

REFLEXED AIRFOIL FORMULAE

New airfoils always seem so exciting! Most of us can barely contain the urge to get into the shop and build a whole airplane around a promising new section. What could be better than a method by which the modeler can create his own new airfoils? Well, for us "'wing nuts," how about a method of getting new airfoils for our tailless creations? To meet this challenge, we offer a small portion of an article written by Reinhard Werner. The entire article appeared in The White Sheet Radio Flying Club's "Flying Wings Special #3," Sean Walbank, Editor.

"Strictly speaking, it cannot be regarded as too profitable to use any home designed wing sections. If we really want to understand what's happening up there, as a matter of principle, we can't but use one of those wind tunnel tested airfoils, measure our model's performance parameters, and draw our conclusions from that. But unfortunately this would reduce our choice to just a handful of Eppler sections, and of course this seems to be quite a bit too restrictive. So just let's go on designing our own super sections, always remembering that two things seem desirable: low C_m and good lift/drag ratio. Personally I'm not wholly happy with this procedure, but I won't entirely deny that good results may come of it. One thing's for sure: we're bound for adventure this way!

"Just one example for such home bred sections: Alex Lippisch gave us a mean camber line with a slight reflex and the crossover point at 87.5% chord. This line was not stable and required quite a bit of sweep and/or twist. Now if we modify this camber line a little, it looks like this:

$$y = \frac{f}{94350} \cdot x \cdot (x - 100) \cdot (x - 75),$$

with x running from 0 to 100, f = % camber.

(We note the denominator, 94350, can be changed to 94500 with the resulting camber

line peaking at exactly the correct value. The 94350 value produces a camber line which is a bit too high. -B²)

"This line has its crossover point at 75% and should be dead stable. It looks interesting, too, with the crossover at 80%:

$$y = \frac{f}{105000} \cdot x \cdot (x - 100) \cdot (x - 80).$$

"Now just add a thickness distribution a la NACA, Quabeck, Kaczanowski or whatever, and you've got a weird looking section. And, well, there's still the Horten camber line:

$$y = \frac{f}{10546875} \cdot x \cdot (100 - x)^3.$$

"So just have a try out there - I'd be delighted to hear of the results!"

This whole concept sounded so intriguing to us that we wrote a computer program to figure out the three camber lines for us. Then we gathered up some thickness distributions we felt might be appropriate for use. The result is an on-screen display of any chosen thickness distribution superimposed over the reflexed meanline with the % camber of our choice. This program, written in Apple's Applesoft BASIC, can be easily modified for use with other graphics-capable computers.

WERNER REFLEXED SECTIONS

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100 D$ = CHR$ (4):TWO = 2: DIM X(30): DIM T(30): DIM
    YU(2,30): DIM YL(2,30): DIM Y75(30): DIM Y80(30): DIM
    H(30):X = 0:Y = 1: DIM C(60,1)
200 TEXT : HOME
300 PRINT "What is the designation of the airfoil that you
    wish computed? ";: INPUT A$
301 REM READ X-AXIS INCREMENTS
302 PRINT D$;"OPEN";A$;".XT"
303 PRINT D$;"READ";A$;".XT"
304 FOR I = 0 TO 30
305 INPUT X(I)
306 INPUT T(I)
307 IF X(I) = 100 AND T(I) = 0 THEN A = I:I = 30
308 NEXT I
310 PRINT D$;"CLOSE";A$;".XT"
320 PRINT : PRINT "And what % thickness? ";: INPUT PT$
330 PT = VAL (PT$)
331 P1 = PT / 10
332 IF PT < 10 THEN PT$ = "0" + PT$
333 PT$ = "-" + PT$
338 PRINT : PRINT "What % camber? ";: INPUT F
1350 REM 75%
1360 HGR : HCOLOR= 3
1400 FOR I = 0 TO A
1500 Y75(I) = F * X(I) * (X(I) - 100) * (X(I) - 75) / 94350
1525 NEXT I
1540 HPLOT X(0) * TWO,50 TO X(A) * TWO,50
1550 HPLOT X(0) * TWO,50 - Y75(0) * TWO
1600 FOR I = 1 TO A
1700 HPLOT TO X(I) * TWO,50 - Y75(I) * TWO
1800 NEXT I
1900 FOR I = 0 TO A
2000 YU(0,I) = (Y75(I) + T(I) * P1)
2050 HPLOT X(I) * TWO,50 - YU(0,I) * TWO
2100 YL(0,I) = (Y75(I) - T(I) * P1)
2150 HPLOT X(I) * TWO,50 - YL(0,I) * TWO
2200 NEXT I
2250 REM 80%
2300 FOR I = 0 TO A
2400 Y80(I) = F * X(I) * (X(I) - 100) * (X(I) - 80) / 105000
2425 NEXT I
2440 HPLOT X(0) * TWO,100 TO X(A) * TWO,100
2450 HPLOT X(0) * TWO,100 - Y80(0) * TWO
2500 FOR I = 1 TO A
2600 HPLOT TO X(I) * TWO,100 - Y80(I) * TWO
2700 NEXT I
2800 FOR I = 0 TO A
2900 YU(1,I) = (Y80(I) + T(I) * P1)
2950 HPLOT X(I) * TWO,100 - YU(1,I) * TWO
3000 YL(1,I) = (Y80(I) - T(I) * P1)

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3050 H PLOT X(I) * TWO,100 - YL(1,I) * TWO
3100 NEXT I
3101 REM HORTEN
3102 FOR I = 0 TO A
3103 H(I) = F * X(I) * ((100 - X(I)) ^ 3) / 10546875
3104 NEXT I
3105 H PLOT X(0) * TWO,150 TO X(A) * TWO,150
3106 H PLOT X(0) * TWO,150 - H(0) * TWO
3107 FOR I = 1 TO A
3108 H PLOT TO X(I) * TWO,150 - H(I) * TWO
3109 NEXT I
3110 FOR I = 0 TO A
3111 YU(2,I) = (H(I) + T(I) * P1)
3112 H PLOT X(I) * TWO,150 - YU(2,I) * TWO
3113 YL(2,I) = (H(I) - T(I) * P1)
3114 H PLOT X(I) * TWO,150 - YL(2,I) * TWO
3115 NEXT I
3150 V TAB (21): PRINT A$; ", reflex at 75% - top
3160 PRINT A$; ", reflex at 80% - middle"
3165 PRINT A$; ", Horten line - bottom"
3170 PRINT "Any key to continue ";
3200 GET W$
5100 TEXT : HOME
5200 PRINT "Save coordinates to disc?"
5210 PRINT " 1. 75% only"
5220 PRINT " 2. 80% only"
5225 PRINT " 3. Horten only"
5230 PRINT " 4. 75% and 80%"
5231 PRINT " 5. 75% and Horten"
5232 PRINT " 6. 80% and Horten"
5233 PRINT " 7. All three"
5240 PRINT " 8. None"
5245 PRINT
5250 GET W: PRINT W
5260 IF W = 1 THEN GOSUB 6000: GOTO 8000
5270 IF W = 2 THEN GOSUB 7000: GOTO 8000
5280 IF W = 3 THEN GOSUB 7600: GOTO 8000
5290 IF W = 4 THEN GOSUB 6000: GOSUB 7000: GOTO 8000
5292 IF W = 5 THEN GOSUB 6000: GOSUB 7600: GOTO 8000
5294 IF W = 6 THEN GOSUB 7000: GOSUB 7600: GOTO 8000
5296 IF W = 7 THEN GOSUB 6000: GOSUB 7000: GOSUB 7600:
GOTO 8000
5298 IF W = 8 THEN GOTO 8000
5300 GOTO 5100
6000 REM 75%
6100 FOR I = 0 TO A
6200 C(I,X) = X(A - I)
6300 C(I,Y) = YU(0,A - I)
6400 NEXT I
6410 FOR I = A + 1 TO 2 * A
6420 C(I,X) = X(I - A)
6430 C(I,Y) = YL(0,I - A)
6440 NEXT I
6500 IF PT$ = "-10" THEN PT$ = ""

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6501 PRINT D$"OPEN";A$;PT$;"-75/";F
6510 PRINT D$"DELETE";A$;PT$;"-75/";F
6520 PRINT D$"OPEN";A$;PT$;"-75/";F
6530 PRINT D$"WRITE";A$;PT$;"-75/";F
6540 FOR I = 0 TO 2 * A
6550 PRINT C(I,X): PRINT C(I,Y)
6560 NEXT I
6570 PRINT D$"CLOSE";A$;PT$;"-75/";F
6999 RETURN
7000 REM 80%
7100 FOR I = 0 TO A
7200 C(I,X) = X(A - I)
7300 C(I,Y) = YU(1,A - I)
7400 NEXT I
7410 FOR I = A + 1 TO 2 * A
7420 C(I,X) = X(I - A)
7430 C(I,Y) = YL(1,I - A)
7440 NEXT I
7500 IF PT$ = "-10" THEN PT$ = ""
7501 PRINT D$"OPEN";A$;PT$;"-80/";F
7510 PRINT D$"DELETE";A$;PT$;"-80/";F
7520 PRINT D$"OPEN";A$;PT$;"-80/";F
7530 PRINT D$"WRITE";A$;PT$;"-80/";F
7540 FOR I = 0 TO 2 * A
7550 PRINT C(I,X): PRINT C(I,Y)
7560 NEXT I
7570 PRINT D$"CLOSE";A$;PT$;"-80/";F
7599 RETURN
7600 REM HORTEN
7610 FOR I = 0 TO A
7620 C(I,X) = X(A - I)
7630 C(I,Y) = YU(2,A - I)
7640 NEXT I
7650 FOR I = A + 1 TO 2 * A
7660 C(I,X) = X(I - A)
7670 C(I,Y) = YL(2,I - A)
7680 NEXT I
7690 IF PT$ = "-10" THEN PT$ = ""
7700 PRINT D$"OPEN";A$;PT$;"-H/";F
7710 PRINT D$"DELETE";A$;PT$;"-H/";F
7720 PRINT D$"OPEN";A$;PT$;"-H/";F
7730 PRINT D$"WRITE";A$;PT$;"-H/";F
7740 FOR I = 0 TO 2 * A
7750 PRINT C(I,X): PRINT C(I,Y)
7760 NEXT I
7770 PRINT D$"CLOSE";A$;PT$;"-H/";F
7999 RETURN
8000 REM AGAIN?
8100 TEXT ; HOME
8200 PRINT "Do you wish to compute another?"
8250 PRINT
8300 PRINT " 1. Different camber or thickness,          same
airfoil"
8400 PRINT " 2. Different airfoil"

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8500 PRINT " 3. End"
8600 PRINT : GET W: PRINT W
8700 IF W = 1 THEN TEXT : HOME : GOTO 320
8710 IF W = 2 THEN GOTO 200
8720 IF W = 3 THEN END
8730 GOTO 8100

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THICKNESS DATA

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10 DIM X(60): DIM T(60)
20 D$ = CHR$(4)
40 TEXT : HOME
50 PRINT "This program will accept input thick- ness
contour coordinates and save the resulting matrix on
disc"
60 PRINT : PRINT "Follow the prompts...";
70 GET W$: PRINT W$
80 TEXT : HOME
120 PRINT "What profile designation? ";; INPUT F$
125 PRINT : PRINT : PRINT "Start with the leading edge
(X = 0, T = 0) and end with the trailing edge (X = 100,
T = 0). This is very important, as the program
will not work properly otherwise."
150 PRINT : PRINT
170 FOR A = 0 TO 60
180 IF A < 10 THEN PRINT " ";
190 PRINT A;" X: ";; INPUT X(A)
200 IF A < 10 THEN PRINT " ";
210 PRINT A;" T: ";; INPUT T(A)
220 PRINT : PRINT "Are these coordinates correct? ";; GET W$:
PRINT W$: IF W$ < > "Y" AND W$ < > "N" THEN HOME :
GOTO 220
230 IF W$ = "N" THEN HOME : GOTO 180
250 PRINT : IF X(A) = 100 AND T(A) = 0 THEN B = A:A = 60
260 NEXT A
280 REM CHECK
290 TEXT : HOME
300 FOR A = 0 TO B
310 IF A < 10 THEN PRINT " ";
320 PRINT A;" X: ";X(A);; HTAB (15): PRINT " T: ";T(A)
330 IF A = 0 GOTO 350
340 IF A / 10 = INT (A / 10) THEN GET W$: PRINT W$: HOME
350 NEXT A
370 PRINT : PRINT "Were all of the above correct? ";; GET W$:
PRINT W$: IF W$ < > "Y" AND W$ < > "N" THEN GOTO 370
380 IF W$ = "Y" GOTO 560
390 PRINT
400 PRINT "Which coordinate(s) were wrong?"
410 PRINT "List them as prompted..."
420 PRINT : PRINT "# = ";; INPUT N
430 PRINT "X or T? ";; GET I$
440 IF I$ < > "X" AND I$ < > "T" THEN GOTO 430

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450 IF I$ = "X" THEN PRINT "This is currently ";X(N)
460 IF I$ = "T" THEN PRINT "This is currently ";T(N)
480 PRINT "Correction needed? ";: GET W$: PRINT W$: IF W$
< > "Y" AND W$ < > "N" THEN GOTO 480
490 IF W$ = "Y" THEN GOTO 510
500 GOTO 520
510 PRINT : PRINT "Input the correct number : ";: INPUT C
512 IF I$ = "X" THEN X(N) = C
514 IF I$ = "T" THEN T(N) = C
520 PRINT : PRINT "Another correction? ";: GET W$: PRINT W$:
IF W$ < > "Y" AND W$ < > "N" THEN GOTO 520
530 IF W$ = "Y" THEN GOTO 420
540 REM ALL CHECKED OK
550 GOTO 290
560 HOME
570 PRINT "The designation of this airfoil is"
575 PRINT F$: PRINT
580 PRINT "(.XT will be added to the file name as it is
SAVED.)": PRINT
590 PRINT "Write to disc? ";: GET W$: PRINT W$: IF W$ < >
"Y" AND W$ < > "N" THEN GOTO 560
600 IF W$ = "N" THEN GOTO 1000
610 HOME : PRINT "Writing to disc... "
620 PRINT D$"OPEN";F$;".XT"
630 PRINT D$"DELETE";F$;".XT"
640 PRINT D$"OPEN";F$;".XT"
650 PRINT D$"WRITE";F$;".XT"
660 FOR A = 0 TO B
670 PRINT X(A): PRINT T(A)
680 NEXT A
690 PRINT D$"CLOSE";F$;".XT"
700 HOME
710 PRINT "Another set of coordinates? ";: GET W$: IF W$ < >
"Y" AND W$ < > "N" THEN GOTO 700
720 IF W$ = "Y" THEN CLEAR : GOTO 10
730 HOME : END
1000 PRINT : PRINT "Do you wish to change the designation of
the profile? Pressing <N> will abort and allow you to
restart at the beginning."
1010 GET W$: PRINT W$
1020 IF W$ < > "Y" AND W$ < > "N" THEN HOME : GOTO 1000
1030 IF W$ = "N" THEN GOTO 700
1040 HOME : PRINT "New designation?": INPUT F$: GOTO 560

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NACA 63-010

<u>X</u>	<u>Y</u>
0.0	0.000
.5	0.829
.75	1.004
1.25	1.275
2.5	1.756
5	2.440
7.5	2.950
10	3.362
15	3.994
20	4.445
25	4.753
30	4.938
35	5.000
40	4.938
50	4.496
60	3.715
70	2.712
80	1.618
85	1.088
90	0.604
95	0.214
100	0.000

NACA 63A-010

<u>X</u>	<u>Y</u>
0.0	0.000
.5	0.816
.75	0.983
1.25	1.250
2.5	1.737
5	2.412
7.5	2.917
10	3.324
15	3.950
20	4.400
25	4.714
30	4.913
35	4.995
40	4.968
50	4.613
60	3.943
70	3.044
80	2.040
90	1.030
95	0.525
100	0.021

NACA 64-010

<u>X</u>	<u>Y</u>
0.0	0.000
0.5	0.820
0.75	0.989
1.25	1.250
2.5	1.701
5	2.343
7.5	2.826
10	3.221
15	3.842
20	4.302
25	4.639
30	4.864
35	4.980
40	4.988
50	4.586
60	3.820
70	2.827
80	1.722
90	0.671
95	0.248
100	0.000

NACA 64A-010

<u>X</u>	<u>Y</u>
0.0	0.000
0.5	0.804
0.75	0.969
1.25	1.225
2.5	1.688
5	2.327
7.5	2.905
10	3.199
15	3.813
20	4.272
25	4.606
30	4.837
35	4.968
40	4.995
45	4.894
50	4.684
55	4.388
60	4.021
70	3.127
80	2.103
85	1.582
90	1.062
95	0.541
100	0.021

NACA 65A-010

X	Y
0.0	0.0
0.5	0.765
0.75	0.928
1.25	1.183
2.5	1.623
5	2.182
7.5	2.650
10	3.040
15	3.658
20	4.127
25	4.483
30	4.742
35	4.912
40	4.995
45	4.983
50	4.863
55	4.632
60	4.304
65	3.899
70	3.432
75	2.912
80	2.352
85	1.771
90	1.188
95	0.604
100	0.021

NACA 65-010

X	Y
0.0	0.000
.5	0.772
.75	0.932
1.25	1.169
2.5	1.574
5	2.177
7.5	2.647
10	3.040
15	3.666
20	4.143
25	4.503
30	4.760
35	4.924
40	4.996
45	4.963
50	4.812
55	4.530
60	4.146
65	3.682
70	3.156
75	2.584
80	1.987
85	1.385
90	0.810
95	0.306
100	0.000

NACA 0010

X	Y
0.0	0.0000
.75	1.2374
1.25	1.5782
2.5	2.1789
5	2.9622
7.5	3.4999
10	3.9023
12.5	4.2128
15	4.4543
20	4.7813
25	4.9510
30	5.0014
35	4.9572
40	4.8358
45	4.6506
50	4.4117
55	4.1270
60	3.8028
65	3.4437
70	3.0533
75	2.6336
80	2.1859
82.5	1.9517
85	1.7105
87.5	1.4621
90	1.2064
92.5	0.9432
95	0.6721
97.5	0.3929
98.75	0.2500
100	0.0000

ELINA

<u>X</u>	<u>X</u>
0.00	0.000
1.25	1.345
2.5	1.925
5	2.71
7.5	3.285
10	3.72
15	4.36
20	4.73
25	4.92
30	4.95
40	4.67
50	4.15
60	3.49
70	2.73
80	1.88
90	1.05
95	0.61
100	0.14

HQ-0/10

<u>X</u>	<u>Y</u>
0.0	0.000
.5	0.722
1.25	1.278
2.5	1.889
5	2.667
10	3.556
15	4.222
20	4.556
25	4.778
30	4.889
35	5.000
40	4.833
50	4.556
60	3.778
70	2.778
80	1.722
85	1.167
90	0.778
95	0.333
100	0.000

SAFTIG

<u>X</u>	<u>Y</u>
0.00	0.000
1.25	1.188
2.5	1.750
5	2.563
7.5	3.125
10	3.563
15	4.188
20	4.625
30	5.000
40	4.813
50	4.375
60	3.750
70	2.875
80	2.063
90	1.063
95	0.500
100	0.063

MARTIN

<u>X</u>	<u>Y</u>
0	0
1.25	1.363
2.5	1.704
5	2.159
7.5	2.613
10	3.068
15	3.772
20	4.318
30	5
40	4.772
50	4.545
60	3.863
70	3.068
80	2.272
90	1.25
95	0.681
100	0

RG 12A

X	Y
0.0000	0.0000
0.2271	0.5299
0.8443	1.0784
2.0069	1.7251
3.5494	2.3201
5.5311	2.8810
7.9224	3.3883
10.7121	3.8352
13.8781	4.2145
17.3980	4.5214
21.2444	4.7532
25.3866	4.9086
29.7905	4.9881
34.4171	4.9933
39.2246	4.9271
44.1676	4.7929
49.1979	4.5951
54.2661	4.3373
59.3208	4.0227
64.3139	3.6467
69.1807	3.2065
73.8474	2.7302
78.2717	2.2558
82.4097	1.8050
86.2125	1.3925
89.6336	1.0291
92.6268	0.7208
95.1461	0.4661
97.1705	0.2565
98.6926	0.1016
99.6628	0.0206
100.0000	0.0000

RG 14A

X	Y
0.0000	0.0000
0.2366	0.5565
0.8755	1.1442
2.0312	1.8072
3.5648	2.4158
5.5341	2.9834
7.9103	3.4907
10.6869	3.9317
13.8421	4.3001
17.3531	4.5921
21.1921	4.8058
25.3279	4.9404
29.7262	4.9979
34.3477	4.9807
39.1514	4.8932
44.0909	4.7403
49.1185	4.5282
54.1830	4.2632
59.2331	3.9519
64.2138	3.6011
69.0747	3.2153
73.7630	2.7906
78.2110	2.3366
82.3647	1.8859
86.1805	1.4653
89.6125	1.0887
92.6159	0.7657
95.1456	0.4959
97.1776	0.2728
98.7002	0.1078
99.6657	0.0218
100.0000	0.0000

RG 15A

X	Y
0.0000	0.0000
0.3049	0.6203
1.1040	1.2661
2.2646	1.8706
3.8801	2.4693
5.8987	3.0163
8.3313	3.5123
11.1535	3.9442
14.3469	4.3071
17.8876	4.5956
21.7489	4.8075
25.8995	4.9414
30.3054	4.9982
34.9280	4.9791
39.7260	4.8875
44.6543	4.7256
49.6654	4.4978
54.7148	4.2026
59.7459	3.8348
64.6897	3.4110
69.4954	2.9611
74.1168	2.5074
78.5038	2.0665
82.6063	1.6519
86.3751	1.2749
89.7635	0.9428
92.7258	0.6611
95.2171	0.4280
97.2166	0.2359
98.7164	0.0935
99.6695	0.0190
100.0000	0.0000