TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 180

MARCEL BESSON WING SECTIONS

By C. Delanghe

From La Technique Aeronautique
October 15, 1922

Washington
January, 1923

MARCEL BESSON WING SECTIONS.*

By G. Delanghe.

The Marcel Besson seaplane, type H.5 is being tested at Saint Raphael. This giant seaplane, weighing with its four 250 HP Salmson engines, more than ten metric tons (11 tons), i.e. more than 10 kg (22.046 lbs) per HP, attained a speed of 130 km (80.8 miles) per hour. Its wing area of 255 sq.m (2744.78 sq.ft), loaded at about 40 kg per sq.m (8.8 lbs per sq.ft), consisted of four wings with a span of 29 m (95.14 ft) and a chord of 2.1 m (6.89 ft). The wings were arranged in two biplane cells staggered with reference to each other, so as to reduce the interaction of their surfaces (or gap resistance) to a minimum. Due to this quadruplane arrangement, Mr. Besson was able to give the wings a short chord and thus reduce the displacements of the center of lift of the whole cell. Furthermore, the airfoil adopted, type M.B.12, which we will examine later, is characterized by a slight proportional displacement of the center of lift, at the usual speeds. For both these reasons, the disturbing couple of the longitudinal equilibrium of the seaplane always remains very small, so that the size of the horizontal stabilizer can be reduced and the piloting made easy.

The airfoil M.B.12, which was used for the seaplane H5 and all the other Besson airplanes, is the result of methodical researches undertaken by Mr. Besson for improving the aerody-

* From La Technique Aéronautique, Oct. 15, 1922, pp. 358-366.

namic properties of airfoils. We give below the dimensions and lift curves of the three airfoils investigated during the course of these researches: M.B.10 (Fig. 1); M.B.11 (Fig. 2); M.B.12 (Fig. 3). A comparison of the three brings out the remarkable properties of No. 12.

1. Maximum lift.- The existence of a maximum lift implies a minimum landing speed, the two being inversely proportional to each other. Polars 10 and 11 present a very definite maximum, $K_y = 0.062$ for the former and 0.072 for the latter. On the contrary, polar 12 shows no maximum for ordinary speeds.

2. Maximum fineness.- The fineness ratio $B = K_x/K_y$ is proportional to thrust. Its minimum gives the value of the minimum slope of the trajectory in gliding flight. For airfoils 10 and 12, the minimum value of B is small, being practically equal to 0.047 for both airfoils, but is higher (0.0625) for airofil 11.

3. Minimum required power.- K_x^2/K_y^3 is characteristic of the power absorbed through the displacement by the airfoil. Its minimum is one of the fundamental factors influencing the altitude of the ceiling and the climbing speed. The curves $K_x^2/K_y^3 = f(K_y)$, joined to the corresponding lift curves, furnish the following results:

Airfoil	No. 10:	Min. value of K_x^2/K_y^3,	0.078
"	No. 11:	" " " ",	0.074
"	No. 12:	" " " ",	0.127

4. Wing-section drag.- Even if it is assumed that no energy is dissipated by friction and gusts, a drag of X_i is always found, intimately connected with the existence of the lift. In fact, an airfoil imparts to the adjacent air a vertical downward motion. In exchange for the energy thus communicated to the air, the airfoil receives from the latter a reaction which is called the lift. But the corresponding kinetic energy communicated to the air can only come from the energy expended against the resistance X_i, which has been called, by analogy with electro-magnetic phenomena, the induced resistance or drag. It is expressed by

$$X_i = \frac{(K_y\ S\ v^2)^2}{\frac{1}{2}\ \rho\ v^2\ \pi\ e^2}$$

in which, $\rho = \lambda/g$, λ being the specific weight of normal air (at 15°C and 760 mm Hg), 1.225 kg/m^3 (.076 lbs/ft^3); so that $\rho = 0.125$; kg/m/sec = (.00237 lbs/ft/sec).

v = airspeed in m/sec;

b = span of wing in meters;

S = area of wing in square meters.

The coefficient of induced drag, defined by the general formula

$$X_i = K_{xi}\ S\ v^2$$

is therefore expressed by

$$K_{xi} = \frac{16\ K_y^2 S}{\pi\ e^2}\ ; \qquad (1)$$

and is entirely independent of the shape of the airfoil.

If we determine the difference between the drag measured experimentally and the induced drag, we find that it is very small and hardly more than the drag due to friction. It is practically independent of the aspect ratio and is mainly dependent on the shape of the airfoil. The better the shape, the smaller this difference is. Hence it bears the name of section drag. If the coefficient of the total drag is K_x and the section drag is K_{xp}, we have

$$K_x = K_x + K_{x\,p}$$

Equation (1) is that of a parabola whose parameter $\frac{1}{32} \pi \frac{b^2}{S}$ depends on the mean aspect ratio b^2/S and whose axis is the axis of the drag K_x.

For any given value of K_y, the difference between the corresponding abscissas of the polar curve and the parabola of induced drag gives the section drag. It is evident that, for airfoils 10 and 11, when K_y increases from about 0.035, the polar curve rapidly diverges from the parabola and that the value of the coefficient K_{xp} becomes considerable. For airfoil 12, on the contrary, the lift curve remains practically parallel to the parabola. Moreover, the minimum value of K_{xp}, which is only 0.0006 for airfoils 10 and 12, is 0.001 for airfoil 11.

To sum up: airfoil 11, the thickest (for which the ratio of maximum thickness to chord is 17.5%, while it is only 11.7% for airfoil 10 and 14.7% for airfoil 12), is the least advantageous from the viewpoints of fineness, minimum power and section drag. Beginning with K_y = about 0.035, airfoil 10 becomes, in its turn, rapidly inferior to airfoil 12, due to the increase of its section drag.

The comparison of airfoil M.B.12 and the Göttingen airfoil 430 shows that the two polar curves coincide completely for values of K_y above 0.02, i.e. for the coefficients generally utilized. But airfoil M.B.12 offers the very great advantage over airfoil 430 of undergoing only a slight relative shifting of the center of pressure. It follows:

1. That the variations of the torsion couple on the airfoil during flight are much smaller.

2. That the variations of the couple disturbing the longitudinal equilibrium of the airplane are smaller and that the same stability can be obtained by means of a smaller horizontal stabilizer.

In order to make allowance for the displacements of the center of lift, we will utilize the curves of the moment coefficients of Fig. 4. Let us recall briefly the significance of these curves. The lift Y and the drag X may be defined by either one of the following pairs of expressions

$$(I)\begin{cases} Y = \frac{1}{2}\rho v^2 C_y S \\ X = \frac{1}{2}\rho v^2 C_x \end{cases} \qquad (II)\begin{cases} Y = K_y S v^2 \Delta \\ X = K_x S v^2 \Delta \end{cases}$$

The dimensionless coefficients C_x and C_y are related numerically to the coefficients K_x and K_y.

(The C_y and C_x coefficients used in the Figures of this note are one hundred times larger than the above, in order to avoid the use of a decimal point, which is generally understood.) Sometimes the resultant is resolved into two directions invariably connected with the wing:

a) The tangential component $T = \frac{1}{2} \rho v^2 C_t S$, parallel to the chord;

b) The normal component $N = \frac{1}{2} \rho v^2 C_n S$, perpendicular to the above.

The coefficients C_x and C_y, or C_n and C_t show the magnitude and direction of the resultant of the action of the air. In order to determine the line of action of this resultant, its point of intersection P with the wing chord is often indicated. This method is inconvenient, since the point of intersection passes to infinity, when the resultant becomes parallel to the chord. The representative curve of the variation of the abscissa of the point P presents infinite branches, on which the interpolations are not very precise. Moreover, in the tunnel test, the rotation moment M is measured with reference to some suitably selected point. The curve representing the variation of M in terms of K_y has no infinite branches, bends slightly inward and lends itself readily to interpolation.

For wings, the leading edge is generally chosen as the center of the moments; or, with greater precision, the perpendicular to the wing-section plane passing through the intersection of the chord and the tangent carried to the leading edge perpendicularly to the chord.

As regards the definition of the coefficient of moment, it is only necessary to divide M by $\frac{1}{2} \rho S v^2$ and by some length (generally the chord c) in order to obtain the dimensionless coefficient

$$C_m = \frac{M}{\frac{1}{2} \rho v^2 S \cdot c}$$

With the system of units employed in France, the coefficient of moment is defined by the expression

$$K_m = \frac{M}{S v^2 c}$$

so that

$$C_m = 100 C_m = 1600 K_m$$

From the curve $C_m = \rho (C_y)$, it is very easy to find graphically the location of the center of pressure on the chord. In practice, C_y differs very little from C_m, so that, in the expression

$$M = \frac{1}{2} \rho v^2 \frac{C_m}{100} S \cdot p$$

(p being the distance from the center of lift to the center of moments), C_m may be replaced by C_y. By definition

$$M = \frac{1}{2} \rho v^2 \frac{C_m}{100} \cdot S c$$

Hence

$$\frac{p}{c} = \frac{C_m}{C_y}$$

Nevertheless, if it is desired to determine the value of p/c corresponding to a point A of the curve $C_m = \rho (C_y)$, we draw through the origin O the line OA to its intersection with the straight line of the equation $C_y = 100$ (Fig. 5). Let x be the abscissa of this point of intersection, measured on the scale of the coefficients C_m. Evidently C_m/C_y (ratio at the point A) = x/100, so that the abscissa x, read on the scale of the coefficients C_m, gives the distance from the center of pressure to the leading edge in per cent of the wing chord.

Let us apply this method to airfoil M.B.12 and Göttingen 430. It is evident that, for $K_y = 0.025$, the position of the center of pressure is the same on both airfoils (p/c = 0.57). But when K_y increases from 0.015 to 0.075, the ratio p/c varies from 0.8 to 0.35 for airfoil 430, while it varies only from 0.63 to 0.51 for the airfoil M.B.12. The relative displacement, which is 45% of the chord on airfoil 430, is only 12% on M.B.12.

To sum up, wing M.B.12 offers the following advantages:

1. A very high lift coefficient at large angles of attack, without the appearance of a maximum at the usual speeds;

2. A very small section drag, even at large angles, so that the total drag approaches as near as possible to the induced drag, an inevitable result of the lift;

3. A small value of the minimum fineness ratio B;

4. A small value of the ratio K_x^2/K_y^3 and the possibility of flight under economical conditions;

5. A small relative displacement of the center of lift, in

comparison with airfoil 430, whence an improvement in stability and ease of piloting and a diminution of torsion stresses in the wing;

6. A thick section very advantageous for construction of spars with a relatively high moment of inertia;

7. A trailing edge much less tapered than that of airfoil 430, hence less difficulty of construction.

MARCEL BESSON WING SECTION 10.

Parabola of induced drag for aspect ratio 5.78.

Polar = curve.

Surface area of model S = span b (.74) x chord c (.128) = 0.0947 m^2

Aspect ratio A = b/c = 5.78

Velocity of air in tunnel - v = 26 m/sec (Eiffel).

Characteristic product vc = 3.33 (proportional to Reynolds number).

Minimum fineness ratio $B = K_x/K_y = 0.0462$.

Maximum of 1/B = 21.6

(Minimum of power)
(Minimum of thrust)

Fig. 1 - Polar curve of Marcel Besson Wing M.B.10 (Eiffel 352).

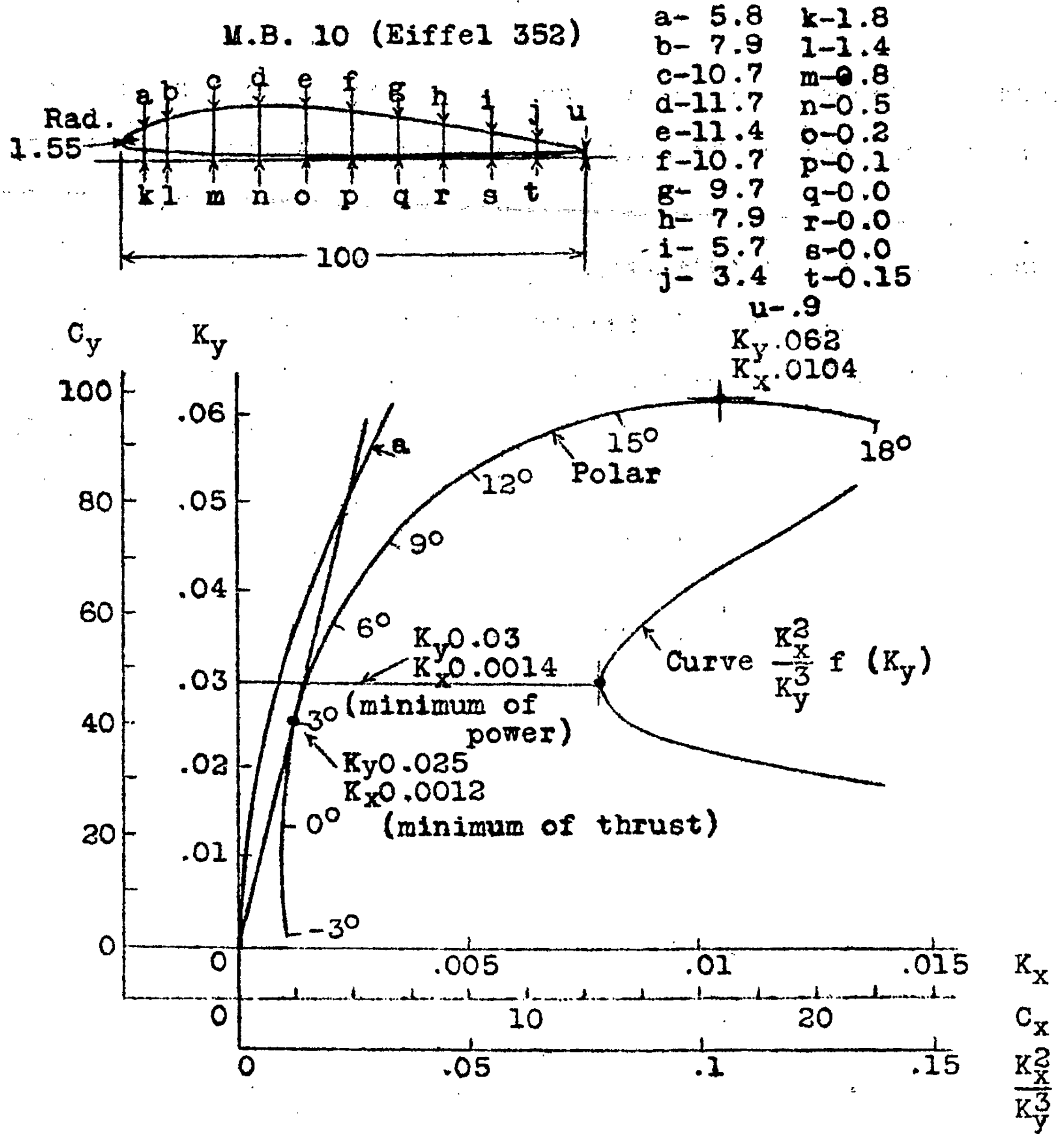
Comparison of lift and moment curves of Göttingen wing section No. 430 (Joukowski) and Marcel Besson section No. 12.

Distance of center of pressure from leading edge in % of chord.

Moment curves C_m.

Parabola of induced drag for aspect ratio 5.

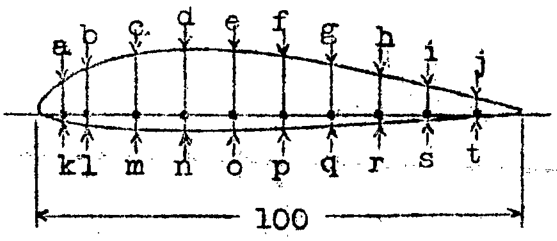
Translated by National Advisory Committee for Aeronautics.



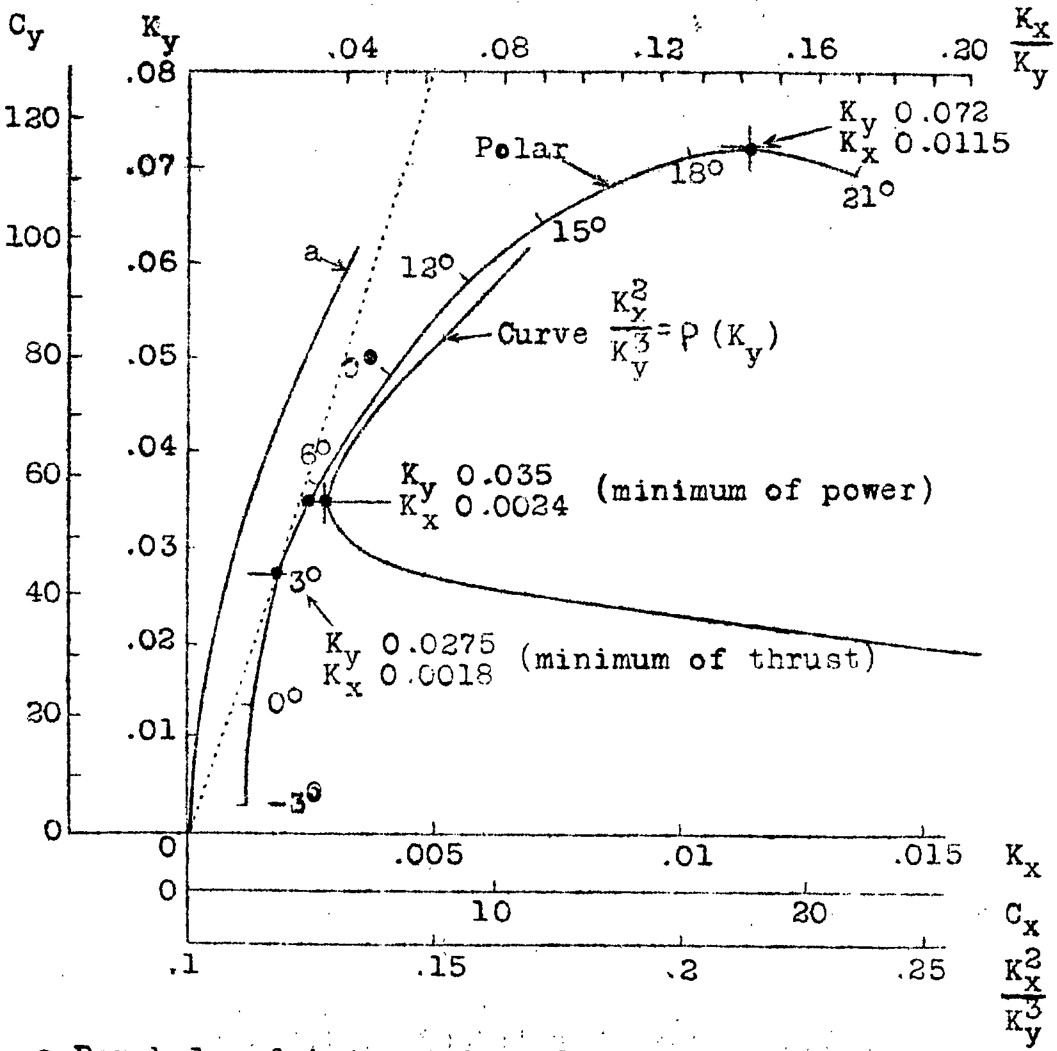
a-Parabola of induced drag for aspect ratio of 5.78
Surface area of model S=span b (.74) x chord c (.128)=.0947 m^2.
Aspect ratio A=b/c=5.78
Velocity of air in tunnel v=26 m/sec (Eiffel)
Characteristic product vc=3.33 (proportional to Reynolds number)
Minimum fineness ratio B=K_x/K_y .0462
Maximum of 1/B=21.6

Fig. 1 Polar curve of Marcel Besson Airfoil No. 10 (Eiffel 352)

M.B. 11 (Eiffel 353)



a- 6[illegible]4	k-1.41
b-10.00	l-2.26
c-13.32	m-3.07
d-14.35	n-3.22
e-13.78	o-3.15
f-12.61	p-2.92
g-10.81	q-2.59
h- 8.55	r-2.15
i- 6.04	s-1.59
j-.3.14	t-1.00



a-Parabola of induced drag for aspect ratio of 5.78

Surface area of model S = span b (.74) x chord c (.128) = .0947 m^2.

Aspect ratio A=b/c=5.78

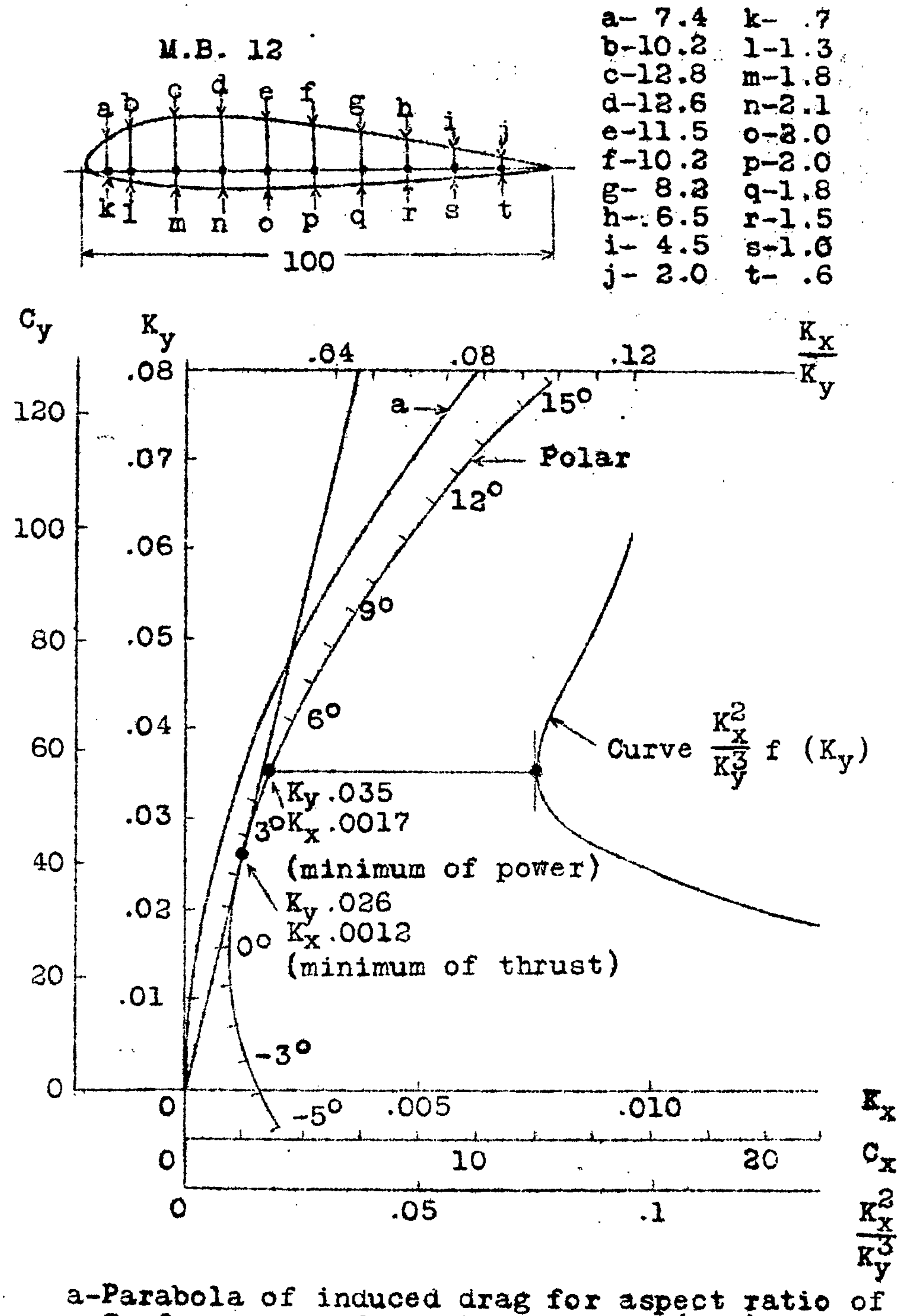
Velocity of air in tunnel v=26 m/sec (Eiffel)

Characteristic product vc=3.33 (proportional to Reynolds number)

Minimum fineness ratio $B=K_x/K_y$ .0626

Maximum of 1/B=16

Fig. 2 Polar curve of Marcel Besson Aitfoil No.11 (Eiffel 353)



a-Parabola of induced drag for aspect ratio of 5.3

Surface area of model S = span b (.78) x chord c (.147) = .1146 m^2

Aspect ratio A=b/c=5.3

Velocity of air in tunnel v=40 m/sec (Saint Cyr)

Characteristic product vc=5.88 (proportional to Reynolds number)

Minimum fineness ratio B=K_x/K_y .047

Maximum of 1/B=21.2

Fig. 3 Polar curve of Marcel Besson Airfoil No. 12

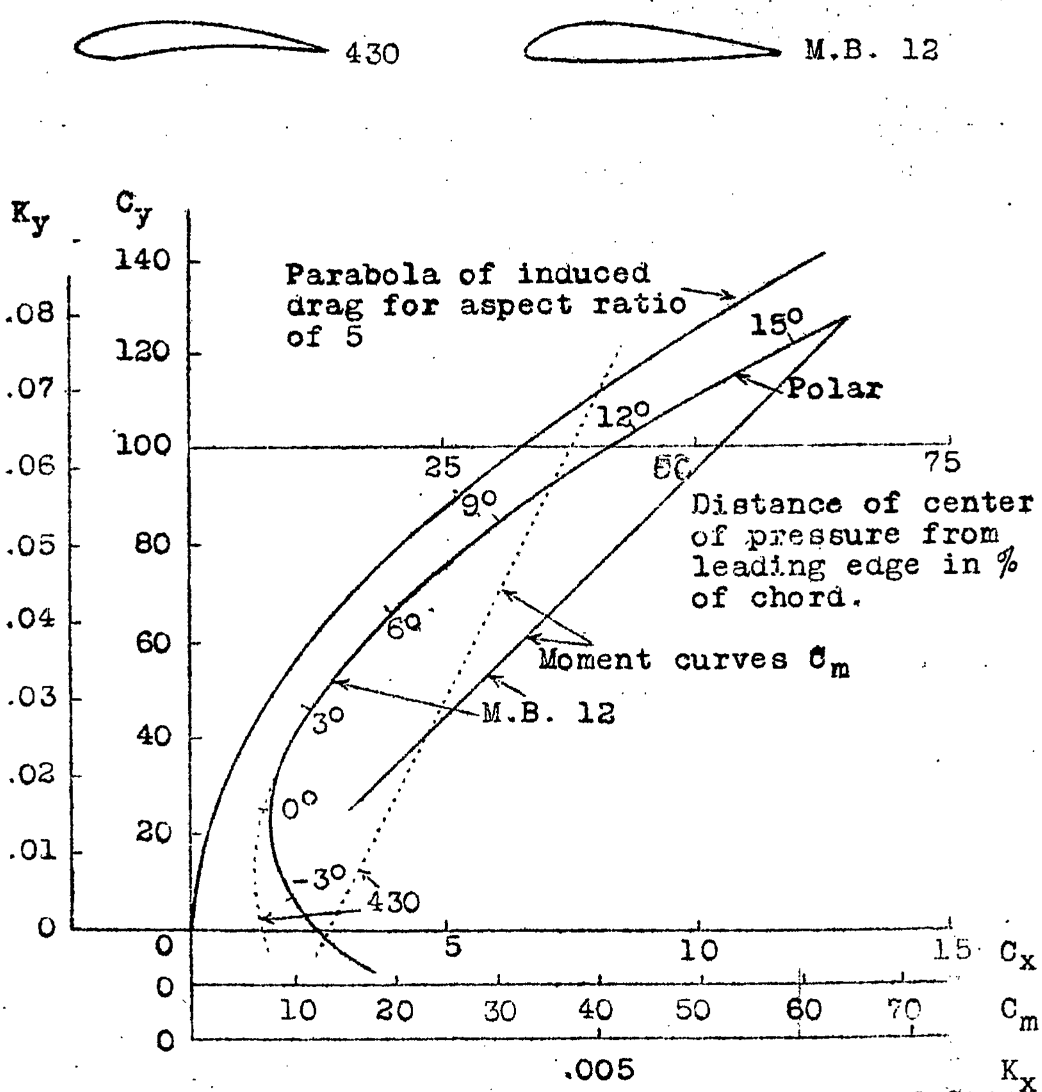


Fig. 4 Comparison of lift and moment curves of Göttingen wing section No. 430 (Joukowski) and Marcel Bessan section No. 12

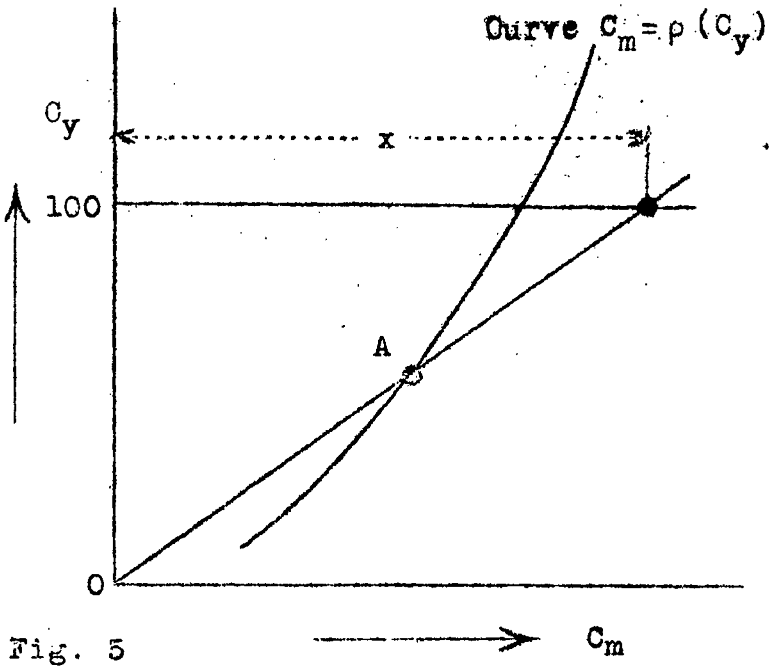


Fig. 5