A new look for old airfoils

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1.—Introduction

After the work already done by Wortmann (ref. 1) and Eppler (ref. 2), very little was left untouched in the field of glider airfoil design, by means of theoretical aerodynamic analysis.

However a semi-empirical approach to the problem, may lead to airfoil families, that could be of interest to designers of aircraft operating at low Reynolds Numbers.

When the NACA 6 series were developed, the airfoils with a = 1 mean line were fully tested and only a few of a = 1 group were considered. The reasons for this were the need for higner critical Mach numbers and the property of the a = 1 mean line of merely shifting the thickness pressure distribution.

On the other hand, the 4 and 5 digit series NACA airfoils were designed with the same thickness distribution law, but the mean line was varied in a systematic way.

2.—The 44 mean line

The main parameters of several 4 and 5 digit airfoils are shown in table 1 and 2.

Two families, the X 4 in the four digit and X 30 in the 5 digit group having high maximum lift and acceptable drag values in the Low Reynolds Number zone (see fig. 1 and 2) were easily recognized to be suitable for glider applications.

Perfil	N.Reynold 10^4	$C_{L\,max}$	$C_{L\,ot}$	C_{Do}	C_{mac}
4212	855	1.71	.33	.0092	-.060
4312	840	1.63	.34	.0095	-.076
4412 *	900	1.68	.50	.0060	-.095
4512	854	1.69	.32	.0095	-.106
4612	847	1.76	.30	.0099	-.124
4712	834	1.82	.30	.0104	-.140
2412	824	1.72	.14	.0061	-.043
4412	792	1.74	.32	.0071	-.088
6412	815	1.67	.48	.0104	-.133
4412	792	1.72	.14	.0061	-.088
4415	792	1.72	.22	.0076	-.085
4418	818	1.57	.13	.0079	-.078

Table 1.—Comparison at same Reynolds Number of some NACA four digit airfoils

Perfil	N.Reynolds 10^{-4}	$C_{L\,max}$	$C_{L\,ot}$	C_{Do}	$C_{m\,ac}$
21012	837	1.63	.04	.0070	-.001
22012	832	1.72	.10	.0071	-.005
23012 *	837	1.74	.08	.0060	-.008
24012	826	1.71	.08	.0072	-.013
25012	824	1.67	.10	.0074	-.019
23012	837	1.74	.08	.0060	-.008
43012	839	1.84	.26	.0068	-.019
63012	829	1.84	.40	.0075	-.033
23012	837	1.74	.08	.0060	-.008
23015	837	1.73	.10	.0067	-.008
23018	816	1.58	.08	.0074	-.006

Table 2.—Comparison at same Reynolds Number of some NACA five digit airfoils

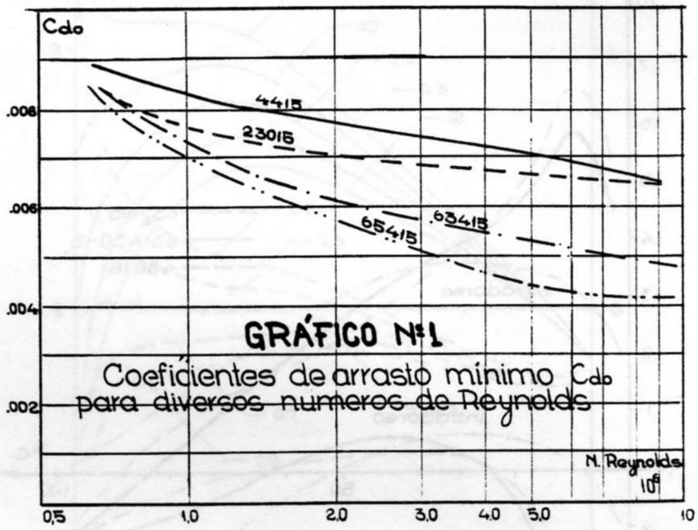


Fig. 1.—Reynolds Number effects over minimum drag coefficients

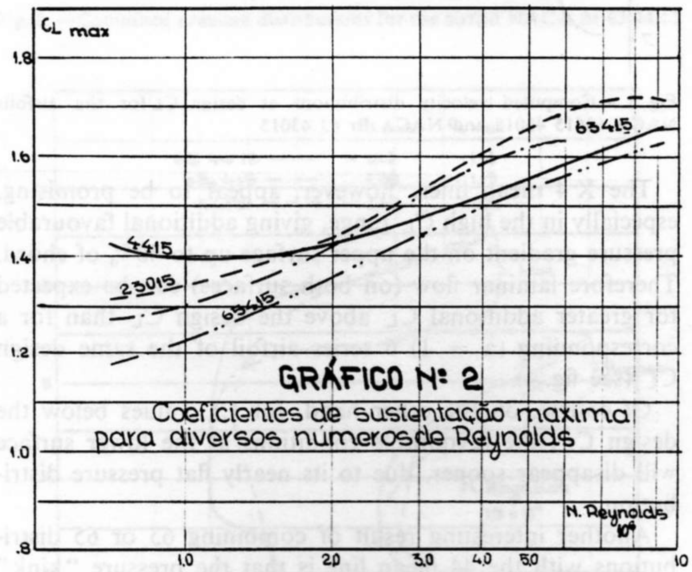


Fig. 2.—Reynolds Number effects over maximum lift coefficients

So before the RJ-5 era, the 44 airfoils were dominant in the class of high performance sailplanes and even today the 230 airfoil is successfully used by Schweizer in U. S.

Göttingen airfoils were also widely used, however, having a different thickness distribution, they are not considered here.

Undoubtedly the good low Reynolds Number performance of these airfoils results from a "lucky" combination of thickness, mean line and the resultant pressure distribution. Howewer to a considerable extent, these characteristics are due to the mean line alone (i. e., moment coefficient). Therefore a question arises: Why not give these mean lines a "new look" with thickness distributions of laminar airfoils?

A preliminary computation of pressure distribution was made for several combinations of X 30 and X 4 mean lines with 63, 64, 65 and 747 NACA thickness distributions (see fig. 3 and 4). Although the X 30 mean lines are very attractive because of their small center of pressure travel ($C_m \sim 0$) the pressure peak near the leading edge will permit laminar flow only for very small or negative C_L values (see fig. 3).

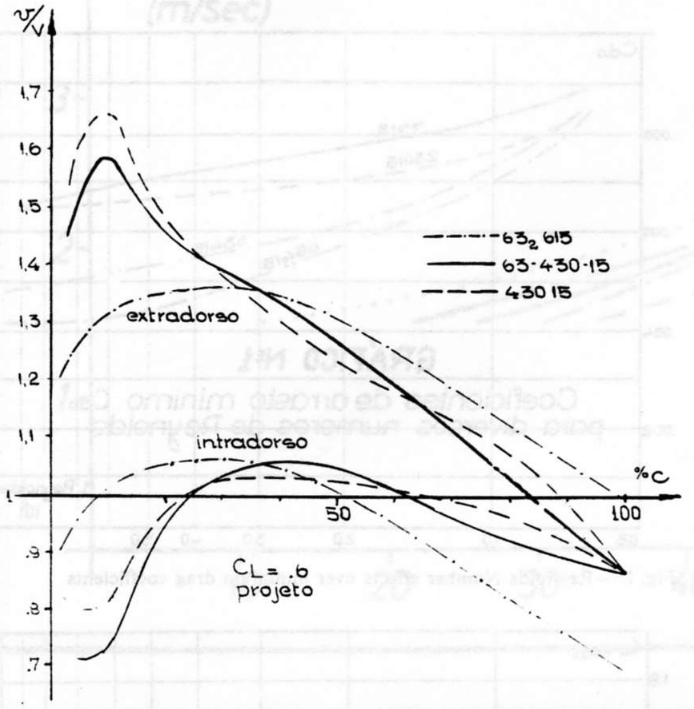


Fig. 3.—Computed velocity distributions at design C_L for the airfoils NACA 63615 43015 and NACA Br 63 43015

The X 4 mean lines, however, appear to be promising, especially in the high C_L range, giving additional favourable pressure gradient on the upper surface up to 40% of chord. Therefore laminar flow (on both surfaces) can be expected for greater additional C_L above the design C_L than for a corresponding ($a = 1$) 6 series airfoil of the same design C_L (see fig. 4).

Of course, on the other hand, for C_L values below the design C_L, the favourable conditions at the lower surface will disappear sooner, due to its nearly flat pressure distribution.

Another interesting result of combining 63 or 65 distributions with the 44 mean line is that the pressure "kink" in the upper surface is smoothed out (see fig. 4).

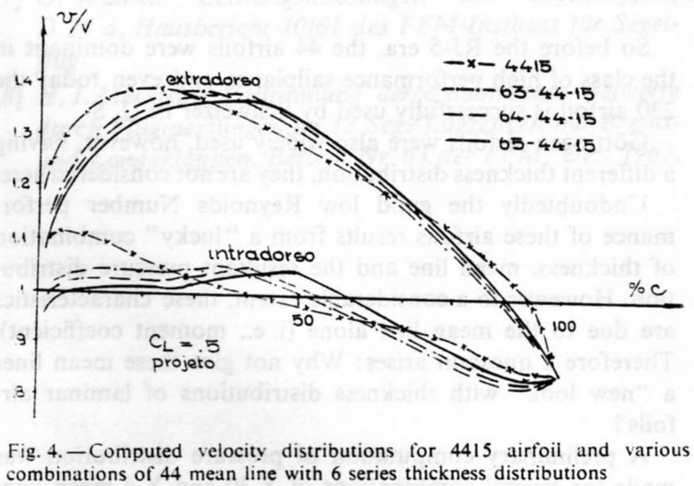


Fig. 4.—Computed velocity distributions for 4415 airfoil and various combinations of 44 mean line with 6 series thickness distributions

3.—The "new" family characteristics

From the above considerations we can expect the following characteristics for the "new" family.

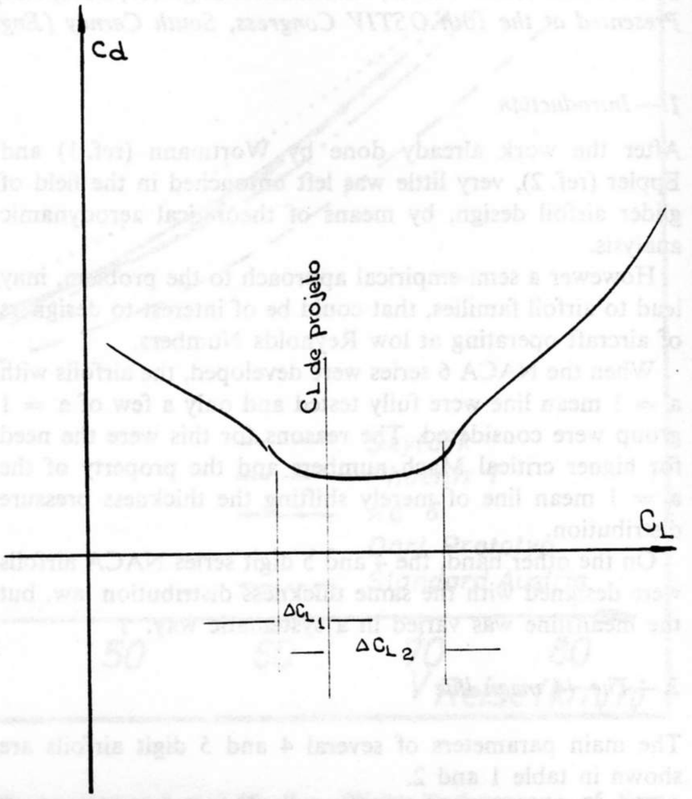


Fig. 5.—Typical polar of a "new" family airfoil

3.1.—A laminar low drag bucket, which is asymmetrically placed with respect to the design C_L, the displacement being towards higher lift coefficients proportional to the camber (X digit) (see fig. 5).

3.2.—The maximum lift coefficients will be probably higher than those of corresponding 6 family airfoils, and slightly inferior to those of the X 422 airfoil of the same thickness.

3.3.—A moment coefficient practically unchanged with respect to the original four digit airfoil.

This last property is very important, because it will permit to modernize many of the good but obsolete gliders utilizing 44 wing section such as the Brazilian BN-1, without great

NACA Br 65-44-15				NACA Br 63-44-12			
Extradorso		Intradorso		Extradorso		Intradorso	
X_u	y_u	X_L	y_L	X_u	y_u	X_L	y_L
0	——	R = 1,505	tgα .1975	0	——	R = 1.087	tgα .1975
.926	1.917	1.574	−1.425	0.961	1.737	1.539	−1.245
2.072	2.768	2.928	−1.800	2.113	2.550	2.887	−1.582
4.440	4.133	5.560	−2.259	4.495	3.818	5.505	−1.944
6.865	5.267	8.135	−2.549	6.932	4.855	8.068	−2.137
9.324	6.255	10.676	−2.755	9.401	5.744	10.599	−2.244
14.317	7.898	15.683	−3.024	14.404	7.199	15.596	−2.325
19.380	9.192	20.620	−3.192	19.468	8.315	20.532	−2.315
24.495	10.182	25.505	−3.308	24.573	9.133	25.427	−2.259
29.642	10.893	30.358	−3.393	29.703	9.673	30.297	−2.173
40.000	11.489	40.000	−3.498	40.000	9.920	40.000	−1.920
50.158	11.055	49.842	−3.277	50.119	9.258	49.881	−1.480
60.272	9.668	59.728	−2.556	60.197	7.972	59.803	−0.860
70.306	7.590	69.694	−1.590	70.214	6.203	69.786	−0.203
80.253	5.061	79.747	−0.617	80.169	4.117	79.831	+0.327
90.126	2.359	89.874	+0.097	90.078	1.925	89.922	+0.519
90.052	1.064	94.948	+0.214	95.003	0.887	94.997	+0.391
100.000	0	100.000	0	100.000	0	100.000	0

Table 3.—Coordinates of 65 44 15 and 63 44 12 airfoils

structural investigation. Wing torsion and equilibrium tail loads will remain practically unchanged with the introduction of the new airfoil whose thickness may be suitably chosen to fit the previous spar heights.

The writer expects to prove experimentally the above-mentioned characteristics in the nearly finished CTA low turbulence tunnel, but also believes that this could be done easier and sooner elsewhere.

He also proposes the following nomenclature for the new family:

NACA-Br-6Y-X4-ZZ

where XY and Z are digit numbers indicating

Y—position of maximum thickness in tenths of the chord
X—maximum ordinate of mean line in % of the chord
Z—airfoil thickness in % of the chord

4.—Example

In table 3 and figures 6 to 10 are presented the contour ordinates, computed pressure distribution and expected low

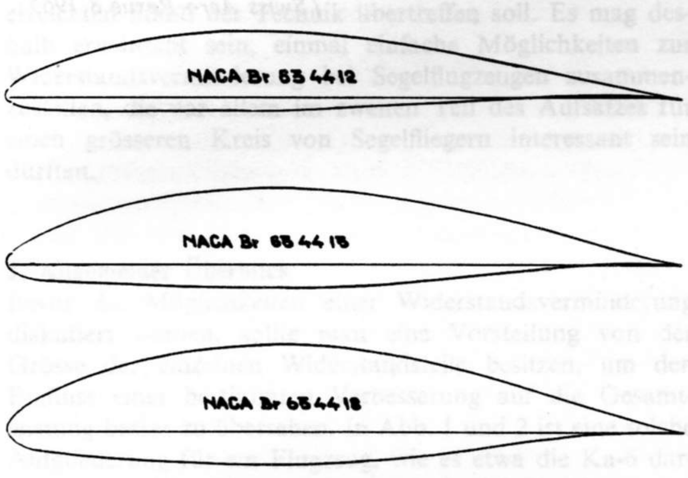


Fig. 6.—Some airfoil contours of the "new" family.

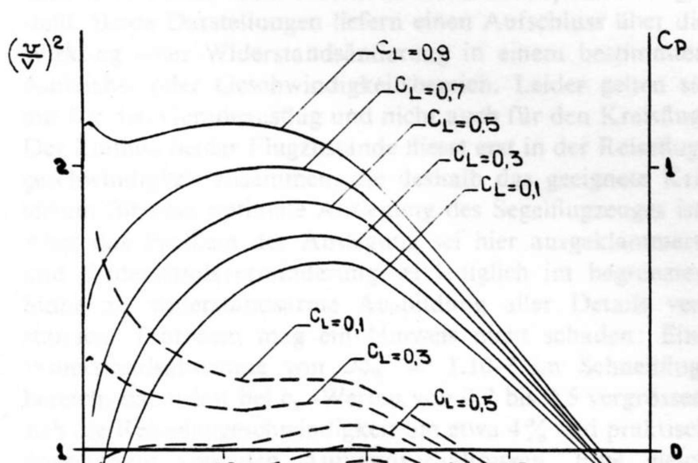


Fig. 7.—Computed pressure distributions for the airfoil NACA Br 65 44 15.

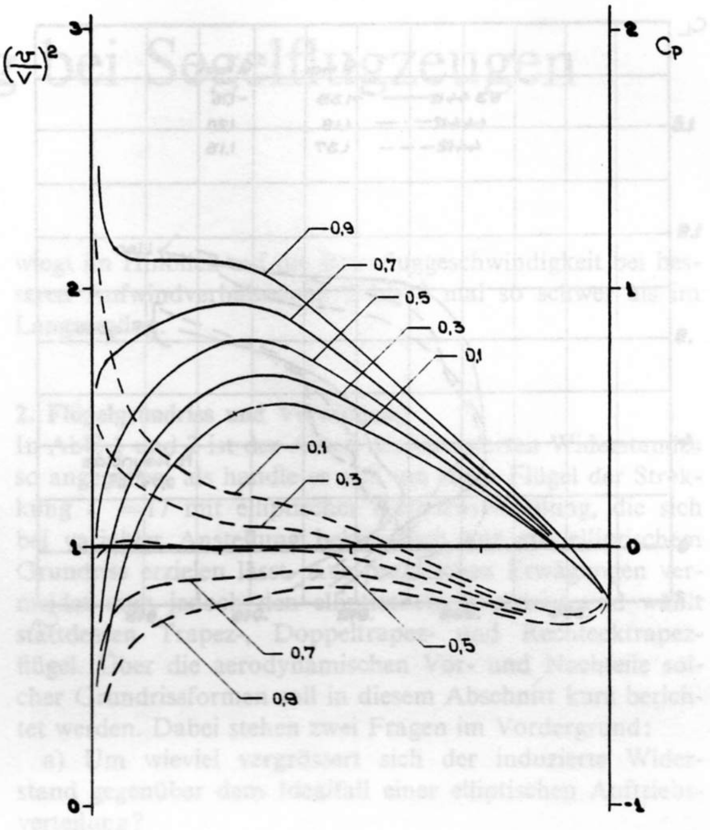


Fig. 8.—Computed pressure distributions for the airfoil NACA Br 63 44 12

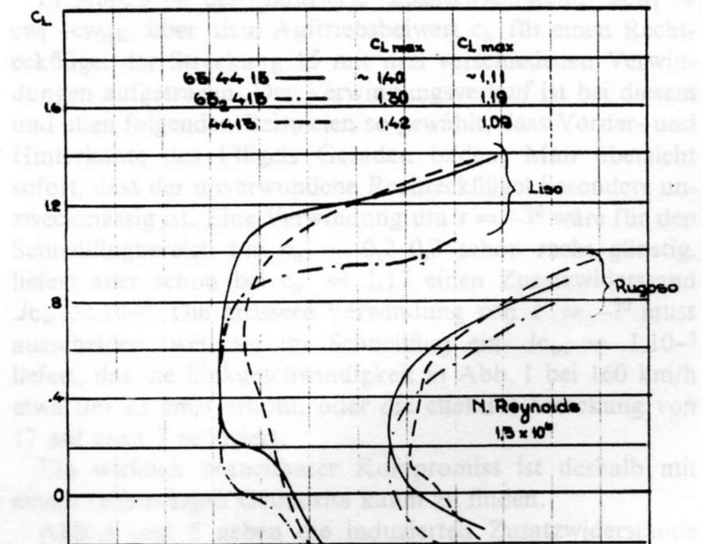
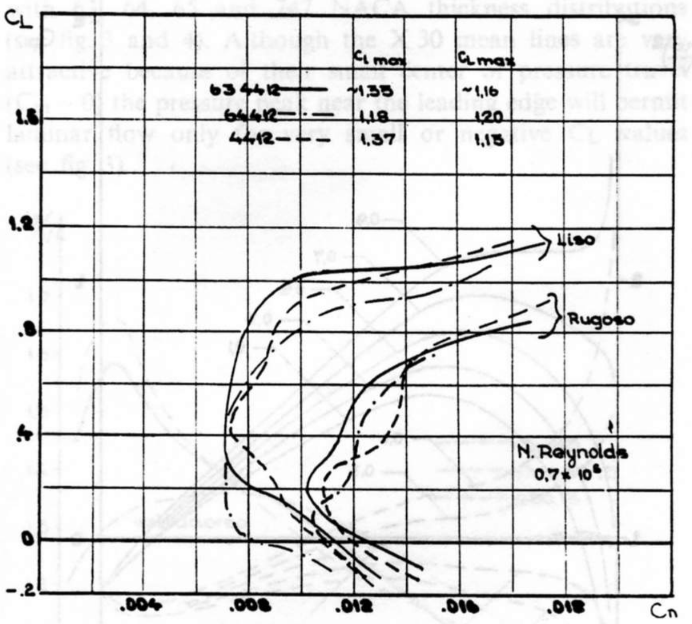


Fig. 9.—Probable characteristics of the airfoil 65 44 15 for a Reynolds Number of $1,5 \times 10^6$.

Reynolds characteristics for two sample airfoils; the NACA Br 65 44 15 and 63 44 12.

The writer believes that these two airfoils are suitable for root and tip sections of low sink, all purpose and training gliders operating in "British-like" weather.

For "hot penetrators" and "Texas-like" weather a less cambered 34 or 24 mean line should be used. Also a 18% thickness may be used to improve the C_L range of laminar flow and it will be more suitable for sailplanes with higher wing loadings.



5.—*References*

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Fig. 10.—Probable characteristics of the airfoil 63 44 12 for a Reynolds Number of $0,7 \times 10^6$.

(Swiss Aero-Revue 8/1965)