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DESIGN CRITERIONS FOR THE DIMENSIONS OF THE FOREBODY OF A LONG-RANGE FLYING BOAT

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ADVANCE [redacted] REPORT

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SUMMARY

A correlation is made of the gross-load coefficient and the forebody length-beam ratio for a limited number of present-day multiengine long-range flying boats for which the spray characteristics are known. The spray criterion and the derived relationships permit a choice of dimensions of the forebody for various degrees of seaworthiness and permit the evaluation of the relative effect of forebody length, beam, and length-beam ratio for a proposed design.

It is concluded that the gross-load coefficient for comparable spray characteristics varies as the square of the forebody length-beam ratio. The forebody length has a relatively greater influence than the beam on the low-speed spray characteristics. When the length and the beam are both varied to maintain comparable sizes of forebody, the effect of length is not so pronounced as when length alone is varied. Large increases in length-beam ratio are required for comparable sizes of hull to obtain a definite improvement in the spray characteristics. Comparable spray characteristics may be obtained with a smaller forebody by use of high length-beam ratios.

INTRODUCTION

The size of the forebody of a flying boat represents a compromise between flight requirements and seaworthiness at low speeds on the water. If the length and the beam are too great, the structural weight and the aerodynamic drag limit the performance of the aircraft. If the length and the beam are too small, the spray characteristics become a limitation in gross weight, intensify maintenance problems, and increase the hazards of operation in rough water. The best over-all design is one for which the maximum gross weight and the seaworthiness required for the intended service have been properly estimated and operating experience with similar flying boats has been considered.

The beneficial effect of increasing forebody length or forebody length-beam ratio on spray characteristics at low speeds has been demonstrated (references 1 and 2). A general relationship between beam loading and length-beam ratio for a large number of actual seaplanes is given in reference 3.

This paper presents a correlation of the beam loading and the forebody length-beam ratio of a limited number of contemporary multiengine long-range flying boats for which the spray characteristics in service are known. The results of the correlation have been of value in analyzing the differences in the spray characteristics of the various flying boats and in estimating the hydrodynamic qualities of similar proposed designs in advance of model tests with powered propellers. The spray criterion and the derived relationships permit relative effects of forebody length, beam, and length-beam ratio to be studied analytically. The conclusions drawn are useful in preliminary design and as a guide for the improvement of flying-boat hulls.

DATA

The essential particulars and the known spray characteristics of six flying boats are summarized in table I. Only boats for which operating experience is definitely known are included. The notes regarding spray are based on observation of motion pictures and of actual take-offs, conversations with pilots and maintenance personnel, and studies of available flight reports. No attempt is made to consider all the factors influencing the spray, such as the lines of the forebody, propeller and wing clearances, and power loading.

The distinctions in spray characteristics are drawn as objectively as possible for purposes of analysis and would be open to question in individual cases. Most of the flying boats have, because of military urgency, been operated successfully at heavier overloads and under more adverse sea conditions than would normally be considered practicable. Such operation is outside the scope of the present study.

In table I the symbols used are defined as follows:

L_f/b forebody length-beam ratio

C_{Δ_o} gross-load coefficient (Δ_o/wb^3)

where

L_f length of forebody from bow to step, feet

b maximum beam, feet

Δ_o gross load, pounds

w specific weight of sea water (64 lb/cu ft).

ANALYSIS AND DISCUSSION

The Spray Criterion k

A logarithmic plot of C_{Δ_o} against L_f/b for the flying boats listed in table I is shown in figure 1. In this plot the spray characteristics are indicated by keyed symbols that fall in an orderly manner according to the differences in the reported characteristics of the various flying boats. On the plot the symbols denoting similar spray characteristics lie along straight lines having equations of the form.

$$C_{\Delta_o} = k\left(\frac{L_f}{b}\right)^2 \qquad (1)$$

where k has the following values:

For flying boats with excessive spray........... 0.0975

For flying boats with spray that is heavy but acceptable for overload..................... 0.0825

For flying boats with spray considered satisfactory for normal operations........................ 0.0675

For the flying boat with very light spray........ 0.0525

The constant k apparently varies more or less linearly with the severity of the spray characteristics and is, therefore, a suitable criterion for investigating the effect of changes in the dimensions of the forebody on the spray or for determining the dimensions of a forebody for various degrees of seaworthiness.

Derived Relationships

Relationship between C_{Δ_o} and L_f/b.- Equation (1) indicates that, for a given value of k and hence for comparable spray characteristics, C_{Δ_o} varies as $(L_f/b)^2$. Thus, as the length-beam ratio of the forebody of a given flying boat is increased, a considerably higher value of C_{Δ_o} is permissible. This conclusion parallels that of reference 2.

Relative importance of L_f and b.- It has been noted in tank tests that an increase in forebody length alone is relatively more effective in improving spray characteristics at low speeds than the same percentage increase in beam alone. It may be observed from figure 1 that an increase in L_f results in a favorable change in L_f/b with no change in C_{Δ_o}. On the other hand, an increase in b results in a faborable change in C_{Δ_o}, but this change is offset to some extent by a reduction in L_f/b.

The relative importance of length and beam is also shown by the spray criterion k. By combining the definition of C_{Δ_o} and equation (1), the following expression for the spray criterion is obtained:

$$k = \frac{\Delta_o}{wbL_f^2} \qquad (2)$$

Hence, for a given Δ_o, k varies inversely as the first power of b but as the square of L_f.

Effect of L_f and L_f/b for comparable sizes of hull.- As pointed out in reference 2, the effect of L_f/b for a series of hulls is more nearly isolated if the sizes of the hulls remain comparable. This condition is nearly satisfied by maintaining equal plan form areas and approximately equal structural weights of bottom or by holding the product $L_f b$ constant. Let

$$L_f b = c \tag{3}$$

where c is a constant representing the size of the forebody. If equation (3) is combined with equation (2),

$$k = \frac{\Delta_o}{w c L_f} \tag{4}$$

Hence, for a given Δ_o and $L_f b$, the spray criterion k varies inversely as the first power of L_f. From equation (3)

$$L_f = \left(c \frac{L_f}{b}\right)^{1/2} \tag{5}$$

When equation (5) is combined with equation (4),

$$k = \frac{\Delta_o}{w c^{3/2} \left(\frac{L_f}{b}\right)^{1/2}} \tag{6}$$

Hence, for a given Δ_o and $L_f b$, the spray criterion k varies inversely as the square root of L_f/b.

Effect of L_f/b for comparable spray characteristics.- The trend toward improved spray characteristics with increase in L_f/b when $L_f b$ is held constant, indicates the possibility of an over-all improvement in design by the use of high length-beam ratios. In equation (2), k

remains the same and comparable spray characteristics are maintained if $L_f^2 b$ is held constant as L_f/b is varied. By transposing terms in equation (6)

$$c^{3/2} = \frac{\Delta_o}{wk\left(\frac{L_f}{b}\right)^{1/2}}$$

or

$$c = \left(\frac{\Delta_o}{wk}\right)^{2/3} \frac{1}{\left(\frac{L_f}{b}\right)^{1/3}}$$

Hence, for a given Δ_o and k, c varies inversely as the cube root of L_f/b.

CONCLUSIONS

1. The spray characteristics of several multiengine long-range flying boats are satisfactorily related by the expression

$$C_{\Delta_o} = k\left(\frac{L_f}{b}\right)^2$$

where

C_{Δ_o} gross-load coefficient (Δ_o/wb^3)

L_f/b forebody length-beam ratio

k nondimensional coefficient varying from 0.0975 for boats with excessive spray to 0.0525 for boats with very light spray.

2. A value of the spray criterion k of 0.0675 corresponds to satisfactory spray characteristics in

normal service and is recommended for determining the dimensions of the forebody in preliminary design.

3. For a given gross weight, the spray criterion k varies inversely as the beam and inversely as the square of the forebody length. The forebody length has a relatively greater influence than the beam on the spray characteristics.

4. For a given gross weight and product of forebody length and beam (size of forebody), the spray criterion k varies inversely as the forebody length and inversely as the square root of the forebody length-beam ratio. Large increases in length-beam ratio are required to obtain a definite improvement in spray characteristics.

5. For a given gross weight and value of the spray criterion k, the product of forebody length and beam (size of forebody) varies inversely as the cube root of the forebody length-beam ratio. High length-beam ratios permit the use of a smaller size of forebody for comparable spray characteristics.

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TABLE I

PARTICULARS AND SPRAY CHARACTERISTICS OF SIX

MULTIENGINE, LONG-RANGE FLYING BOATS

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

Flying boat	Number of engines	Forebody length-beam ratio, L_f/b	Gross-load coefficient, C_{Δ_0}	Spray Characteristics
A	2	2.49	0.43	Satisfactory bow spray. Negligible spray through propellers and striking wing or tail surfaces. Successfully operated under wide variety of adverse wind and sea conditions.
			.50	Heavy bow spray. Maintenance and corrosion problems increased but acceptable for overload under average sea conditions.
B	4	2.97	0.89	Excessive bow spray. Water through propellers drenches engines, wing and tail surfaces. Erosion of dural propellers with any additional overload prohibitive.
C	2	3.14	0.93	Excessive bow spray. Water through propellers in smooth water almost obscures nacelles and center section of wing. Large auxiliary spray strips required for any additional overload.
D	2	3.35	0.75	Satisfactory bow spray. Water through propellers strikes flaps and tail surfaces but not enough for corrosion and maintenance problem. Successfully operated under wide variety of wind and sea conditions.
			.94	Heavy bow spray. Propellers, flaps, and tail surfaces heavily wetted in smooth water. Acceptable for occasional overload with steel propellers.
E	4	3.61	0.69	Light bow spray. No spray through propellers except in heavy seas. Maintenance and corrosion problems negligible. Dural propellers satisfactory for long periods between overhauls.
F	2	3.62	0.85	Satisfactory bow spray. No spray through propellers in moderate choppy waves. Considered very seaworthy for rough water operation.
			1.10	Heavy bow spray. Propellers, wing and tail surfaces in the spray but hull apparently capable of a slight further increase in gross weight. Acceptable for overload with steel propellers.

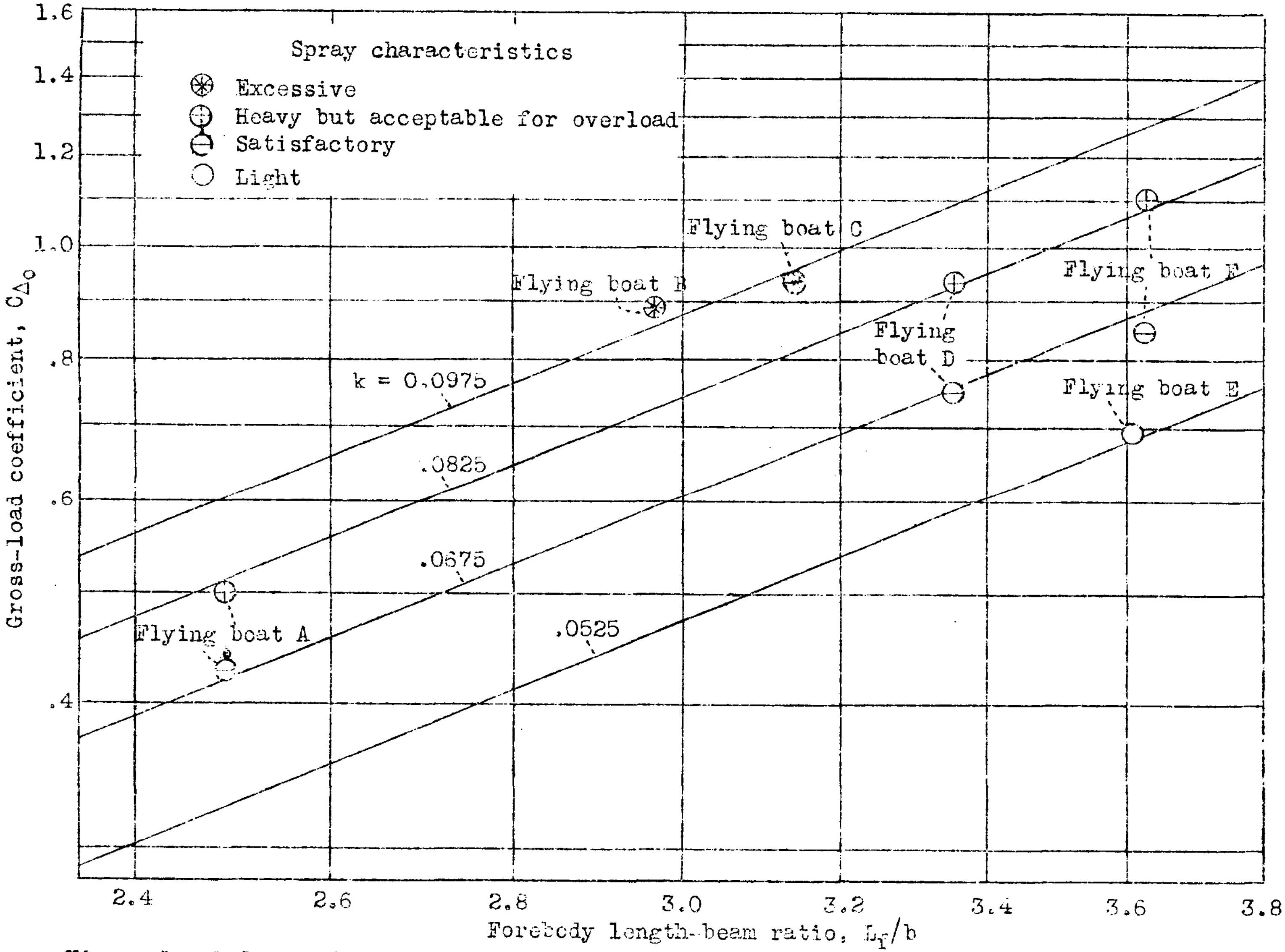

Figure 1.- Relation between gross-load coefficient and forebody length-beam ratio for the long-range flying boats described in table I. $C_{\Delta_o} = k(L_f/b)^2$.

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ABSTRACT:

Essential particulars and known spray characteristics of six flying boats for which operating experience is definitely known are summarized. Correlation of the beam loading and the forebody length-beam ratio of the flying boats is presented. Spray criterion and the derived relationships permit relative effects of forebody length, beam, and length-beam ratio to be studied analytically. It is concluded that the gross-load coefficient for comparable spray characteristics varies as the square of the forebody length-beam ratio.

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