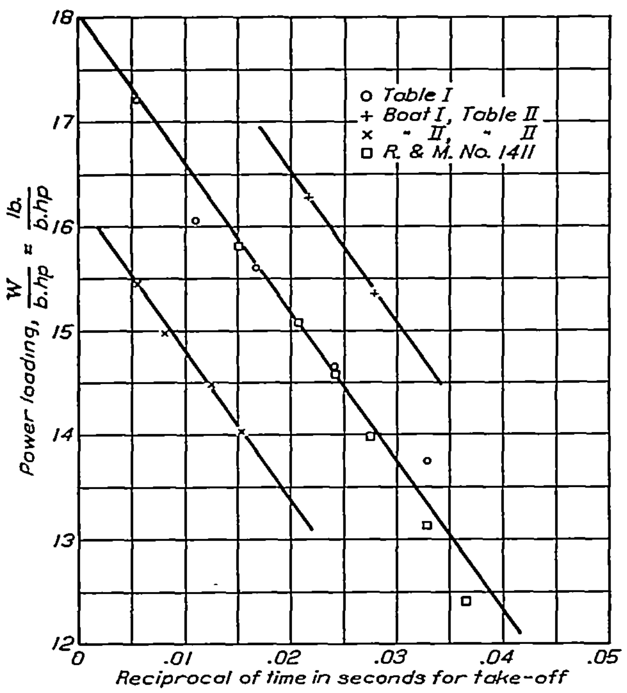

FIGURE 3.—Take-off curves for flying boats

for K. The value of $K=140$ in Figure 3 obviously fits the two sets of data combined and gives good agreement with the data from Table II as well. The relation of equation (1) therefore becomes

$$\left(\frac{W_m}{\text{b. hp}}\right)=\left(\frac{W}{\text{b. hp}}\right)+\frac{140}{t} \tag{3}$$

or

$$\left(\frac{W}{\text{b. hp}}\right)=\left(\frac{W_m}{\text{b. hp}}\right)-\frac{140}{t} \tag{3a}$$

The vertical displacement of the lines in Figure 3 is due to differences in propulsive efficiency and total resistance. Flying boat No. I of Table II has very low drag due to good hull lines and ample wing surface of high aspect ratio. Flying boat No. II of the same table has considerably more hull and wing drag with the addition of an excessive amount of parasite resistance. The flying boats of Tables I and III are quite similar except for size. The locations of the lines on Figure 3 are in accordance with these conditions.

It would be desirable to use thrust power, t. hp, instead of brake horsepower, b. hp, in equation (1), if the propeller efficiency were readily obtained. However, the differences would be small with modern designs and the probable improvement does not appear to justify the increased difficulty in practical use.

ESTIMATION OF MAXIMUM LOAD

Equation (3) supplies a very simple method for estimation of the maximum load that can be taken off by a seaplane or flying boat. All that is required is a single timed take-off with a known gross load. Substitution of this observed take-off time and the corresponding power loading $\frac{W}{\text{b. hp}}$ into equation (3) gives the maximum power loading corresponding to infinite time. The gross load is then found from equation (2) if desired, but this is of academic interest only. The practical limit may be set according to conditions at, say, 60 seconds or 120 seconds, and equation (3a) solved for the corresponding power loading.

It is of interest to check the indications of Figure 3 against observed or calculated data. In the tests given in Figure 1, the maximum load appears to be approximately 19,000 pounds. The calculated maximum loads substituting the take off time and power loading for each run into equation (3), are given in Table IV. The values range from 19,000 to 19,800 pounds, a maximum deviation of about 4 per cent from the actual value. This means that the maximum load could have been predicted within 4 per cent by the first run or within about 2 per cent from any of the succeeding runs.

In a similar manner the total resistance curves given on Figure 1 of reference 1 indicate that the limiting load for the "Singapore I" is just less than 30,000, while the calculated maximum loads for each run of Table III, as given in Table V range from 28,750 to 29,600 pounds. This is less than 4 per cent deviation, or about the same accuracy as shown by Table IV. As might be expected, the greatest deviation occurs at the light loads. In using this method it appears desirable that a load giving a run of about 50 seconds to 60 seconds be used if maximum accuracy is to be attained.

Multiplying both sides of equation (3) by b. hp gives

$$W_m = W + \frac{140 \text{ b. hp}}{t} \tag{4}$$

this gives the maximum load W_m directly when the value of t is known for a given weight. For example, assume that the time for take-off is 35 seconds with a gross load of 15,000 pounds and 1,000 b. hp. Then by substitution in equation (4)

$$W_m = 15{,}000 + \frac{140 \times 1000}{35}$$

$$= 19{,}000 \text{ pounds.}$$

This is the maximum possible load for an unlimited run in a calm. A more practical problem is to find the load that can be taken off in a specified time, say, 60 seconds. If this load is designated the service load W_s and the specified maximum time by t_s, the substitution in equation (4) gives

$$W_s = W_o + 140 \text{ b. hp} \left(\frac{1}{t_o} - \frac{1}{t_s}\right) \tag{5}$$

t_o being the observed take-off time with the load W_o. Using the values $t_o = 35$ sec., $W_o = 15{,}000$ pounds, and b. hp $= 1{,}000$ from the example above it is found, for $t_s = 60$

$$W_s = 15{,}000 + 140 \times 1{,}000 \left(\frac{1}{35} - \frac{1}{60}\right)$$

$$= 16{,}667 \text{ pounds.}$$

If the specified maximum time is $t_s = 120$ sec.

$$W_s = 15{,}000 + 140 \times 1{,}000 \left(\frac{1}{35} - \frac{1}{120}\right)$$

$$= 17{,}833 \text{ pounds.}$$

Bureau of Aeronautics,
Navy Department,
Washington, D. C., *Sept., 1932.*

REFERENCES

1. Coombes, L. P., and Read, R. H.: The Effect of Various Types of Lateral Stabilizers on the Take-Off of a Flying Boat. R. & M. No. 1411, British A. R. C., 1932.
2. Diehl, W. S.: Engineering Aerodynamics, Chapter XV. The Ronald Press Co., Inc., New York City, 1928.

TABLE I.—OBSERVED TAKE-OFF DATA ON A FLYING BOAT

(Tests by Patrol Plane Squadron 7-F)

Run No.	Gross weight W lb.	Power loading $\frac{W}{\text{b. hp}}$	Time to take off t sec.	Reciprocal of time to take off $\frac{1}{t}$	Remarks
1	14,824	13.75	30.5	0.0328	4-knot wind.
2	15,808	14.65	41.4	.0241	5-knot wind.
3	16,825	15.60	60.3	.0166	2-knot wind.
4	17,350	16.05	92.0	.0109	2-knot tail wind.
5	18,600	17.20	190.0	.0053	4-knot cross wind. Plane had to be taken into shoal water to get on step.
6	18,991	17.50	--------	--------	Did not get off after getting on step under same conditions as in run 5.

TABLE II.—OBSERVED TAKE-OFF DATA ON TWO FLYING BOATS

Type	Gross weight W lb.	Power loading $\frac{W}{\text{b. hp}}$	Time to take off t sec.	Reciprocal of time to take off $\frac{1}{t}$	Remarks
I	19,945	15.35	36	0.0278	2×650 b. hp. Tests at Anacostia Naval Air Station.
	21,145	16.26	46	.0217	
II	15,000	14.03	65	.0154	2×535 b. hp. Tests in glassy water at Naval Aircraft Factory.
	15,500	14.50	80	.0125	
	16,000	14.96	123	.0081	
	16,500	15.42	180	.0055	

TABLE III.—TAKE-OFF DATA FROM TABLES I AND II OF BRITISH A. R. C. R. & M. No. 1411

Gross weight W lb.	Power loading $\frac{W}{\text{b. hp}}$	Time for take-off t sec.	Reciprocal of time for take-off $\frac{1}{t}$	Remarks
20,350	12.38	27.5	0.0364	1,645 b.hp, gear ratio 0.477.
21,580	13.12	30.5	.0328	4-blade propeller:
23,000	13.98	36.3	.0275	P=12.0 ft.
24,000	14.58	41.3	.0242	D=12.5 ft.
24,800	15.07	48.0	.0208	
26,000	15.80	66.0	.0151	

TABLE IV.—CALCULATED MAXIMUM LOADS FOR TAKE-OFF

Using Observed Data from Table I with Equation (3)

t sec.	$\frac{140}{t}$	$\left(\frac{W}{\text{b.hp}}\right)$	$\left(\frac{W_m}{\text{b.hp}}\right)$	W_{max}
30.5	4.59	13.75	18.34	19,800
41.4	3.38	14.65	18.03	19,500
60.3	2.32	15.60	17.92	19,400
92.0	1.52	16.05	17.57	19,000
190.0	.74	17.20	17.94	19,400

Table V.—CALCULATED MAXIMUM LOADS FOR TAKE-OFF

Using Observed Data from Table III with Equation (3)

Time for take-off t sec.	$\frac{140}{t}$	$\left(\frac{W}{\text{b. hp}}\right)$	$\left(\frac{W_m}{\text{b. hp}}\right)$	W_{max}
27.5	5.10	12.38	17.48	28,750
30.5	4.60	13.12	17.72	29,150
36.3	3.86	13.98	17.84	29,350
41.3	3.39	14.58	17.97	29,600
48.0	2.92	15.07	17.99	29,600
66.0	2.12	15.80	17.92	29,500