

March 20, 1928.

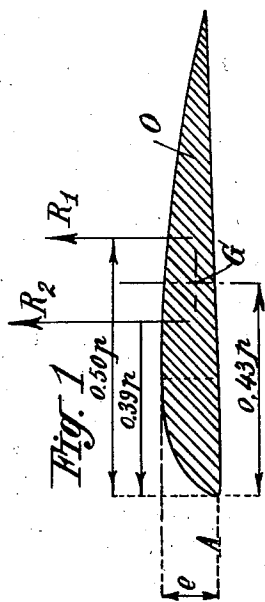
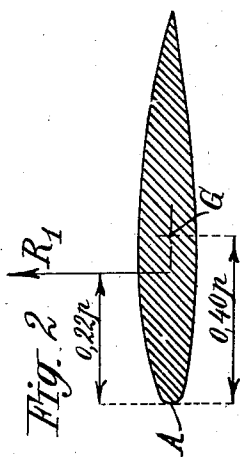
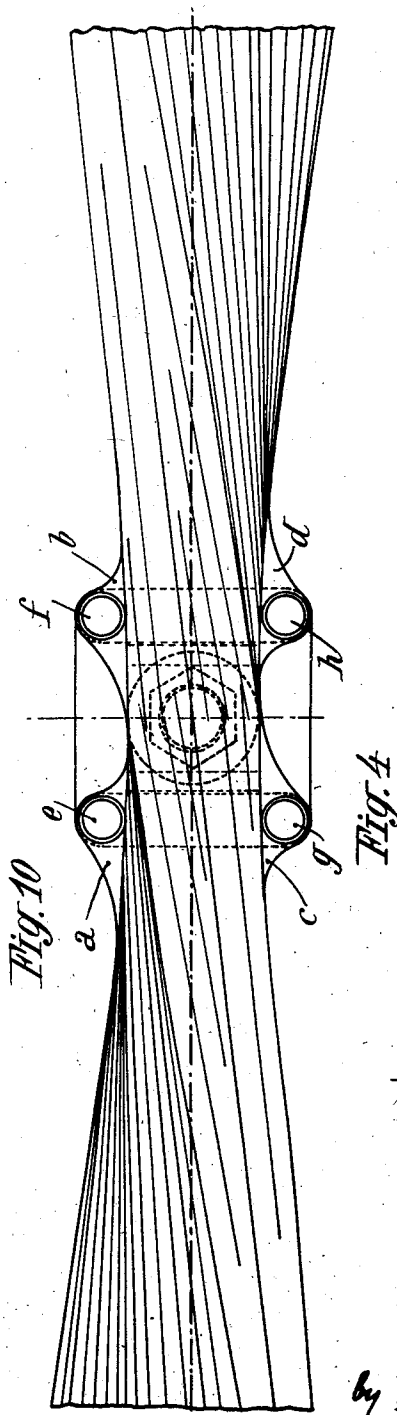
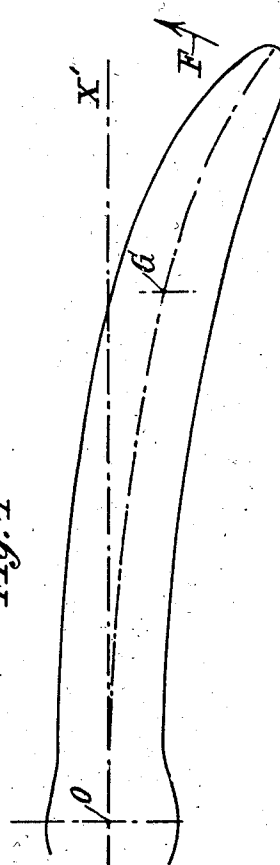
1,663,512

L. BREGUET

PROPELLER

Filed Dec. 17, 1927

4 Sheets-Sheet 1



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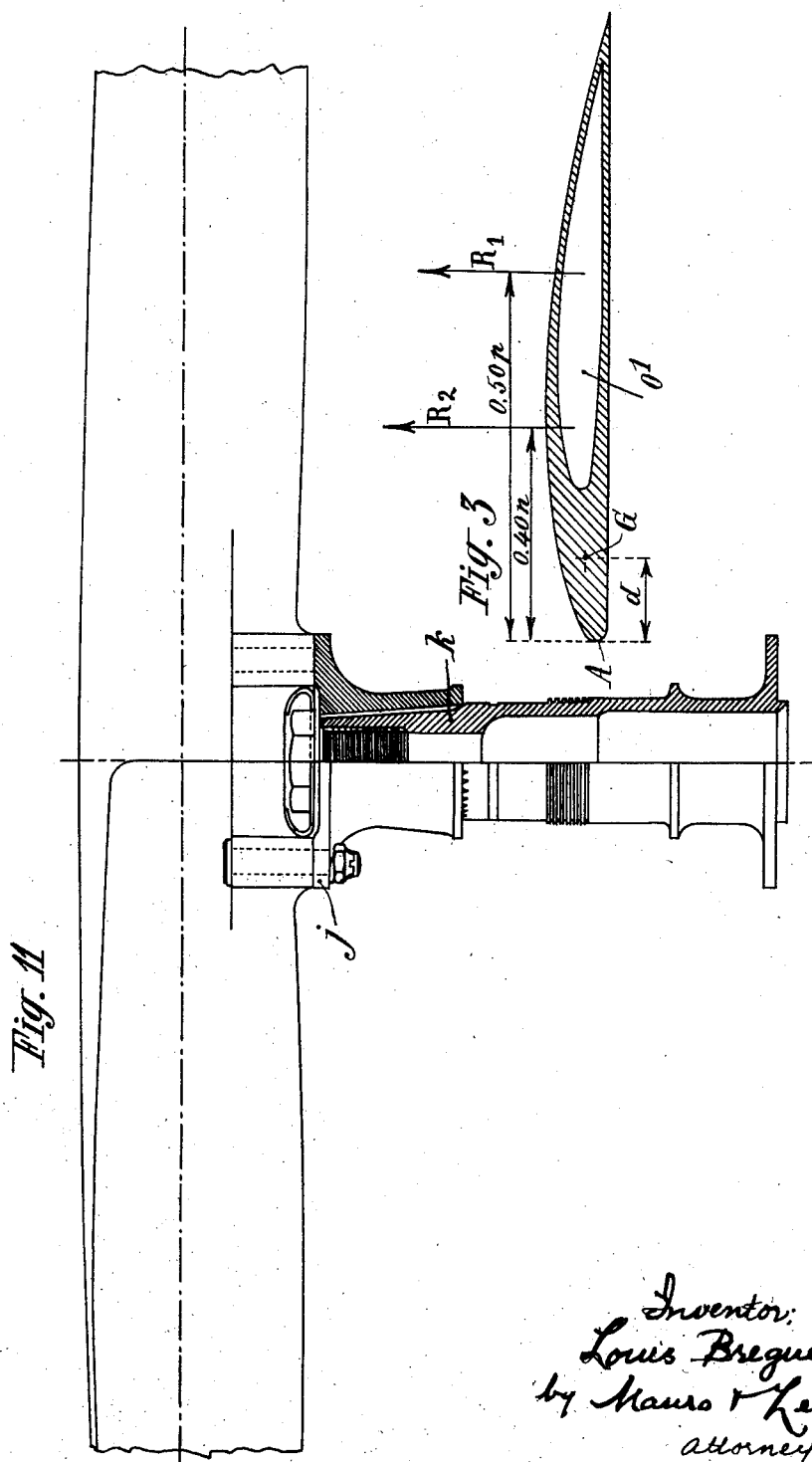
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4 Sheets-Sheet 2



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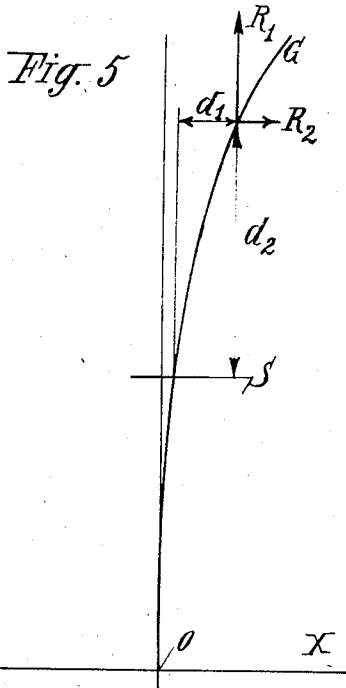
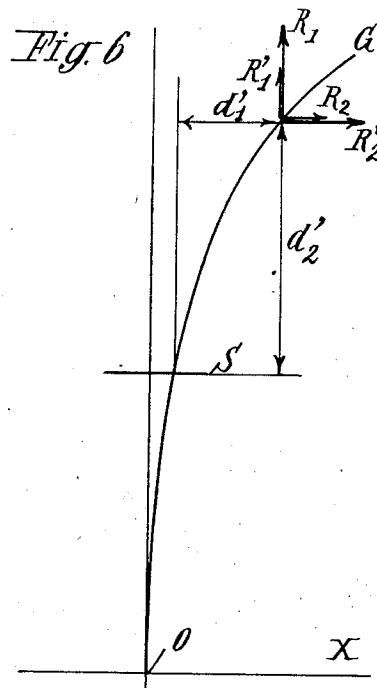
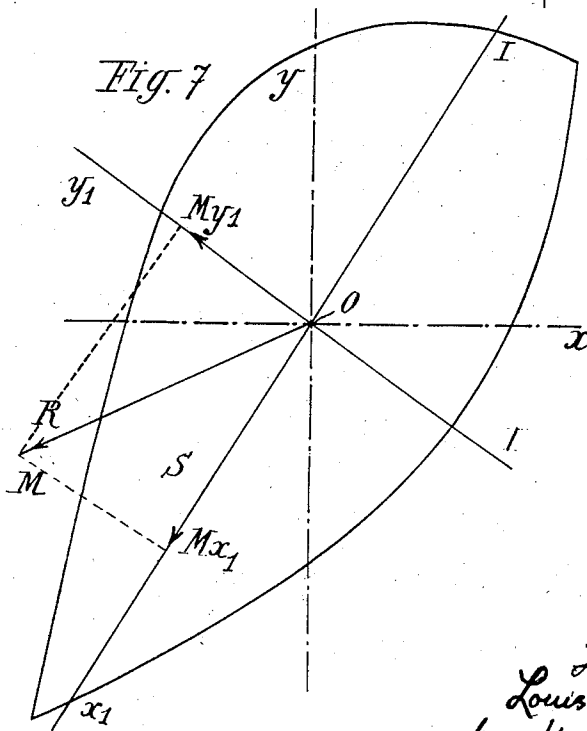
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4 Sheets-Sheet 3



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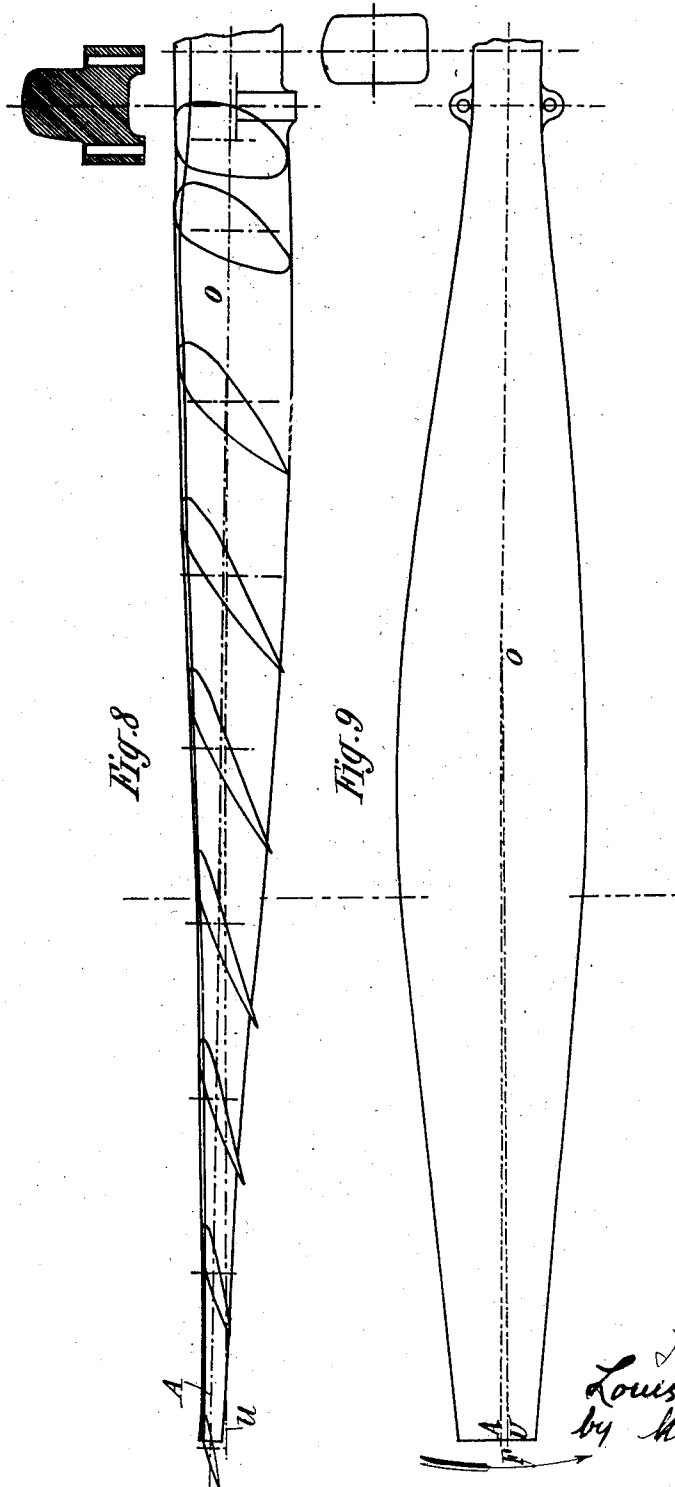
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PROPELLER

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE.

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PROPELLER.

Application filed December 17, 1927, Serial No. 240,853, and in France September 1, 1926.

The distortions to which propellers are subjected will usually modify their properties, and chiefly in the case of propellers with thin blades. This effect is more strongly marked in the case of metallic propellers, in which the blades consist of metallic plates which are suitably bent into shape.

in a direction such that the pitch will increase with an increase of thrust, when the apparatus rises, thus reducing the efficiency as well as the number of revolutions, and hence reducing the ascensional speed.

For instance, in the case of a solid propeller in which the section of a blade o is shown in Fig. 1, this section representing an approved outline in current use, the center of gravity G of the section is usually situated at a point corresponding to about 43 per cent of the length of the section, starting from the leading edge A . The centre of thrust is displaced from R_1 to R_2 between 39 per cent and 50 per cent of the distance from the leading edge A , and it is thus adjacent the centre of gravity during an ascending flight (operation at increased thrust), but will be situated much to the rear when in horizontal flight near the ground with full admission of gas (operation at low thrust), so that the propeller will tend to increase its pitch upon increase of thrust when rising and to lose pitch upon decrease of thrust when horizontal. Due to the distortion of the blades, the difference between the aerodynamic effects in these two conditions will exceed the difference offered by a rigid propeller, and the device will show greater variations in efficiency.

For a metallic propeller whose cross sections have a uniform relative thickness of 10 per cent (the ratio between the maximum thickness e of the section and the length of the section p Fig. 1) the difference between the operating angle when in level flight with full gas admission, and the angle when rising which is about 4 per cent on the average for the section situated at $\frac{2}{3}$ of the radius, will be increased by 50 per cent, by virtue of the elastic deformation due to torsion.

If the propeller is so constructed as in normal practice that this difference between these angles includes the attacking angle corresponding to the aerodynamic factor or coefficient, of the aforesaid cross-section (the said coefficient being $\frac{C_y}{C_x}$ in which C_y is the thrust and C_x the trail or drift,) it is observed that the said coefficient will be re-

The present invention has chiefly for its object a metallic propeller in which all such defects are obviated. The cross sections of the propeller blades are herein gradually increased in area from the end of the blade to the hub, and due to this form I am enabled to improve the aerodynamic properties of the propeller by diminishing the prejudicial deformation due to torsion, and also to increase the strength, the duration and the reliability of the propeller.

In one form of construction, the shape given to the propeller blade is such that the surface at its middle part will be a surface formed by rectilinear generatrices, and the surface at the end of the blade will consist of a cone whose axis is displaced to the rear of the axis of reference, and is then twisted and is optionally bent.

The propeller may be constructed without a hub, and may be secured by bolts inserted through suitable lugs provided at a point near the centre of the propeller.

The following description with reference to the appended drawings which are given by way of example, shows the manner in which the said invention is carried into effect.

Figs. 1 to 7 are diagrammatic views of an explanatory nature.

Fig. 8 shows an outline of the propeller blade, together with various cross sections, and

Fig. 9 is a corresponding view in the 90° position.

Fig. 10 is a view on a larger scale, corresponding to Fig. 9, showing the regulated surface of the central part.

Fig. 11 is an outline view of the middle part of the propeller.

In propellers having an approved outline according to current practice, the displacements of the centre of thrust take place

duced by 4.5 per cent when in rising flight and by 8% for level flight with open throttle, so that the efficiency will not be the same for the two cases.

8 If due account is taken of this elastic deformation in the optimum adaptation of the propeller for level flight, this latter will be all the more unfavourable when in ascending flight. The efficiency will thus be
10 reduced, and further, the increase in the pitch will cause a great reduction in the number of revolutions, and hence a reduction in the ascending speed and in the aptitude of the aeroplane to leave the ground.

15 If the solid propeller is given a cross section in which the centre of thrust is not displaced, such as a symmetrical section, the pitch of the propeller will usually be increased in the two aforesaid conditions of
20 flight, i. e. level flight with open throttle and ascending flight, but the increase will be greater when rising than on a level, so that the prejudicial difference between the angles of incidence will increase to a less degree
25 than in the preceding case. In fact, for a symmetrical propeller section, as shown in Fig. 2, whose centre of gravity G is situated at about 40 per cent from the leading edge A, and the centre of thrust R¹ at 22 per cent, the
30 propeller traction when in ascending flight being about 1.4 times the traction in level flight, the said propeller will increase in pitch to a greater degree when rising than in level flight, and the increase in the difference between the angles of incidence will be
35 about 35 per cent for a metallic propeller whose relative thickness is 10 per cent, and the variation in the aerodynamic factor will be 6.5 per cent.

40 To obviate such defects I provide various improvements in the construction of wood or metal propellers, whereby the neutral line or median line of gravity will be brought forwardly of the centre of thrust.

45 According to these improvements, the rear part of the propeller is made hollow, as shown at σ^1 Fig. 3, so that the greater mass of the material will be located near the leading edge or I may make a suitable choice of
60 heterogeneous substances, the substances having the mass or density being placed at or near the leading edge, or like means may be employed. Referring to the case of Fig. 1, and if this is applied to a hollow blade
55 (Fig. 3) having a cross section in which the centre of thrust is displaced between R₁ and R₂ from 40 per cent to 50 per cent of the length of the section (Fig. 3), it is simply necessary to place the neutral line G sufficiently near the leading edge in order that
60 the moment of torsion which tends to reduce the pitch of the propeller will be greater at increased thrust, as when in ascending flight.

65 If the traction or thrust when rising is 1.4 times the traction on the level, I may place

the neutral line G at a distance d from the leading edge which is less than 22 per cent of the length of the cross section.

However, this principle is not generally applicable, due to practical considerations. 70

Like results may be obtained by curving the neutral line towards the rear of the propeller.

Fig. 4 is a front view of a propeller blade thus arranged; it rotates about an axis O
75 perpendicular to the figure in the direction of the arrow F. The neutral line G of this blade is curved in the rear of the plane OX.

In certain cases, this arrangement is subjected to certain additional flexion stresses due to centrifugal force, which is a disadvantage. 80

To recapitulate, it is observed that a propeller blade is distorted by torsion about its
85 neutral line, or axis of the blade, by virtue of changes in the couple due to aerodynamic efforts whose lines of action are usually displaced and whose values change.

This distortion takes place in uncompensated propeller blades in a direction such that the efficiency is changed, and it becomes worse according as the blade can be more readily distorted. 90

When in ascending flight, the action of the aerodynamic resultants will tend to increase the pitch; the resulting increase in the leading angle causes firstly a reduction of the efficiency of the propeller and secondly a reduction of the number of revolutions, and hence a diminution of the maximum power which the engine may be called upon to furnish when rising. 95

Due to these two causes, the speed in ascending flight will be reduced. 100

The known methods for obviating such defects have had but little success by reason of practical difficulties.

The metallic propeller, which is comprised in the present invention, is chiefly characterized by the following features whereby the said defects are obviated. 110

The relative thickness of the cross sections, i. e. the ratio of the maximum thickness to the length of the section, increases gradually from the outer edge of the blades to the hub. Due to this gradual increase, I can greatly increase the polar moment of inertia, i. e. the moment of inertia with reference to the centre of gravity, relatively to cross sections which have the same area but whose relative thickness is smaller, and this affords a solid which will withstand the deformations due to torsion which act as a rule, in the case of propellers, to change the functioning of the engine and propeller combination. 115

In these conditions, the said arrangement serves chiefly to increase the general efficiency of the propeller by reducing the 120 125 130

elastic distortions which are prejudicial to the efficiency.

For each cross section, the relative thickness of the outlines (or cross sections) is carefully selected in such manner that the variations of the angle of the aerodynamic action between the extreme conditions of functioning, which variations increase from the end of the blade to the propeller shaft, will correspond to the greatest possible values of the minimum aerodynamic coefficient of the sections, as above defined. I am thus justified in the use of outlines which are thin at the ends and of outlines which are thicker at the hub, in which case the variations in the incidence are greater.

The propeller according to the invention comprises compact sections adjacent the hub which have a stout and substantially rectangular shape. The shape of the said sections is such that their moments of inertia about any axis will allow them to withstand accidental stresses other than the stresses comprised in the usual calculations. On the contrary, the propellers whose shape in the part adjacent the hub is that of a flat metallic member, will be subjected to an abnormal stress under accidental stresses when the axis of the flexion couple of the forces resulting from these stresses is parallel with the main axis of the section.

The shape of the cross-sections or outlines of the propeller according to the invention is shown in Fig. 8, which shows various cross-sections suitably spaced apart.

By reason of its construction, my said propeller is adapted to withstand distortion caused by flexion, so that I consider it advantageous to employ a construction in which the neutral line will assume a determined form when in the inoperative position, whereby the variations in the whole of the metal will be a minimum between the different rates of functioning, in spite of the relative variations of the value of the aerodynamic stresses and the centrifugal stresses, whose flexion couples will thus be more or less compensated, and this will occasion stresses which will be properly added to the other elastic stresses.

In Fig. 5, OG represents the neutral line of a propeller blade, which is rotatable on the axis OX' and whose equilibration is considered in certain conditions of functioning, for instance when operating with open throttle and in level flight.

The moment which is the resultant of the centrifugal stresses R_1 and the aerodynamic stresses R_2 , relatively to the section S of the propeller, for example, is nil;

$$-2R_1d_1 + 2R_2d_2 = 0$$

In other operating conditions in which the centrifugal stresses are reduced in the ratio of 0.7 and the aerodynamic stresses are in-

creased in the ratio of 1.3, the moment of flexion due to the aerodynamic stresses is

$$0.72R_1d_1;$$

the moment of flexion due to the aerodynamic stresses is

$$1.32R_2d_2;$$

the resulting moment is

$$M_R = 1.32R_2d_2 - 0.72R_1d_1, \quad 75$$

whence

$$M_R = (1.3 - 0.7)2R_1d_1 = 0.62R_1d_1.$$

The stress due to this moment is added to the stresses due to centrifugal force.

I may, in accordance with the invention, so dispose the apparatus that the said resulting moment will be distributed between the two operating conditions specified, by properly curving the neutral line or fibre.

This arrangement is shown diagrammatically in Figs. 6 and 7. Let us consider a cross-section of a blade perpendicular to the neutral line; S is the surface of this section which is shown in Fig. 7. It is required to determine the stresses in this section for given operating conditions R of the aeroplane.

The diagrams show firstly, the moment of the aerodynamic effects M_a acting upon the portion of the blade comprised between the section S and the end of the blade; secondly, the moment of the centrifugal effects M_c acting upon the portion of the blade comprised between the section S and the end of the said blade; this moment depends upon the form which is given to the neutral line or fibre.

The combination of these moments affords a resultant M_R , which is projected upon the main axes of inertia O_x 1 and Oy_1 at Mx_1 and My_1 (Fig. 7).

If N represents the resultants of the centrifugal stresses on the portion between the section S and the end of the blade, the stress at a given point on the co-ordinates x, y will be

$$n = \frac{N}{S} + \frac{Mx_1}{Ix_1} \cdot y - \frac{My_1}{Iy_1} \cdot x \quad 115$$

in which Ix_1 and Iy_1 are the principal moments of inertia.

If x_1 and y_1 are the co-ordinates at the point of minimum flexion, this will give the stress n_m at the point of maximum stress for the stated conditions of flight.

If the aeroplane proceeds in a continuous manner from the condition of rest to any of the possible conditions of flight it is observed that in any cross-section of the propeller, the points of greatest stress on the outline of the cross-section will be subjected to variable rates of work, which pass through maximum for determined conditions $R' R'' R'''$ etc. . . .

If these maximum stresses are designated by n_m^a , n_m^b , n_m^c etc. .; there will be two values which are greater than the others, for instance n_m^a and n_m^c , which may be termed
 5 the extreme maximum stresses.

The moment M_a which is due to the aerodynamic stresses, and the stress N , are constant; but the moment M_c (moment of centrifugal stresses) can be changed by modifying the neutral line OG (Fig. 6) so that
 10 I may regulate the rate of work at the points of maximum stress and so dispose the apparatus that the extreme stresses n_m^a and n_m^c will be adjacent one another, and irrespectively of the functioning of the apparatus,
 15 the propeller will in all cases operate under the same coefficient of stress.

All propellers in which according to the preceding calculations the extreme working conditions n_m^a and n_m^c differ by at least 30
 20 per cent, are propellers whose neutral line has a form which is comprised in the present invention.

This form which I give to the neutral line, as a result of the comparative observations of the stresses in different conditions of flight, presents a new character as compared with the known arrangements in which the equilibration is observed for a given condition of functioning, or as compared with
 30 the construction in which the blades may assume a certain position, or form due to elasticity, or due to a certain degree of freedom of motion, according to the Renard device, by which position or form the flexion due to
 35 air reaction will be equilibrated by the centrifugal forces.

In the deformable propeller, I add to the said effects, the elastic stresses due to the
 40 variations in the curvature

$$\Delta\varphi$$

of the neutral line or fibre.

$$45 \quad R = \Delta\varphi \cdot E \cdot v.$$

in which E is the modulus of elasticity of the metal, and v the distance from the point of maximum stress to the neutral line. This stress is not sufficiently taken into consideration, as a general rule.
 50

Since my said propeller is, by virtue of its form, but little subject to deformation I reduce the amplitude of the vibrations, and thus increase the strength of the metal
 55 against alternate actions.

For an equal rate or working, my said propeller will be more reliable and more durable than a propeller having a thin cross section.

60 In principle, my said propeller is manufactured by shaping it from a forged, or other, blank, starting with a straight piece of metal whose axis is preferably parallel with the axis of the propeller which is
 65 gradually twisted or flattened as concerns the

angles or is distorted by any suitable means, from the hub to the ends, in order to form the blades. The cutting operation is effected by machine or by like means. The outer surface may preferably have the form of a
 70 regulated surface.

I have represented by way of example in Figs. 8 to 11 and chiefly in Fig. 10 a propeller whose central part is formed by two generatrices parallel with the plane of rotation which is the plane of the Figure 10.
 75

In Fig. 9, the regulated surface extends from the centre of the propeller to the vertical line shown a little beyond half the radial length. From this line to the end of the blade, the form is similar to that of a flattened cone whose axis OA is brought to the rear of the line OU which is the main axis of the propeller; the latter rotates according to the arrow F.
 80 85

The said cone is twisted, and in order to give to the cross-section the proper aerodynamic effects they may be bent after trimming, so as to obtain the exact neutral line desired.
 90

One of the main features of my said propeller consists in the fact that it is not provided with a hub, and the device is secured by the lugs $a b c d$ (Fig. 10) provided at the centre of the propeller; these being traversed by the bolts $e f g h$ which are herein four in number, said bolts engaging and fastening the propeller to a plate j mounted on the crankshaft k of the engine (Fig. 11).
 95 100

What I claim is:

1. A propeller blade in which the cubical content of the leading edge portion is of greater specific gravity than that of the remaining portion.
2. A propeller blade having a hollow interior portion in the section remote from the leading edge to dispose the median line of gravity forwardly of the center of thrust.
3. A propeller blade having a portion within its surface rearwardly of the leading edge portion reduced in mass sufficiently to locate the median line of gravity between the leading edge and the line of thrust.
4. A propeller blade in which the median line of gravity is situated between the leading edge and the line of thrust, and closer to the leading edge.
5. A propeller blade having a body whose cubical content is composed of two substances of widely different specific gravity, the leading edge portion being composed mostly of the heavier substance and the remaining portion composed mostly of the lighter substance to locate the median line of gravity between the leading edge portion and the line of thrust.

In testimony whereof I have signed this specification.

LOUIS BREGUET.