THE DU 86-084/18

Flug- und Modelltechnik announced a new airfoil for *conventional tailed sailplanes* in its February, 1990, issue - the DU 86-084/18. While one might wonder how this airfoil works at all, work it does, and very well. Our first look at this new section triggered our memory banks into action, and we soon had a compact "family tree" assembled which outlined the underlying philosophy and aerodynamics of its design.

EPPLER 662

The first in this tree, the Eppler 662, was included in a 1979 paper presented by Dr. Richard Eppler in which he discussed several new airfoils designed by means of his computer program. The E 662 was specifically designed for full sized sailplanes with full span flaps capable of both positive and negative deflections. Full span flaps normally pose a challenge for the aerodynamicist; Dr. Eppler designed an airfoil which could take full advantage of this configuration.

The flap, of about 20% chord, is capable of movement within a minimum -7.5^{o} (up) to $+10.0^{o}$ (down) range. To understand why this section works so well, it's important to remember this point: when the flap is down the Reynolds number is rather low; when the flap is up the Reynolds number is very high. Dr. Eppler was able to utilize the hinge line to advantage during flap deflections.

With the flap positively deflected (down) the suction peak at the hinge line promotes a transition ramp which greatly improves the airflow over the aft part of the upper surface; during negative flap deflections the hinge line stabilizes the lower surface laminar boundary layer.

The theoretical polars for the E 662 appear to be excellent, but we don't know if the E 662 has ever been used on a full sized sailplane.

HQ 35/12.29

The second airfoil in the tree, the HQ 35/12.29, was found in a 1985 paper by J.L. van Ingen and L.M.M. Boermans, both of Delft University of Technology in The Netherlands. The latter part of their paper contained the results of tests run on low Reynolds number airfoils, one of which was this section by K.H. Horstmann and A. Quast (not Helmut Quabeck, as the HQ prefix would seem to indicate). This airfoil was also designed for full sized sailplanes with full span flaps, but it has less drag than the E 662.

The HQ 35/12.29 is 12.29% thick, with a flap chord of just 13.5%. The deflection range for the flap is, at a minimum, from -4^{o} to $+28^{o}$ and is to be used full span. Of interest here is the significant drag reduction achieved at all flap deflection angles with the attachment of "zig-zag" turbulators at 69% chord on the upper surface, and at 83% chord on the lower.

The concave corner present at the flap hinge leads to local separation of the turbulent boundary layer as expected, but filling and rounding the corner results in no further drag reduction than is achieved with the turbulators alone.

DU 86-084/18

It is fairly obvious the primary subject of this article, the DU 86-084/18, is a direct descendant of the above sections, but particularly the HQ 35/12.29. The DU 86-084/18 is 8.4% thick and was specifically designed for F3B and F3E aircraft with full span flaps. (F3B and F3E in this case signify the general FAI type designations, not the multi-round competitions.)

The flap is of 18% chord and has a deflection range of at least -5^{o} to $+15^{o}$. Much consideration went into the boundary layer changes taking place at various Reynolds numbers and flap deflections.

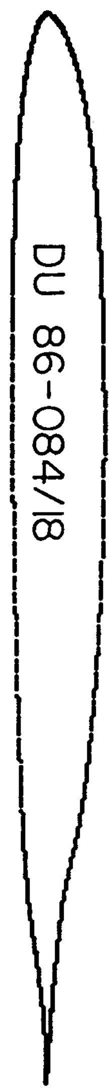
"Zig-zag" turbulators are used, just as on the HQ section; they are placed at 67% chord on the upper surface and 78% on the lower. This artificial turbulation produces a significant drag reduction.

The DU 86-084/18 was used on an F3B type aircraft which broke the previous world speed record by 20%, achieving an average 250.4 km/h (155.6 mph) - that's how well it works. (FAI rules for speed records have been changed. Lap distance has been increased, and this results in lower average speeds than previously recorded.)

As the Reynolds numbers of our models rise, we will no doubt see our airfoils become more closely allied with those of full size soaring. The DU 86-084/18 clearly shows this direction.

DU 86-084/18

100	0	.00336	-.04726
99.88200	.01447	.15717	-.31004
99.53665	.0583	.52525	-.57736
98.99013	.11925	1.08302	-.85296
98.23506	.17817	1.83287	-1.11716
97.25984	.24032	2.76332	-1.37678
96.06422	.31488	3.87149	-1.62443
94.65337	.40844	5.15408	-1.85711
93.03528	.52965	6.60709	-2.07293
91.2222	.6837	8.22607	-2.27012
89.22955	.8769	10.00638	-2.44734
87.06801	1.09809	11.94246	-2.60385
84.72141	1.34217	14.02826	-2.73971
82.17831	1.67666	16.2565	-2.85504
79.56653	2.20332	18.61926	-2.94976
77.03317	2.79601	21.10864	-3.02423
74.53438	3.26522	23.71603	-3.0796
71.9594	3.62654	26.43152	-3.11721
69.28009	3.92896	29.24452	-3.13827
66.51482	4.17247	32.14399	-3.14417
63.67622	4.42331	35.11781	-3.13606
60.77684	4.62555	38.15422	-3.11475
57.82917	4.80102	41.24124	-3.08161
54.84557	4.95081	44.36585	-3.03845
51.83809	5.07531	47.51444	-2.9864
48.81872	5.17501	50.67352	-2.92648
45.79983	5.25045	53.8289	-2.85963
42.79392	5.30151	56.96652	-2.78628
39.81293	5.32781	60.07223	-2.70638
36.86865	5.32933	63.13174	-2.62052
33.97267	5.30581	66.13135	-2.5263
31.13605	5.25702	69.05754	-2.4225
28.36955	5.18325	71.89732	-2.30875
25.68385	5.08479	74.63852	-2.18080
23.08928	4.96201	77.26988	-2.03913
20.59593	4.81538	79.78017	-1.87273
18.2135	4.64516	82.15536	-1.67216
15.95123	4.45172	84.4124	-1.41497
13.81801	4.23513	86.5874	-1.10373
11.82156	3.99464	88.68765	-.7996
9.96773	3.72991	90.68719	-.53887
8.26129	3.44198	92.55052	-.33242
6.7067	3.13251	94.24745	-.17859
5.30788	2.80381	95.75055	-.08113
4.0688	2.45893	97.0405	-.02878
2.9929	2.09987	98.10382	-.0029
1.33511	1.35292	98.93387	.00425
.75531	.97171	99.528	.0034
.33386	.59511	99.87941	.00059
.07521	.25174	100	0



SUPPLEMENTARY INFORMATION TO "ON THE 'WING..." #24

Eppler 662

NASA Conference Publication 2085
Science and Technology of Low Speed and Motorless Flight, Part I
Proceedings of a symposium held at NASA Langley Research Center, Hampton VA, and sponsored by NASA Langley and the Soaring Society of America
March 29-30, 1979
Perry W. Hanson, Editor
National Technical Information Service #N79-23889-23903
5285 Port Royal Road
Springfield VA 22161

N79-23896 Some New Airfoils, by Dr. Richard Eppler, University of Stuttgart, Stuttgart, West Germany

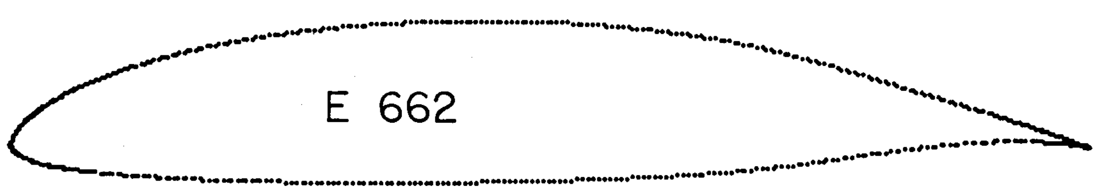
Also in this publication are articles concerning optimum tailplane design for sailplanes, the effects of disturbances on a wing (by Eppler), length and bursting of separation bubbles, and simple total energy sensors.

"Sailplanes with normally hinged flaps are a standard application of airfoils. The difficulties with this application come from two requirements. First, the flap-down case usually corresponds to a Reynolds number of 10^6 or below. For this case, laminar separation bubbles can be dangerous. This danger is increased by the steep adverse pressure gradient immediately downstream of the suction peak at the flap hinge. Second, the negative-flap-deflection (up) case corresponds to $R > 3 \times 10^6$. For this case, transition can occur earlier than desired. For a zero pressure gradient at these Reynolds numbers, the boundary layer is not stable enough to remain laminar for 60% to 70% of the surface and, therefore, a certain favorable pressure gradient is necessary to keep the boundary layer laminar.

"Airfoil 662 was designed for this application... The pressure recovery on the upper surface for the undeflected-flap case must be less than would be possible for the case where no flap deflections were intended. A flap deflection in either direction increases the amount of adverse pressure gradient. Severe separation would occur in these cases if the pressure recovery for the undeflected case were already approaching the separation limit. The flap deflection can, however, be exploited in a favorable sense as well. For the flap-down case, a distinct transition ramp forms between the original pressure recovery and the suction peak caused by the flap. On the lower surface, an additional favorable pressure gradient occurs with the flap up which stabilizes the laminar boundary layer at the higher Reynolds numbers. Attention to all of these details together with the careful designing of the leading-edge suction region results in the good performance... Notice that, at low C_l and low Rn, a lower-surface separation was again permitted."

EPPLER 662

100.000	0.000	.003	-.074
99.642	.118	.351	-.733
98.640	.483	1.336	-1.289
97.117	1.056	2.879	-1.875
95.113	1.745	4.966	-2.210
92.609	2.516	7.571	-2.567
89.626	3.395	10.668	-2.858
86.231	4.390	14.221	-3.088
82.500	5.493	18.189	-3.264
78.528	6.682	22.522	-3.392
74.435	7.890	27.165	-3.474
70.276	8.968	32.061	-3.512
65.983	9.824	37.148	-3.506
61.519	10.489	42.363	-3.456
56.922	10.988	47.642	-3.357
52.232	11.331	52.919	-3.206
47.501	11.525	58.130	-2.993
42.776	11.570	63.214	-2.702
38.108	11.470	68.116	-2.302
33.541	11.225	72.841	-1.742
29.121	10.841	77.449	-1.061
24.891	10.324	81.940	-.382
20.891	9.681	86.229	.169
17.159	8.923	90.177	.509
13.729	8.062	93.628	.611
10.631	7.113	96.423	.500
7.892	6.094	98.431	.276
5.535	5.024	99.613	.077
3.578	3.926	100.000	-.000
2.037	2.828		
.921	1.761		
.239	.770		



HQ35/12.29

Proceedings of the Conference on Low Reynolds Number Airfoil Aerodynamics
Sponsored by NASA Langley Research Center, Hampton VA, the U.S. Navy Office of Naval Resarch, and the University of Notre Dame, Department of Aerospace and Mechanical Engineering
June, 1985
Thomas J. Mueller, Ph.D., Editor; Department of Aerospace and Mechanical Engineering; University of Notre Dame; Notre Dame IN 46556.

Research on Laminar Separation Bubbles at Delft University of Technology in Relation to Low Reynolds Number Aerodynamics, by J.L. van Ingens and L.M.M. Boermans, Department of Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands

Also included in this publication are articles concerning low Reynolds number airfoil design (one by Eppler, another by Selig), effects of aspect ratio on the hysteresis loop, the effect of trip wires on air flow, and several articles on laminar separation bubbles.

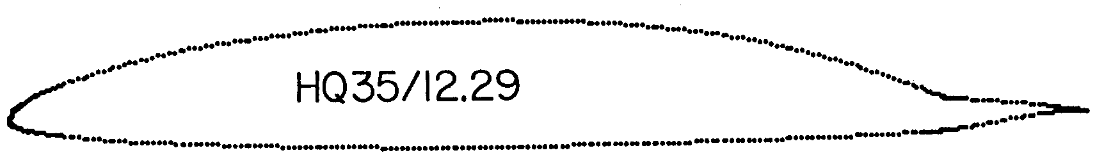
"Another airfoil for sailplane application, HQ35/12.29, designed by K.H. Horstmann and A. Quast of DFVLR Braunschweig (West-Germany)... This 12.29% c thick airfoil has a camber changing flap of 13.5% chord length. In actual practice this flap extends along the whole span of the sailplane wing. Very long laminar flow regions are present on both the upper and lower surface as shown in the measured pressure distributions. Due to the stability of the laminar boundary layer and the pressure rise on the rear of the airfoil, laminar separation bubbles are present again. ...drag decrease obtained with zig-zag tape, mentioned before, at 69% c on the upper surface and 83% c on the lower surface...

"The concave corner in the upper and/or lower surface contour at the flap hinge leads to local separation of the turbulent boundary layer. Systematically filling and rounding of this corner did not result in a drag reduction. More research is needed to exploit this phenomenon."

HQ35/12.29

100	0
97.5	.23
95	.69
90	1.04
86.5	1.27
86.5	1.27
85	1.85
80	3.7
75	5.32
70	6.47
65	7.52
60	8.09
55	8.55
50	8.79
45	8.9
40	8.79
35	8.67
30	8.32
25	7.75
20	7.17
15	6.36
10	5.09
5	3.58
2.5	2.54
1	1.5
.5	1.16
.25	.92
0	0

.25	-.35
.5	-.46
1	-.69
2.5	-1.04
5	-1.39
10	-1.97
15	-2.2
20	-2.43
25	-2.62
30	-2.77
35	-2.83
40	-2.89
45	-2.89
50	-2.83
55	-2.77
60	-2.66
65	-2.55
70	-2.43
75	-2.31
80	-2.08
85	-1.85
86.5	-1.73
- flap hinge line -	
86.5	-1.73
90	-1.16
95	-.23
97.5	0
100	0



"Zig-Zag" Turbulator

A "zig-zag" turbulator for use on the DU 86-084/18, or for experimentation, is available from Glasfaser-Flugzeugbau, Hafner Weg, 7431 Grabenstetten, Germany. A length of 14 meters (nearly 46 ft.) costs 63,-DM (about US$42.00 at the current exchange rate).

A domestic source for zig-zag turbulators is Hobby Lobby International, Inc., 5614 Franklin Pike Circle, Brentwood TN 37027. The material from Hobby Lobby comes in two different styles and four different colors (white, black, red, or yellow). Each package contains 47" of 1/8" wide zig-zag strip, and 24" of 2" wide material which is zig-zag cut at one edge and straight on the other. The narrow "Z band" is as used on the DU 86-084/18 section, while the wider is described as being a combination turbulator and hinge gap cover. For $5.45 you can get both turbulators, as described above, in a single package.

Some reports indicate that a zig-zag turbulator is more efficient (better turbulation for less drag) than a "trip strip."