TECHNICAL MEMORANDUMS

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No. 258

NEW APPLICATION OF PRINCIPLE OF VARIABLE-CAMBER AIRFOIL.
(Lachassagne system)

By A. Toussaint.

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NEW APPLICATION OF PRINCIPLE OF VARIABLE-CAMBER AIRFOIL.*
(Lachassagne system)

By A. Toussaint.

In studying the application of his system of varying the
camber of airfoil sections, Mr. Lachassagne has just obtained
a series of airfoil sections whose polar envelope presents
truly remarkable aerodynamic properties.

We gave in No. 39 (January 6, 1923) of this bulletin the
description of the mechanism employed by Mr. Lachassagne for
varying the camber. By starting with section 429 and applying
to it variations in the camber compatible with the mechanism,
the inventor successively obtained Nos. 430, 431, 432 and 438,
as shown in Figure 1. In order to obtain them, Mr. Lachassagne
made a rib with the initial section 429. This rib has the three
usual parts.

1. A leading edge rigidly attached to a piece representing
the front movable spar.

2. A central portion whose lower member is rigidly attached
to pieces representing the movable front and rear spars and
whose upper member, attached only to the front spar, slides on
the upper member of the trailing edge.

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3. A rear portion rigidly attached to the piece represent-
ing the movable rear spar.

By changing the form of this rib we can obtain the shapes
corresponding to various cambers. Thus we obtained the airfoil
sections shown in Figure 1. They correspond to different cam-
bers of a Lachassagne variable-camber airfoil.

Wind tunnel tests.- Wooden models were made corresponding
to these sections, for testing in the Eiffel wind tunnel. The
airfoils thus tested were of rectangular plan with uniform cross-
section and had the following dimensions: span 60 cm (23.62 in.);
chord 10 cm (3.94 in.); aspect ratio 6; area 600 sq.cm (93.00
sq.in.).

The velocity of the air stream being 28 meters (91.86 feet)
per second, the results obtained are proportional to a charac-
teristic product Vl, equal to 2.8 sq.m (30.14 sq.ft.) per
second.

Figures 2 and 3 give these results (Report 100B, Eiffel
Laboratory). Figure 7 gives, on a larger scale, the polars,
fineness ratios and the polar envelope which characterizes the
aerodynamic properties of the deformable airfoil. The polar
envelope is parallel to the induced parabola (or theoretical
polar) throughout a considerable portion of its length. The
corresponding airfoil-section drag varies from $C_{x_0} = 0.8$ to
$C_{x_0} = 1$, which corresponds to the sole drag due to the friction
of the air on the wing. The maximum fineness ratio is 24 for
$C_y = 37$.

Remark.- We see, on Figure 7, that most of the polars intersect near $C_y = 92$ and $C_x = 5.6$. This peculiarity has already been observed in groups of airfoil sections corresponding to a variable camber airfoil. This was taken into account in plotting the polar envelope and the fineness curves.

Comparison with other airfoils.- It is interesting to compare this polar envelope with the polar envelopes of other known airfoils. Figure 8 gives this comparison and Figure 9 gives the different airfoil sections compared (Taken from Bulletin Technique of the S.T.Ae., March 12, 1923).

We have first compared the polar envelope (EL) for two airfoils, No. 1 A and No. 31 A, which have practically the same relative thickness as the variable-camber airfoil. The airfoil 1 A (Halbronn) has a slightly smaller C_x at lift coefficients below $C_y = 20$. The polar 1A coincides with the polar EL up to $C_y = 55$. Beyond this point it falls decidedly below EL. The wing 31A (Dewoitine) also has a slightly smaller C_x up to $C_y = 12$. Beyond this lift coefficient the polar 31A is slightly less than the polar EL.

This result was, moreover, to be anticipated, since the airfoils 1A and 31A with moderate camber cannot have, at the same time, the advantages of a small C_x and a large C_y.

The comparison is then continued with airfoils of greater camber, but relatively greater thickness.

a) Airfoil 73A (Göttingen 430 or Joukowski airfoil section),

$m/c = 13.8\%$ and $o/c = 5\%$, gives a polar parallel to EL up to about $C_y = 100$. The airfoil-section drag of 73A is, however, greater than for EL.

b) Airfoil 27A (Dewoitine), $m/c = 17\%$ and $o/c = 7.33\%$, is the one for which the polar remains parallel to EL the longest, with, however, a higher airfoil-section drag. This airfoil No. 27A is, moreover, considered by many engineers as the best of its class.

c) Airfoil 20A (Royer), $m/c = 17.4\%$ and $o/c = 8.85\%$, has a maximum C_y which exceeds that of EL, but its polar is considerably below EL for all lift coefficients below $C_y = 157$.

The result of this comparison is that, from the standpoint of the aerodynamic qualities C_x, C_y and fineness ratio C_y/C_x, a variable-camber airfoil, susceptible of including the sections which have given the polar EL, is superior to the best airfoils known with constant section.

The only airfoil of this type, capable of competing with the airfoil EL, would be airfoil 27A (Dewoitine). It is well, however, to remark that the latter airfoil has a much greater relative maximum thickness than EL (17% instead of 9.6%). It would, therefore, be better to compare airfoil 27A with a variable-camber airfoil whose constituent sections would also have a maximum thickness of $m/c = 17\%$. It is, in fact, known that the maximum lift coefficient increases, within certain limits, with m/c. It is also known that the increasing of m/c renders it

possible to extend the upper limits of o/c, by retarding the appearance of the harmful phenomena due to the breaking away of the air filaments from the contour of the airfoil section. It is not unreasonable, therefore, to assume that, with a group of well plotted airfoil sections of 17% maximum relative thickness, we can obtain a polar envelope whose maximum C_y is above 160 and consequently preferable in this respect to 27A.

However that may be, the aerodynamic properties of the polar envelope of the new Lachassagne variable-camber airfoils appear susceptible of applications of practical importance to aviation.

Translated by
National Advisory Committee
for Aeronautics.

Fig. 1

E 429

E 430

E 431

E 432

E 438

a

a

Mean between upper
camber and chord
of all airfoils

Fig. 1

Fig. 2

o/c max.=2.67%

Angle of
attack
taken
relative
to this   0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1
line   E 429
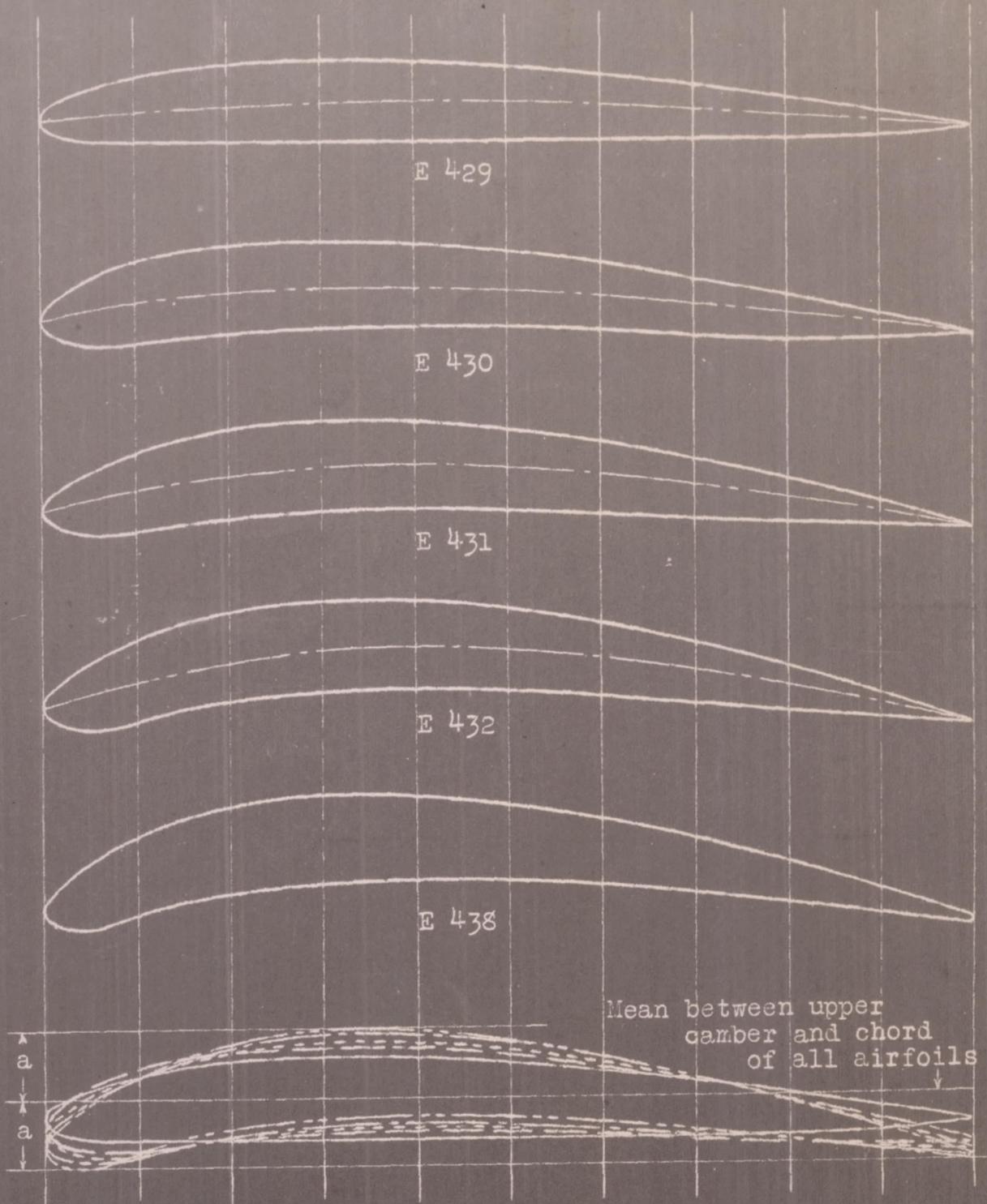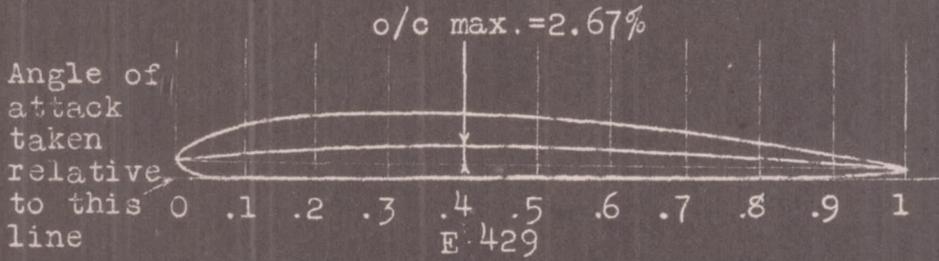
Angle of attack	-3°	0°	3°	6°	9°	12°	15°
100 C_y	-4.05	17.40	40.40	61.70	80.50	99.00	101.50
100 C_x	1.66	1.14	1.70	3.02	4.65	6.75	11.50
C_y/C_x		15.30	23.80	20.50	17.30	14.70	8.85
100 C_m		8.70	14.50	19.60	24.20	29.80	30.40

K_x=lb/ft^2-mi./hr.

.0000 .0001 .0002 .0003 .0004 .0005 .0006 .0007

K_x=kg/m^2-m/sec

Fig. 2

Fig. 4

o/c max.=5.9%

0   .1   .2   .3   .4   .5   .6   .7   .8   .9   1

E 431
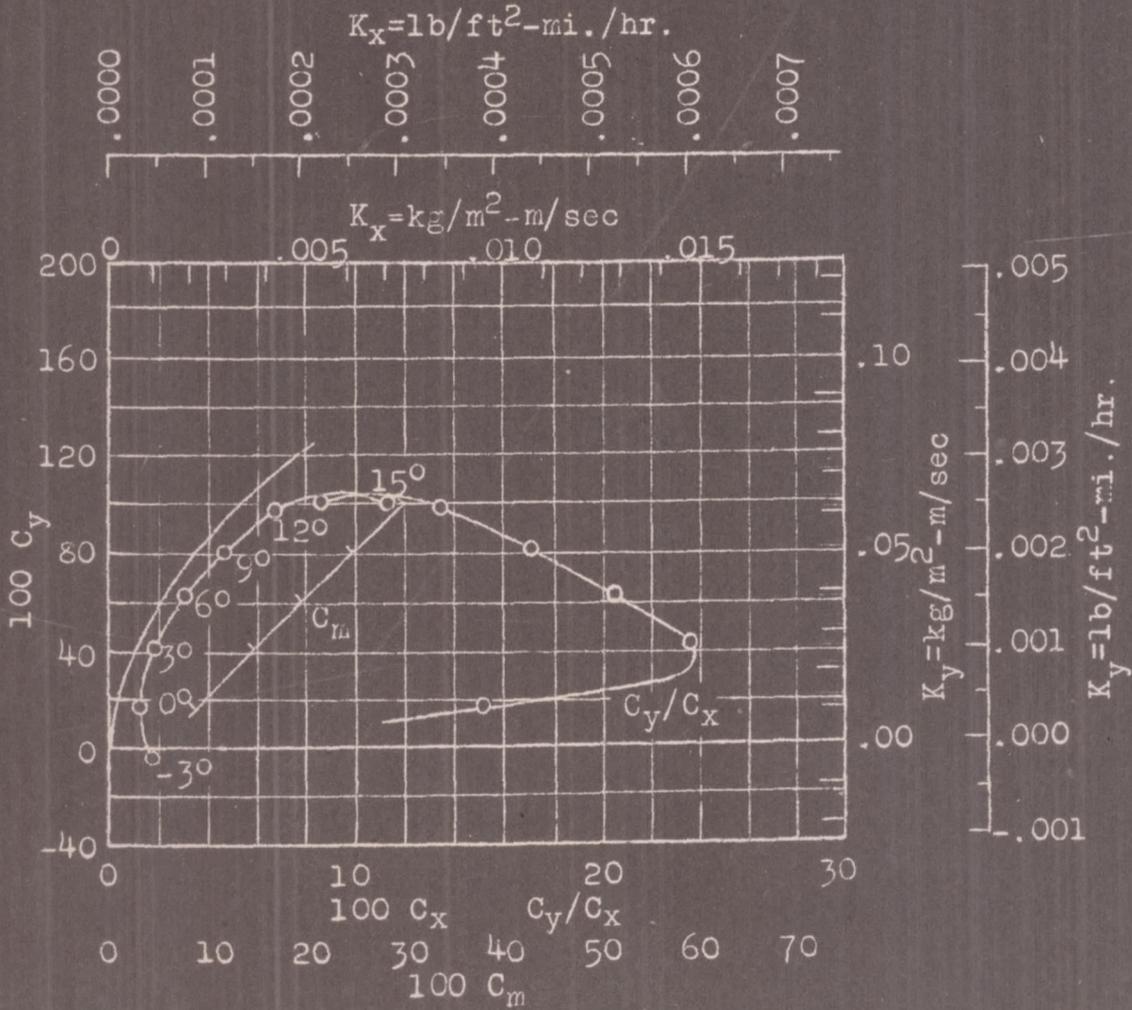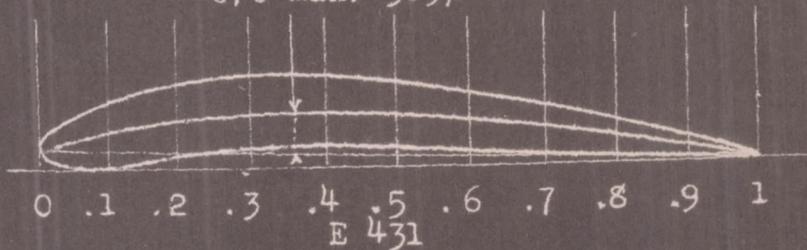
Angle of attack	-6°	-1.7 -3°	1.3 0°	4.3 3°	7.3 6°	10.3 9°	13.3 12°	16.3 15°
100 C_y	5.34	26.70	49.70	71.00	90.00	110.00	123.00	127.00
100 C_x	1.68	1.95	2.33	3.70	5.48	7.90	10.35	14.40
C_y/C_x	3.18	13.70	21.70	19.20	16.60	13.90	11.90	8.82
100 C_m			21.90	27.80	33.30	36.70	39.30	38.20

$K_x = lb/ft^2 - mi./hr.$

.0000   .0001   .0002   .0003   .0004   .0005   .0006   .0007

$K_x = kg/m^2 - m/sec$
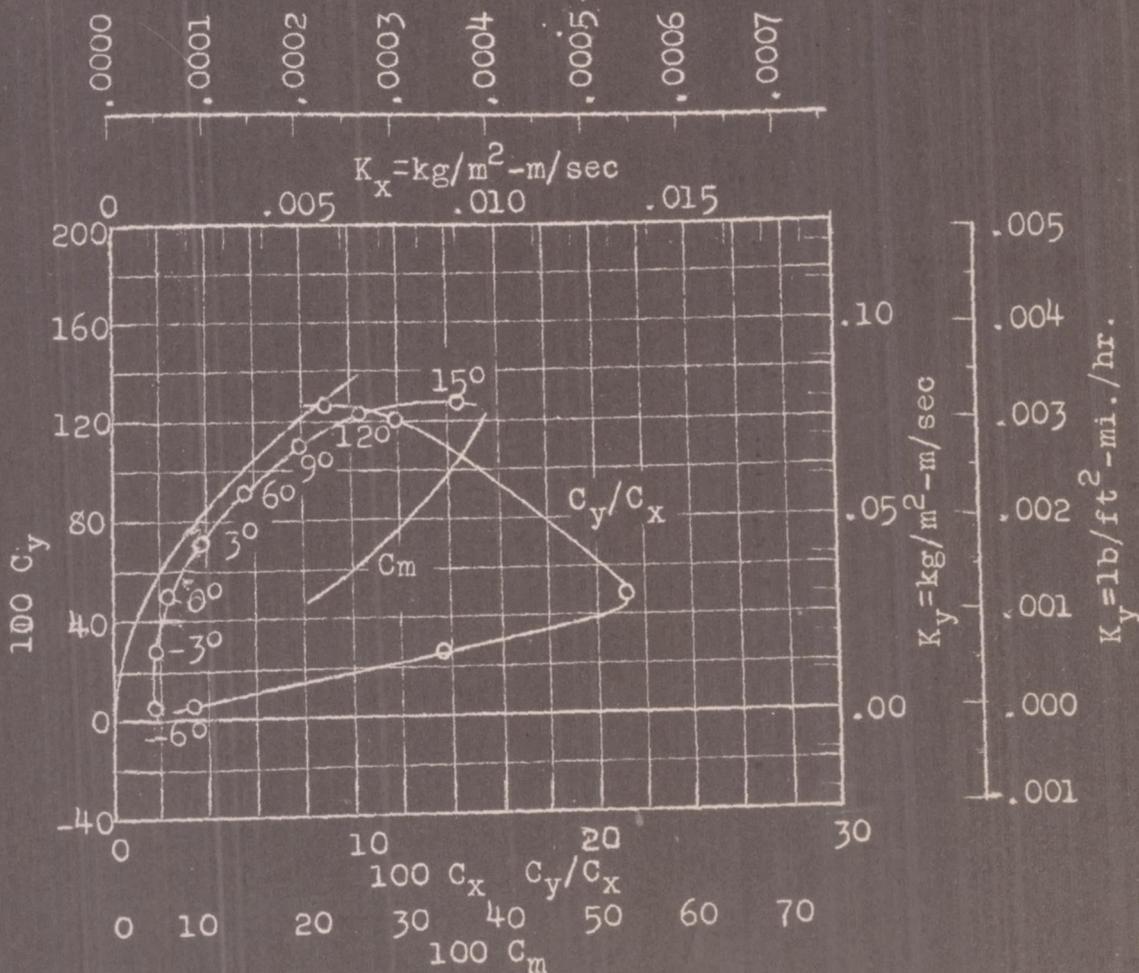
Fig. 4

Fig. 5

o/c max.=7.67%

0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1
E 432
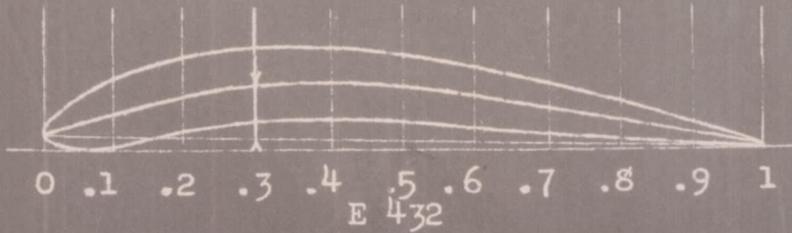
Angle of attack	-6°	-3°	0°	3°	6°	9°	12°	15°
	-1.8	1.2	4.2	7.2	10.2	13.2	16.2	
100 C_y	6.55	31.40	53.00	75.50	98.00	119.00	128.00	129.00
100 C_x	5.85	2.17	2.70	4.16	6.25	8.80	11.00	15.60
C_y/C_x	1.12	14.50	19.70	18.20	15.70	13.50	11.60	8.30
100 C_m		18.90	22.50	28.70	35.60	42.50	45.10	46.10

$K_x = lb/ft^2-mi./hr.$

.0000 .0001 .0002 .0003 .0004 .0005 .0006 .0007

$K_x = kg/m^2-m/sec$

Fig. 5

Fig. 6

o/c max.=9%

E 438

Wind velocity 28 m/sec (91.86 ft./sec.)
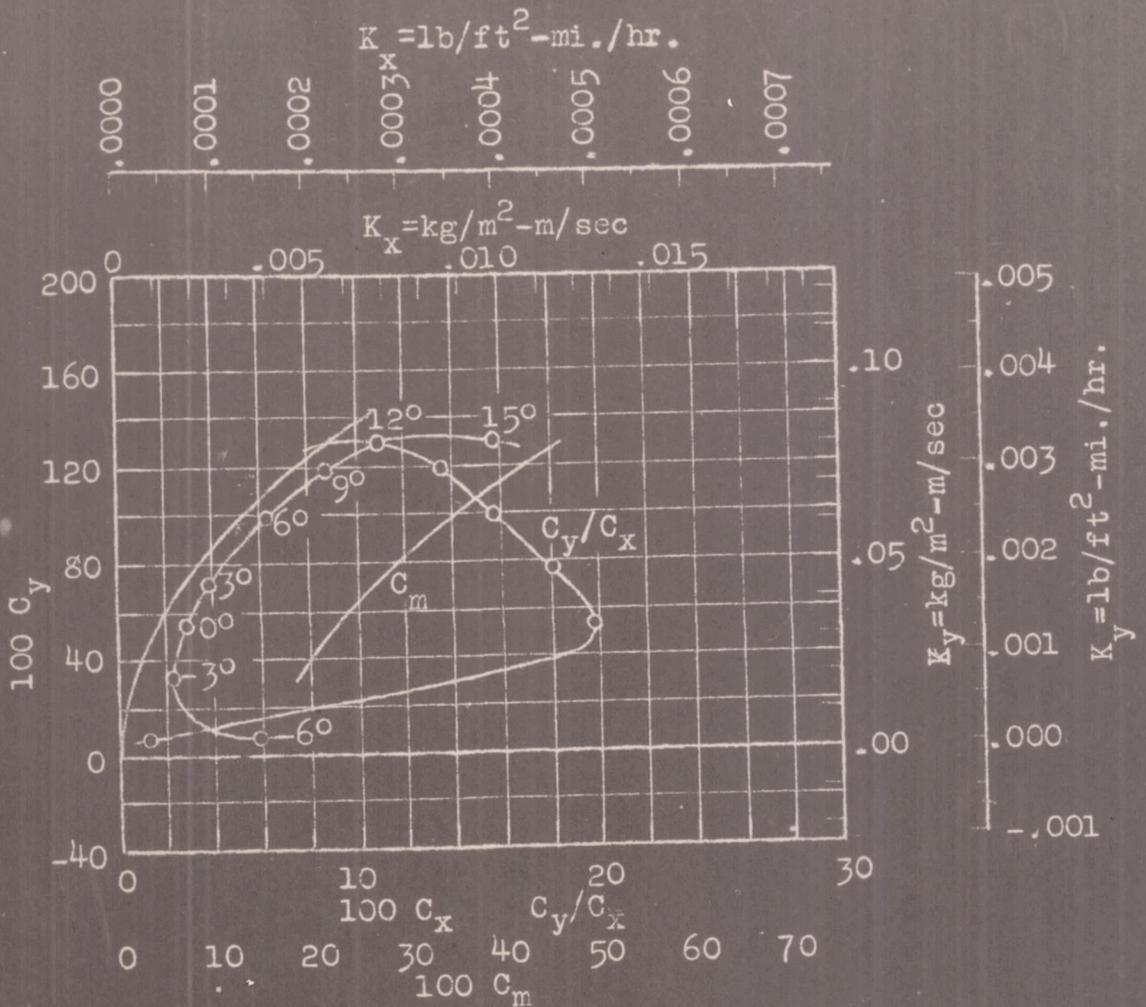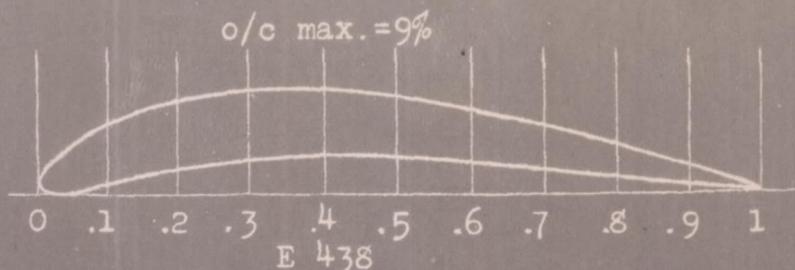
Angle of attack	-9°	-6°	-3°	0°	3°	6°	9°	12°	15°	18°
100 C_y	-4.25	8.6	31.2	60.0	83.0	107.0	126.0	148.0	158.0	154.0
100 C_x	9.90	7.30	5.42	3.75	4.95	7.05	9.75	13.80	17.80	22.90
C_y/C_x		1.18	5.75	16.0	16.8	15.2	12.95	10.70	8.85	6.72
100 C_m		8.60	18.7	27.6	32.4	40.5	47.20	55.50	60.00	59.20

100 C_y	-3.25	9.2	33.4	56.8	82.0	Wind velocity 15 m/sec
100 C_x	10.00	7.0	6.25	4.95	5.75	(49.2 ft./sec.)
C_y/C_x		1.31	5.40	11.6	14.4	
100 C_m						

K_x lb/ft^2-mi./hr.

.0000 .0001 .0002 .0003 .0004 .0005 .0006 .0007

K_x=kg/m^2-m/sec
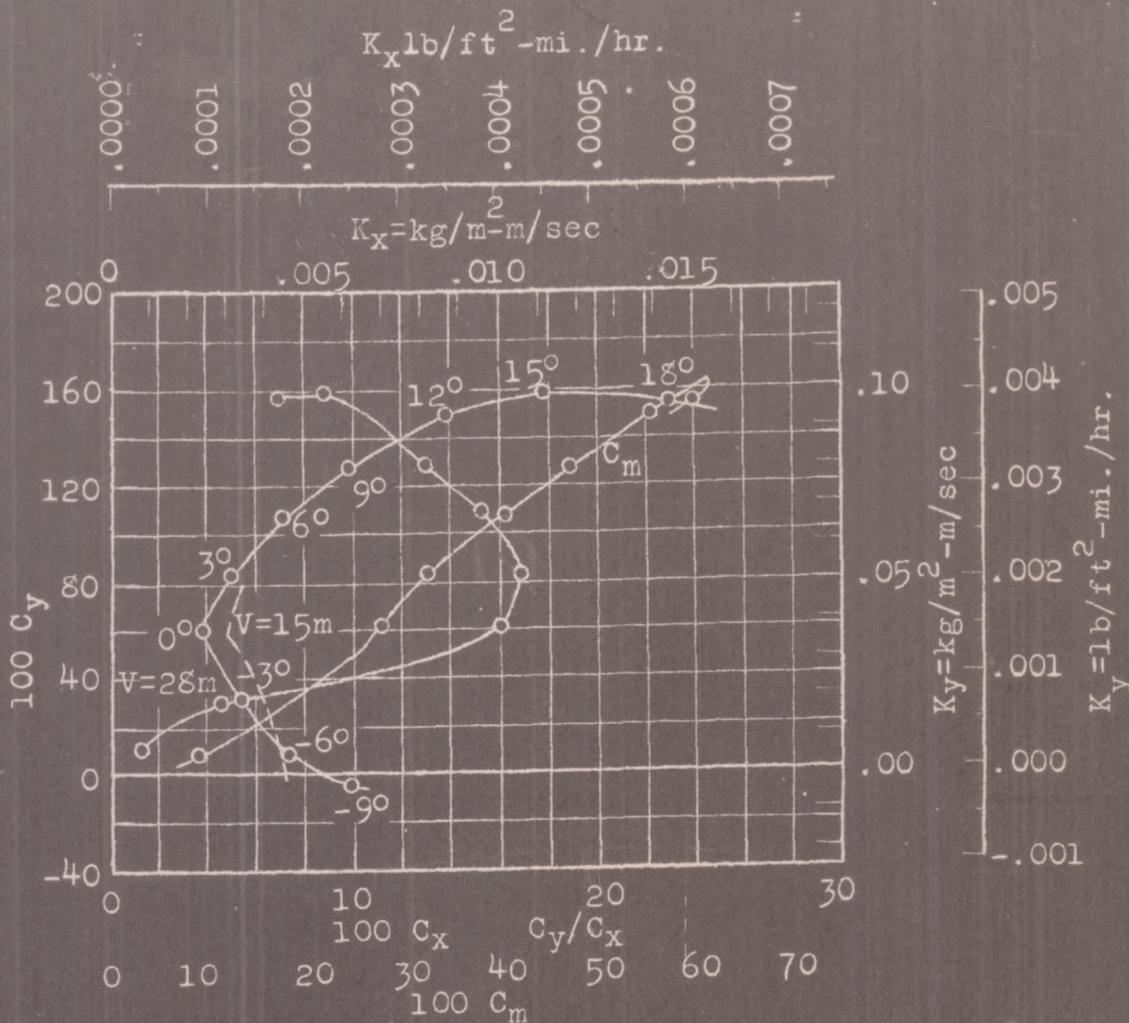
Fig. 6
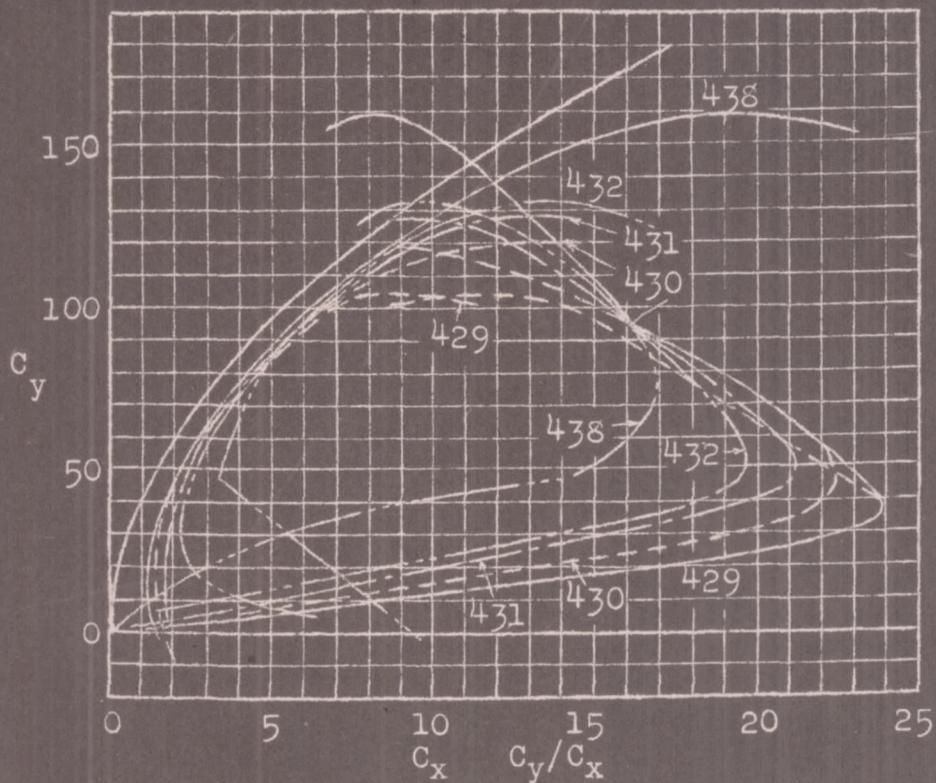
Fig. 7

Fig. 7 Lachassagne variable-camber airfoils.
Polars and fineness ratios of airfoils
E 429, 430, 431, 432 & 438 (deformable or
variable-camber.)

Fig. 8

Polar envelope (Lachassagne)
"   "   1A airfoil (Halbronn)
"   "   31A   "   (Dewoitine)
"   "   73A   "   (Gottingen 430)
"   "   27A   "   (Dewoitine)
"   "   20A   "   (Royer)
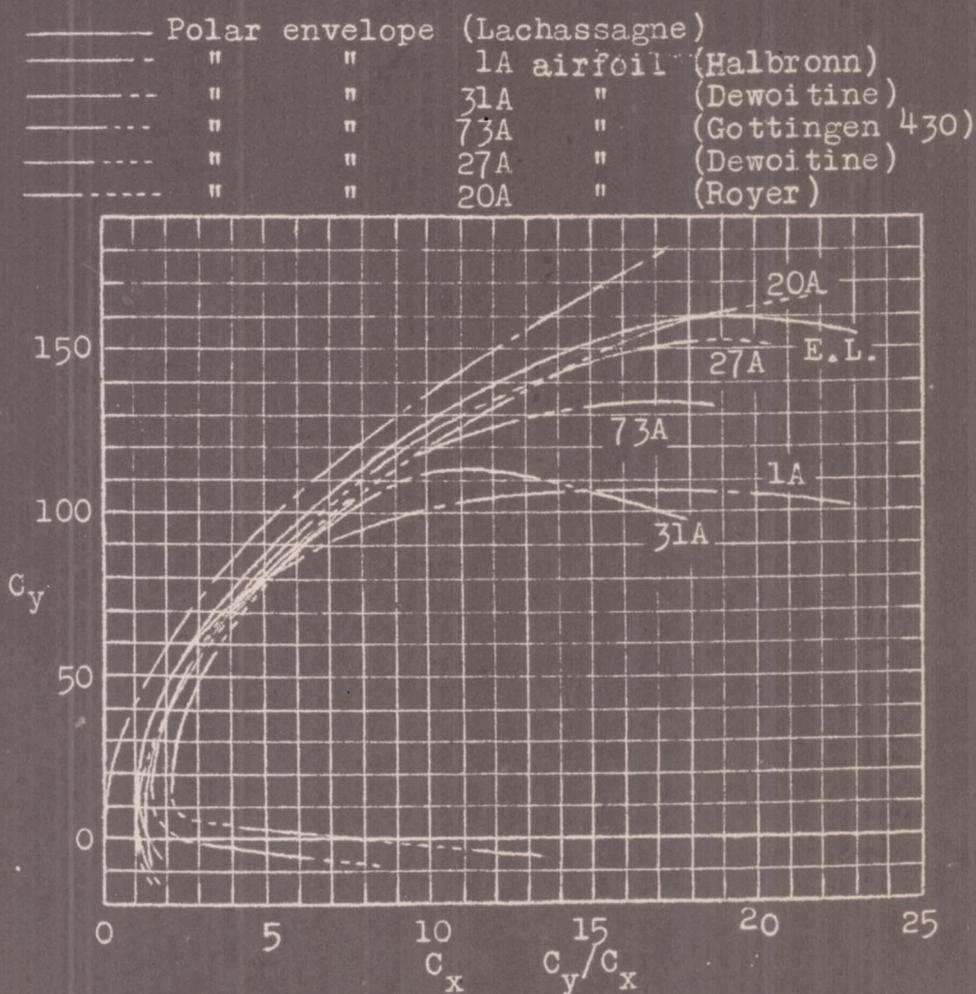
Fig. 8 Comparison of polar envelope of Lachassagne
airfoil with the polars of other airfoils.

Fig. 9

Lachassagne variable
camber airfoil. Max.
thickness 9.6%.Camber
variable,2.7 to 9%

Airfoil S.C.34 S.T.
Aé,1A (Halbronn)
m/c=8% o/c=3.33%

Airfoil S.C.95 S.T.
Aé,31A (Dewoitine)
m/c=9% o/c=2.80%

Airfoil S.C.56 S.T.
Aé,73A (Göttingen 430)
m/c=13.8% o/c=5%

Airfoil S.C.86 S.T.
Aé,27A (Dewoitine)
m/c=17% o/c=7.33%

Airfoil S.C.103 S.T.
Aé,20A (Royer)
m/c=17.5% o/c=8.85%
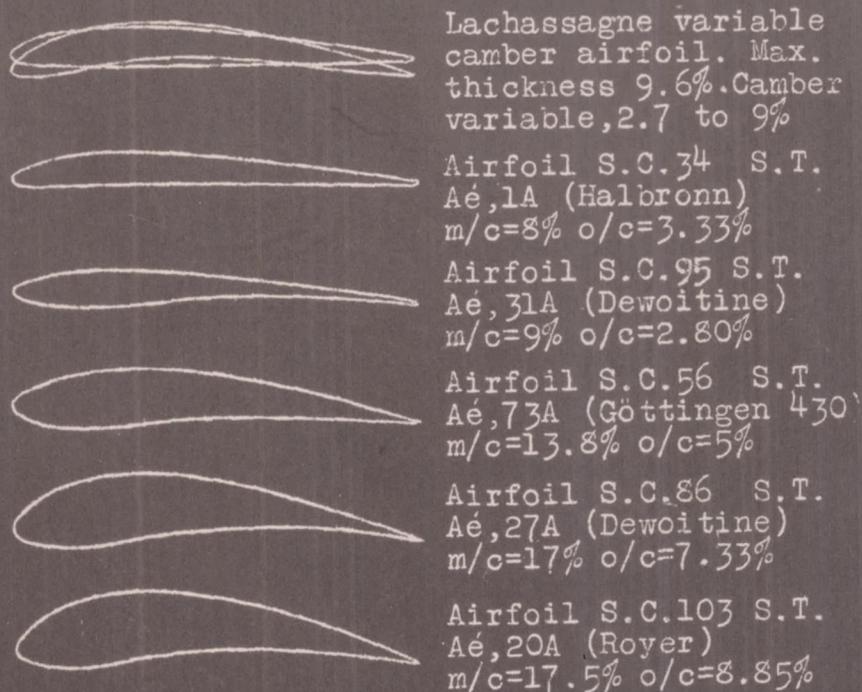
Fig. 9 Comparison of different airfoils with the
Lachassagne deformable (or variable-camber)
airfoil.