June 2003 • NREL/SR-500-33295

Subcontractor Report

Theoretical Aerodynamic Analyses of Six Airfoils for Use on Small Wind Turbines

Period of Performance: July 11, 2002–October 31, 2002

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Port Matilda, Pennsylvania

National Renewable Energy Laboratory

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Contract No. DE-AC36-99-GO10337

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Prepared under Subcontract No. ACX-2-32232-01

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Foreword

The U.S. Department of Energy (DOE), working through its National Renewable Energy Laboratory (NREL), is engaged in a comprehensive research effort to improve the understanding of wind turbine aeroacoustics. Motivation for this effort is the desire to exploit the large expanse of low wind speed sites that tend to be closer to U.S. load centers. Quiet wind turbines are an inducement to widespread deployment, so the goal of NREL's aeroacoustic research is to develop tools for use by U.S. industry in developing and deploying highly efficient, quiet wind turbines at these low wind speed sites. NREL's National Wind Technology Center (NWTC) is implementing a multifaceted approach that includes wind tunnel tests, field tests, and theoretical analyses in direct support of low wind speed turbine development by its industry partners. NWTC researchers are working hand in hand with industry engineers to ensure that research findings are available to support ongoing design decisions.

The work described in the present report focuses on the theoretical aerodynamic analysis of airfoils that are candidates for use on small wind turbines. Admittedly, the connection between this *aerodynamic* work and NREL's *aeroacoustic* research is somewhat vague. But without a knowledge of both aerodynamic and aeroacoustic performance of airfoils, engineers are frustrated in making decisions on new blade designs. This is particularly true for small wind turbines, which operate at low Reynolds numbers at which airfoil aerodynamic characteristics are both sensitive and difficult to predict. Thus, the present work needs to be considered in the context of the broader research effort on aeroacoustics for small wind turbines.

Wind tunnel *aerodynamic* tests and *aeroacoustic* tests have been performed on six airfoils that are candidates for use on small wind turbines. Results are documented in the following NREL reports:

> "Wind Tunnel Aeroacoustic Tests of Six Airfoils for Use on Small Wind Turbines"
> Stefan Oerlemans, Principal Investigator, the Netherlands National Aerospace Laboratory
>
> "Wind Tunnel Aerodynamic Tests of Six Airfoils for Use on Small Wind Turbines"
> Michael Selig, Principal Investigator, University of Illinois at Urbana-Champaign (UIUC)

These reports provide a valuable airfoil database for designers who wish to consider the tested airfoils. But inevitably, they will wish to evaluate other airfoils that have not been tested. This presents a dilemma. Not only are wind tunnel tests expensive, but it is often difficult to schedule the required facilities within the overall timeframe of a project development plan. This conundrum begs the question, "Is it really necessary to conduct wind tunnel tests, or can we rely on theoretical predictions?" Predicting the aeroacoustic emission spectra of a particular airfoil shape is extremely difficult, but predicting the aerodynamic characteristics of a particular airfoil shape is a routine, well-established practice. Nevertheless, there is always some uncertainty about the accuracy of the predictions compared to wind tunnel tests or field performance. And there are questions about the efficacy of the two principal airfoil analysis methods: the Eppler and XFOIL codes. To address these related issues, at least in part, a theoretical analysis was commissioned of the same airfoils tested in the wind tunnel. The results are documented in the following NREL report:

> "Theoretical Aerodynamic Analyses of Six Airfoils for Use on Small Wind Turbines Using Eppler and XFOIL Codes"
> Dan M. Somers and Mark D. Maughmer; Principal Investigators; Airfoils, Incorporated

The possession of both theoretically predicted aerodynamic characteristics and wind tunnel test data for the same six airfoils provides the extraordinary opportunity to compare the performance, measured by energy capture, of wind turbine rotors designed with the different data. This will provide the desired insight to assist designers in deciding whether to pursue wind tunnel tests. Although some differences in the resulting blade planforms (chord and twist distributions) can be expected, a more important question relates to the difference in energy capture and its significance in driving the choices that need to be made during the preliminary design stage. These issues are addressed in a report that compares the differences in Eppler and XFOIL predictions to the UIUC wind tunnel tests and examines the planform and energy capture differences in resulting blade designs. This report is titled:

> "Comparison of Optimized Aerodynamic Performance for Small Wind Turbine Rotors Designed with Theoretically Predicted versus Experimentally Measured Airfoil Characteristics"
> Michael Selig, Principal Investigator, University of Illinois at Urbana-Champaign (UIUC)

Another research effort undertaken in support of the U.S. wind turbine industry involves a series of aerocoustic field tests conducted at the NWTC. Using well-documented, consistently applied test procedures, noise spectra were measured for eight small wind turbine configurations. Test results provide valuable information to the manufacturers, as well as the potential users of these turbines. To our knowledge, this is the first comprehensive database of noise data for small wind turbines. Results of this effort are documented in another NREL report, titled:

> "Aeroacoustic Field Tests of Eight Small Wind Turbines"
> J. van Dam and A. Huskey, Principal Investigators, NREL's National Wind Technology Center

Each of the documents described above will be published as a stand-alone NREL report. Undoubtedly, some results will also be presented in various journal articles or conference papers. All of the NREL reports will be available on NREL's NWTC Web site at http://www.nrel.gov/wind/. Collectively, these five reports represent a significant compendium of information on the aerodynamics and aeroacoustics of contemporary small wind turbines. Therefore, NREL will publish all five reports on compact disc (CD).

This work represents a significant commitment of DOE resources as well as a significant human commitment over an extended period of time. I am sure I express the sentiments of all the research participants in saying we sincerely hope the results of these efforts prove beneficial to the wind energy community.

Paul G. Migliore
NREL/NWTC Project Manager

Abstract

Theoretical analyses of six airfoils—the E 387, FX 63-137, S822, S834, SD2030, and SH3055—have been performed for Reynolds numbers from 0.10 x 10^6 to 1.00 x 10^6 using the Eppler Airfoil Design and Analysis Code and the XFOIL code. The results from both codes exhibit the typical Reynolds number and roughness effects. Comparisons of the results from the two codes generally show good agreement, particularly for Reynolds numbers greater than 0.10 x 10^6. The maximum lift coefficient predicted by the XFOIL code is about 0.2 higher, and the Reynolds number and roughness effects are larger. The magnitudes of the zero-lift angle and pitching-moment coefficients predicted by the Eppler code are greater.

Introduction

The analyses performed under this study are intended to provide theoretical predictions[1] for comparison with experimental measurements at low Reynolds numbers and to provide a comparison between two widely used theoretical methods, the Eppler Airfoil Design and Analysis Code (References 1 and 2) and the XFOIL code (Reference 3). The airfoils analyzed are the E 387 (Reference 4), the FX 63-137 (Reference 5), the S822 (Reference 6), the S834 (Reference 7), the SD2030 (Reference 8), and the SH3055.

Symbols

C_p	pressure coefficient
c	airfoil chord, m
c_d	section profile-drag coefficient
c_l	section lift coefficient
c_m	section pitching-moment coefficient about quarter-chord point
R	Reynolds number based on free-stream conditions and airfoil chord
x	airfoil abscissa, m
y	airfoil ordinate, m
α	angle of attack relative to x-axis, deg

[1] Airfoils, Incorporated cautions the reader by inserting the following disclaimer: "Because of the limitations of the codes (References 1–3) employed in this study, the results presented are in no way guaranteed to be accurate—either in an absolute or in a relative sense. This statement applies to the entire study."

Subscripts:

max	maximum
min	minimum
S	separation
T	transition

Abbreviations:

L.	lower surface
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NREL	National Renewable Energy Laboratory
S.	boundary-layer separation location, x_S/c
T.	boundary-layer transition location, x_T/c
U.	upper surface

Airfoils

The E 387 airfoil (Reference 4) is intended for model sailplanes having Reynolds numbers greater than 0.2×10^6. Its thickness is 9.1-percent chord. It has been tested in several wind tunnels (References 9–11), making it a de facto, low Reynolds number, calibration standard. The coordinates of the E 387 airfoil are contained in Table I, and its shape is shown in Figure 1, along with those of other airfoils.

The FX 63-137 airfoil (Reference 5) is intended for human-powered aircraft. Its thickness is 13.7-percent chord. The coordinates of the FX 63-137 airfoil contained in Reference 5 are not smooth, probably because of numerical errors in the design method used (Reference 12). Therefore, the coordinates have been smoothed using the Eppler code. The smoothing results in a rotation of the airfoil, which was removed by Michael S. Selig.[2] The smoothed and rerotated coordinates, which correspond to an airfoil thickness of 13.6-percent chord, are contained in Table II.

[2] Associate Professor, Department of Aeronautical and Astronautical Engineering, University of Illinois at Urbana-Champaign.

The S822 airfoil (Reference 6) is intended for the 90-percent blade radial station of 3- to 10-meter-diameter, stall-regulated and variable-speed/variable-pitch, horizontal-axis wind turbines. Its design Reynolds number is 0.6×10^6 and its thickness is 16.0-percent chord. Because this airfoil is proprietary to the National Renewable Energy Laboratory (NREL), the coordinates are not in the public domain. The S834 airfoil (Reference 7) is intended for the 95-percent blade radial station of 1- to 3-meter-diameter, variable-speed/variable-pitch, horizontal-axis wind turbines. Its design Reynolds number is 0.4×10^6 and its thickness is 15.0-percent chord. Because this airfoil is proprietary to NREL, the coordinates are not in the public domain.

The SD2030 airfoil (Reference 8) is intended for radio-control sailplanes having Reynolds numbers from about 0.15×10^6 to about 0.5×10^6. Its thickness is 8.6-percent chord. The coordinates of the SD2030 airfoil are contained in Table III.

The SH3055 airfoil is intended for a 7-meter-diameter, variable-speed, horizontal-axis wind turbine requiring a wide angle-of-attack range. Its design Reynolds number is 0.3×10^6 and its thickness is 16.4-percent chord. The design coordinates comprise 142 points, which exceeds the array size in the Eppler code. Accordingly, every other point was eliminated for the present analysis. Because this airfoil is proprietary to the Bergey Windpower Company, the coordinates are not in the public domain.

Theory

Codes

Eppler Airfoil Design and Analysis Code

The Eppler Airfoil Design and Analysis Code (References 1 and 2) combines a conformal-mapping method for the design of airfoils with prescribed velocity-distribution characteristics, a panel method for the analysis of the potential flow about given airfoils, and an integral boundary-layer method. The latest version of the code, PROFIL00, was used in this study.

The potential-flow analysis method employs panels with parabolic vorticity distributions. The geometry of the panels is determined by a spline fit of the airfoil coordinates, with the end points of the panels being the input airfoil coordinates. The flow condition, which requires the inner tangential velocity to be zero, is satisfied at each airfoil coordinate (i.e., at the end points of the panels, not the midpoints). Two angles of attack, 0° and 90°, are analyzed. The flow at an arbitrary angle of attack is derived from these two solutions by superposition. The entire procedure does not require any restrictions on the input point distribution, smoothing, or rearranging of the coordinates; only the original airfoil coordinates are used. An option is included, by which additional points can be splined in between the original coordinates, that allows more precise results to be obtained should a portion of the airfoil have a sparse distribution of points. An option is provided for smoothing airfoils. In addition, several options

are available for the generation of coordinates for NACA 4-digit (Reference 13), 5-digit (References 14 and 15), and 6-series airfoils (Reference 16), as well as FX airfoils (Reference 5).

The laminar and turbulent boundary-layer development is computed using integral momentum and energy equations. The approximate solutions obtained from the laminar boundary-layer method agree very well with exact solutions. The turbulent boundary-layer method is based on the best available empirical skin-friction, dissipation, and shape-factor laws.

Of special interest are the predictions of separation and transition. The prediction of separation is determined by the shape factor based on energy and momentum thicknesses. The prediction of transition is based on an empirical criterion that contains the Reynolds number, based on local conditions and momentum thickness and the shape factor. The criterion considers the instability history of the boundary layer. The results are comparable to those predicted by the e^n method (References 17 and 18). The criterion contains a "roughness factor" that allows various degrees of surface roughness, or free-stream turbulence, to be simulated. The prediction of transition results in a switch from the laminar skin-friction, dissipation, and shape-factor laws to the turbulent ones, without changing the shape factor or momentum thickness. A procedure that determines the drag due to laminar separation bubbles has also been incorporated into the code.

The lift and pitching-moment coefficients are determined from the potential flow. Viscous corrections are then applied to these coefficients. The lift-curve slope, in which no separation is present, is reduced to 2π from its theoretical value. In other words, the potential-flow thickness effects are assumed to be offset by the boundary-layer displacement effects. Lift- and pitching-moment-coefficient corrections due to separation are also included. As an option, the displacement effect on the velocity distributions and the lift and pitching-moment coefficients can be computed. The boundary-layer characteristics at the trailing edge are used for the computation of the profile-drag coefficient by a Squire-Young (Reference 19) type formula.

XFOIL Code

The XFOIL code (Reference 3) combines a conformal-mapping method for the design of airfoils with prescribed pressure distributions, a panel method for the analysis of the potential flow about given airfoils, and an integral boundary-layer method. The latest version of the code, XFOIL 6.94, was used in this study.

The inviscid formulation is a linear-vorticity stream-function panel method. A general two-dimensional flow field is constructed by the superposition of a free-stream flow, a vortex sheet on the airfoil surface, and a source sheet on the airfoil surface and the wake. The airfoil contour and wake trajectory are discretized into straight panels. Each airfoil panel has a linear vorticity distribution, and each airfoil and wake panel also has a constant source strength associated with it. The source strengths are later related to quantities that define the viscous layer. The system of equations obtained to solve for the vorticity and source strengths is closed with an explicit Kutta condition. An option is included that allows the velocity distribution over a portion of the airfoil to be modified (mixed-inverse problem).

The boundary-layer development and wake are described with a two-equation lagged-dissipation integral boundary-layer formulation and an envelope e^n transition criterion. The entire viscous solution is strongly interacted with the incompressible potential flow using a surface transpiration model, which allows the calculation of limited regions of separated flow. The drag is determined from the momentum thickness of the wake far downstream.

Procedure

Although the E 387, S822, and S834 airfoils were designed using the Eppler code, the airfoil coordinates were used in the present analysis, instead of the design input, for consistency. Thus, all the airfoils were analyzed using the panel method in the Eppler code, not the conformal-mapping method.

The inviscid pressure distributions are predicted using the Eppler code.

The section characteristics are predicted using both codes for Reynolds numbers of 0.10 x 10^6 to 1.00 x 10^6. The computations were performed with transition free and with transition fixed at 2-percent chord on the upper surface and 5-percent chord on the lower surface.

Because the free-stream Mach number for all relevant wind-turbine operating conditions remains below 0.3, all results are incompressible.

Because the maximum lift coefficient computed by the Eppler code is not always realistic, an empirical criterion has been applied to the computed results. This criterion assumes that the maximum lift coefficient has been reached if the drag coefficient of the upper surface is greater than $0.01719\ (1 \times 10^6/R)^{1/8}$, which is based on correlations with results for Reynolds numbers from 0.7 x 10^6 to 1.5 x 10^6 from the Pennsylvania State University Low-Speed, Low-Turbulence Wind Tunnel. Also, because of boundary-layer displacement effects not accounted for in the present analysis, the zero-lift angle of attack is generally overpredicted by about 10 percent and the pitching-moment coefficient by about 20 percent.

The XFOIL code did not reach a converged solution at some angles of attack, which is most apparent in the tabulations of the section characteristics in the appendices[3].

Discussion of Results

Pressure Distributions

The inviscid pressure distributions for the nonproprietary airfoils, the E 387, FX 63-137, and SD2030, at angles of attack of 0° and 4° are shown in Figure 2.

[3] Airfoils, Incorporated inserted this statement to acknowledge the gaps in the tabulations and noted that "Because the report was not intended to provide a thorough code evaluation, no attempt was made to explore the myriad code differences."

Section Characteristics

Reynolds Number Effects

The section characteristics of the E 387, FX 63-137, S822, S834, SD2030, and SH3055 airfoils are shown in Figures 3 through 8 and tabulated in appendices A through F, respectively. The variations of maximum lift coefficient and minimum profile-drag coefficient with Reynolds number are shown in Figures 9 and 10, respectively. In general, the maximum lift coefficient increases with increasing Reynolds number and the profile-drag coefficient and the width of the low-drag, lift-coefficient range decreases. An exception is the maximum lift coefficient of the SH3055 airfoil with transition free, which is almost constant. The zero-lift angle of attack and the zero-lift pitching-moment coefficient are relatively unaffected by Reynolds number. All of these effects are typical of the Reynolds number effects on section characteristics[4].

Effect of Roughness

The effect of roughness on the section characteristics of the E 387, FX 63-137, S822, S834, SD2030, and SH3055 airfoils is shown in Figures 3 through 8, respectively. In general, the maximum lift coefficients of the E 387, S822, S834, and SD2030 airfoils are essentially unaffected by fixing transition because transition on the upper surface is predicted to occur forward of 2-percent chord at the maximum lift coefficient. The maximum lift coefficients of the FX 63-137 and SH3055 airfoils are decreased by fixing transition. In almost all cases, the drag coefficients are adversely affected by the roughness. The magnitudes of the zero-lift angle of attack, lift-curve slope, and pitching-moment coefficients generally decrease with transition fixed, particularly as predicted by the XFOIL code. All of these effects are typical of the effect of roughness on section characteristics.

Comparison of Theoretical Results

Comparisons of the results from the two codes (Figures 3–8) generally show good agreement, particularly for Reynolds numbers greater than 0.10×10^6, which are characteristic of all the intended applications. The variations of maximum lift coefficient with Reynolds number predicted by both codes show similar trends (Figure 9), although higher maximum lift coefficients, by about 0.2, are predicted by the XFOIL code. The variations of minimum drag coefficient with Reynolds number predicted by both codes show similar trends (Figure 10), although a larger Reynolds number effect is predicted by the XFOIL code. The widths of the low-drag ranges agree well. Greater magnitudes of the zero-lift angle of attack and zero-lift pitching-moment coefficient are predicted by the Eppler code, probably because of the displacement effects mentioned previously. A larger roughness effect on the lift-curve slope and pitching-moment coefficients is predicted by the XFOIL code.

[4] Editor's note: Abrupt changes in drag polars ($c_l - c_d$ plots) are not unusual for very low Reynolds numbers of 150,000 or less, and the behavior is often observed in wind tunnel test results as well.

Concluding Remarks

Theoretical analyses of six airfoils—the E 387, FX 63-137, S822, S834, SD2030, and SH3055—have been performed for Reynolds numbers from 0.10 x 10^6 to 1.00 x 10^6 using the Eppler Airfoil Design and Analysis Code and the XFOIL code. The results from both codes exhibit the typical Reynolds number and roughness effects. Comparisons of the results from the two codes generally show good agreement, particularly for Reynolds numbers greater than 0.10 x 10^6. The maximum lift coefficient predicted by the XFOIL code is about 0.2 higher, and the Reynolds number and roughness effects are larger. The magnitudes of the zero-lift angle and pitching-moment coefficients predicted by the Eppler code are greater.

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TABLE I.- E 387 AIRFOIL COORDINATES

Upper Surface		Lower Surface	
x/c	y/c	x/c	y/c
0.00044	0.00234	0.00091	—0.00286
.00519	.00931	.00717	—.00682
.01423	.01726	.01890	—.01017
.02748	.02562	.03596	—.01265
.04493	.03408	.05827	—.01425
.06643	.04238	.08569	—.01500
.09185	.05033	.11800	—.01502
.12094	.05775	.15490	—.01441
.15345	.06448	.19599	—.01329
.18906	.07037	.24083	—.01177
.22742	.07529	.28892	—.00998
.26813	.07908	.33968	—.00804
.31078	.08156	.39252	—.00605
.35505	.08247	.44679	—.00410
.40077	.08173	.50182	—.00228
.44767	.07936	.55694	—.00065
.49549	.07546	.61147	.00074
.54394	.07020	.66472	.00186
.59272	.06390	.71602	.00268
.64136	.05696	.76475	.00320
.68922	.04975	.81027	.00342
.73567	.04249	.85202	.00337
.78007	.03540	.88944	.00307
.82183	.02866	.92205	.00258
.86035	.02242	.94942	.00196
.89510	.01679	.97118	.00132
.92554	.01184	.98705	.00071
.95128	.00763	.99674	.00021
.97198	.00423	1.00000	.00000
.98729	.00180		
.99677	.00043		
1.00000	.00000		

TABLE II.- FX 63-137 AIRFOIL COORDINATES (SMOOTHED AND REROTATED)

Upper Surface		Lower Surface	
x/c	y/c	x/c	y/c
0.000000	0.003558	0.000329	0.000467
.001396	.010983	.001389	—.002407
.004602	.018262	.004595	—.006298
.009932	.026653	.009923	—.009727
.017353	.035426	.017353	—.012634
.026854	.044103	.026844	—.015058
.038374	.052482	.038367	—.017059
.051883	.060564	.051871	—.018697
.067301	.068359	.067287	—.020021
.084568	.075838	.084563	—.021073
.103623	.082960	.103610	—.021871
.124377	.089656	.124359	—.022385
.146729	.095877	.146718	—.022604
.170610	.101562	.170588	—.022519
.195888	.106652	.195880	—.022099
.222474	.111077	.222463	—.021323
.250257	.114799	.250237	—.020162
.279098	.117766	.279083	—.018615
.308896	.119930	.308880	—.016641
.339511	.121281	.339489	—.014250
.370803	.121810	.370789	—.011461
.402662	.121516	.402640	—.008274
.434928	.120402	.434913	—.004759
.467482	.118486	.467467	—.000985
.500172	.115800	.500161	.002959
.532860	.112363	.532845	.006943
.565416	.108227	.565400	.010847
.597679	.103443	.597673	.014552
.629540	.098079	.629525	.017929
.660840	.092218	.660826	.020888
.691448	.085989	.691435	.023369
.721245	.079493	.721232	.025313
.750081	.072870	.750077	.026690
.777858	.066232	.777860	.027481
.804445	.059687	.804441	.027687
.829732	.053297	.829730	.027297
.853600	.047122	.853596	.026332
.875959	.041202	.875961	.024852
.896710	.035579	.896705	.022919
.915761	.030251	.915756	.020611

TABLE II.- Concluded

Upper Surface		Lower Surface	
x/c	y/c	x/c	y/c
0.933033	0.025219	0.933027	0.017999
.948446	.020465	.948447	.015124
.961950	.015966	.961946	.012096
.973465	.011745	.973466	.009025
.982962	.007902	.982965	.006112
.990390	.004625	.990386	.003585
.995721	.002116	.995719	.001636
.998926	.000545	.998925	.000415
.999994	.000001	.999994	.000001

TABLE III.- SD2030 AIRFOIL COORDINATES

Upper Surface		Lower Surface	
x/c	y/c	x/c	y/c
0.00000	0.00017	0.00249	—0.00501
.00281	.00657	.01071	—.00935
.00995	.01371	.02419	—.01306
.02150	.02096	.04296	—.01601
.03752	.02803	.06693	—.01829
.05798	.03475	.09584	—.01997
.08273	.04100	.12941	—.02113
.11158	.04664	.16727	—.02183
.14432	.05157	.20896	—.02213
.18069	.05576	.25401	—.02207
.22034	.05917	.30191	—.02170
.26288	.06179	.35208	—.02106
.30788	.06360	.40396	—.02018
.35488	.06460	.45693	—.01908
.40336	.06478	.51038	—.01780
.45282	.06415	.56368	—.01634
.50273	.06268	.61621	—.01471
.55259	.06038	.66738	—.01286
.60189	.05724	.71670	—.01076
.65019	.05328	.76373	—.00848
.69709	.04856	.80802	—.00616
.74219	.04320	.84906	—.00398
.78512	.03742	.88632	—.00210
.82542	.03150	.91925	—.00066
.86252	.02564	.94728	.00024
.89593	.01992	.96985	.00059
.92535	.01438	.98643	.00049
.95059	.00930	.99659	.00017
.97128	.00510	1.00001	.00000
.98686	.00212		
.99665	.00049		
1.00000	.00000		

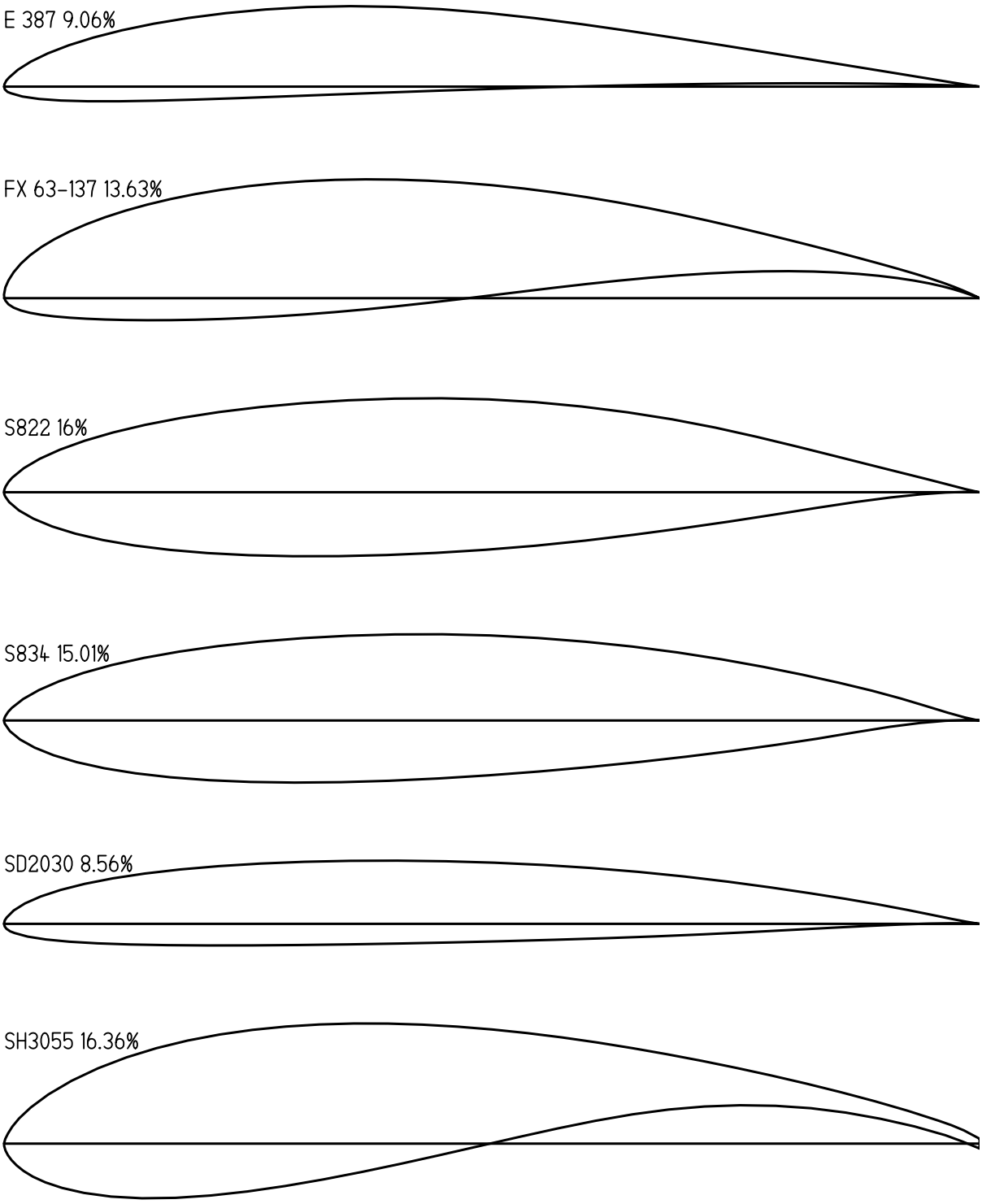
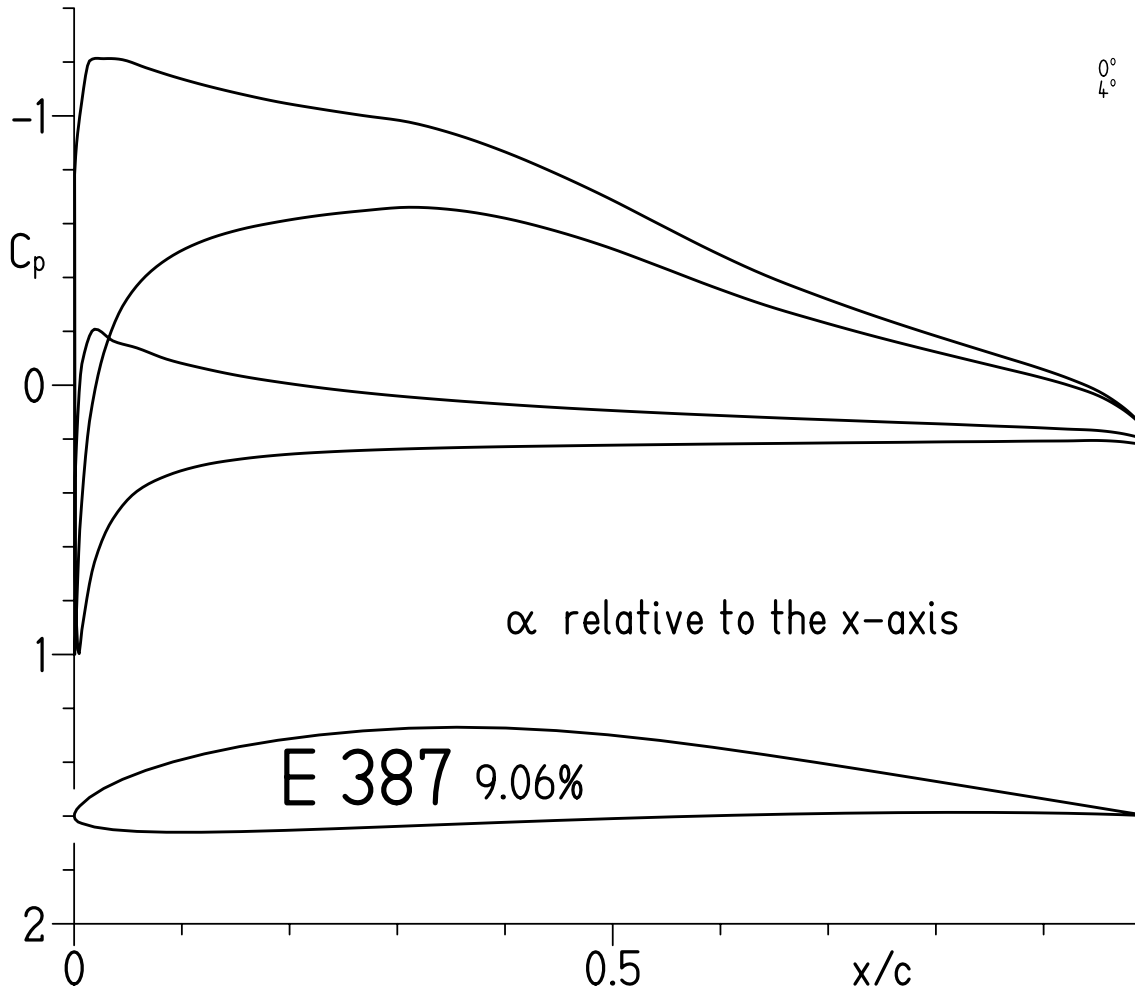
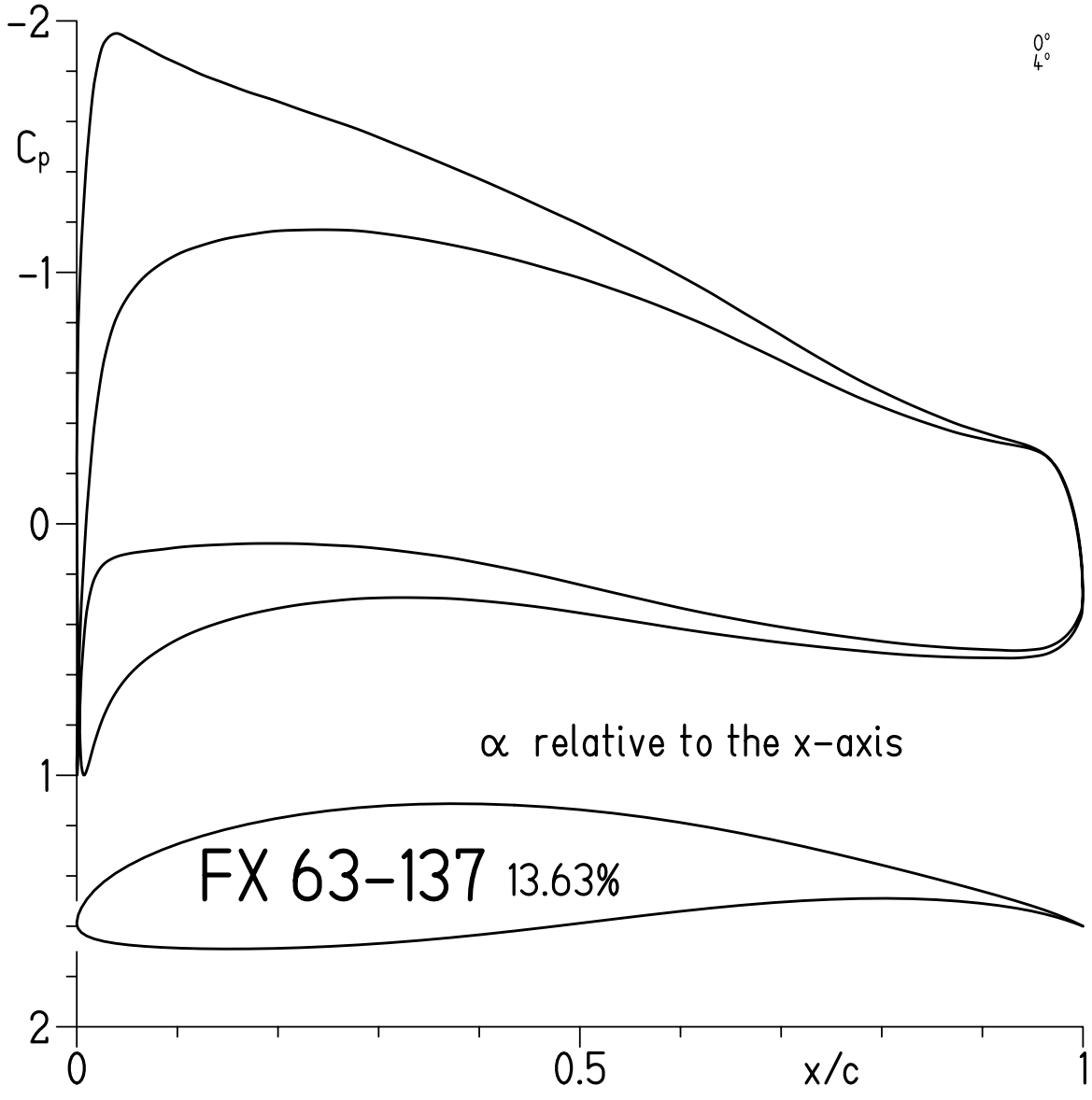


Figure 1.- Airfoil shapes.



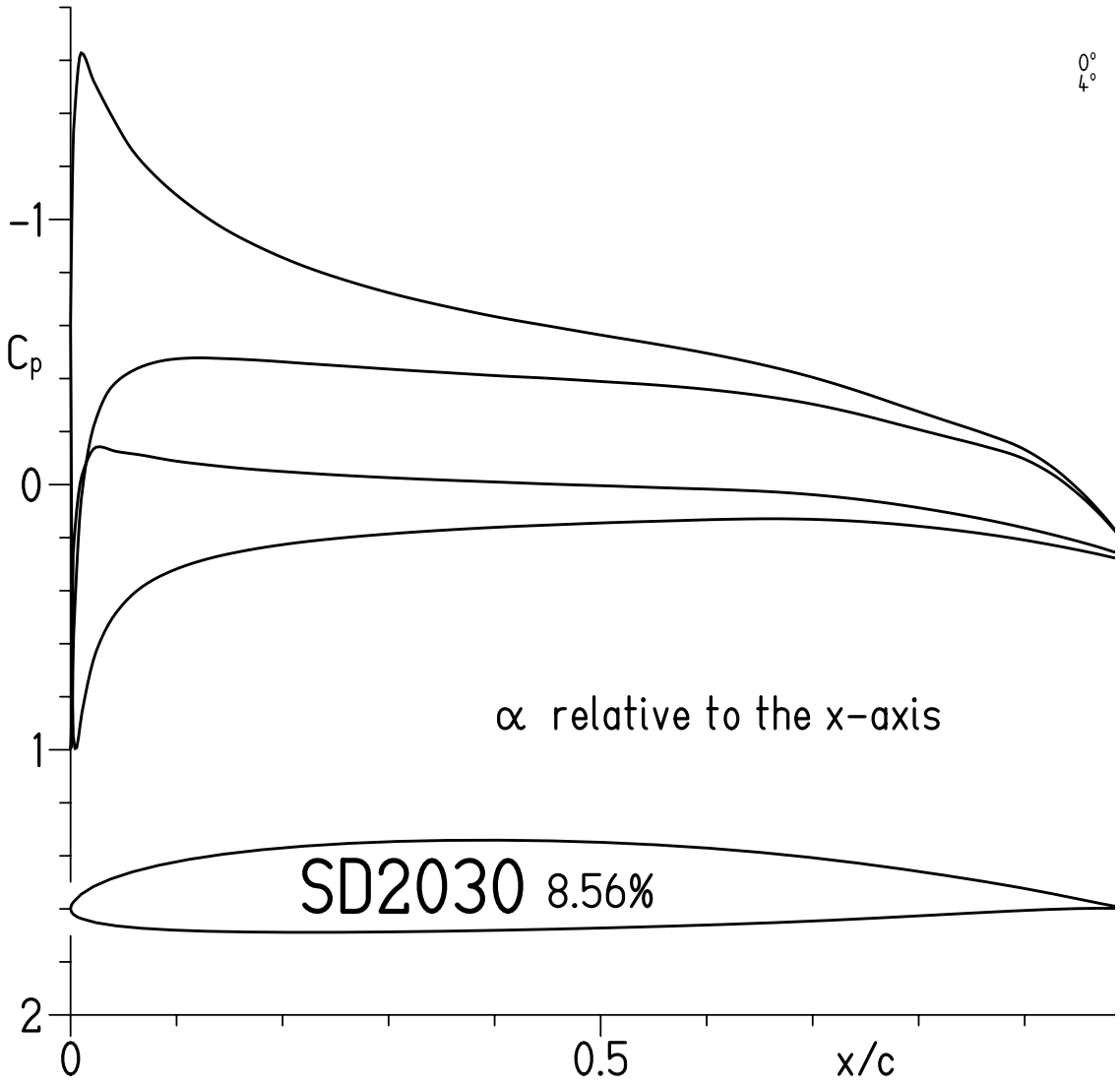
(a) E 387.

Figure 2.- Inviscid pressure distributions for nonproprietary airfoils at $\alpha = 0°$ and $4°$.



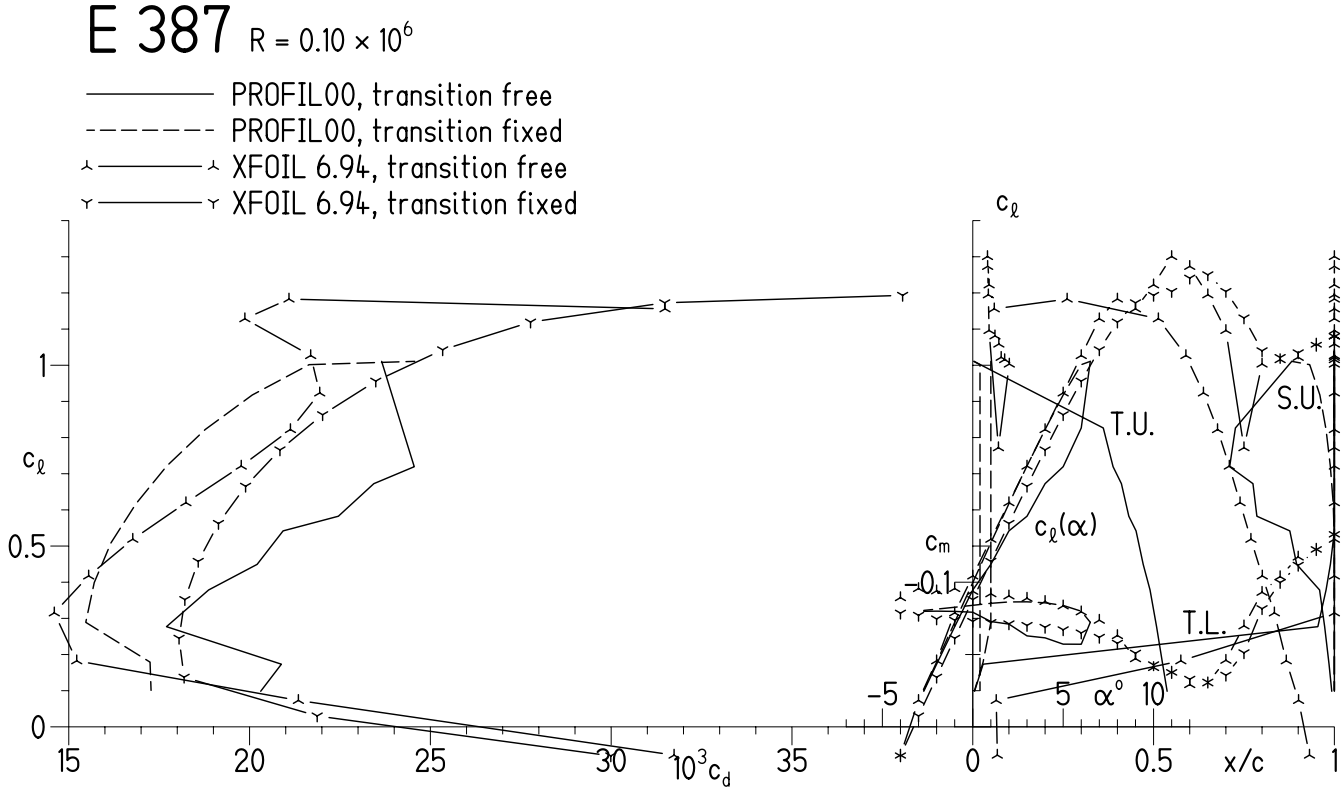
(b) FX 63-137.

Figure 2.- Continued.



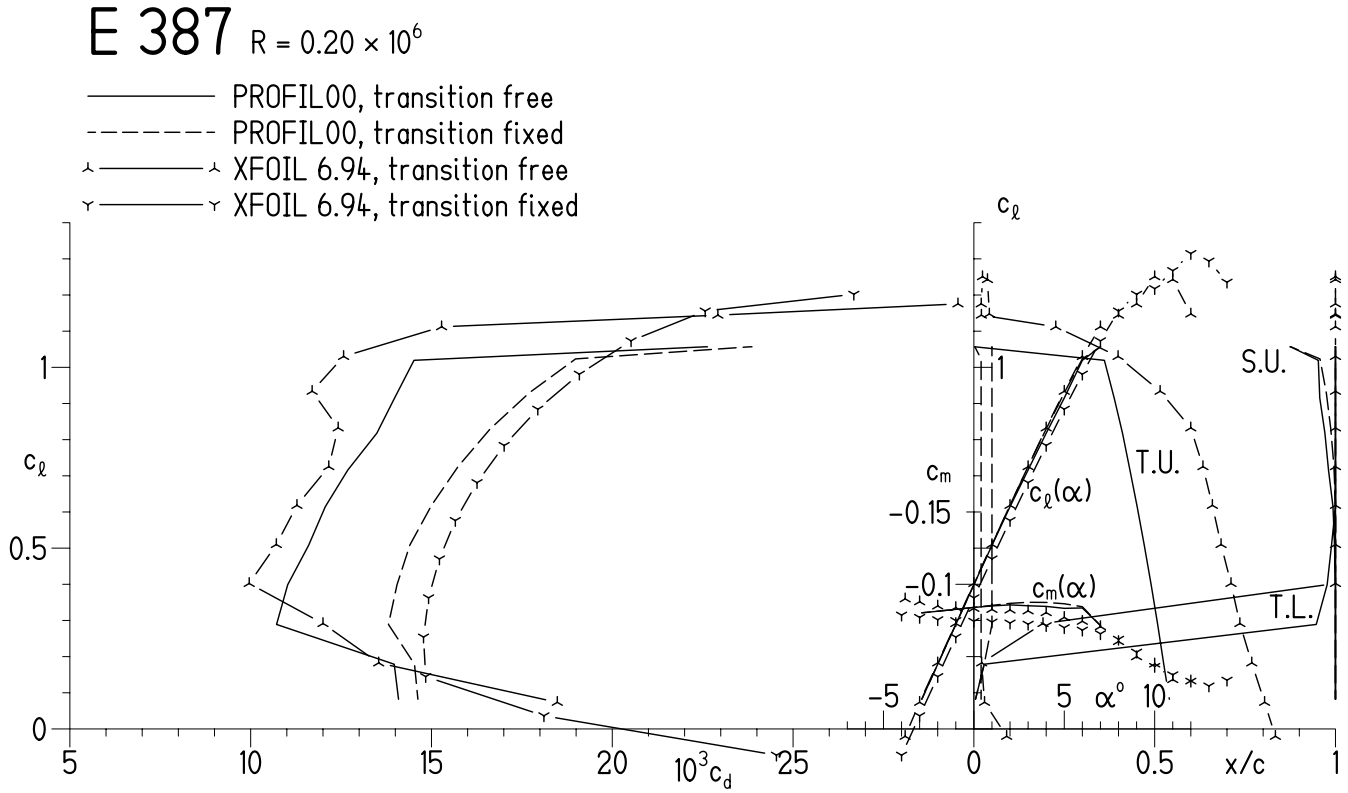
(c) SD2030.

Figure 2.- Concluded.



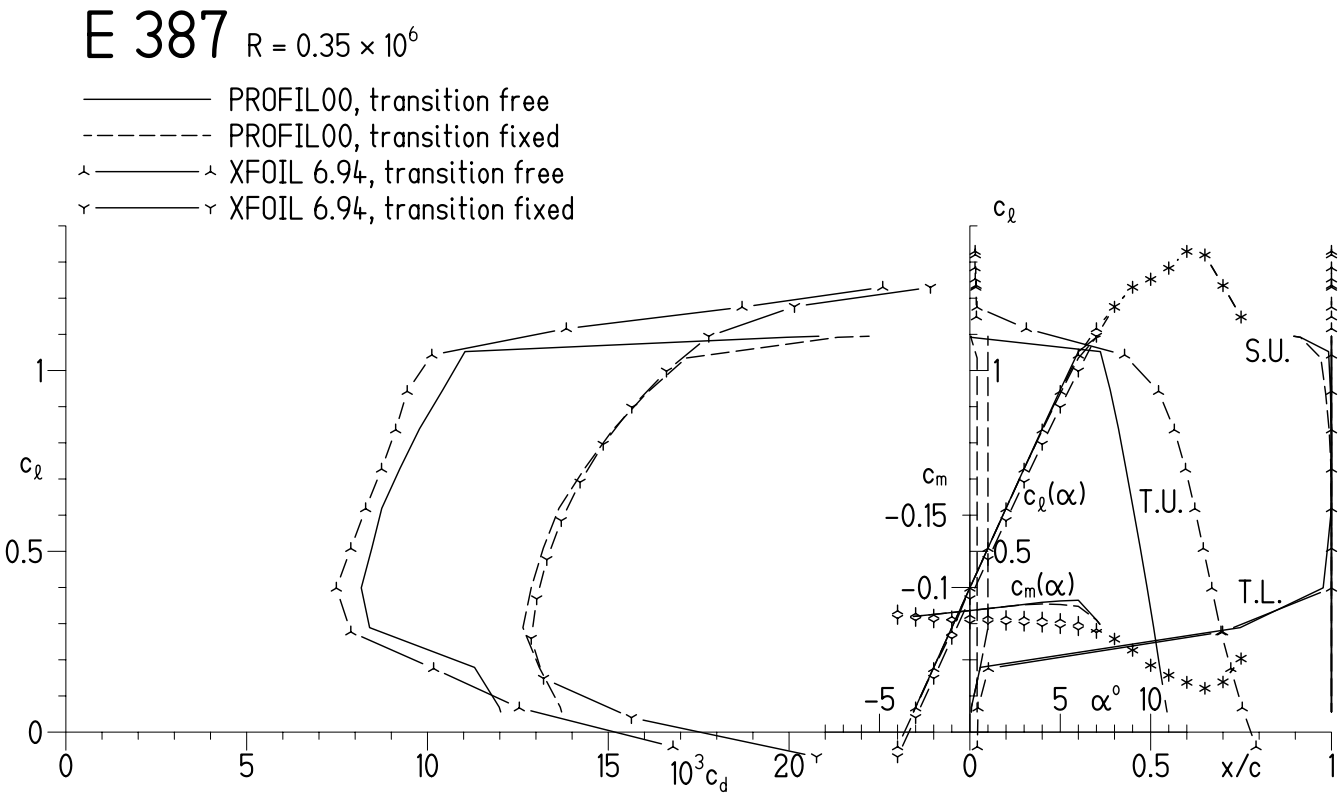
(a) $R = 0.10 \times 10^6$.

Figure 3.- Section characteristics of E 387 airfoil with transition free and transition fixed.



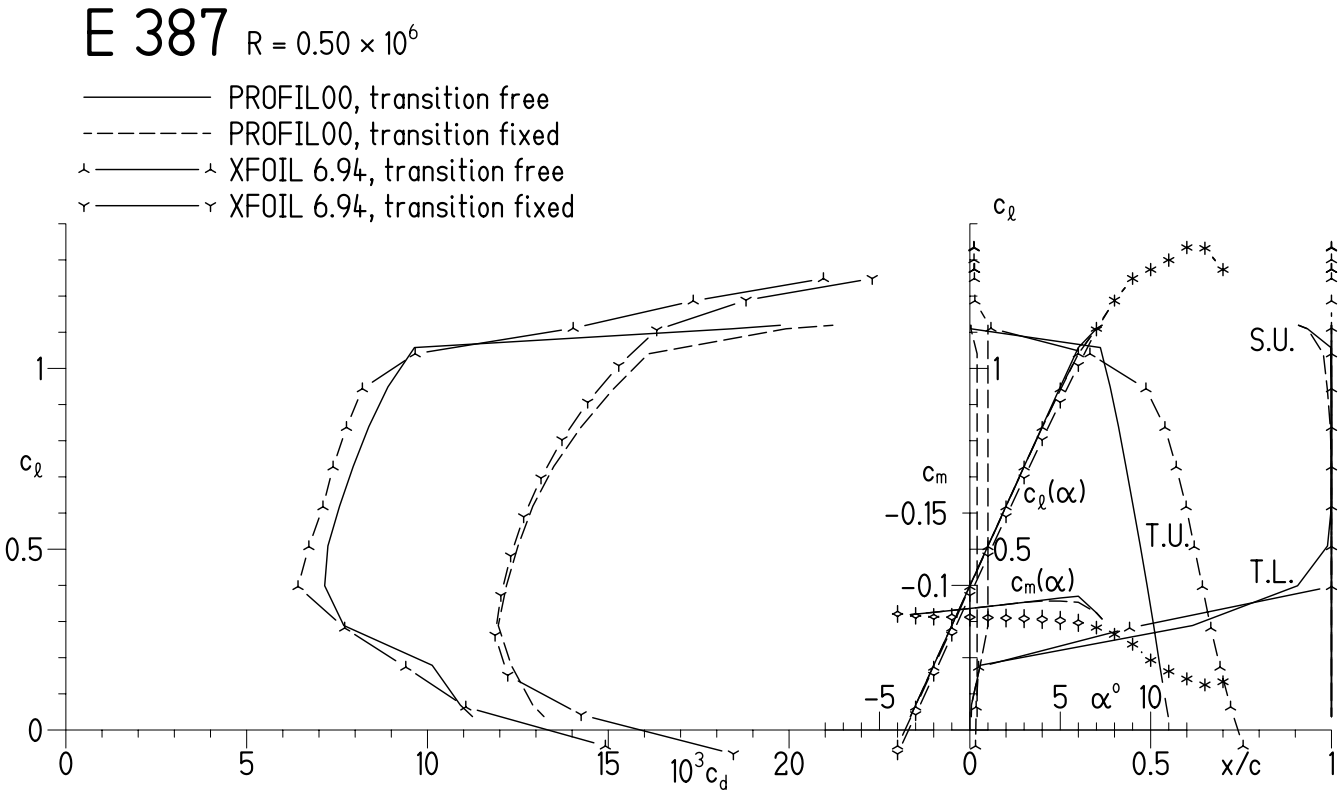
(b) $R = 0.20 \times 10^6$.

Figure 3.- Continued.



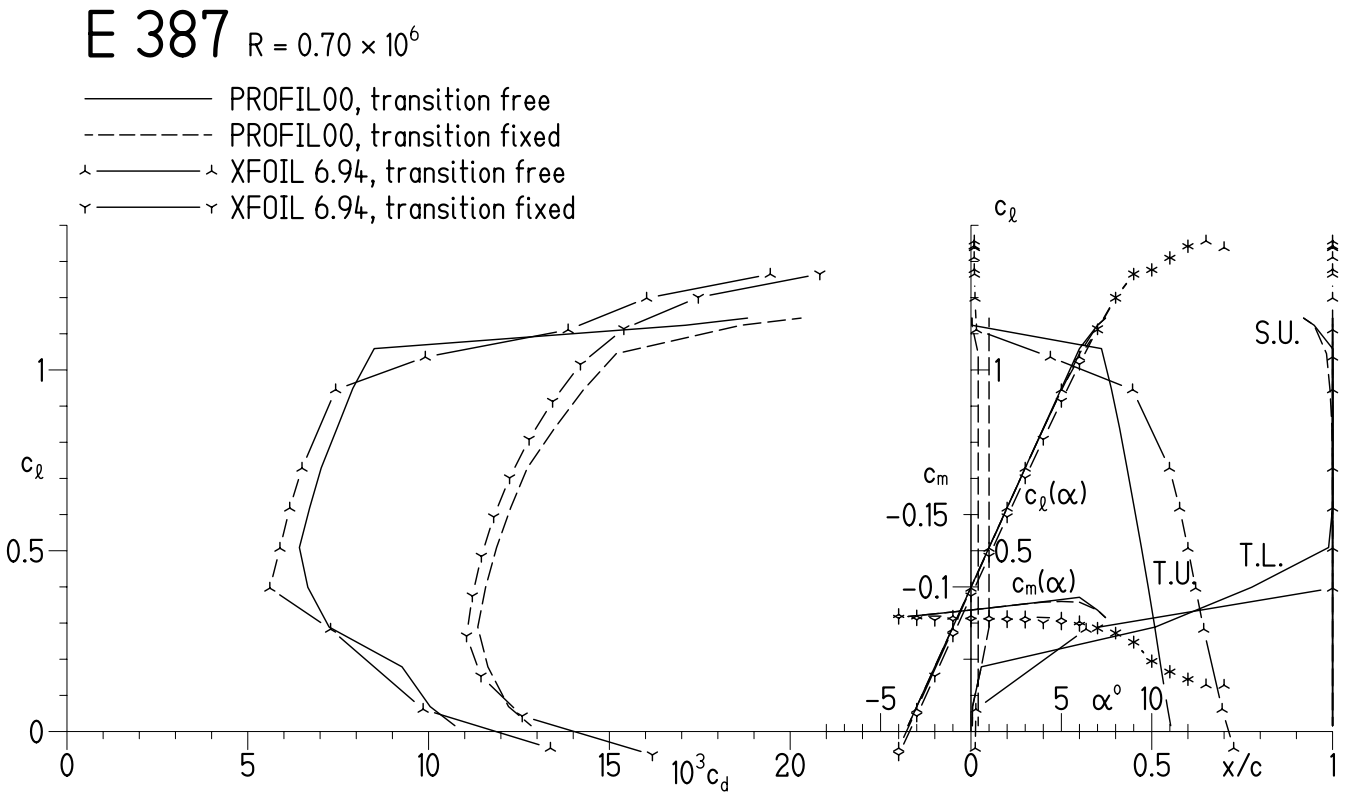
(c) $R = 0.35 \times 10^6$.

Figure 3.- Continued.



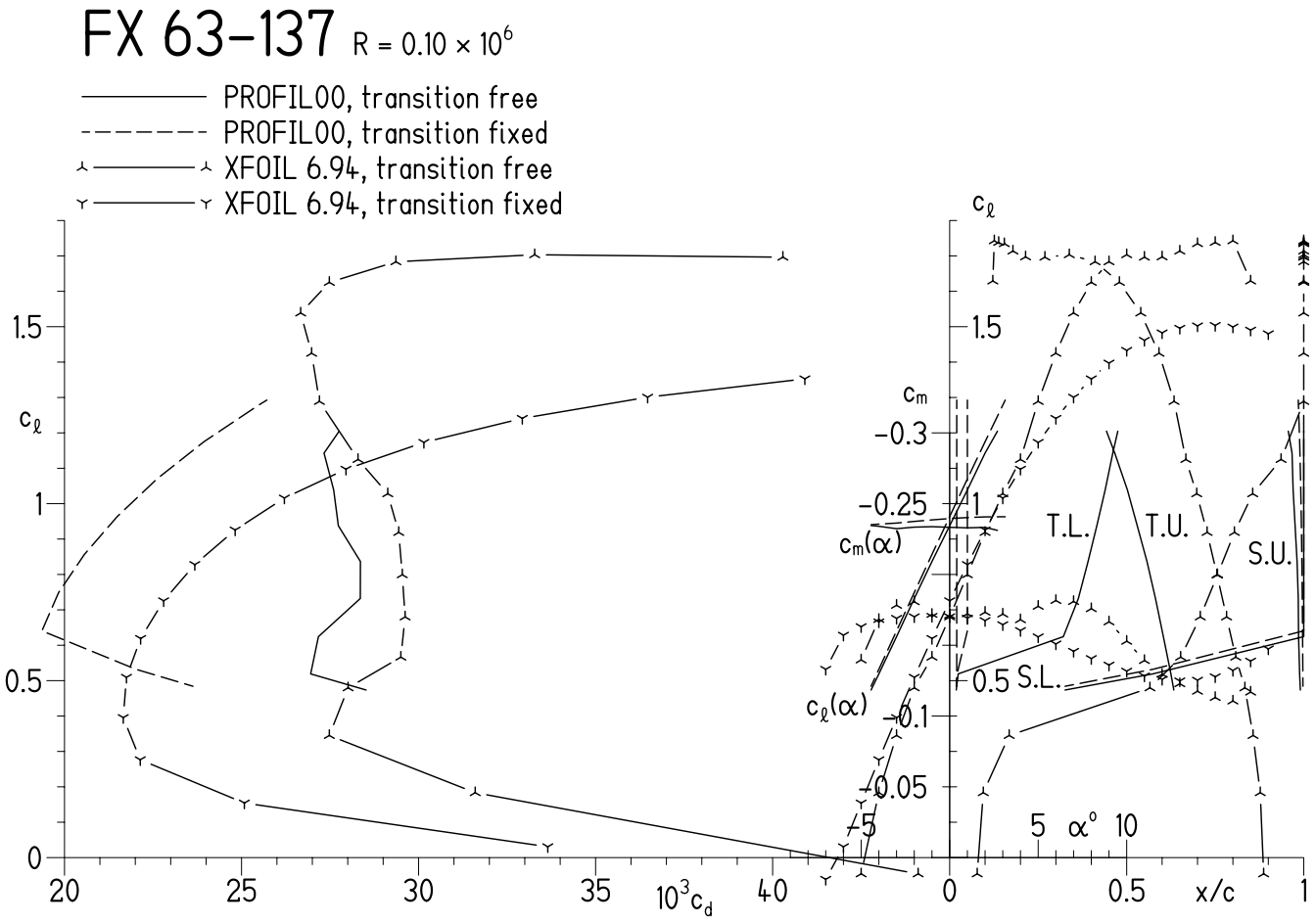
(d) $R = 0.50 \times 10^6$.

Figure 3.- Continued.



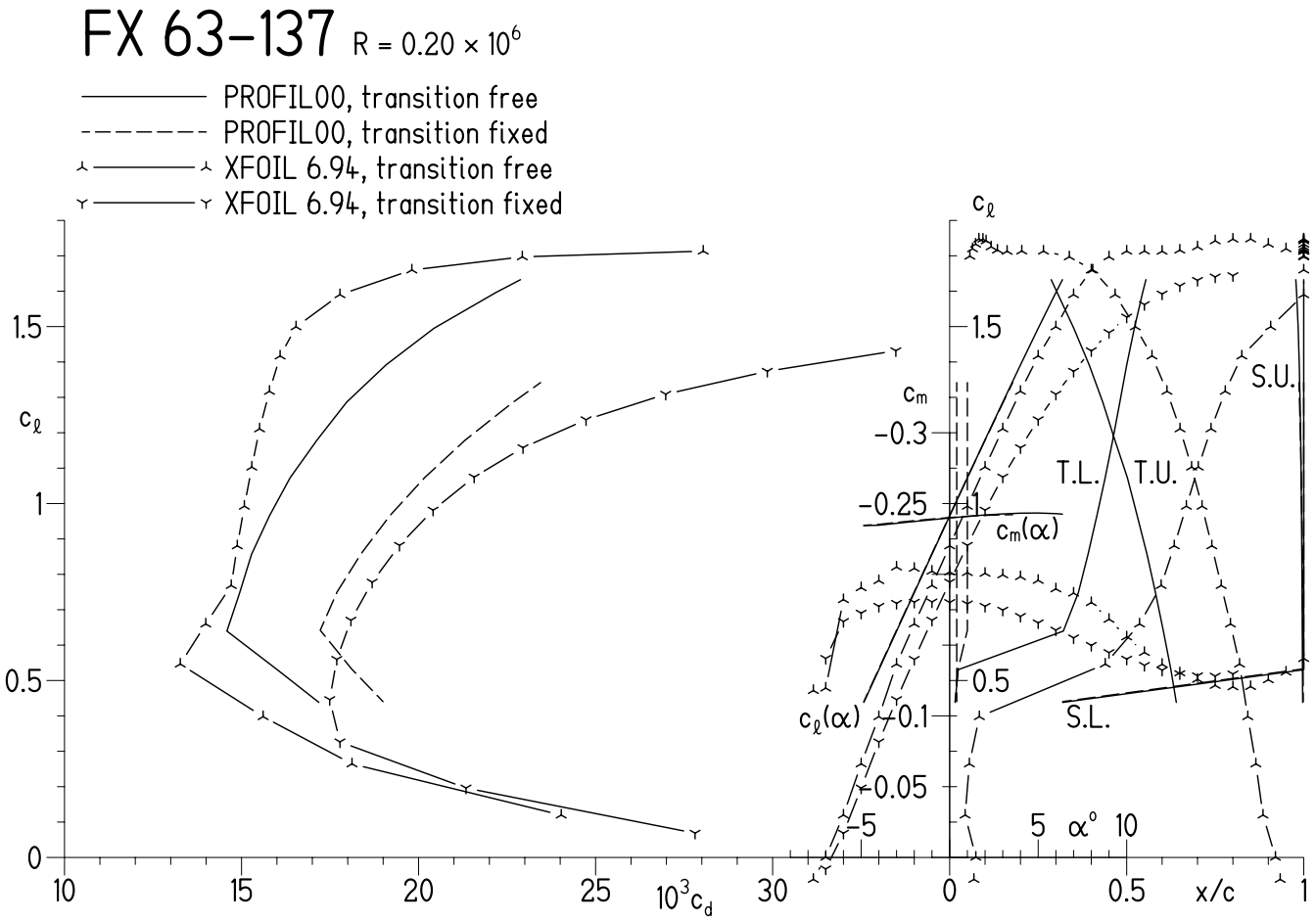
(e) $R = 0.70 \times 10^6$.

Figure 3.- Concluded.



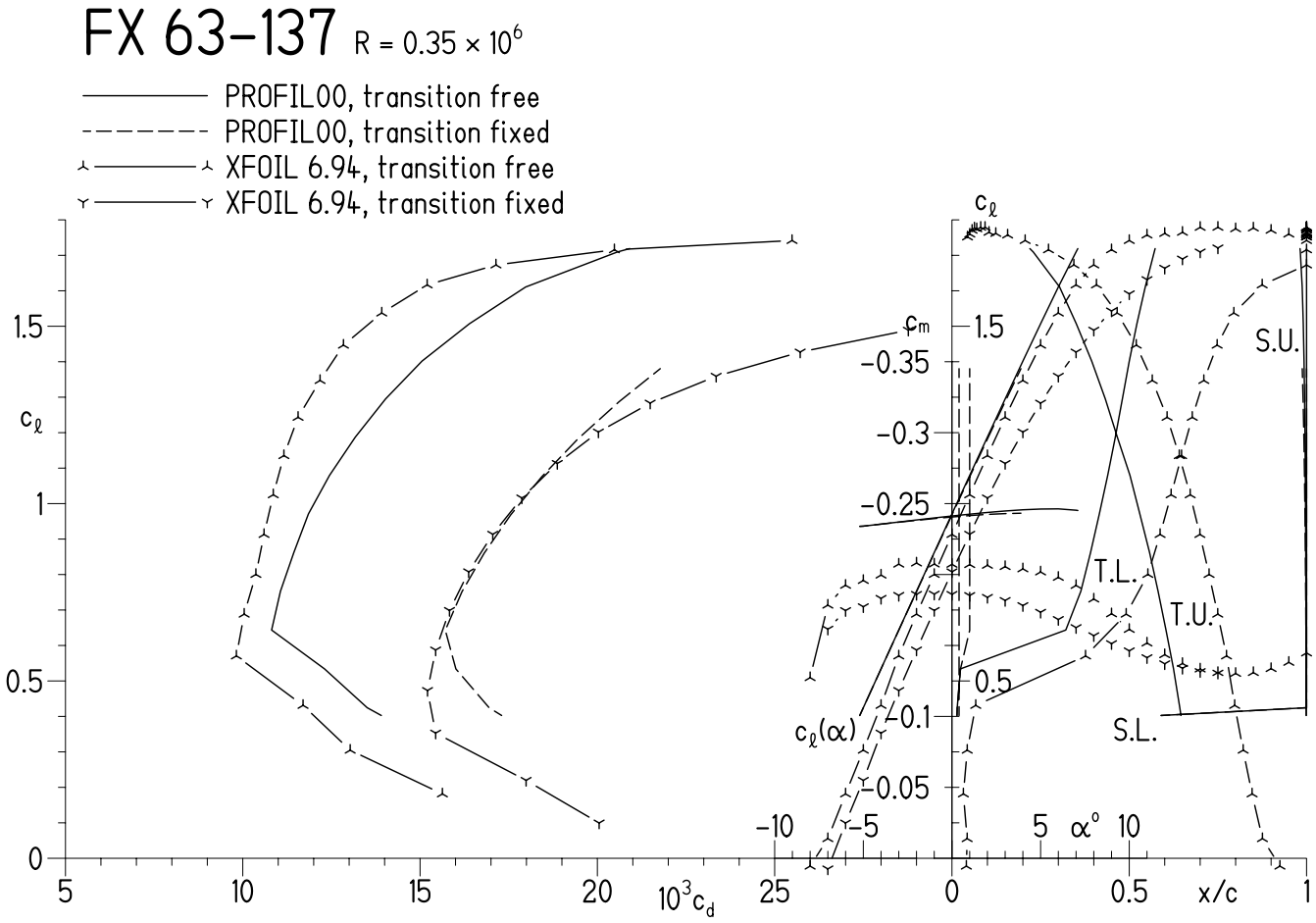
(a) $R = 0.10 \times 10^6$.

Figure 4.- Section characteristics of FX 63-137 airfoil with transition free and transition fixed.



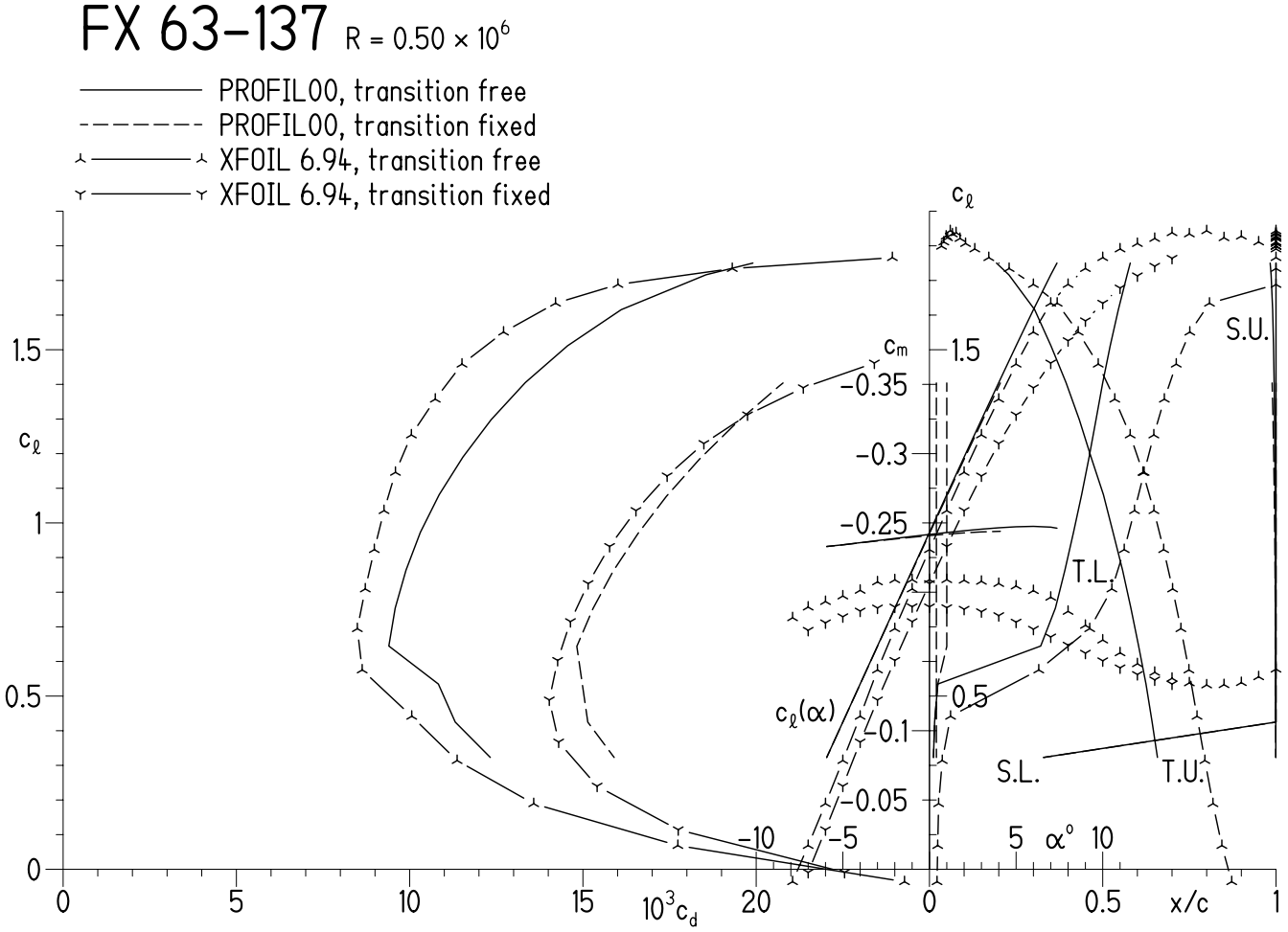
(b) $R = 0.20 \times 10^6$.

Figure 4.- Continued.



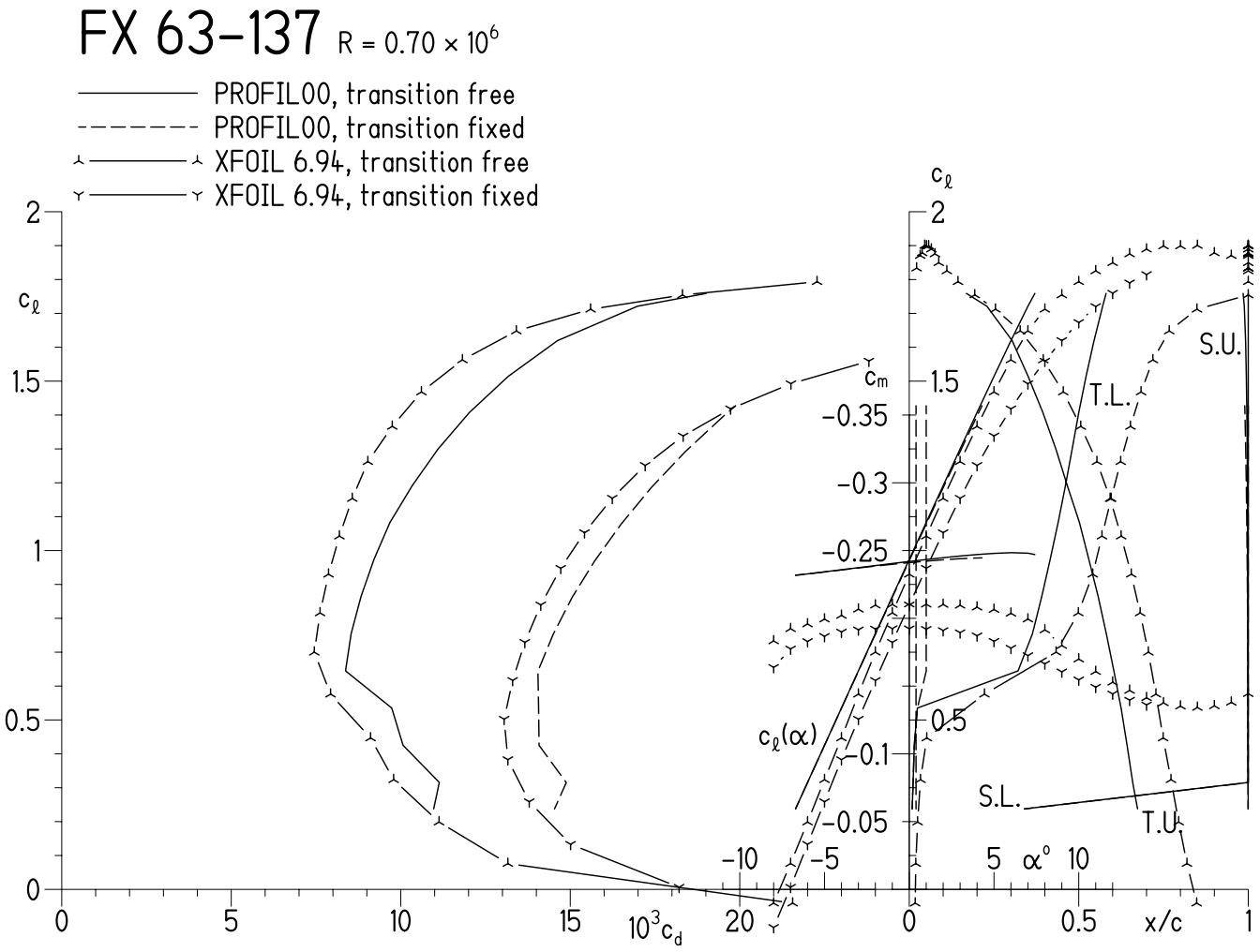
(c) $R = 0.35 \times 10^6$.

Figure 4.- Continued.



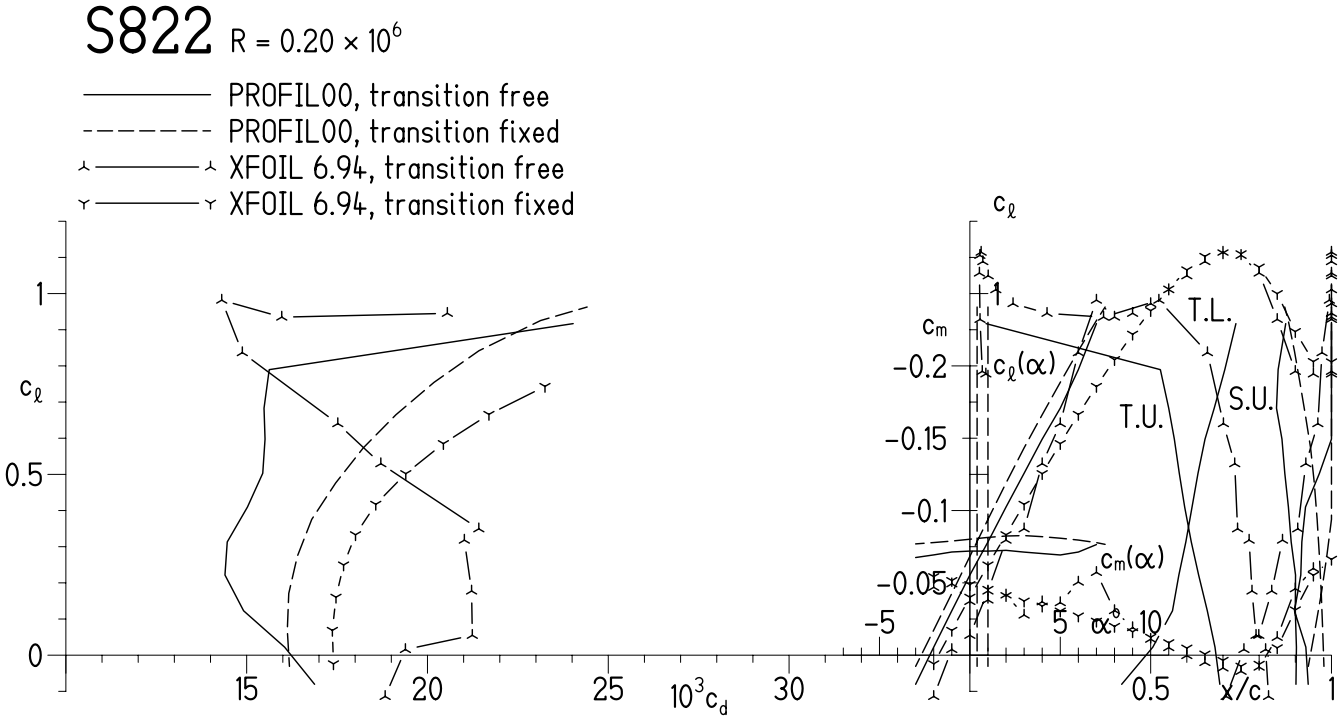
(d) $R = 0.50 \times 10^6$.

Figure 4.- Continued.



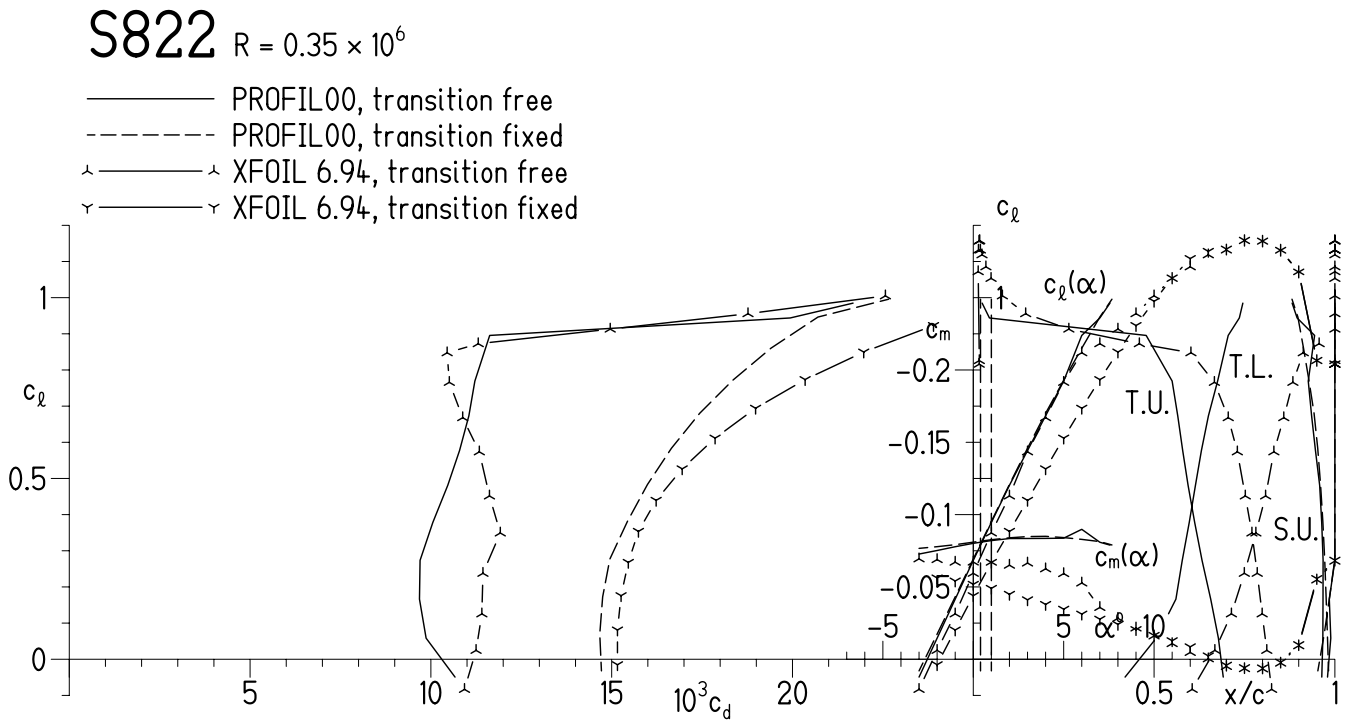
(e) $R = 0.70 \times 10^6$.

Figure 4.- Concluded.



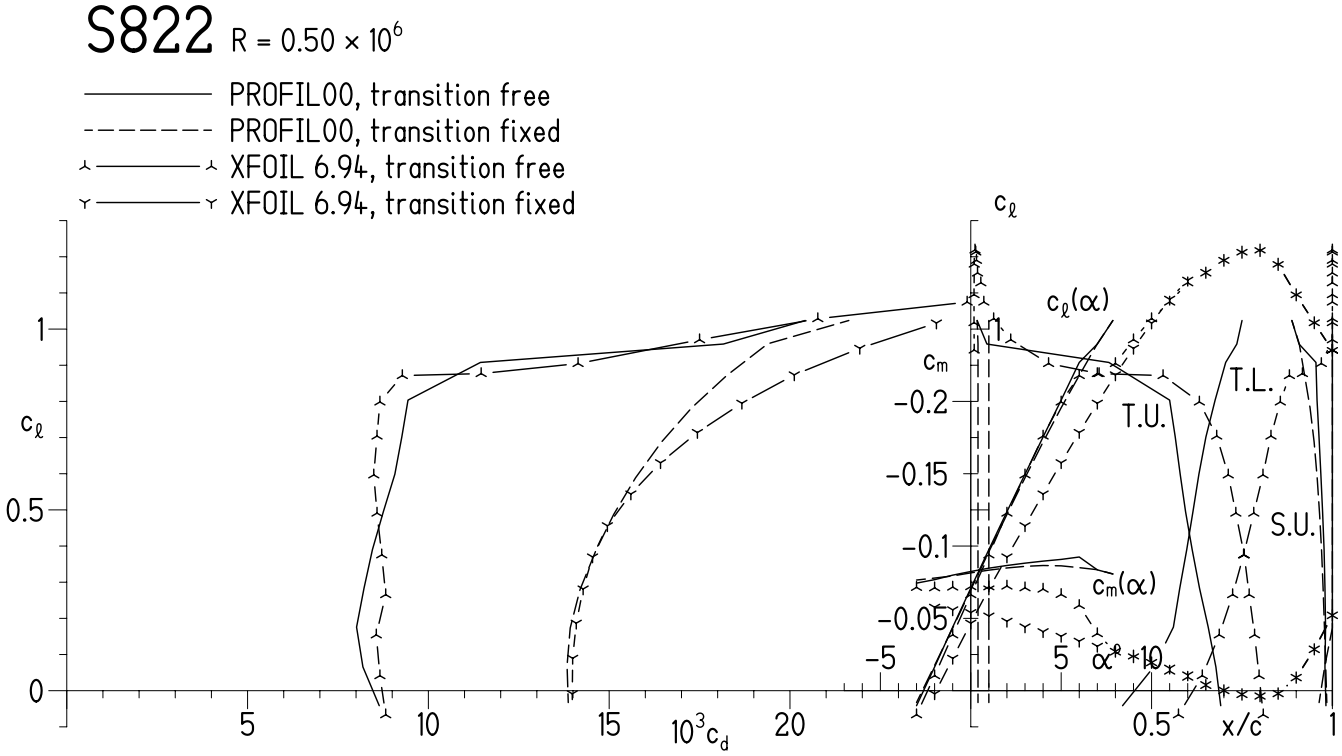
(a) $R = 0.20 \times 10^6$.

Figure 5.- Section characteristics of S822 airfoil with transition free and transition fixed.



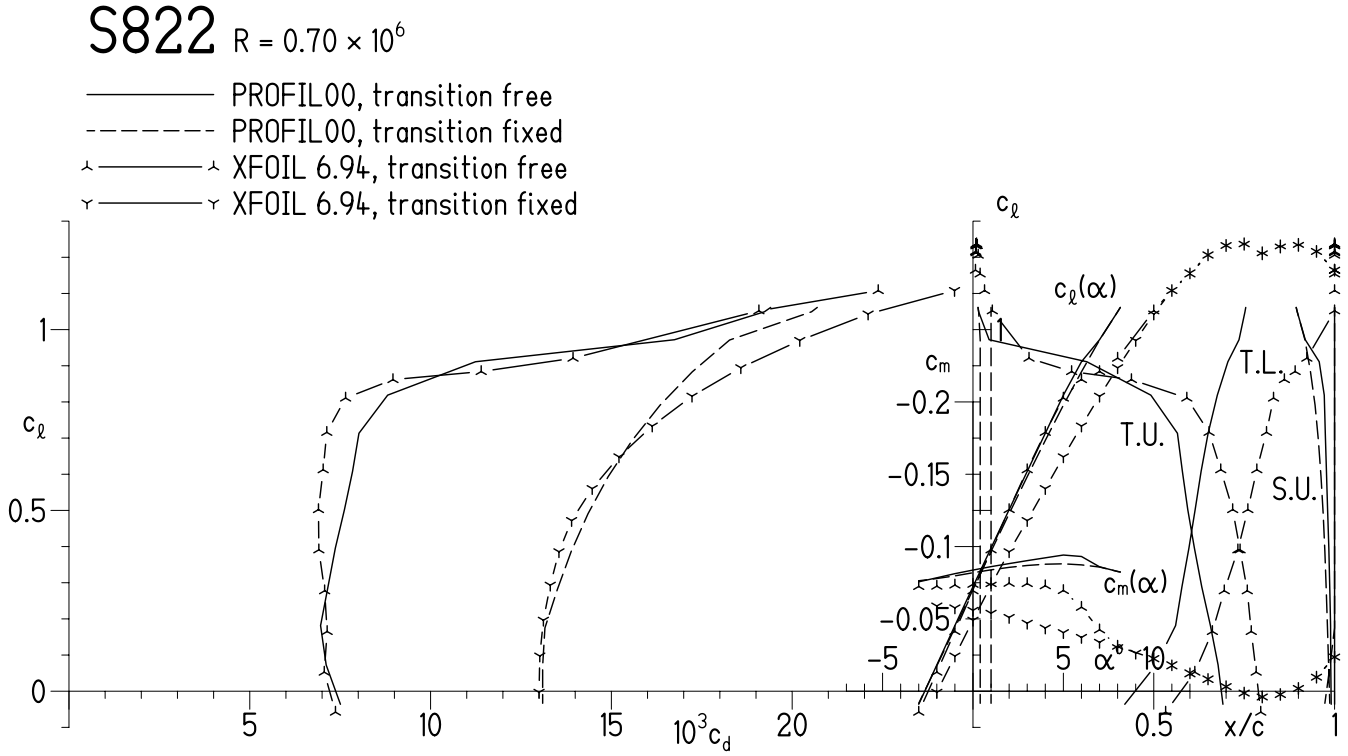
(b) $R = 0.35 \times 10^6$.

Figure 5.- Continued.



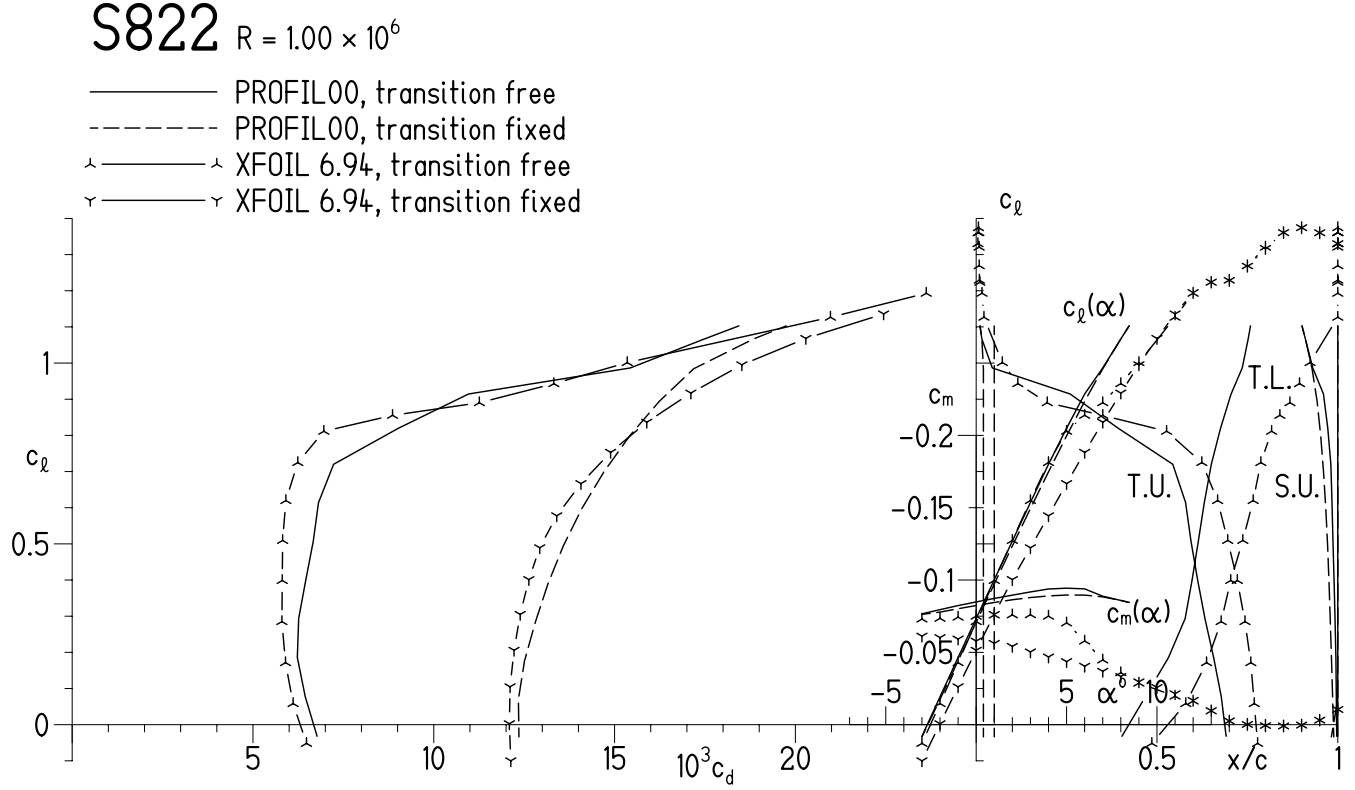
(c) $R = 0.50 \times 10^6$.

Figure 5.- Continued.



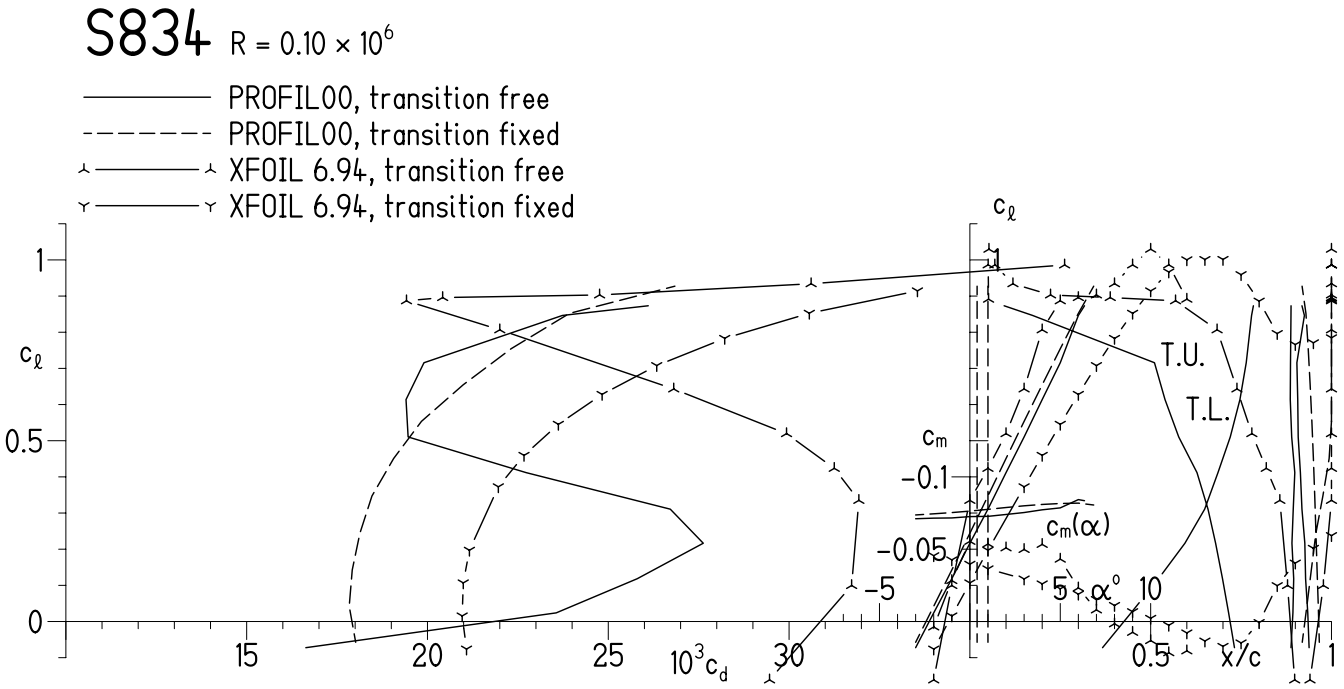
(d) $R = 0.70 \times 10^6$.

Figure 5.- Continued.



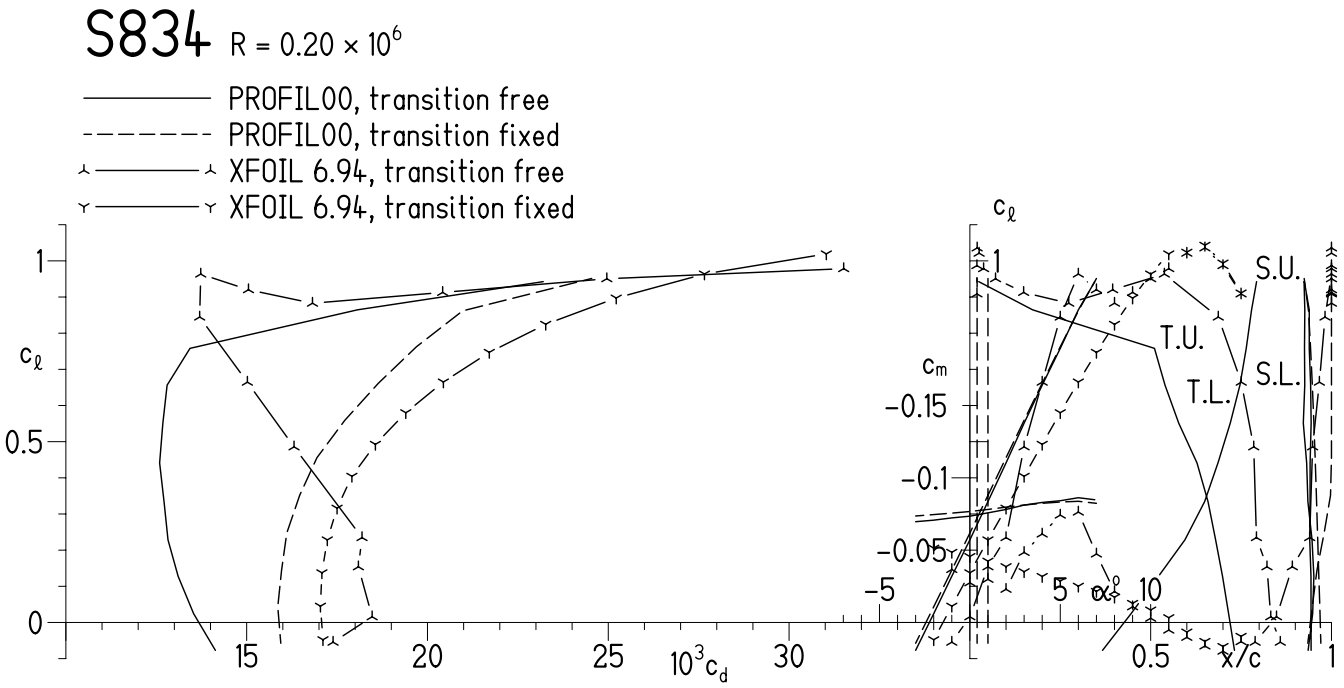
(e) $R = 1.00 \times 10^6$.

Figure 5.- Concluded.



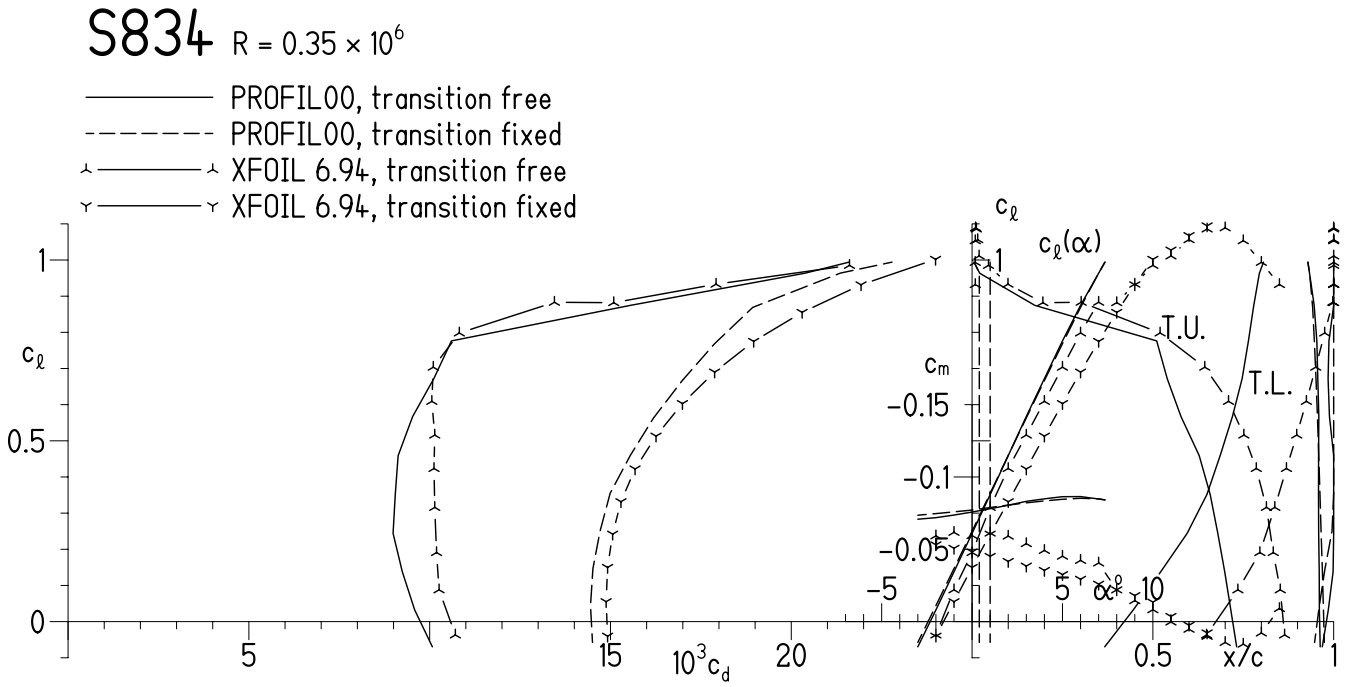
(a) $R = 0.10 \times 10^6$.

Figure 6.- Section characteristics of S834 airfoil with transition free and transition fixed.



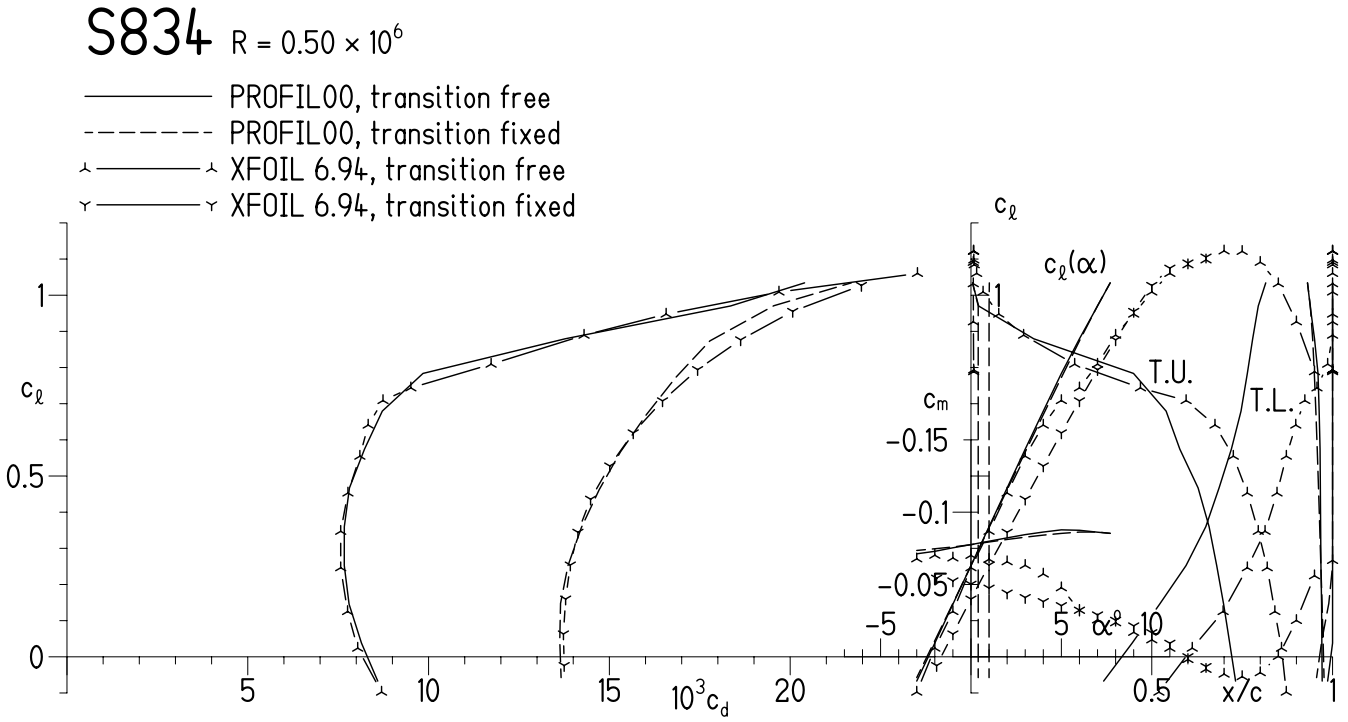
(b) $R = 0.20 \times 10^6$.

Figure 6.- Continued.



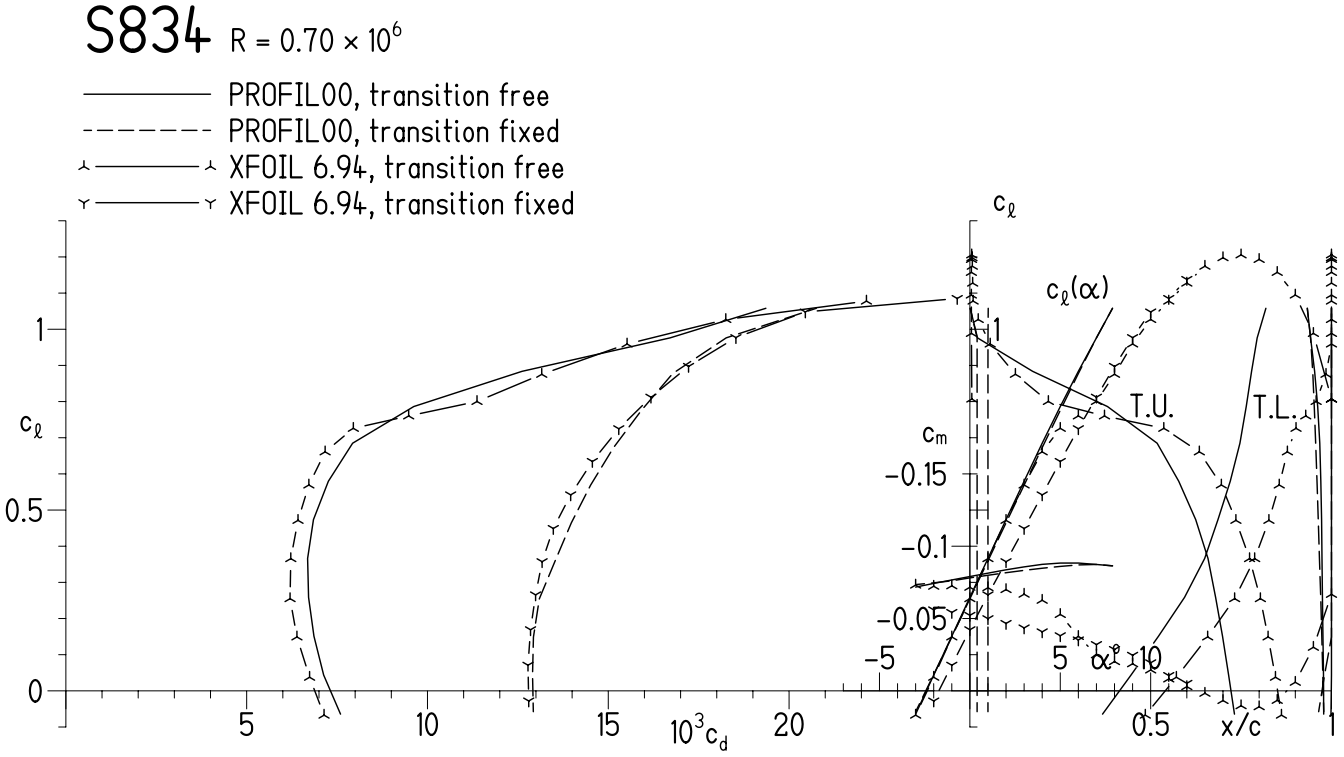
(c) $R = 0.35 \times 10^6$.

Figure 6.- Continued.



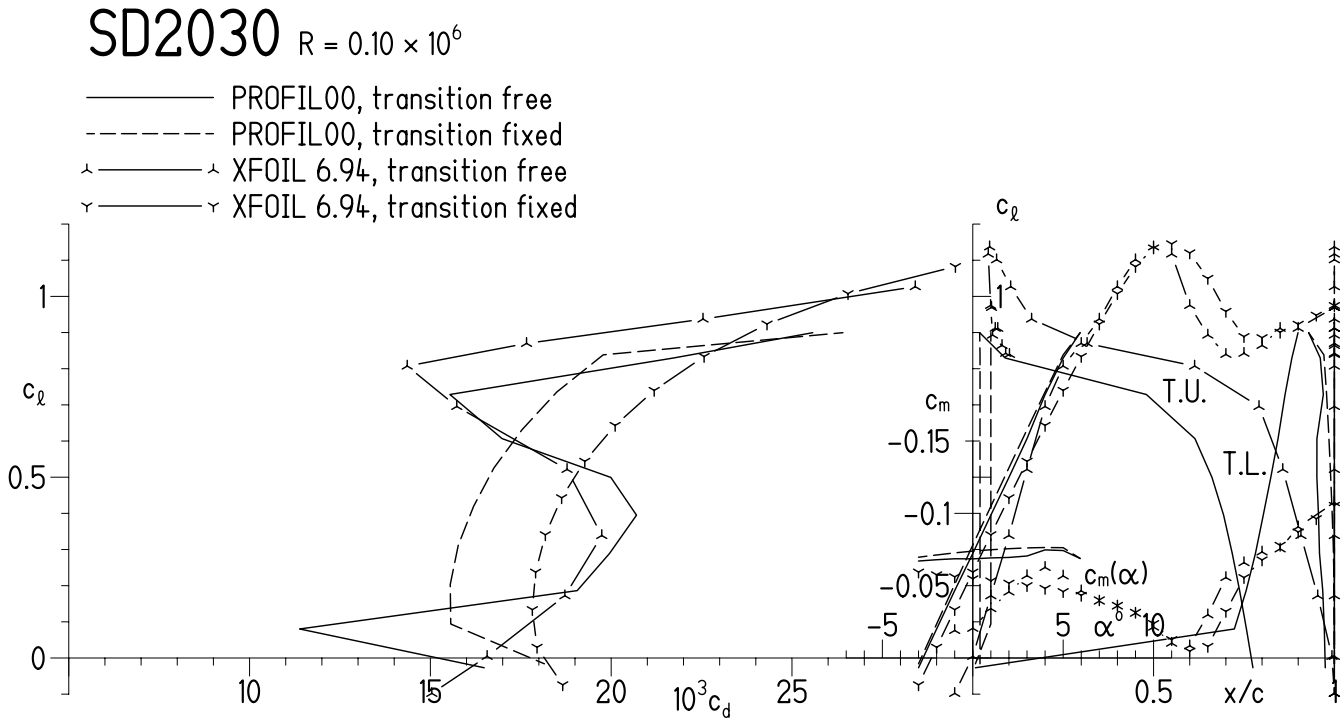
(d) $R = 0.50 \times 10^6$.

Figure 6.- Continued.



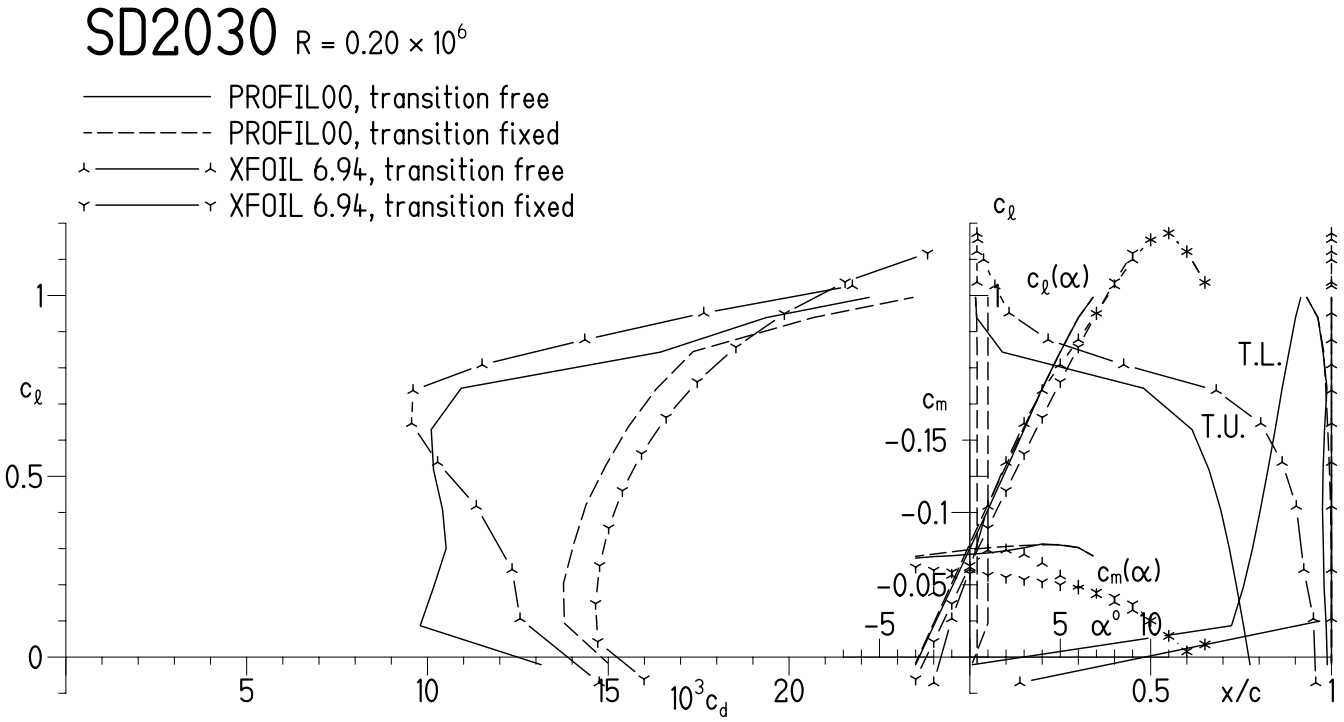
(e) $R = 0.70 \times 10^6$.

Figure 6.- Concluded.



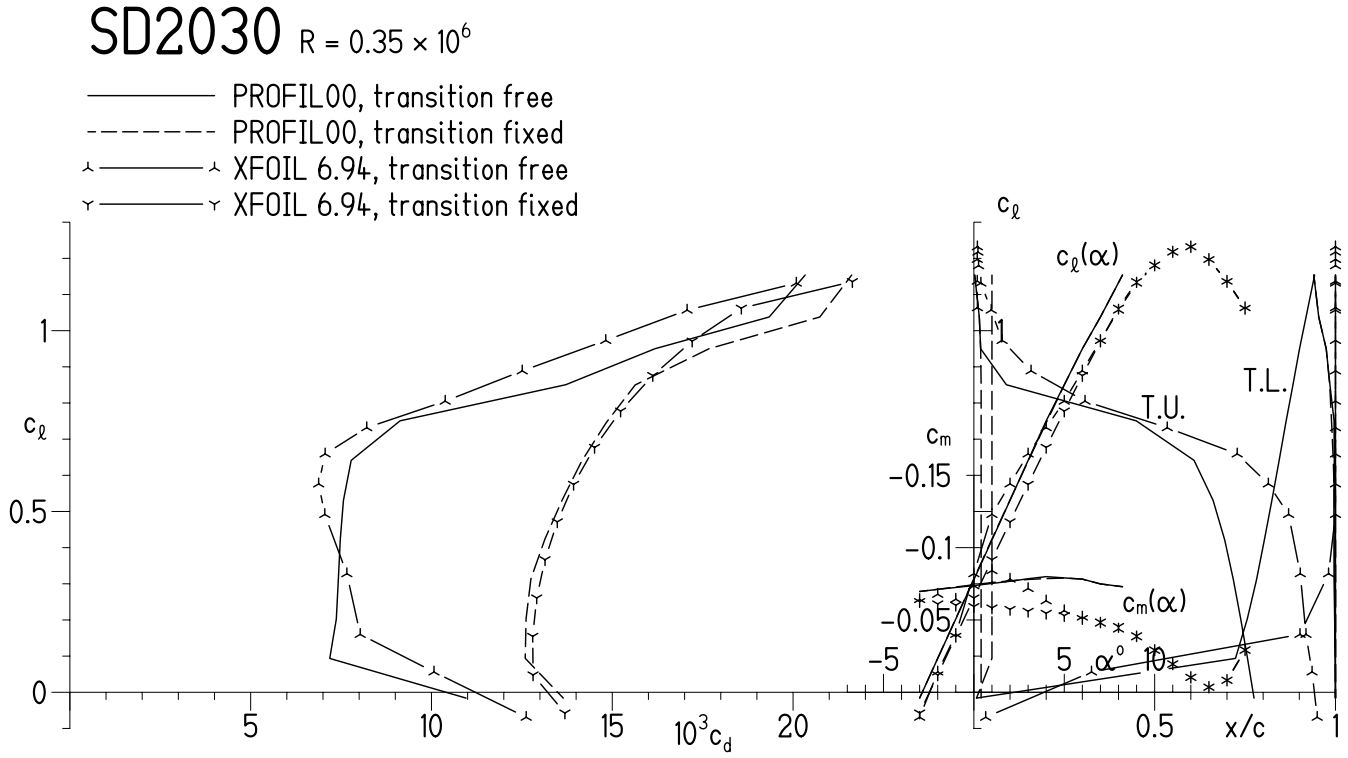
(a) $R = 0.10 \times 10^6$.

Figure 7.- Section characteristics of SD2030 airfoil with transition free and transition fixed.



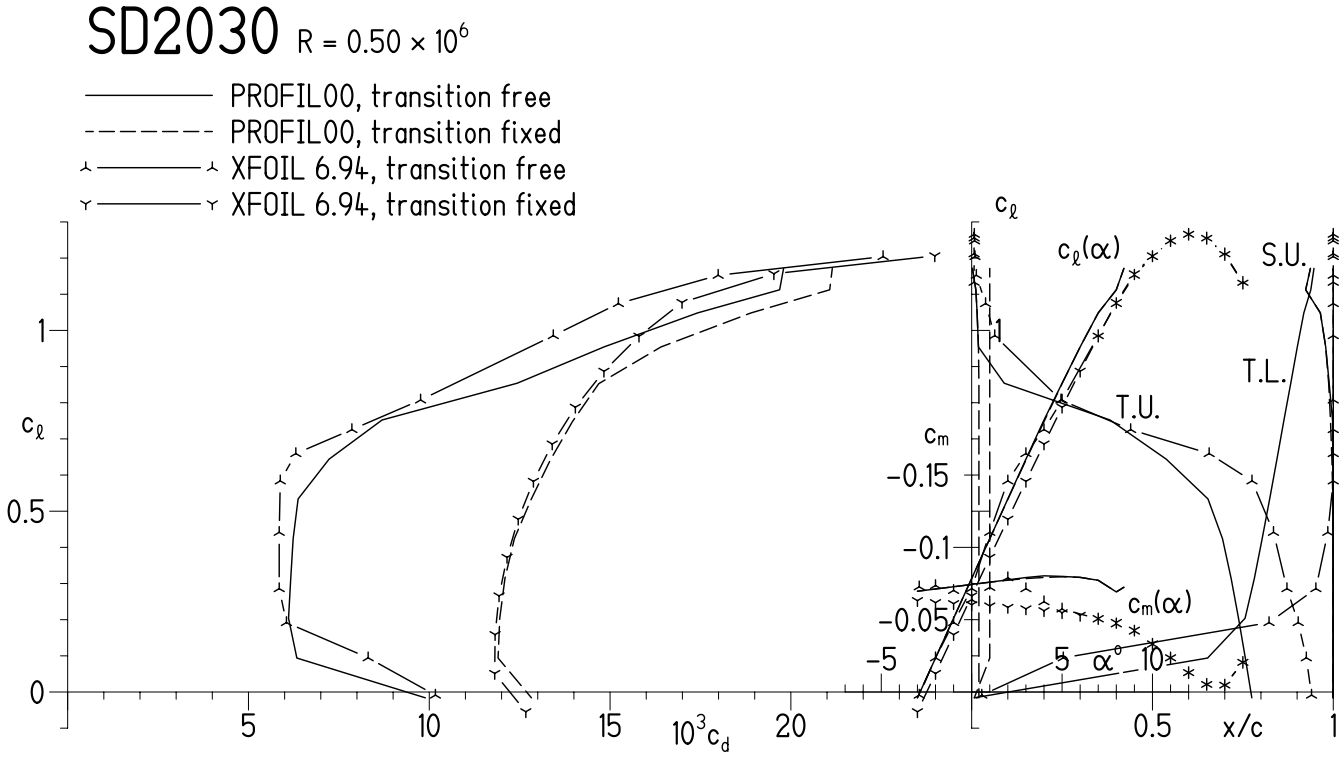
(b) $R = 0.20 \times 10^6$.

Figure 7.- Continued.



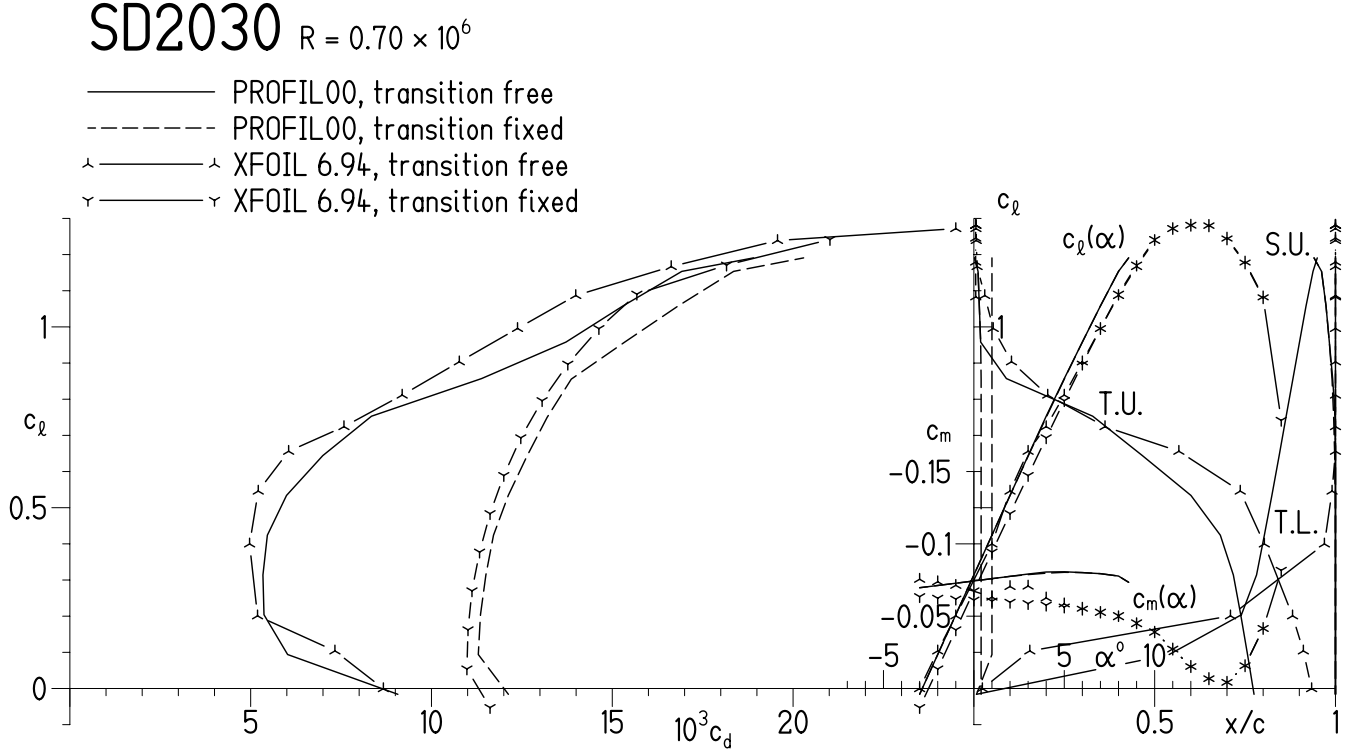
(c) $R = 0.35 \times 10^6$.

Figure 7.- Continued.



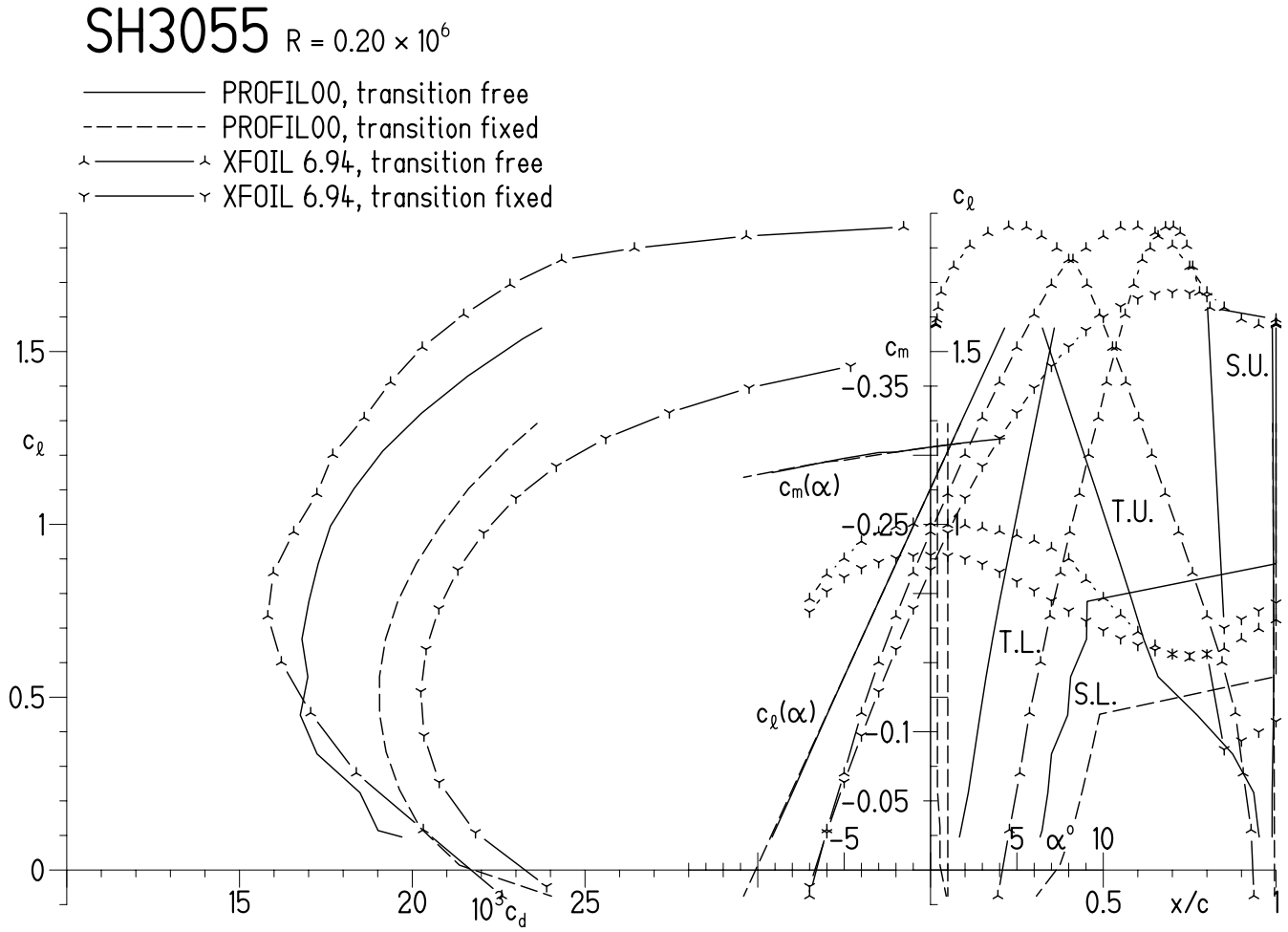
(d) $R = 0.50 \times 10^6$.

Figure 7.- Continued.



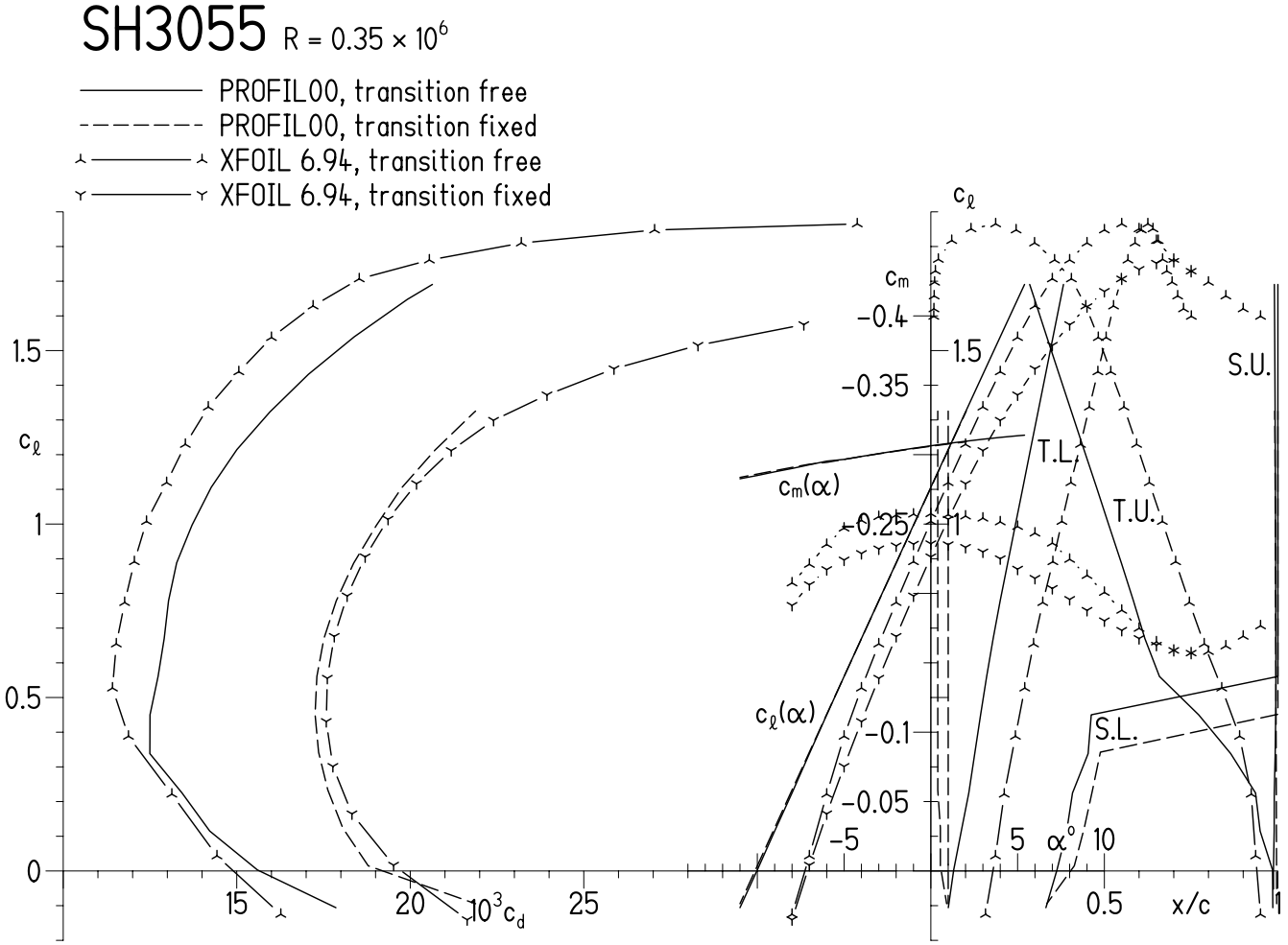
(e) $R = 0.70 \times 10^6$.

Figure 7.- Concluded.



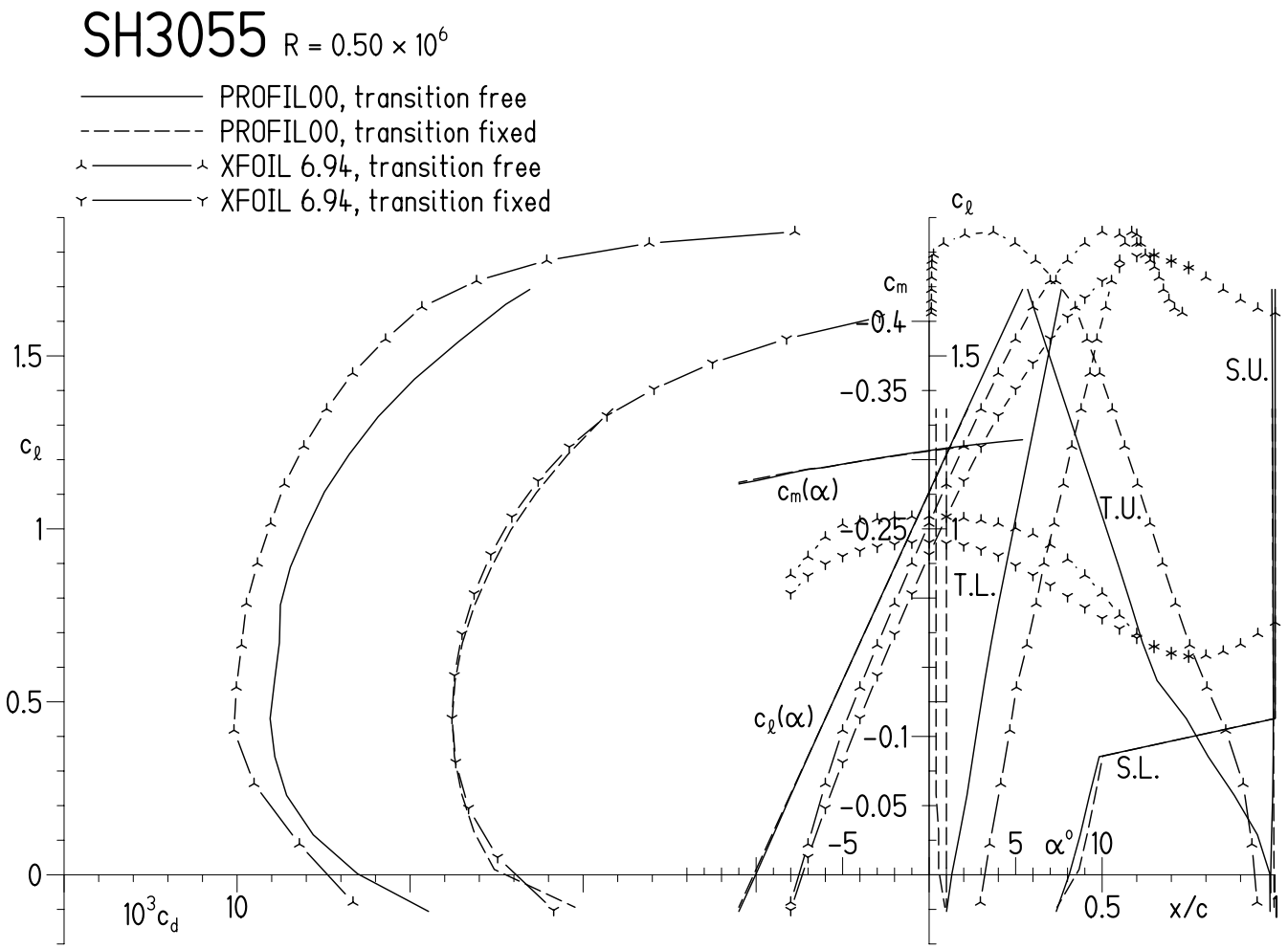
(a) $R = 0.20 \times 10^6$.

Figure 8.- Section characteristics of SH3055 airfoil with transition free and transition fixed.



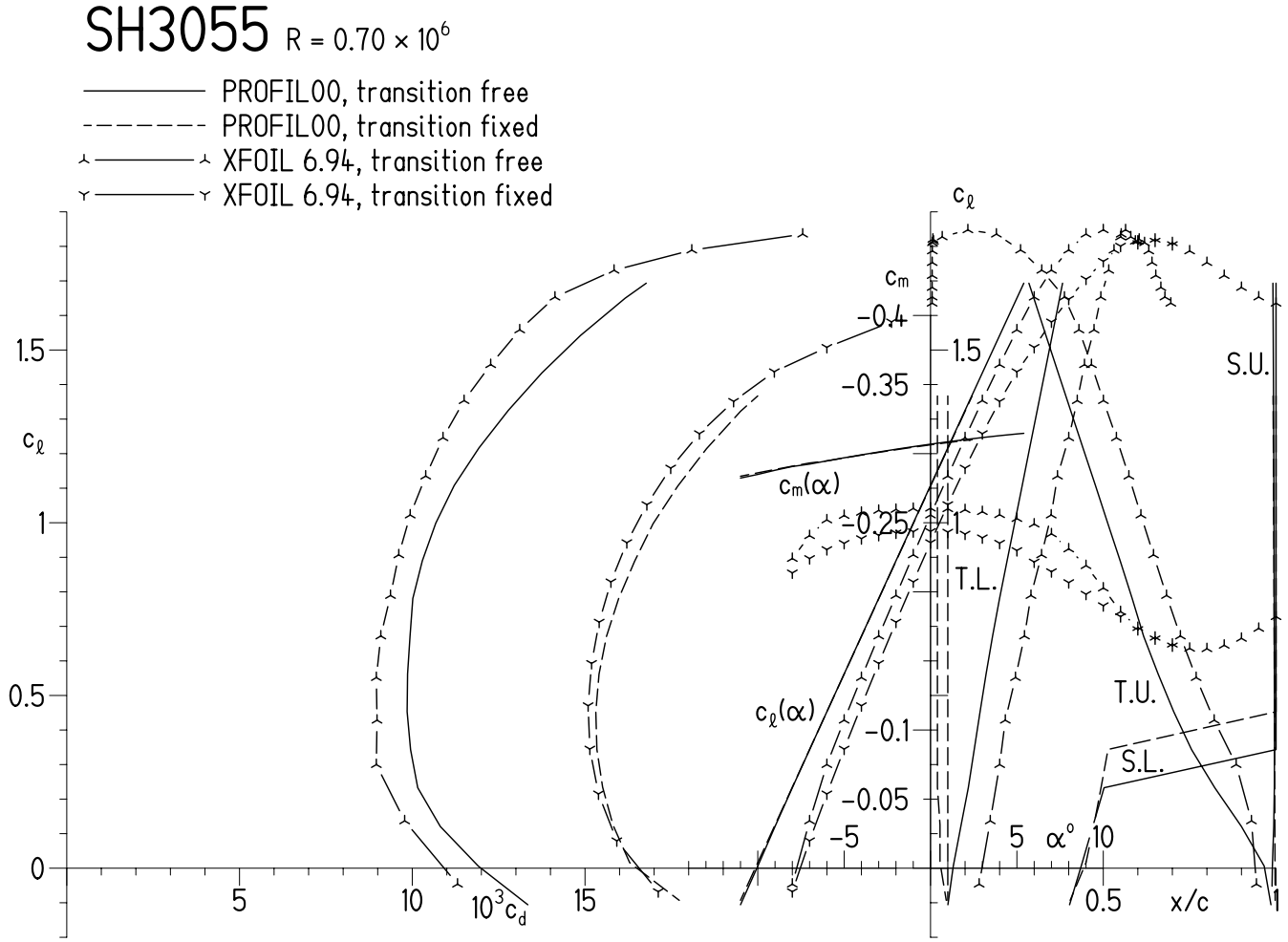
(b) $R = 0.35 \times 10^6$.

Figure 8.- Continued.



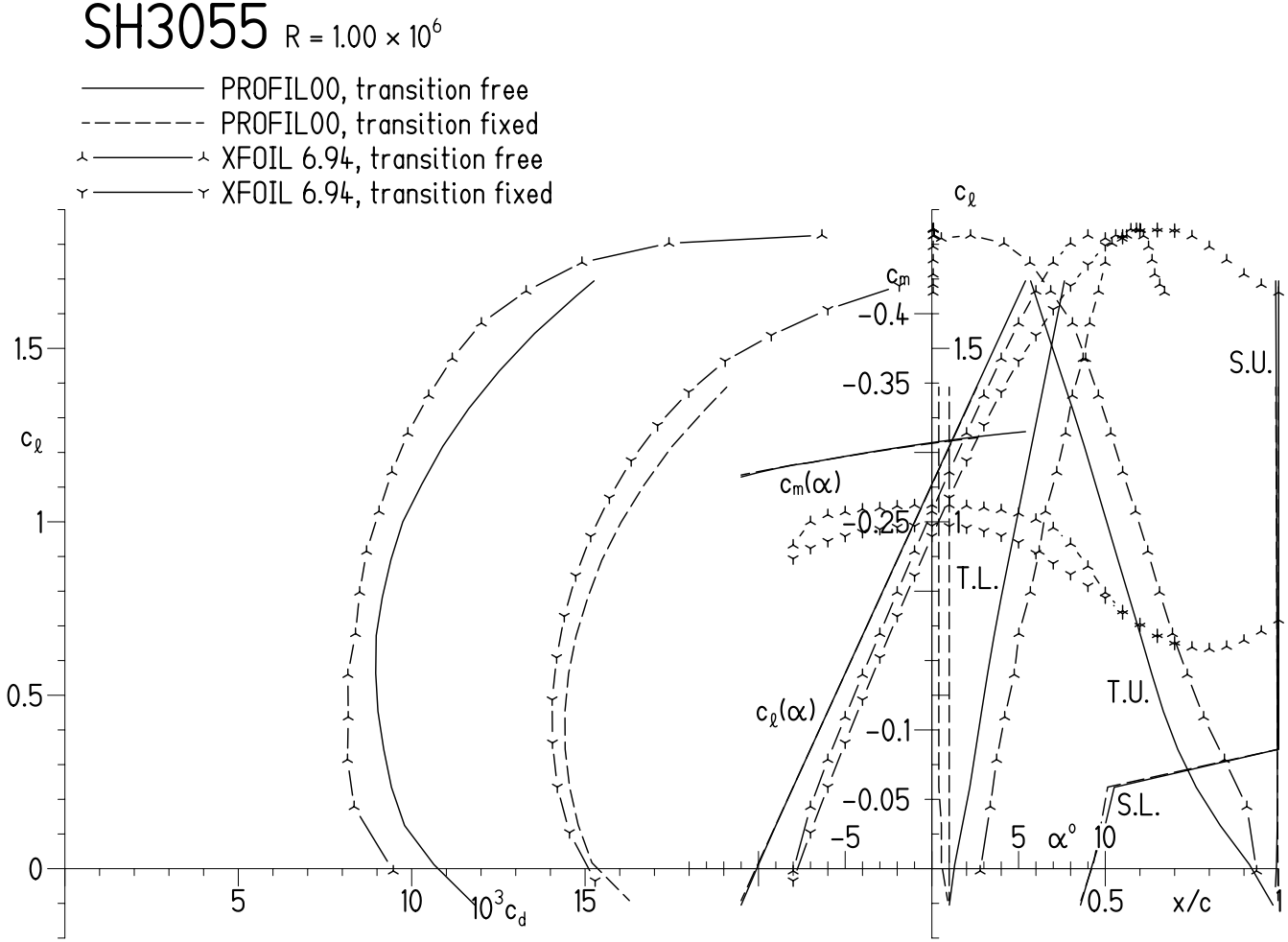
(c) $R = 0.50 \times 10^6$.

Figure 8.- Continued.



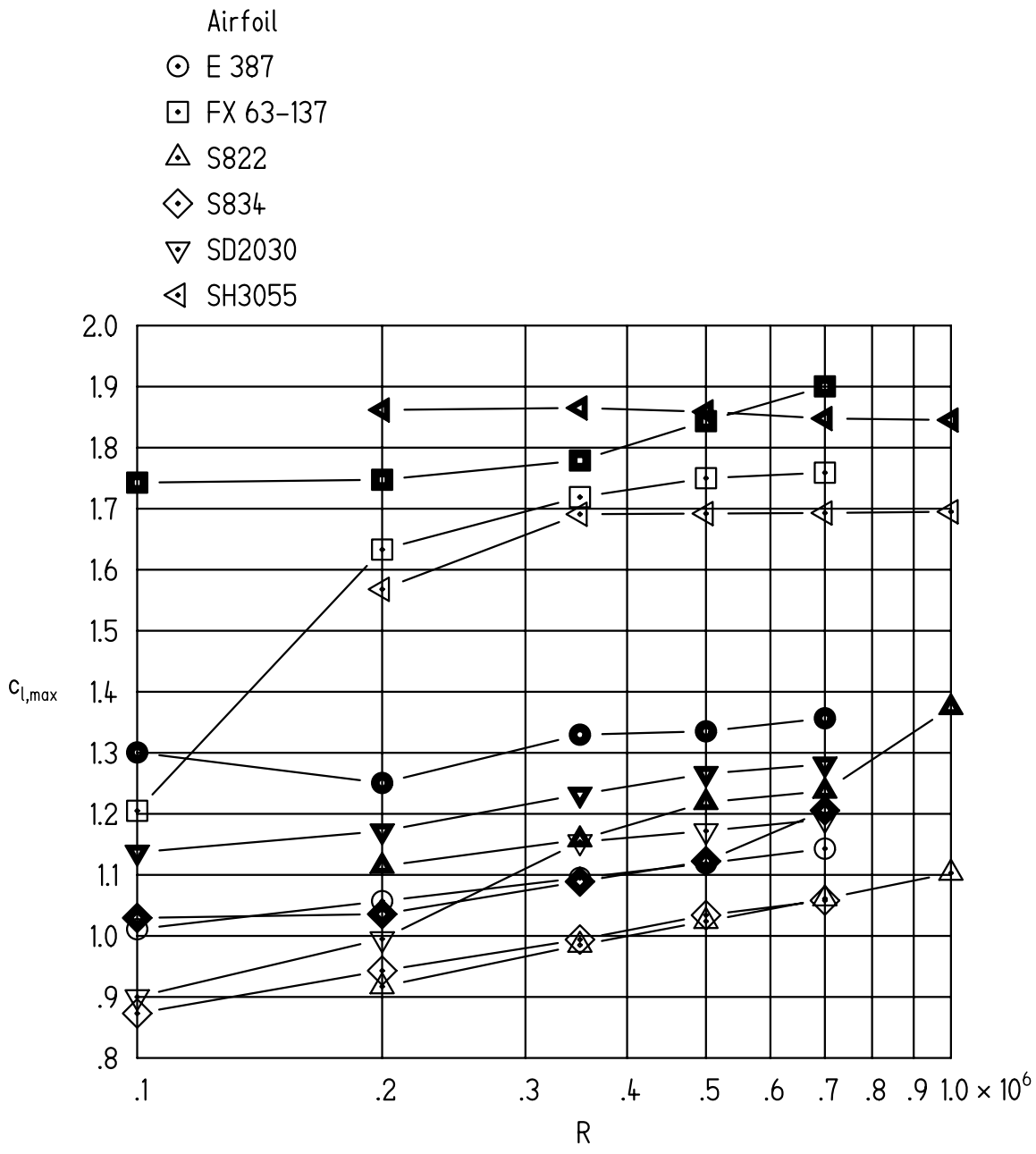
(d) $R = 0.70 \times 10^6$.

Figure 8.- Continued.



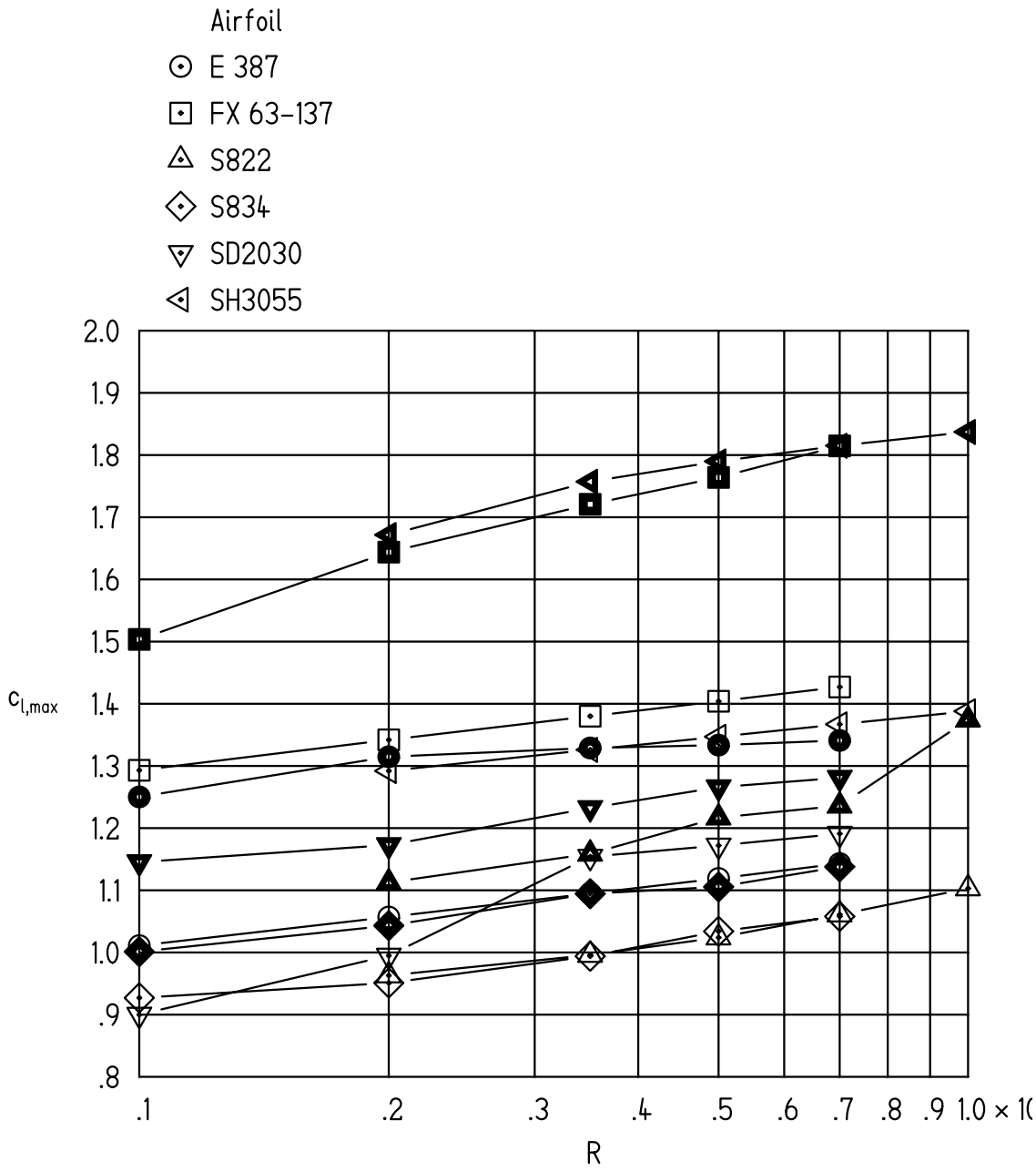
(e) $R = 1.00 \times 10^6$.

Figure 8.- Concluded.



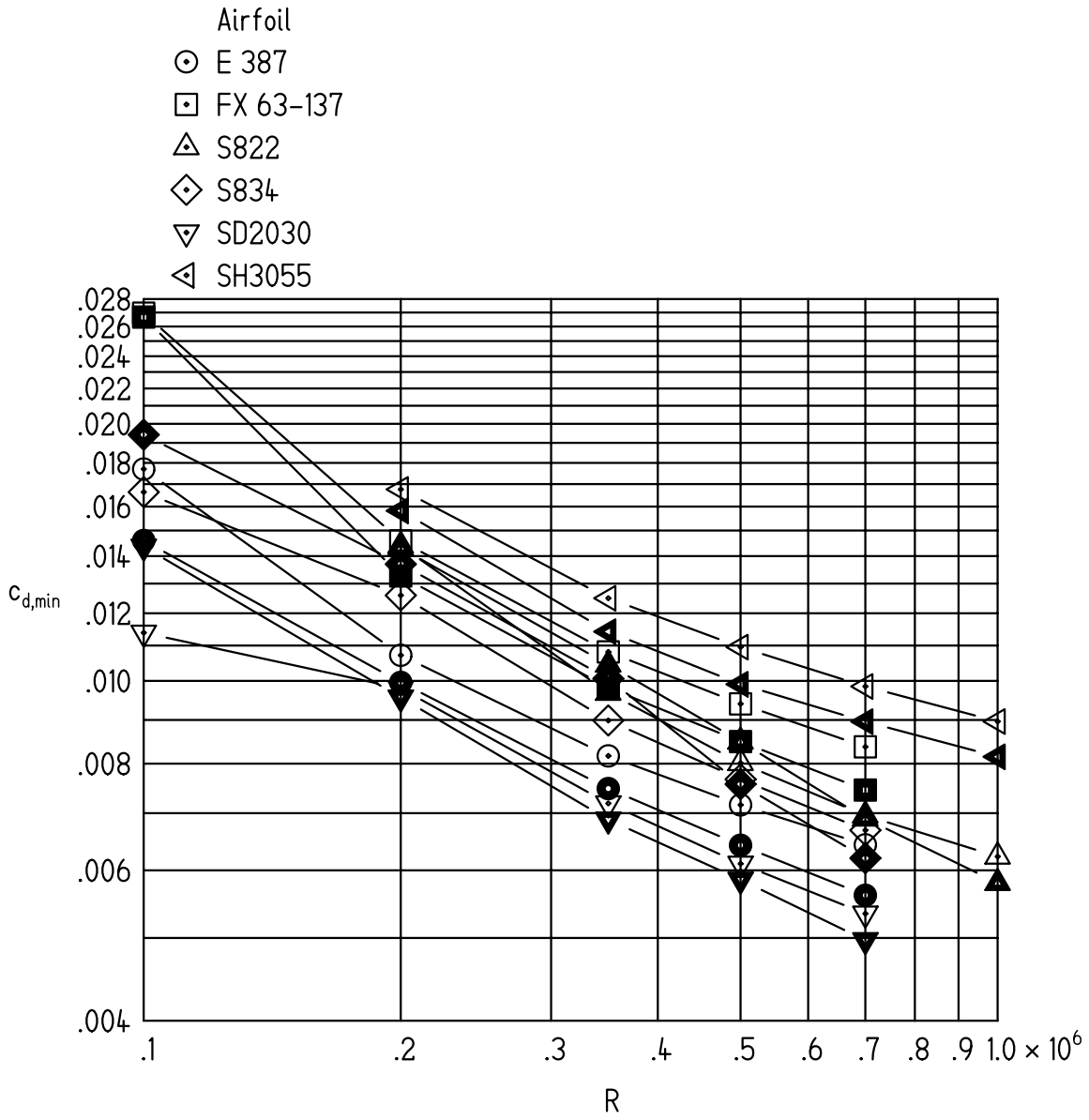
(a) Transition free.

Figure 9.- Variation of maximum lift coefficient with Reynolds number. Open symbols represent PROFIL00 results; solid symbols, XFOIL 6.94 results.



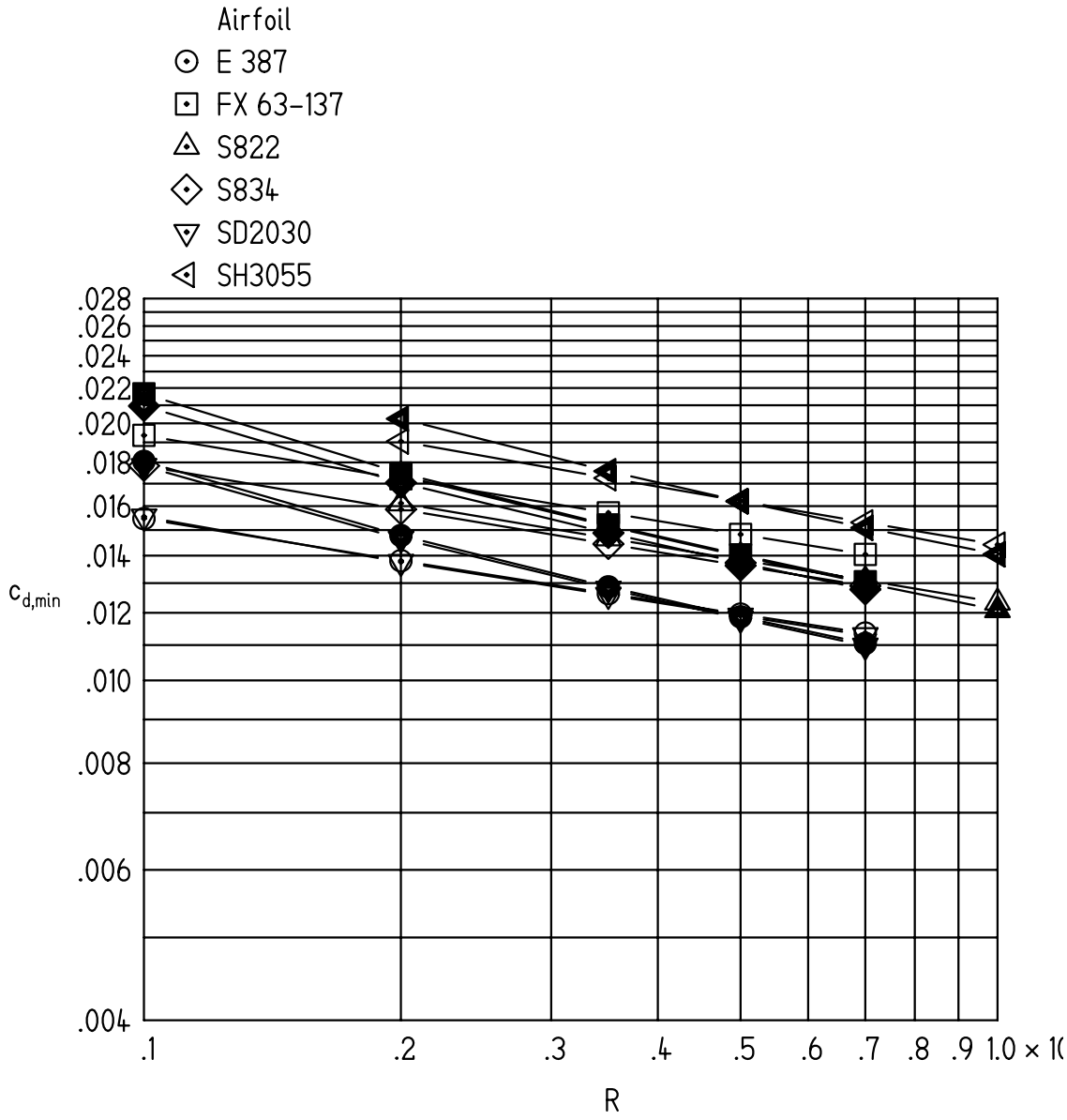
(b) Transition fixed.

Figure 9.- Concluded.



(a) Transition free.

Figure 10.- Variation of minimum profile-drag coefficient with Reynolds number. Open symbols represent PROFIL00 results; solid symbols, XFOIL 6.94 results.



(b) Transition fixed.

Figure 10.- Concluded.

APPENDIX A

SECTION CHARACTERISTICS OF E 387 AIRFOIL

$R = 0.10 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-2.71	0.098	0.020307	-0.0799	0.101	0.017276	-0.0805
-2.00	0.173	0.020880	-0.0800	0.179	0.017248	-0.0814
-1.00	0.277	0.017703	-0.0798	0.289	0.015470	-0.0827
0.00	0.379	0.018868	-0.0792	0.399	0.015705	-0.0840
1.00	0.449	0.020209	-0.0728	0.509	0.016168	-0.0854
2.00	0.542	0.020927	-0.0710	0.617	0.016859	-0.0863
3.00	0.582	0.022456	-0.0629	0.721	0.017712	-0.0864
4.00	0.673	0.023437	-0.0615	0.822	0.018774	-0.0857
5.00	0.719	0.024554	-0.0572	0.918	0.020076	-0.0839
6.00	0.827	0.024221	-0.0571	1.002	0.021646	-0.0799
6.50	1.011	0.023653	-0.0723	1.011	0.024568	-0.0723

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-4.00	-0.0783	0.03174	-0.0893	-0.0803	0.02999	-0.0786
-3.00	0.0730	0.02135	-0.0956	0.0301	0.02187	-0.0771
-2.00	0.1826	0.01522	-0.0940	0.1373	0.01819	-0.0746
-1.00	0.3151	0.01460	-0.0956	0.2450	0.01805	-0.0737
0.00	0.4172	0.01555	-0.0937	0.3520	0.01821	-0.0729
1.00	0.5187	0.01677	-0.0920	0.4576	0.01858	-0.0721
2.00	0.6198	0.01824	-0.0905	0.5625	0.01914	-0.0712
3.00	0.7210	0.01977	-0.0889	0.6654	0.01989	-0.0701
4.00	0.8220	0.02113	-0.0867	0.7659	0.02084	-0.0688
5.00	0.9233	0.02194	-0.0836	0.8632	0.02202	-0.0671
6.00	1.0267	0.02169	-0.0795	0.9561	0.02349	-0.0649
7.00	1.1285	0.01987	-0.0737	1.0427	0.02534	-0.0619
8.00	1.1830	0.02109	-0.0631	1.1194	0.02777	-0.0578
9.00	1.1559	0.03149	-0.0471	1.1727	0.03148	-0.0509
10.00	1.2222	0.04002	-0.0410	1.1933	0.03806	-0.0429
11.00	1.3006	0.05206	-0.0378	1.2040	0.04719	-0.0375
12.00	1.2733	0.06631	-0.0292	1.2409	0.05691	-0.0329
13.00	1.1947	0.08644	-0.0304	1.2502	0.07103	-0.0309
14.00	1.0961	0.11630	-0.0460	1.2041	0.09133	-0.0357
15.00	0.7719	0.15607	-0.0698	1.1308	0.12014	-0.0512
16.00	1.0032	0.20759	-0.0930	1.0400	0.16777	-0.0817
17.00	1.0154	0.22360	-0.1038	1.0214	0.20270	-0.0998
18.00	1.0218	0.23932	-0.1174	1.0343	0.22539	-0.1117
19.00	1.0585	0.25794	-0.1228	1.0550	0.24502	-0.1225
20.00	1.0811	0.27017	-0.1333	1.0791	0.26294	-0.1329

$R = 0.20 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-2.88	0.082	0.014089	-0.0803	0.082	0.014625	-0.0803
-2.00	0.179	0.013970	-0.0814	0.179	0.014531	-0.0814
-1.00	0.289	0.010716	-0.0827	0.289	0.013810	-0.0827
0.00	0.399	0.011025	-0.0840	0.399	0.014048	-0.0840
1.00	0.508	0.011601	-0.0850	0.509	0.014404	-0.0854
2.00	0.615	0.012064	-0.0858	0.619	0.015005	-0.0868
3.00	0.716	0.012687	-0.0852	0.726	0.015740	-0.0876
4.00	0.818	0.013489	-0.0847	0.830	0.016623	-0.0875
5.00	0.915	0.013980	-0.0834	0.929	0.017702	-0.0865
6.00	1.019	0.014517	-0.0836	1.023	0.018986	-0.0845
7.00	1.057	0.022579	-0.0715	1.057	0.023812	-0.0715
7.01	1.057	0.022632	-0.0713	1.057	0.023864	-0.0713

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-4.00				-0.0725	0.02454	-0.0787
-3.80	-0.0205	0.03097	-0.0899			
-3.00	0.0735	0.01848	-0.0879	0.0364	0.01811	-0.0771
-2.00	0.1825	0.01354	-0.0850	0.1448	0.01484	-0.0755
-1.00	0.2914	0.01200	-0.0839	0.2541	0.01478	-0.0749
0.00	0.4022	0.00996	-0.0833	0.3626	0.01492	-0.0744
1.00	0.5099	0.01071	-0.0826	0.4701	0.01522	-0.0739
2.00	0.6182	0.01128	-0.0822	0.5764	0.01566	-0.0732
3.00	0.7253	0.01216	-0.0816	0.6812	0.01626	-0.0724
4.00	0.8324	0.01242	-0.0804	0.7840	0.01701	-0.0714
5.00	0.9337	0.01170	-0.0771	0.8843	0.01794	-0.0700
6.00	1.0300	0.01257	-0.0744	0.9812	0.01909	-0.0683
7.00	1.1121	0.01528	-0.0707	1.0733	0.02052	-0.0658
8.00	1.1443	0.02292	-0.0604	1.1558	0.02257	-0.0620
9.00	1.1754	0.02956	-0.0499	1.2021	0.02668	-0.0531
10.00	1.2506	0.04214	-0.0449	1.2177	0.03323	-0.0432
11.00	1.2427	0.06044	-0.0341	1.2675	0.04116	-0.0374
12.00	1.1474	0.08210	-0.0332	1.3148	0.05219	-0.0330
13.00				1.2938	0.06682	-0.0297
14.00				1.2355	0.08678	-0.0337

$R = 0.35 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.12	0.056	0.012025	-0.0800	0.056	0.013710	-0.0800
-3.00	0.069	0.011984	-0.0801	0.069	0.013672	-0.0801
-2.00	0.179	0.011302	-0.0814	0.179	0.013091	-0.0814
-1.00	0.289	0.008400	-0.0827	0.289	0.012640	-0.0827
0.00	0.399	0.008169	-0.0840	0.399	0.012869	-0.0840
1.00	0.509	0.008462	-0.0854	0.509	0.013204	-0.0854
2.00	0.619	0.008737	-0.0868	0.619	0.013636	-0.0868
3.00	0.729	0.009239	-0.0883	0.728	0.014340	-0.0881
4.00	0.839	0.009781	-0.0898	0.834	0.015113	-0.0886
5.00	0.947	0.010424	-0.0907	0.936	0.016048	-0.0882
6.00	1.052	0.011037	-0.0912	1.034	0.017152	-0.0870
7.00	1.092	0.019928	-0.0776	1.092	0.021343	-0.0776
7.19	1.095	0.020823	-0.0746	1.095	0.022213	-0.0746

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-4.00	-0.0405	0.01679	-0.0838	-0.0684	0.02076	-0.0786
-3.00	0.0670	0.01254	-0.0820	0.0401	0.01564	-0.0772
-2.00	0.1759	0.01017	-0.0809	0.1486	0.01321	-0.0762
-1.00	0.2771	0.00788	-0.0797	0.2591	0.01287	-0.0757
0.00	0.3982	0.00748	-0.0807	0.3685	0.01302	-0.0753
1.00	0.5079	0.00788	-0.0802	0.4771	0.01330	-0.0750
2.00	0.6179	0.00829	-0.0799	0.5848	0.01370	-0.0745
3.00	0.7274	0.00873	-0.0795	0.6911	0.01422	-0.0739
4.00	0.8358	0.00912	-0.0789	0.7958	0.01486	-0.0732
5.00	0.9423	0.00944	-0.0779	0.8984	0.01565	-0.0722
6.00	1.0428	0.01012	-0.0759	0.9983	0.01661	-0.0708
7.00	1.1158	0.01384	-0.0711	1.0945	0.01778	-0.0689
8.00	1.1752	0.01870	-0.0643	1.1769	0.02015	-0.0645
9.00	1.2304	0.02259	-0.0568	1.2299	0.02391	-0.0565
10.00	1.2532	0.02793	-0.0464	1.2515	0.02921	-0.0460
11.00	1.2841	0.03527	-0.0395	1.2824	0.03650	-0.0392
12.00	1.3297	0.04450	-0.0345	1.3289	0.04572	-0.0343
13.00	1.3200	0.05895	-0.0303	1.3188	0.06024	-0.0303
14.00	1.2356	0.08392	-0.0346	1.2345	0.08523	-0.0347
15.00	1.1484	0.11483	-0.0507	1.1474	0.11619	-0.0510

$R = 0.50 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.29	0.037	0.011245	-0.0798	0.037	0.013221	-0.0798
-3.00	0.069	0.010908	-0.0801	0.069	0.012912	-0.0801
-2.00	0.179	0.010131	-0.0814	0.179	0.012317	-0.0814
-1.00	0.289	0.007686	-0.0827	0.289	0.011958	-0.0827
0.00	0.399	0.007158	-0.0840	0.399	0.012183	-0.0840
1.00	0.509	0.007247	-0.0854	0.509	0.012504	-0.0854
2.00	0.619	0.007569	-0.0868	0.619	0.012914	-0.0868
3.00	0.729	0.007947	-0.0883	0.729	0.013493	-0.0883
4.00	0.839	0.008378	-0.0898	0.837	0.014240	-0.0892
5.00	0.949	0.008908	-0.0913	0.940	0.015114	-0.0891
6.00	1.058	0.009641	-0.0925	1.040	0.016105	-0.0883
7.00	1.110	0.018424	-0.0810	1.110	0.019915	-0.0810
7.31	1.119	0.019759	-0.0768	1.119	0.021210	-0.0768

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-4.00	-0.0443	0.01492	-0.0820	-0.0661	0.01846	-0.0785
-3.00	0.0636	0.01106	-0.0806	0.0422	0.01425	-0.0773
-2.00	0.1738	0.00940	-0.0799	0.1512	0.01222	-0.0766
-1.00	0.2820	0.00771	-0.0800	0.2619	0.01187	-0.0761
0.00	0.3967	0.00642	-0.0801	0.3719	0.01203	-0.0759
1.00	0.5070	0.00672	-0.0798	0.4812	0.01230	-0.0756
2.00	0.6173	0.00711	-0.0795	0.5896	0.01266	-0.0753
3.00	0.7275	0.00739	-0.0792	0.6968	0.01314	-0.0748
4.00	0.8368	0.00776	-0.0788	0.8025	0.01372	-0.0742
5.00	0.9437	0.00820	-0.0780	0.9064	0.01443	-0.0734
6.00	1.0403	0.00966	-0.0760	1.0079	0.01529	-0.0722
7.00	1.1111	0.01403	-0.0711	1.1063	0.01634	-0.0705
8.00	1.1866	0.01735	-0.0662	1.1885	0.01881	-0.0663
9.00	1.2484	0.02095	-0.0594	1.2486	0.02230	-0.0592
10.00	1.2741	0.02580	-0.0485	1.2723	0.02709	-0.0480
11.00	1.3006	0.03274	-0.0408	1.2984	0.03399	-0.0403
12.00	1.3352	0.04106	-0.0355	1.3335	0.04227	-0.0352
13.00	1.3330	0.05491	-0.0313	1.3315	0.05612	-0.0311
14.00	1.2740	0.07597	-0.0334	1.2725	0.07721	-0.0333

$R = 0.70 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.48	0.016	0.010728	-0.0795	0.016	0.012835	-0.0795
-3.00	0.069	0.010043	-0.0801	0.069	0.012211	-0.0801
-2.00	0.179	0.009265	-0.0814	0.179	0.011640	-0.0814
-1.00	0.289	0.007250	-0.0827	0.289	0.011361	-0.0827
0.00	0.399	0.006661	-0.0840	0.399	0.011577	-0.0840
1.00	0.509	0.006428	-0.0854	0.509	0.011881	-0.0854
2.00	0.619	0.006712	-0.0868	0.619	0.012271	-0.0868
3.00	0.729	0.007031	-0.0883	0.729	0.012731	-0.0883
4.00	0.839	0.007469	-0.0898	0.838	0.013478	-0.0895
5.00	0.949	0.007905	-0.0913	0.944	0.014270	-0.0899
6.00	1.059	0.008497	-0.0928	1.045	0.015190	-0.0894
7.00	1.124	0.017106	-0.0839	1.124	0.018642	-0.0839
7.44	1.143	0.018821	-0.0788	1.143	0.020301	-0.0788

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-4.00	-0.0461	0.01337	-0.0809	-0.0646	0.01619	-0.0783
-3.00	0.0616	0.00985	-0.0799	0.0430	0.01259	-0.0773
-2.00				0.1533	0.01145	-0.0769
-1.00	0.2830	0.00729	-0.0797	0.2643	0.01105	-0.0766
0.00	0.3965	0.00561	-0.0800	0.3748	0.01121	-0.0764
1.00	0.5069	0.00589	-0.0797	0.4846	0.01146	-0.0762
2.00	0.6180	0.00616	-0.0795	0.5936	0.01180	-0.0759
3.00	0.7283	0.00650	-0.0793	0.7015	0.01224	-0.0756
4.00				0.8081	0.01278	-0.0751
5.00	0.9452	0.00743	-0.0784	0.9130	0.01343	-0.0744
6.00	1.0355	0.00991	-0.0759	1.0159	0.01420	-0.0734
7.00	1.1109	0.01386	-0.0714	1.1138	0.01540	-0.0716
8.00	1.1985	0.01603	-0.0680	1.2007	0.01746	-0.0681
9.00	1.2648	0.01945	-0.0619	1.2654	0.02082	-0.0617
10.00	1.2776	0.02541	-0.0489	1.2757	0.02670	-0.0484
11.00	1.3109	0.03174	-0.0416	1.3088	0.03302	-0.0411
12.00	1.3430	0.03951	-0.0364	1.3410	0.04074	-0.0359
13.00	1.3566	0.05138	-0.0323			
14.00	1.3383	0.06440	-0.0320			

APPENDIX B

SECTION CHARACTERISTICS OF FX 63-137 AIRFOIL

$R = 0.10 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-4.44	0.473	0.028518	-0.2346	0.484	0.023629	-0.2351
-4.00	0.519	0.026953	-0.2340	0.532	0.022020	-0.2355
-3.00	0.624	0.027172	-0.2323	0.641	0.019363	-0.2363
-2.00	0.732	0.028354	-0.2334	0.749	0.019834	-0.2375
-1.00	0.837	0.028358	-0.2337	0.857	0.020562	-0.2385
0.00	0.938	0.027734	-0.2333	0.964	0.021490	-0.2395
1.00	1.039	0.027603	-0.2329	1.070	0.022611	-0.2402
2.00	1.143	0.027330	-0.2333	1.175	0.023937	-0.2407
2.70	1.205	0.027759	-0.2311			
3.00				1.278	0.025481	-0.2408
3.14				1.293	0.025717	-0.2407

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-7.00				-0.0614	0.05222	-0.1330
-6.00				0.0307	0.03365	-0.1571
-5.00	-0.0460	0.04411	-0.1396	0.1542	0.02508	-0.1631
-4.00	0.1834	0.03160	-0.1682	0.2765	0.02214	-0.1665
-3.00	0.3450	0.02748	-0.1782	0.3956	0.02166	-0.1690
-2.00	0.4796	0.02801	-0.1807	0.5094	0.02175	-0.1701
-1.00	0.5663	0.02950	-0.1718	0.6191	0.02215	-0.1704
0.00	0.6799	0.02962	-0.1712	0.7256	0.02280	-0.1701
1.00	0.7991	0.02954	-0.1722	0.8280	0.02368	-0.1691
2.00	0.9187	0.02944	-0.1733	0.9256	0.02482	-0.1674
3.00	1.0279	0.02913	-0.1720	1.0159	0.02621	-0.1645
4.00	1.1248	0.02829	-0.1680	1.0973	0.02795	-0.1604
5.00	1.2888	0.02720	-0.1775	1.1731	0.03015	-0.1559
6.00	1.4248	0.02698	-0.1816	1.2409	0.03293	-0.1509
7.00	1.5386	0.02667	-0.1809	1.3008	0.03647	-0.1457
8.00	1.6252	0.02748	-0.1758	1.3526	0.04091	-0.1406
9.00	1.6834	0.02936	-0.1665	1.3972	0.04638	-0.1360
10.00	1.7033	0.03328	-0.1528	1.4331	0.05299	-0.1317
11.00	1.6964	0.04029	-0.1392	1.4615	0.06097	-0.1283
12.00	1.6972	0.04887	-0.1295	1.4825	0.07032	-0.1259
13.00	1.7137	0.05766	-0.1228	1.4955	0.08122	-0.1248
14.00	1.7346	0.06684	-0.1175	1.5022	0.09375	-0.1253
15.00	1.7382	0.07849	-0.1131	1.5035	0.10775	-0.1277
16.00	1.7427	0.09062	-0.1106	1.4990	0.12319	-0.1322
17.00	1.6291	0.11862	-0.1169	1.4903	0.13980	-0.1388
18.00				1.4800	0.15688	-0.1474

$R = 0.20 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-4.85	0.438	0.017185	-0.2345	0.440	0.018997	-0.2346
-4.00	0.530	0.016009	-0.2347	0.533	0.018105	-0.2353
-3.00	0.640	0.014587	-0.2360	0.642	0.017223	-0.2366
-2.00	0.748	0.014948	-0.2373	0.751	0.017701	-0.2379
-1.00	0.857	0.015284	-0.2386	0.859	0.018380	-0.2390
0.00	0.965	0.015787	-0.2398	0.966	0.019194	-0.2401
1.00	1.073	0.016372	-0.2409	1.073	0.020171	-0.2410
2.00	1.180	0.017138	-0.2419	1.179	0.021315	-0.2416
3.00	1.286	0.017968	-0.2427	1.284	0.022636	-0.2420
3.56				1.342	0.023446	-0.2421
4.00	1.392	0.019080	-0.2432			
5.00	1.495	0.020434	-0.2433			
6.00	1.596	0.022183	-0.2429			
6.37	1.633	0.022879	-0.2425			

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-7.70	-0.0620	0.07027	-0.1179			
-7.00	0.0007	0.06399	-0.1196	-0.0324	0.04885	-0.1406
-6.00	0.1197	0.02403	-0.1821	0.0686	0.02781	-0.1667
-5.00	0.2643	0.01812	-0.1905	0.1962	0.02134	-0.1726
-4.00	0.3977	0.01561	-0.1955	0.3266	0.01778	-0.1774
-3.00	0.5463	0.01327	-0.2051	0.4460	0.01749	-0.1795
-2.00	0.6596	0.01399	-0.2042	0.5597	0.01769	-0.1803
-1.00	0.7683	0.01471	-0.2022	0.6704	0.01809	-0.1805
0.00	0.8804	0.01488	-0.2017	0.7779	0.01869	-0.1801
1.00	0.9923	0.01508	-0.2012	0.8819	0.01946	-0.1791
2.00	1.1029	0.01529	-0.2007	0.9814	0.02041	-0.1774
3.00	1.2109	0.01551	-0.1996	1.0748	0.02157	-0.1747
4.00	1.3170	0.01579	-0.1983	1.1578	0.02295	-0.1703
5.00	1.4168	0.01609	-0.1957	1.2368	0.02473	-0.1657
6.00	1.4992	0.01654	-0.1897	1.3089	0.02698	-0.1606
7.00	1.5900	0.01778	-0.1867	1.3737	0.02985	-0.1551
8.00	1.6598	0.01981	-0.1800	1.4317	0.03348	-0.1498
9.00	1.6970	0.02293	-0.1682	1.4831	0.03801	-0.1447
10.00	1.7132	0.02804	-0.1558	1.5270	0.04356	-0.1401
11.00	1.7135	0.03586	-0.1448	1.5622	0.05021	-0.1357
12.00	1.7127	0.04516	-0.1364	1.5920	0.05808	-0.1323
13.00	1.7160	0.05522	-0.1304	1.6149	0.06724	-0.1298
14.00	1.7252	0.06527	-0.1258	1.6305	0.07767	-0.1283
15.00	1.7422	0.07434	-0.1215	1.6402	0.08940	-0.1281
16.00	1.7470	0.08599	-0.1205	1.6439	0.10255	-0.1296
17.00	1.7474	0.09815	-0.1207			
18.00	1.7329	0.11370	-0.1255			
19.00	1.7197	0.12872	-0.1309			
20.00	1.6987	0.14618	-0.1405			

$R = 0.35 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-5.20	0.403	0.013907	-0.2340	0.403	0.017301	-0.2340
-5.00	0.425	0.013509	-0.2341	0.425	0.016947	-0.2341
-4.00	0.534	0.012304	-0.2356	0.534	0.016010	-0.2355
-3.00	0.644	0.010813	-0.2370	0.643	0.015712	-0.2369
-2.00	0.753	0.011063	-0.2385	0.752	0.016182	-0.2382
-1.00	0.862	0.011440	-0.2399	0.860	0.016808	-0.2394
0.00	0.971	0.011852	-0.2413	0.968	0.017555	-0.2406
1.00	1.079	0.012446	-0.2425	1.075	0.018430	-0.2416
2.00	1.188	0.013175	-0.2438	1.182	0.019448	-0.2424
3.00	1.295	0.014027	-0.2448	1.288	0.020615	-0.2429
3.89				1.380	0.021774	-0.2432
4.00	1.402	0.015055	-0.2456			
5.00	1.507	0.016391	-0.2462			
6.00	1.611	0.017977	-0.2463			
7.00	1.710	0.020569	-0.2453			
7.10	1.719	0.020915	-0.2451			

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-8.00	-0.0222	0.06014	-0.1273			
-7.00	0.0553	0.03139	-0.1784	-0.0300	0.03242	-0.1615
-6.00	0.1814	0.01563	-0.1924	0.0995	0.02005	-0.1746
-5.00	0.3047	0.01303	-0.1958	0.2197	0.01799	-0.1773
-4.00	0.4310	0.01170	-0.1996	0.3530	0.01544	-0.1832
-3.00	0.5704	0.00982	-0.2073	0.4731	0.01521	-0.1853
-2.00	0.6882	0.01004	-0.2081	0.5872	0.01544	-0.1860
-1.00	0.8002	0.01037	-0.2074	0.6987	0.01583	-0.1862
0.00	0.9129	0.01060	-0.2072	0.8077	0.01637	-0.1860
1.00	1.0248	0.01086	-0.2070	0.9136	0.01705	-0.1852
2.00	1.1352	0.01116	-0.2065	1.0159	0.01787	-0.1839
3.00	1.2432	0.01156	-0.2056	1.1132	0.01887	-0.1817
4.00	1.3470	0.01218	-0.2040	1.2018	0.02003	-0.1781
5.00	1.4466	0.01284	-0.2018	1.2833	0.02149	-0.1734
6.00	1.5372	0.01392	-0.1980	1.3590	0.02335	-0.1683
7.00	1.6165	0.01520	-0.1923	1.4273	0.02572	-0.1626
8.00	1.6728	0.01714	-0.1827	1.4890	0.02877	-0.1569
9.00	1.7156	0.02048	-0.1723	1.5432	0.03267	-0.1513
10.00	1.7417	0.02549	-0.1613	1.5914	0.03752	-0.1462
11.00	1.7572	0.03233	-0.1517	1.6315	0.04344	-0.1414
12.00	1.7617	0.04122	-0.1435	1.6636	0.05052	-0.1371
13.00	1.7649	0.05118	-0.1373	1.6896	0.05900	-0.1339
14.00	1.7788	0.06103	-0.1334	1.7094	0.06871	-0.1316
15.00	1.7790	0.07303	-0.1309	1.7208	0.07982	-0.1305
16.00	1.7748	0.08618	-0.1303			
17.00	1.7770	0.09899	-0.1309			
18.00	1.7706	0.11357	-0.1337			
19.00	1.7598	0.12865	-0.1381			
20.00	1.7517	0.14380	-0.1447			

$R = 0.50 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-5.93	0.323	0.012327	-0.2330	0.323	0.015902	-0.2330
-5.00	0.425	0.011315	-0.2342	0.425	0.015141	-0.2342
-4.00	0.535	0.010829	-0.2357	0.534	0.014983	-0.2356
-3.00	0.645	0.009399	-0.2373	0.644	0.014824	-0.2370
-2.00	0.754	0.009583	-0.2388	0.753	0.015290	-0.2384
-1.00	0.863	0.009894	-0.2402	0.861	0.015875	-0.2397
0.00	0.973	0.010308	-0.2417	0.969	0.016589	-0.2408
1.00	1.082	0.010852	-0.2431	1.077	0.017410	-0.2419
2.00	1.190	0.011537	-0.2444	1.184	0.018361	-0.2428
3.00	1.298	0.012351	-0.2455	1.290	0.019440	-0.2435
4.00	1.405	0.013338	-0.2465	1.395	0.020658	-0.2439
4.09				1.404	0.020775	-0.2439
5.00	1.511	0.014556	-0.2472			
6.00	1.616	0.016106	-0.2475			
7.00	1.716	0.018552	-0.2469			
7.36	1.750	0.019906	-0.2462			

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-7.90	-0.0360	0.02428	-0.1815			
-7.00	0.0685	0.01774	-0.1892	-0.0089	0.02255	-0.1725
-6.00	0.1892	0.01358	-0.1932	0.1142	0.01775	-0.1779
-5.00	0.3138	0.01137	-0.1972	0.2402	0.01541	-0.1823
-4.00	0.4416	0.01006	-0.2013	0.3675	0.01430	-0.1864
-3.00	0.5753	0.00863	-0.2074	0.4889	0.01403	-0.1886
-2.00	0.6945	0.00849	-0.2089	0.6031	0.01427	-0.1893
-1.00	0.8092	0.00872	-0.2090	0.7152	0.01464	-0.1895
0.00	0.9228	0.00898	-0.2090	0.8249	0.01515	-0.1894
1.00	1.0353	0.00926	-0.2090	0.9321	0.01577	-0.1888
2.00	1.1458	0.00959	-0.2086	1.0359	0.01653	-0.1877
3.00	1.2538	0.01005	-0.2078	1.1357	0.01743	-0.1859
4.00	1.3571	0.01074	-0.2062	1.2295	0.01849	-0.1831
5.00	1.4582	0.01151	-0.2044	1.3120	0.01975	-0.1784
6.00	1.5507	0.01271	-0.2011	1.3903	0.02136	-0.1733
7.00	1.6342	0.01421	-0.1963	1.4617	0.02341	-0.1677
8.00	1.6883	0.01601	-0.1861	1.5262	0.02605	-0.1618
9.00	1.7343	0.01931	-0.1760	1.5836	0.02947	-0.1560
10.00	1.7658	0.02393	-0.1654	1.6344	0.03380	-0.1505
11.00	1.7908	0.02983	-0.1562	1.6783	0.03914	-0.1454
12.00	1.8065	0.03749	-0.1483	1.7134	0.04556	-0.1406
13.00	1.8211	0.04593	-0.1421	1.7412	0.05342	-0.1367
14.00	1.8377	0.05508	-0.1378	1.7640	0.06242	-0.1337
15.00	1.8342	0.06741	-0.1345			
16.00	1.8434	0.07859	-0.1330			
17.00	1.8232	0.09425	-0.1332			
18.00	1.8278	0.10698	-0.1347			
19.00	1.8110	0.12319	-0.1389			
20.00	1.7986	0.13865	-0.1444			

$R = 0.70 \times 10^6$

PROFIL00	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-6.71	0.238	0.010971	-0.2318	0.237	0.014535	-0.2318
-6.00	0.316	0.011138	-0.2328	0.315	0.014883	-0.2327
-5.00	0.425	0.010067	-0.2343	0.425	0.014081	-0.2342
-4.00	0.535	0.009735	-0.2358	0.535	0.014066	-0.2357
-3.00	0.645	0.008371	-0.2374	0.644	0.014046	-0.2371
-2.00	0.755	0.008536	-0.2389	0.753	0.014499	-0.2385
-1.00	0.864	0.008828	-0.2405	0.862	0.015056	-0.2399
0.00	0.974	0.009209	-0.2419	0.970	0.015727	-0.2411
1.00	1.083	0.009681	-0.2434	1.078	0.016501	-0.2422
2.00	1.192	0.010339	-0.2447	1.185	0.017386	-0.2432
3.00	1.300	0.011102	-0.2460	1.292	0.018393	-0.2440
4.00	1.407	0.012025	-0.2471	1.397	0.019525	-0.2445
4.29				1.427	0.019879	-0.2446
5.00	1.514	0.013172	-0.2479			
6.00	1.619	0.014622	-0.2484			
7.00	1.721	0.016983	-0.2481			
7.41	1.759	0.019010	-0.2470			

XFOIL 6.94	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-8.00	-0.0407	0.02156	-0.1833	-0.1122	0.02917	-0.1638
-7.00	0.0762	0.01316	-0.1923	0.0064	0.01821	-0.1774
-6.00	0.1986	0.01113	-0.1958	0.1331	0.01501	-0.1829
-5.00	0.3236	0.00979	-0.1994	0.2588	0.01379	-0.1867
-4.00	0.4468	0.00911	-0.2021	0.3830	0.01316	-0.1899
-3.00	0.5760	0.00793	-0.2067	0.5023	0.01305	-0.1915
-2.00	0.6999	0.00745	-0.2097	0.6167	0.01330	-0.1921
-1.00	0.8158	0.00762	-0.2102	0.7291	0.01366	-0.1924
0.00	0.9300	0.00787	-0.2105	0.8396	0.01413	-0.1923
1.00	1.0425	0.00819	-0.2104	0.9477	0.01472	-0.1919
2.00	1.1535	0.00857	-0.2102	1.0529	0.01542	-0.1910
3.00	1.2622	0.00903	-0.2096	1.1545	0.01624	-0.1894
4.00	1.3663	0.00975	-0.2082	1.2514	0.01721	-0.1871
5.00	1.4679	0.01061	-0.2065	1.3382	0.01833	-0.1830
6.00	1.5625	0.01182	-0.2037	1.4183	0.01973	-0.1780
7.00	1.6479	0.01341	-0.1994	1.4924	0.02151	-0.1725
8.00	1.7121	0.01560	-0.1914	1.5592	0.02381	-0.1664
9.00	1.7543	0.01831	-0.1799	1.6200	0.02678	-0.1605
10.00	1.7934	0.02228	-0.1699	1.6732	0.03060	-0.1546
11.00	1.8253	0.02738	-0.1607	1.7203	0.03540	-0.1492
12.00	1.8494	0.03395	-0.1528	1.7597	0.04124	-0.1442
13.00	1.8754	0.04104	-0.1468	1.7900	0.04834	-0.1396
14.00	1.8895	0.04988	-0.1414	1.8147	0.05679	-0.1361
15.00	1.8990	0.06020	-0.1376			
16.00	1.8990	0.07239	-0.1352			
17.00	1.9004	0.08455	-0.1342			
18.00	1.8785	0.10081	-0.1354			
19.00	1.8706	0.11530	-0.1380			
20.00	1.8335	0.13465	-0.1444			

APPENDIX C

SECTION CHARACTERISTICS OF S822 AIRFOIL

$R = 0.20 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.081	0.016879	-0.0675	-0.031	0.016183	-0.0769
-2.00	0.022	0.016050	-0.0693	0.069	0.016124	-0.0779
-1.00	0.123	0.014915	-0.0713	0.171	0.016164	-0.0789
0.00	0.222	0.014400	-0.0720	0.273	0.016400	-0.0802
1.00	0.313	0.014463	-0.0719	0.376	0.016800	-0.0814
2.00	0.410	0.015022	-0.0725	0.476	0.017460	-0.0824
3.00	0.503	0.015445	-0.0713	0.573	0.018225	-0.0827
4.00	0.597	0.015508	-0.0703	0.665	0.019129	-0.0819
5.00	0.683	0.015480	-0.0693	0.754	0.020180	-0.0809
6.00	0.790	0.015623	-0.0713	0.842	0.021423	-0.0796
7.00	0.917	0.024029	-0.0765	0.925	0.023128	-0.0778
7.48				0.963	0.024416	-0.0766

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-2.00	-0.1142	0.01883	-0.0469	-0.0239	0.01740	-0.0543
-1.00	0.0156	0.01939	-0.0493	0.0686	0.01737	-0.0516
0.00	0.0548	0.02124	-0.0371	0.1603	0.01747	-0.0488
1.00	0.1773	0.02122	-0.0381	0.2495	0.01768	-0.0455
2.00	0.3180	0.02102	-0.0416	0.3331	0.01801	-0.0412
3.00	0.3493	0.02142	-0.0277	0.4173	0.01857	-0.0374
4.00	0.5294	0.01871	-0.0369	0.5021	0.01940	-0.0339
5.00	0.6402	0.01752	-0.0363	0.5852	0.02044	-0.0305
6.00	0.8365	0.01488	-0.0505	0.6659	0.02170	-0.0271
7.00	0.9817	0.01431	-0.0572	0.7433	0.02325	-0.0235
8.00	0.9348	0.01597	-0.0308	0.8174	0.02510	-0.0199
9.00	0.9453	0.02055	-0.0190	0.8877	0.02730	-0.0162
10.00	0.9722	0.02564	-0.0110	0.9530	0.02996	-0.0124
11.00	1.0107	0.03073	-0.0052	1.0125	0.03320	-0.0086
12.00	1.0491	0.03664	0.0003	1.0656	0.03710	-0.0049
13.00	1.0883	0.04467	0.0051	1.1029	0.04262	-0.0008
14.00	1.1143	0.05332	0.0089	1.1126	0.05159	0.0036
15.00	1.1056	0.06496	0.0112	1.1101	0.06388	0.0076
16.00	1.0566	0.08375	0.0083	1.0733	0.08199	0.0063
17.00	0.9285	0.12193	-0.0123	1.0000	0.10788	-0.0051
18.00	0.7848	0.18526	-0.0459	0.8950	0.14779	-0.0313
19.00	0.7776	0.21665	-0.0599	0.8121	0.19808	-0.0553
20.00				0.8111	0.22630	-0.0663

$R = 0.35 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.049	0.010668	-0.0727	-0.032	0.014717	-0.0767
-2.00	0.058	0.009868	-0.0752	0.070	0.014671	-0.0778
-1.00	0.166	0.009685	-0.0778	0.173	0.014751	-0.0792
0.00	0.274	0.009701	-0.0801	0.277	0.014950	-0.0809
1.00	0.378	0.010054	-0.0820	0.381	0.015435	-0.0826
2.00	0.481	0.010467	-0.0835	0.483	0.015990	-0.0840
3.00	0.577	0.010793	-0.0835	0.583	0.016652	-0.0848
4.00	0.673	0.011051	-0.0836	0.680	0.017435	-0.0850
5.00	0.769	0.011217	-0.0837	0.771	0.018347	-0.0841
6.00	0.896	0.011627	-0.0898	0.860	0.019404	-0.0829
7.00	0.944	0.019937	-0.0809	0.946	0.020705	-0.0813
7.56	0.985	0.021676	-0.0789			
7.67				0.996	0.022660	-0.0790

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.0834	0.01093	-0.0694			
-2.00	0.0245	0.01125	-0.0689	-0.0151	0.01516	-0.0562
-1.00	0.1254	0.01141	-0.0671	0.0809	0.01516	-0.0541
0.00	0.2376	0.01144	-0.0672	0.1758	0.01526	-0.0518
1.00	0.3491	0.01192	-0.0671	0.2679	0.01546	-0.0490
2.00	0.4515	0.01162	-0.0650	0.3537	0.01574	-0.0449
3.00	0.5735	0.01134	-0.0665	0.4395	0.01623	-0.0411
4.00	0.6680	0.01088	-0.0625	0.5266	0.01695	-0.0379
5.00	0.7657	0.01051	-0.0592	0.6116	0.01786	-0.0346
6.00	0.8475	0.01045	-0.0527	0.6942	0.01898	-0.0312
7.00	0.8726	0.01131	-0.0358	0.7734	0.02035	-0.0277
8.00	0.9130	0.01496	-0.0283	0.8496	0.02197	-0.0241
9.00	0.9556	0.01877	-0.0216	0.9229	0.02390	-0.0205
10.00	1.0049	0.02257	-0.0161	0.9900	0.02626	-0.0165
11.00	1.0532	0.02672	-0.0108	1.0544	0.02901	-0.0128
12.00	1.0852	0.03238	-0.0047	1.1081	0.03268	-0.0086
13.00	1.1184	0.03837	-0.0003	1.1280	0.03946	-0.0023
14.00	1.1317	0.04767	0.0050	1.1343	0.04945	0.0041
15.00	1.1577	0.05546	0.0065	1.1587	0.05719	0.0058
16.00	1.1561	0.06720	0.0067	1.1565	0.06895	0.0060
17.00	1.1313	0.08405	0.0027	1.1310	0.08575	0.0020
18.00	1.0718	0.10903	-0.0093	1.0708	0.11070	-0.0101
19.00	0.8259	0.19285	-0.0548	0.8265	0.19504	-0.0558
20.00	0.8158	0.22461	-0.0678	0.8168	0.22662	-0.0685

$R = 0.50 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.041	0.008641	-0.0744	-0.033	0.013868	-0.0765
-2.00	0.066	0.008190	-0.0768	0.070	0.013836	-0.0779
-1.00	0.176	0.008014	-0.0799	0.173	0.013923	-0.0793
0.00	0.283	0.008220	-0.0824	0.279	0.014193	-0.0815
1.00	0.390	0.008453	-0.0847	0.384	0.014619	-0.0833
2.00	0.495	0.008755	-0.0866	0.487	0.015125	-0.0848
3.00	0.599	0.009073	-0.0882	0.589	0.015730	-0.0860
4.00	0.702	0.009266	-0.0896	0.688	0.016447	-0.0865
5.00	0.804	0.009437	-0.0908	0.782	0.017284	-0.0863
6.00	0.908	0.011440	-0.0924	0.872	0.018252	-0.0851
7.00	0.959	0.018159	-0.0835	0.959	0.019384	-0.0837
7.86	1.024	0.020421	-0.0807	1.024	0.021628	-0.0807

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.0667	0.00882	-0.0714			
-2.00	0.0414	0.00866	-0.0711	-0.0086	0.01398	-0.0577
-1.00	0.1542	0.00856	-0.0716	0.0896	0.01399	-0.0559
0.00	0.2655	0.00882	-0.0719	0.1867	0.01409	-0.0540
1.00	0.3755	0.00871	-0.0718	0.2813	0.01428	-0.0516
2.00	0.4910	0.00858	-0.0723	0.3699	0.01454	-0.0480
3.00	0.5966	0.00849	-0.0711	0.4562	0.01495	-0.0441
4.00	0.7041	0.00858	-0.0702	0.5440	0.01560	-0.0408
5.00	0.7983	0.00866	-0.0665	0.6305	0.01642	-0.0376
6.00	0.8714	0.00928	-0.0589	0.7141	0.01744	-0.0342
7.00	0.8769	0.01146	-0.0394	0.7950	0.01867	-0.0307
8.00	0.9047	0.01414	-0.0267	0.8734	0.02012	-0.0272
9.00	0.9704	0.01750	-0.0240	0.9469	0.02193	-0.0234
10.00	1.0287	0.02077	-0.0193	1.0168	0.02405	-0.0195
11.00	1.0746	0.02490	-0.0135	1.0826	0.02656	-0.0156
12.00	1.1279	0.02874	-0.0093	1.1352	0.03019	-0.0109
13.00	1.1551	0.03479	-0.0036	1.1567	0.03653	-0.0042
14.00	1.1901	0.04098	0.0000	1.1900	0.04269	-0.0004
15.00	1.2131	0.04892	0.0027	1.2121	0.05053	0.0025
16.00	1.2188	0.05926	0.0038	1.2169	0.06081	0.0036
17.00	1.1797	0.07672	0.0021	1.1784	0.07823	0.0019
18.00	1.0952	0.10486	-0.0089	1.0943	0.10618	-0.0092
19.00	1.0178	0.13622	-0.0284	1.0172	0.13721	-0.0288
20.00	0.9420	0.17440	-0.0519	0.9407	0.17600	-0.0523

$R = 0.70 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.036	0.007507	-0.0756	-0.033	0.013100	-0.0763
-2.00	0.073	0.007113	-0.0784	0.070	0.013100	-0.0779
-1.00	0.182	0.006958	-0.0813	0.175	0.013163	-0.0797
0.00	0.289	0.007164	-0.0838	0.281	0.013505	-0.0819
1.00	0.396	0.007367	-0.0861	0.387	0.013890	-0.0839
2.00	0.502	0.007618	-0.0882	0.491	0.014354	-0.0856
3.00	0.608	0.007843	-0.0903	0.593	0.014910	-0.0869
4.00	0.713	0.008019	-0.0922	0.694	0.015575	-0.0878
5.00	0.819	0.008814	-0.0941	0.791	0.016346	-0.0881
6.00	0.911	0.011242	-0.0931	0.883	0.017238	-0.0873
7.00	0.972	0.016745	-0.0860	0.971	0.018270	-0.0859
8.00	1.049	0.019233	-0.0828	1.049	0.020536	-0.0828
8.15	1.061	0.019406	-0.0824	1.061	0.020694	-0.0824

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.0580	0.00737	-0.0724			
-2.00	0.0526	0.00706	-0.0726	-0.0030	0.01300	-0.0589
-1.00	0.1651	0.00714	-0.0734	0.0973	0.01302	-0.0576
0.00	0.2777	0.00707	-0.0739	0.1963	0.01312	-0.0559
1.00	0.3909	0.00691	-0.0744	0.2932	0.01331	-0.0539
2.00	0.5022	0.00690	-0.0746	0.3857	0.01355	-0.0510
3.00	0.6124	0.00703	-0.0744	0.4720	0.01390	-0.0470
4.00	0.7158	0.00713	-0.0729	0.5604	0.01447	-0.0437
5.00	0.8106	0.00765	-0.0696	0.6482	0.01521	-0.0405
6.00	0.8617	0.00896	-0.0580	0.7334	0.01613	-0.0372
7.00	0.8840	0.01140	-0.0424	0.8159	0.01723	-0.0338
8.00	0.9209	0.01394	-0.0311	0.8946	0.01858	-0.0301
9.00				0.9700	0.02021	-0.0263
10.00	1.0520	0.01908	-0.0224	1.0431	0.02210	-0.0226
11.00	1.1079	0.02238	-0.0175	1.1082	0.02449	-0.0183
12.00	1.1539	0.02658	-0.0120	1.1569	0.02829	-0.0127
13.00	1.2059	0.03057	-0.0081	1.2068	0.03223	-0.0085
14.00	1.2328	0.03682	-0.0031	1.2324	0.03842	-0.0032
15.00	1.2374	0.04619	0.0013	1.2360	0.04774	0.0013
16.00	1.2126	0.05967	0.0040	1.2095	0.06129	0.0040
17.00	1.2317	0.06954	0.0023	1.2283	0.07114	0.0022
18.00	1.2358	0.08272	-0.0019	1.2329	0.08414	-0.0019
19.00	1.2162	0.10067	-0.0097	1.2162	0.10067	-0.0097
20.00	1.1643	0.12540	-0.0236	1.1643	0.12540	-0.0236

$R = 1.00 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.032	0.006773	-0.0766	-0.034	0.012355	-0.0762
-2.00	0.077	0.006446	-0.0795	0.070	0.012340	-0.0778
-1.00	0.186	0.006227	-0.0823	0.177	0.012510	-0.0802
0.00	0.294	0.006264	-0.0849	0.283	0.012808	-0.0824
1.00	0.401	0.006463	-0.0873	0.389	0.013156	-0.0845
2.00	0.508	0.006668	-0.0895	0.494	0.013581	-0.0864
3.00	0.614	0.006813	-0.0918	0.597	0.014094	-0.0879
4.00	0.720	0.007230	-0.0938	0.699	0.014705	-0.0890
5.00	0.820	0.009021	-0.0944	0.798	0.015416	-0.0896
6.00	0.914	0.010962	-0.0939	0.894	0.016238	-0.0896
7.00	0.986	0.015434	-0.0888	0.984	0.017186	-0.0884
8.00	1.067	0.017486	-0.0859	1.067	0.018844	-0.0859
8.46	1.103	0.018437	-0.0845	1.103	0.019747	-0.0845

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.0519	0.00648	-0.0730	-0.1000	0.01213	-0.0612
-2.00	0.0583	0.00611	-0.0735	0.0026	0.01209	-0.0602
-1.00	0.1714	0.00590	-0.0743	0.1048	0.01211	-0.0592
0.00	0.2850	0.00580	-0.0750	0.2057	0.01222	-0.0578
1.00	0.3987	0.00581	-0.0758	0.3049	0.01239	-0.0562
2.00	0.5094	0.00582	-0.0759	0.4013	0.01263	-0.0541
3.00	0.6197	0.00591	-0.0760	0.4893	0.01293	-0.0503
4.00	0.7248	0.00624	-0.0750	0.5777	0.01340	-0.0468
5.00	0.8113	0.00696	-0.0703	0.6668	0.01407	-0.0436
6.00	0.8554	0.00886	-0.0578	0.7532	0.01489	-0.0404
7.00	0.8903	0.01126	-0.0447	0.8365	0.01589	-0.0369
8.00	0.9430	0.01332	-0.0359	0.9171	0.01711	-0.0333
9.00	1.0013	0.01535	-0.0287	0.9952	0.01852	-0.0296
10.00				1.0681	0.02029	-0.0257
11.00	1.1267	0.02097	-0.0197	1.1359	0.02244	-0.0214
12.00	1.1930	0.02362	-0.0163	1.1949	0.02533	-0.0168
13.00	1.2234	0.02902	-0.0095	1.2239	0.03064	-0.0097
14.00	1.2293	0.03685	-0.0025	1.2284	0.03848	-0.0026
15.00	1.2692	0.04274	-0.0002	1.2677	0.04426	-0.0001
16.00	1.3205	0.04792	0.0005	1.3169	0.04946	0.0007
17.00	1.3608	0.05446	0.0009	1.3608	0.05446	0.0009
18.00	1.3744	0.06424	0.0003	1.3744	0.06424	0.0003
19.00	1.3604	0.07899	-0.0031	1.3604	0.07899	-0.0031
20.00	1.3301	0.09790	-0.0105	1.3301	0.09790	-0.0105

APPENDIX D

SECTION CHARACTERISTICS OF S834 AIRFOIL

$R = 0.10 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.072	0.016636	-0.0711	-0.057	0.018015	-0.0737
-2.00	0.024	0.023560	-0.0715	0.042	0.017836	-0.0745
-1.00	0.118	0.025801	-0.0716	0.143	0.017920	-0.0753
0.00	0.216	0.027627	-0.0725	0.244	0.018131	-0.0763
1.00	0.311	0.026715	-0.0727	0.347	0.018465	-0.0775
2.00	0.412	0.022729	-0.0740	0.451	0.019065	-0.0788
3.00	0.510	0.019465	-0.0754	0.554	0.019834	-0.0800
4.00	0.614	0.019407	-0.0772	0.655	0.020987	-0.0809
5.00	0.716	0.019903	-0.0786	0.754	0.022313	-0.0816
6.00	0.846	0.023732	-0.0843	0.852	0.023926	-0.0818
6.34	0.873	0.026106	-0.0835			
6.85				0.927	0.026843	-0.0806

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-2.00				-0.0762	0.02108	-0.0455
-1.00				0.0154	0.02096	-0.0426
0.00	-0.1616	0.02946	0.0038	0.1068	0.02099	-0.0396
1.00	0.0995	0.03173	-0.0283	0.1971	0.02116	-0.0364
2.00	0.3349	0.03193	-0.0554			
3.00	0.4235	0.03125	-0.0536	0.3726	0.02196	-0.0294
4.00	0.5195	0.02993	-0.0509	0.4595	0.02267	-0.0260
5.00	0.6431	0.02681	-0.0498	0.5454	0.02362	-0.0226
6.00	0.8066	0.02200	-0.0533	0.6281	0.02483	-0.0189
7.00	0.8869	0.01942	-0.0431	0.7078	0.02634	-0.0152
8.00	0.8959	0.02042	-0.0232	0.7830	0.02822	-0.0111
9.00	0.9031	0.02476	-0.0080	0.8525	0.03056	-0.0068
10.00	0.9341	0.03061	0.0016	0.9144	0.03355	-0.0022
11.00	0.9860	0.03762	0.0075	0.9666	0.03746	0.0026
12.00	1.0295	0.05115	0.0132	1.0003	0.04315	0.0079
13.00	0.9863	0.06508	0.0216	1.0011	0.05284	0.0135
14.00	0.8913	0.08565	0.0203	1.0013	0.06576	0.0172
15.00				0.9593	0.08436	0.0148
16.00				0.8860	0.11135	0.0007
17.00				0.7964	0.15166	-0.0248
18.00				0.7659	0.18454	-0.0404
19.00				0.7708	0.20885	-0.0506
20.00				0.7846	0.23119	-0.0594

$R = 0.20 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.077	0.014134	-0.0697	-0.057	0.015944	-0.0736
-2.00	0.024	0.013534	-0.0707	0.043	0.015860	-0.0746
-1.00	0.128	0.013104	-0.0723	0.145	0.015965	-0.0756
0.00	0.228	0.012824	-0.0735	0.247	0.016109	-0.0767
1.00	0.334	0.012714	-0.0758	0.351	0.016465	-0.0781
2.00	0.441	0.012593	-0.0781	0.456	0.016943	-0.0797
3.00	0.551	0.012682	-0.0812	0.559	0.017715	-0.0812
4.00	0.656	0.012800	-0.0830	0.662	0.018643	-0.0824
5.00	0.758	0.013432	-0.0842	0.762	0.019695	-0.0833
6.00	0.865	0.018063	-0.0862	0.862	0.020972	-0.0838
6.91	0.943	0.023202	-0.0849			
7.00				0.951	0.024542	-0.0824

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-2.00				-0.0477	0.01711	-0.0514
-1.00	-0.0547	0.01739	-0.0366	0.0451	0.01704	-0.0485
0.00	0.0156	0.01847	-0.0274	0.1374	0.01708	-0.0456
1.00	0.1538	0.01809	-0.0298	0.2284	0.01723	-0.0424
2.00	0.2346	0.01819	-0.0229	0.3161	0.01750	-0.0386
3.00	0.4855	0.01631	-0.0484	0.4043	0.01791	-0.0351
4.00	0.6644	0.01502	-0.0611	0.4927	0.01856	-0.0318
5.00	0.8445	0.01370	-0.0742	0.5801	0.01940	-0.0286
6.00	0.9634	0.01373	-0.0763	0.6651	0.02044	-0.0251
7.00	0.9201	0.01505	-0.0473	0.7470	0.02171	-0.0215
8.00	0.8828	0.01682	-0.0213	0.8246	0.02327	-0.0175
9.00	0.9127	0.02042	-0.0108	0.8972	0.02522	-0.0132
10.00	0.9505	0.02496	-0.0029	0.9637	0.02766	-0.0086
11.00	0.9784	0.03151	0.0053	1.0193	0.03103	-0.0033
12.00	1.0211	0.03731	0.0103	1.0240	0.04000	0.0066
13.00	1.0357	0.04994	0.0163	1.0432	0.05349	0.0131
14.00	0.9868	0.06655	0.0199	0.9940	0.06945	0.0166
15.00	0.9085	0.08955	0.0133	0.9112	0.09314	0.0096

$R = 0.35 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.070	0.010075	-0.0708	-0.057	0.014503	-0.0736
-2.00	0.032	0.009585	-0.0719	0.044	0.014448	-0.0747
-1.00	0.138	0.009244	-0.0737	0.147	0.014515	-0.0759
0.00	0.244	0.008988	-0.0758	0.250	0.014711	-0.0771
1.00	0.351	0.009048	-0.0781	0.355	0.014991	-0.0789
2.00	0.459	0.009128	-0.0805	0.460	0.015548	-0.0806
3.00	0.567	0.009530	-0.0832	0.564	0.016193	-0.0821
4.00	0.672	0.010115	-0.0849	0.667	0.016985	-0.0835
5.00	0.776	0.010603	-0.0864	0.769	0.017880	-0.0846
6.00	0.875	0.015551	-0.0864	0.869	0.018935	-0.0853
7.00	0.963	0.020376	-0.0848	0.964	0.021361	-0.0849
7.35	0.994	0.021598	-0.0841	0.994	0.022785	-0.0841

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-2.00	-0.0370	0.01071	-0.0593	-0.0402	0.01492	-0.0531
-1.00	0.0878	0.01026	-0.0617	0.0552	0.01488	-0.0507
0.00	0.1909	0.01019	-0.0595	0.1499	0.01492	-0.0482
1.00	0.3158	0.01014	-0.0612	0.2420	0.01506	-0.0451
2.00	0.4234	0.01012	-0.0591	0.3317	0.01529	-0.0416
3.00	0.5158	0.01014	-0.0539	0.4222	0.01568	-0.0384
4.00	0.6090	0.01006	-0.0492	0.5131	0.01626	-0.0354
5.00	0.7035	0.01010	-0.0452	0.6031	0.01699	-0.0325
6.00	0.7981	0.01082	-0.0423	0.6902	0.01788	-0.0293
7.00	0.8831	0.01345	-0.0405	0.7750	0.01896	-0.0259
8.00	0.8820	0.01509	-0.0219	0.8552	0.02030	-0.0220
9.00	0.9331	0.01792	-0.0145	0.9315	0.02193	-0.0180
10.00	0.9851	0.02161	-0.0082	1.0020	0.02399	-0.0135
11.00	1.0111	0.02751	0.0003	1.0276	0.02957	-0.0036
12.00	1.0562	0.03247	0.0053	1.0676	0.03465	0.0025
13.00	1.0857	0.03900	0.0102	1.0945	0.04113	0.0078
14.00	1.0890	0.04920	0.0144			
15.00	1.0533	0.06516	0.0156			
16.00	0.9934	0.08795	0.0079			
17.00	0.9321	0.11644	-0.0090			

$R = 0.50 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.067	0.008595	-0.0712	-0.058	0.013665	-0.0735
-2.00	0.038	0.008145	-0.0729	0.045	0.013628	-0.0747
-1.00	0.146	0.007802	-0.0754	0.148	0.013650	-0.0759
0.00	0.252	0.007669	-0.0776	0.252	0.013855	-0.0775
1.00	0.360	0.007670	-0.0799	0.357	0.014226	-0.0794
2.00	0.467	0.007812	-0.0822	0.462	0.014718	-0.0811
3.00	0.574	0.008228	-0.0845	0.566	0.015304	-0.0827
4.00	0.680	0.008721	-0.0863	0.670	0.016024	-0.0841
5.00	0.784	0.009846	-0.0878	0.772	0.016834	-0.0853
6.00	0.880	0.013778	-0.0875	0.874	0.017779	-0.0862
7.00	0.970	0.018353	-0.0862	0.971	0.019546	-0.0863
7.70	1.034	0.020399	-0.0854	1.034	0.021690	-0.0854

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.0978	0.00870	-0.0677			
-2.00	0.0238	0.00804	-0.0702			
-1.90				-0.0241	0.01375	-0.0544
-1.00	0.1251	0.00776	-0.0683	0.0633	0.01373	-0.0525
0.00	0.2462	0.00757	-0.0701	0.1598	0.01379	-0.0502
1.00	0.3470	0.00757	-0.0674	0.2539	0.01392	-0.0475
2.00	0.4529	0.00777	-0.0657	0.3445	0.01413	-0.0441
3.00	0.5547	0.00810	-0.0632	0.4360	0.01448	-0.0410
4.00	0.6407	0.00833	-0.0572	0.5279	0.01501	-0.0382
5.00	0.7086	0.00874	-0.0477	0.6194	0.01566	-0.0354
6.00	0.7436	0.00951	-0.0321	0.7080	0.01647	-0.0323
7.00	0.8091	0.01173	-0.0255	0.7944	0.01744	-0.0290
8.00	0.8893	0.01430	-0.0235	0.8767	0.01863	-0.0253
9.00	0.9476	0.01657	-0.0169	0.9553	0.02007	-0.0214
10.00	1.0087	0.01969	-0.0117	1.0271	0.02197	-0.0167
11.00	1.0602	0.02352	-0.0059	1.0749	0.02558	-0.0094
12.00	1.0841	0.02973	0.0019	1.0892	0.03220	-0.0001
13.00	1.0975	0.03763	0.0087	1.1055	0.03963	0.0067
14.00	1.1224	0.04515	0.0120			
15.00	1.1211	0.05626	0.0137			
16.00	1.0909	0.07260	0.0110			
17.00	1.0317	0.09762	-0.0003			
18.00	0.9263	0.13782	-0.0251			
19.00	0.7884	0.20237	-0.0560			
20.00	0.7933	0.22861	-0.0666			

$R = 0.70 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.064	0.007596	-0.0717	-0.058	0.012927	-0.0735
-2.00	0.044	0.007129	-0.0743	0.045	0.012906	-0.0747
-1.00	0.151	0.006860	-0.0767	0.149	0.012930	-0.0761
0.00	0.259	0.006712	-0.0790	0.255	0.013094	-0.0781
1.00	0.366	0.006685	-0.0814	0.360	0.013532	-0.0799
2.00	0.473	0.006847	-0.0837	0.465	0.013978	-0.0817
3.00	0.580	0.007260	-0.0857	0.569	0.014512	-0.0833
4.00	0.685	0.007930	-0.0875	0.673	0.015146	-0.0848
5.00	0.786	0.009621	-0.0883	0.776	0.015917	-0.0860
6.00	0.884	0.012616	-0.0884	0.878	0.016781	-0.0871
7.00	0.976	0.016710	-0.0874	0.976	0.018262	-0.0874
7.89	1.058	0.019359	-0.0864	1.058	0.020753	-0.0864

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.0673	0.00714	-0.0731			
-2.00	0.0375	0.00674	-0.0723	-0.0280	0.01280	-0.0560
-1.00	0.1490	0.00639	-0.0726	0.0709	0.01278	-0.0542
0.00	0.2549	0.00620	-0.0716	0.1690	0.01285	-0.0522
1.00	0.3656	0.00622	-0.0713	0.2654	0.01299	-0.0499
2.00	0.4714	0.00642	-0.0700	0.3572	0.01317	-0.0466
3.00	0.5692	0.00672	-0.0668	0.4490	0.01348	-0.0435
4.00	0.6608	0.00717	-0.0626	0.5420	0.01396	-0.0408
5.00	0.7259	0.00795	-0.0528	0.6344	0.01456	-0.0381
6.00	0.7602	0.00948	-0.0376	0.7249	0.01529	-0.0352
7.00	0.8002	0.01137	-0.0249	0.8122	0.01618	-0.0320
8.00	0.8753	0.01316	-0.0202	0.8973	0.01722	-0.0286
9.00	0.9591	0.01552	-0.0187	0.9769	0.01853	-0.0246
10.00	1.0269	0.01825	-0.0144	1.0478	0.02045	-0.0194
11.00	1.0778	0.02214	-0.0082	1.0851	0.02465	-0.0106
12.00	1.1275	0.02617	-0.0029	1.1378	0.02804	-0.0052
13.00	1.1742	0.03058	0.0017			
14.00	1.1978	0.03718	0.0067			
15.00	1.2056	0.04647	0.0103			
16.00	1.1930	0.05920	0.0110			
17.00	1.1572	0.07716	0.0066			
18.00	1.0945	0.10341	-0.0059			
19.00	0.9884	0.14246	-0.0301			
20.00	0.8069	0.22465	-0.0667			

APPENDIX E

SECTION CHARACTERISTICS OF SD2030 AIRFOIL

$R = 0.10 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.027	0.016489	-0.0670	-0.016	0.018153	-0.0697
-2.00	0.080	0.011386	-0.0679	0.094	0.015564	-0.0712
-1.00	0.186	0.019061	-0.0686	0.203	0.015550	-0.0727
0.00	0.289	0.019955	-0.0685	0.312	0.015772	-0.0739
1.00	0.395	0.020701	-0.0692	0.419	0.016195	-0.0748
2.00	0.499	0.019991	-0.0695	0.526	0.016760	-0.0756
3.00	0.607	0.016982	-0.0705	0.631	0.017537	-0.0761
4.00	0.729	0.015541	-0.0747	0.736	0.018500	-0.0764
5.00	0.830	0.021718	-0.0743	0.838	0.019779	-0.0763
5.94	0.900	0.025575	-0.0688	0.900	0.026408	-0.0688

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00				-0.0741	0.01866	-0.0594
-2.00				0.0296	0.01795	-0.0575
-1.00	-0.0980	0.01504	-0.0190	0.1337	0.01782	-0.0561
0.00	0.0044	0.01657	-0.0205	0.2375	0.01791	-0.0547
1.00	0.1720	0.01872	-0.0341	0.3408	0.01818	-0.0533
2.00	0.3386	0.01974	-0.0456	0.4431	0.01863	-0.0517
3.00	0.5214	0.01878	-0.0569	0.5440	0.01927	-0.0500
4.00	0.6955	0.01573	-0.0626	0.6432	0.02011	-0.0481
5.00	0.8072	0.01436	-0.0567	0.7400	0.02119	-0.0459
6.00	0.8699	0.01766	-0.0464	0.8338	0.02257	-0.0433
7.00	0.9372	0.02254	-0.0393	0.9235	0.02431	-0.0402
8.00	1.0268	0.02841	-0.0359	1.0076	0.02655	-0.0364
9.00	1.1013	0.03593	-0.0309	1.0826	0.02952	-0.0316
10.00	1.1369	0.04754	-0.0213	1.1339	0.03426	-0.0238
11.00	1.1170	0.06219	-0.0102	1.1453	0.04468	-0.0127
12.00	0.9750	0.08518	-0.0084	1.1203	0.05955	-0.0047
13.00	0.8929	0.12153	-0.0298	1.0498	0.07992	-0.0080
14.00	0.8395	0.16715	-0.0556	0.9585	0.11641	-0.0322
15.00	0.8425	0.18557	-0.0659	0.8889	0.16020	-0.0556
16.00	0.8643	0.20238	-0.0733	0.8858	0.18594	-0.0678
17.00	0.9116	0.22337	-0.0754	0.9008	0.20664	-0.0779
18.00	0.9118	0.23279	-0.0906	0.9229	0.22508	-0.0871
19.00				0.9479	0.24220	-0.0963
20.00	0.9694	0.26206	-0.1074	0.9746	0.25830	-0.1055

$R = 0.20 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.021	0.013143	-0.0685	-0.016	0.014983	-0.0697
-2.00	0.087	0.009799	-0.0695	0.094	0.013785	-0.0712
-1.00	0.193	0.010168	-0.0701	0.204	0.013761	-0.0728
0.00	0.300	0.010516	-0.0711	0.314	0.014048	-0.0743
1.00	0.408	0.010418	-0.0720	0.422	0.014388	-0.0755
2.00	0.517	0.010169	-0.0735	0.530	0.014930	-0.0765
3.00	0.629	0.010104	-0.0756	0.636	0.015548	-0.0772
4.00	0.744	0.010935	-0.0782	0.741	0.016325	-0.0776
5.00	0.843	0.016444	-0.0774	0.845	0.017347	-0.0778
6.00	0.939	0.019365	-0.0757	0.939	0.020662	-0.0757
6.81	0.995	0.022216	-0.0700	0.995	0.023430	-0.0700

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00				-0.0606	0.01599	-0.0622
-2.00	-0.0709	0.01475	-0.0446	0.0427	0.01471	-0.0600
-1.00	0.1063	0.01256	-0.0566	0.1479	0.01465	-0.0588
0.00	0.2423	0.01234	-0.0621	0.2528	0.01476	-0.0577
1.00	0.4173	0.01135	-0.0740	0.3570	0.01501	-0.0565
2.00	0.5386	0.01028	-0.0741	0.4603	0.01539	-0.0551
3.00	0.6462	0.00956	-0.0710	0.5624	0.01592	-0.0536
4.00	0.7374	0.00960	-0.0649	0.6629	0.01660	-0.0519
5.00	0.8085	0.01151	-0.0562	0.7614	0.01746	-0.0500
6.00	0.8776	0.01435	-0.0491	0.8574	0.01853	-0.0476
7.00	0.9514	0.01764	-0.0432	0.9498	0.01987	-0.0448
8.00	1.0269	0.02175	-0.0379	1.0375	0.02155	-0.0414
9.00	1.0990	0.02512	-0.0324	1.1171	0.02383	-0.0367
10.00	1.1548	0.03159	-0.0251	1.1532	0.03264	-0.0253
11.00	1.1717	0.04372	-0.0144	1.1728	0.04527	-0.0149
12.00	1.1216	0.05754	-0.0037	1.1215	0.05916	-0.0041
13.00	1.0366	0.07945	-0.0085	1.0359	0.08114	-0.0090

$R = 0.35 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.016	0.010956	-0.0697	-0.016	0.013645	-0.0697
-2.00	0.094	0.007187	-0.0711	0.094	0.012593	-0.0712
-1.00	0.203	0.007369	-0.0725	0.204	0.012617	-0.0728
0.00	0.312	0.007424	-0.0738	0.314	0.012751	-0.0743
1.00	0.421	0.007477	-0.0752	0.424	0.013138	-0.0759
2.00	0.531	0.007566	-0.0768	0.532	0.013616	-0.0771
3.00	0.641	0.007780	-0.0785	0.639	0.014155	-0.0780
4.00	0.751	0.009132	-0.0800	0.745	0.014829	-0.0786
5.00	0.850	0.013711	-0.0791	0.850	0.015634	-0.0790
6.00	0.950	0.016177	-0.0782	0.950	0.017674	-0.0782
7.00	1.038	0.019340	-0.0749	1.038	0.020739	-0.0749
8.00	0.430	0.023769	-0.0619	0.430	0.025076	-0.0619
8.22	1.154	0.020335	-0.0730	1.154	0.021621	-0.0730

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.0692	0.01262	-0.0641	-0.0573	0.01369	-0.0627
-2.00	0.0561	0.01007	-0.0677	0.0480	0.01281	-0.0611
-1.00	0.1600	0.00803	-0.0643	0.1547	0.01280	-0.0602
0.00	0.3278	0.00766	-0.0736	0.2609	0.01291	-0.0593
1.00	0.4917	0.00705	-0.0841	0.3666	0.01314	-0.0583
2.00	0.5761	0.00688	-0.0782	0.4714	0.01348	-0.0573
3.00	0.6590	0.00706	-0.0717	0.5750	0.01393	-0.0560
4.00	0.7316	0.00821	-0.0632	0.6773	0.01451	-0.0546
5.00	0.8050	0.01038	-0.0564	0.7778	0.01523	-0.0530
6.00	0.8887	0.01251	-0.0520	0.8760	0.01612	-0.0510
7.00	0.9729	0.01482	-0.0478	0.9711	0.01721	-0.0486
8.00	1.0568	0.01707	-0.0437	1.0622	0.01857	-0.0455
9.00	1.1315	0.02009	-0.0383	1.1357	0.02164	-0.0391
10.00	1.1796	0.02515	-0.0289	1.1816	0.02663	-0.0293
11.00	1.2173	0.03128	-0.0193	1.2189	0.03273	-0.0197
12.00	1.2319	0.03840	-0.0102	1.2323	0.03988	-0.0104
13.00	1.1971	0.05185	-0.0034	1.1966	0.05334	-0.0036
14.00	1.1369	0.07199	-0.0082	1.1358	0.07346	-0.0084
15.00	1.0635	0.10483	-0.0290	1.0617	0.10649	-0.0294

$R = 0.50 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.016	0.009891	-0.0697	-0.016	0.012825	-0.0697
-2.00	0.094	0.006338	-0.0712	0.094	0.011903	-0.0712
-1.00	0.204	0.006108	-0.0728	0.204	0.011949	-0.0728
0.00	0.314	0.006169	-0.0743	0.314	0.012093	-0.0743
1.00	0.424	0.006236	-0.0759	0.424	0.012353	-0.0759
2.00	0.534	0.006373	-0.0775	0.533	0.012819	-0.0773
3.00	0.644	0.007229	-0.0791	0.641	0.013345	-0.0784
4.00	0.752	0.008694	-0.0803	0.748	0.013959	-0.0792
5.00	0.854	0.012432	-0.0799	0.853	0.014689	-0.0797
6.00	0.954	0.014832	-0.0793	0.954	0.016409	-0.0793
7.00	1.048	0.017421	-0.0772	1.048	0.018900	-0.0772
8.00	1.112	0.019690	-0.0692	1.112	0.021074	-0.0692
8.42	1.172	0.019798	-0.0724	1.172	0.021146	-0.0724

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00				-0.0545	0.01267	-0.0632
-2.90	-0.0087	0.01017	-0.0727			
-2.00	0.0945	0.00831	-0.0736	0.0513	0.01181	-0.0618
-1.00	0.1920	0.00605	-0.0702	0.1588	0.01182	-0.0611
0.00	0.2858	0.00585	-0.0638	0.2658	0.01193	-0.0603
1.00	0.4415	0.00585	-0.0723	0.3723	0.01215	-0.0595
2.00	0.5837	0.00588	-0.0790	0.4779	0.01246	-0.0585
3.00	0.6593	0.00631	-0.0714	0.5826	0.01288	-0.0575
4.00	0.7257	0.00786	-0.0624	0.6859	0.01340	-0.0562
5.00	0.8075	0.00976	-0.0574	0.7876	0.01404	-0.0548
6.00				0.8871	0.01483	-0.0530
7.00	0.9855	0.01343	-0.0505	0.9840	0.01580	-0.0508
8.00	1.0742	0.01523	-0.0471	1.0773	0.01699	-0.0481
9.00	1.1524	0.01799	-0.0421	1.1566	0.01953	-0.0428
10.00	1.2042	0.02255	-0.0330	1.2062	0.02398	-0.0333
11.00	1.2475	0.02684	-0.0236	1.2483	0.02827	-0.0237
12.00	1.2658	0.03354	-0.0134	1.2658	0.03496	-0.0134
13.00	1.2556	0.04324	-0.0053	1.2546	0.04466	-0.0052
14.00	1.2119	0.05915	-0.0048	1.2099	0.06059	-0.0047
15.00	1.1330	0.08875	-0.0205	1.1306	0.09025	-0.0205

$R = 0.70 \times 10^6$

PROFIL00

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.016	0.009071	-0.0697	-0.016	0.012127	-0.0697
-2.00	0.094	0.006022	-0.0712	0.094	0.011295	-0.0712
-1.00	0.204	0.005368	-0.0728	0.204	0.011355	-0.0728
0.00	0.314	0.005339	-0.0743	0.314	0.011505	-0.0743
1.00	0.424	0.005461	-0.0759	0.424	0.011716	-0.0759
2.00	0.534	0.005991	-0.0775	0.534	0.012124	-0.0775
3.00	0.644	0.006993	-0.0791	0.642	0.012640	-0.0787
4.00	0.753	0.008342	-0.0805	0.750	0.013199	-0.0797
5.00	0.857	0.011386	-0.0807	0.856	0.013867	-0.0803
6.00	0.958	0.013720	-0.0801	0.958	0.015345	-0.0801
7.00	1.058	0.015296	-0.0794	1.058	0.016823	-0.0794
8.00	1.154	0.016923	-0.0777	1.154	0.018356	-0.0777
8.56	1.191	0.018906	-0.0734	1.191	0.020292	-0.0734

XFOIL 6.94

	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-3.00	-0.0005	0.00867	-0.0755	-0.0527	0.01162	-0.0635
-2.00	0.1038	0.00733	-0.0738	0.0540	0.01098	-0.0624
-1.00	0.2008	0.00519	-0.0713	0.1622	0.01101	-0.0618
0.00				0.2700	0.01112	-0.0611
1.00	0.3996	0.00497	-0.0632	0.3772	0.01133	-0.0604
2.00	0.5458	0.00521	-0.0705	0.4836	0.01162	-0.0596
3.00	0.6559	0.00605	-0.0708	0.5890	0.01200	-0.0587
4.00	0.7241	0.00758	-0.0626	0.6933	0.01247	-0.0576
5.00	0.8113	0.00919	-0.0585	0.7960	0.01306	-0.0563
6.00	0.9033	0.01077	-0.0555	0.8969	0.01377	-0.0548
7.00	0.9956	0.01238	-0.0526	0.9953	0.01463	-0.0528
8.00	1.0867	0.01399	-0.0496	1.0905	0.01568	-0.0504
9.00	1.1668	0.01663	-0.0448	1.1709	0.01816	-0.0454
10.00	1.2389	0.01957	-0.0389	1.2417	0.02102	-0.0392
11.00	1.2718	0.02450	-0.0273	1.2721	0.02591	-0.0272
12.00	1.2813	0.03147	-0.0153	1.2810	0.03287	-0.0151
13.00	1.2807	0.03966	-0.0069	1.2794	0.04106	-0.0067
14.00	1.2455	0.05363	-0.0043	1.2432	0.05505	-0.0042
15.00	1.1793	0.07881	-0.0158	1.1766	0.08025	-0.0157
16.00	1.0830	0.12065	-0.0415	1.0805	0.12217	-0.0415
17.00				0.7416	0.18775	-0.0817

APPENDIX F

SECTION CHARACTERISTICS OF SH3055 AIRFOIL

$R = 0.20 \times 10^6$

PROFIL00	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-10.82				-0.076	0.024029	-0.2840
-10.00				0.014	0.021366	-0.2860
-9.17	0.096	0.019700	-0.2874			
-9.00	0.114	0.019010	-0.2878	0.123	0.020222	-0.2884
-8.00	0.224	0.018487	-0.2902	0.233	0.019629	-0.2908
-7.00	0.336	0.017244	-0.2929	0.342	0.019242	-0.2931
-6.00	0.448	0.016759	-0.2953	0.451	0.019055	-0.2953
-5.00	0.559	0.016978	-0.2978	0.560	0.019052	-0.2964
-4.00	0.668	0.016807	-0.2998	0.669	0.019228	-0.2984
-3.00	0.777	0.017008	-0.3020	0.778	0.019582	-0.3004
-2.00	0.886	0.017278	-0.3023	0.886	0.020116	-0.3023
-1.00	0.995	0.017632	-0.3041	0.995	0.020813	-0.3041
0.00	1.104	0.018317	-0.3059	1.104	0.021631	-0.3058
1.00	1.212	0.019149	-0.3076	1.212	0.022698	-0.3074
1.74				1.292	0.023612	-0.3085
2.00	1.321	0.020259	-0.3091			
3.00	1.429	0.021606	-0.3105			
4.00	1.537	0.023196	-0.3117			
4.29	1.568	0.023745	-0.3121			

XFOIL 6.94	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-7.00	-0.0746	0.02259	-0.1962	-0.0475	0.02389	-0.1867
-6.00	0.1163	0.02032	-0.2137	0.1087	0.02183	-0.2015
-5.00	0.2804	0.01838	-0.2253	0.2541	0.02078	-0.2117
-4.00	0.4544	0.01706	-0.2376	0.3886	0.02034	-0.2182
-3.00	0.6016	0.01621	-0.2444	0.5163	0.02025	-0.2226
-2.00	0.7349	0.01582	-0.2484	0.6385	0.02040	-0.2255
-1.00	0.8600	0.01598	-0.2506	0.7561	0.02077	-0.2272
0.00	0.9781	0.01657	-0.2510	0.8686	0.02132	-0.2277
1.00	1.0886	0.01724	-0.2498	0.9758	0.02207	-0.2271
2.00	1.2019	0.01770	-0.2496	1.0766	0.02300	-0.2251
3.00	1.3083	0.01861	-0.2476	1.1686	0.02417	-0.2213
4.00	1.4111	0.01937	-0.2451	1.2492	0.02560	-0.2155
5.00	1.5120	0.02029	-0.2423	1.3234	0.02744	-0.2087
6.00	1.6069	0.02149	-0.2384	1.3950	0.02975	-0.2021
7.00	1.6937	0.02283	-0.2330	1.4580	0.03269	-0.1948
8.00	1.7656	0.02432	-0.2250	1.5141	0.03638	-0.1874
9.00	1.7991	0.02643	-0.2099	1.5617	0.04111	-0.1801
10.00	1.8341	0.02967	-0.1968	1.5998	0.04709	-0.1733
11.00	1.8603	0.03422	-0.1845	1.6305	0.05447	-0.1674
12.00	1.8618	0.04160	-0.1722	1.6530	0.06343	-0.1626
13.00	1.8438	0.05285	-0.1624	1.6656	0.07409	-0.1589
14.00	1.8065	0.06835	-0.1558	1.6716	0.08619	-0.1565
15.00	1.7458	0.08880	-0.1532	1.6691	0.10008	-0.1559
16.00	1.6717	0.11316	-0.1553	1.6598	0.11533	-0.1569
17.00	1.6274	0.13460	-0.1602	0.6998	0.04850	-0.0872
18.00	1.5934	0.15473	-0.1672	0.7255	0.05879	-0.0935
19.00	1.5772	0.17226	-0.1745	0.7504	0.07000	-0.0999
20.00	1.5811	0.18615	-0.1809	0.7728	0.08382	-0.1075

$R = 0.35 \times 10^6$

PROFIL00	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-11.00	-0.106	0.017858	-0.2826	-0.094	0.021881	-0.2836
-10.00	0.003	0.015596	-0.2850	0.015	0.018789	-0.2860
-9.00	0.115	0.014221	-0.2876	0.124	0.018054	-0.2884
-8.00	0.225	0.013424	-0.2900	0.233	0.017624	-0.2908
-7.00	0.338	0.012497	-0.2927	0.342	0.017358	-0.2931
-6.00	0.450	0.012501	-0.2953	0.452	0.017257	-0.2945
-5.00	0.561	0.012733	-0.2966	0.561	0.017309	-0.2966
-4.00	0.670	0.012909	-0.2987	0.670	0.017511	-0.2986
-3.00	0.779	0.013035	-0.3008	0.778	0.017867	-0.3006
-2.00	0.888	0.013269	-0.3027	0.887	0.018369	-0.3025
-1.00	0.997	0.013712	-0.3046	0.996	0.019022	-0.3043
0.00	1.106	0.014266	-0.3064	1.105	0.019753	-0.3061
1.00	1.215	0.015005	-0.3081	1.213	0.020711	-0.3077
2.00	1.323	0.015956	-0.3097	1.321	0.021833	-0.3092
2.04				1.326	0.021881	-0.3092
3.00	1.432	0.017066	-0.3111			
4.00	1.540	0.018386	-0.3124			
5.00	1.648	0.019916	-0.3136			
5.40	1.691	0.020638	-0.3140			

XFOIL 6.94	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-8.00	-0.1252	0.01627	-0.2075	-0.1405	0.02164	-0.1914
-7.00	0.0433	0.01443	-0.2209	0.0167	0.01952	-0.2063
-6.00	0.2212	0.01313	-0.2352	0.1647	0.01832	-0.2172
-5.00	0.3882	0.01188	-0.2470	0.3014	0.01777	-0.2241
-4.00	0.5271	0.01142	-0.2526	0.4308	0.01758	-0.2288
-3.00	0.6542	0.01153	-0.2553	0.5555	0.01761	-0.2321
-2.00	0.7736	0.01177	-0.2564	0.6761	0.01781	-0.2343
-1.00	0.8913	0.01205	-0.2571	0.7928	0.01818	-0.2355
0.00	1.0074	0.01240	-0.2574	0.9055	0.01870	-0.2358
1.00	1.1192	0.01298	-0.2567	1.0138	0.01936	-0.2351
2.00	1.2295	0.01352	-0.2557	1.1164	0.02018	-0.2332
3.00	1.3371	0.01418	-0.2542	1.2119	0.02118	-0.2299
4.00	1.4388	0.01506	-0.2515	1.2990	0.02240	-0.2250
5.00	1.5375	0.01600	-0.2482	1.3723	0.02394	-0.2175
6.00	1.6284	0.01720	-0.2434	1.4475	0.02587	-0.2109
7.00	1.7066	0.01853	-0.2362	1.5152	0.02829	-0.2036
8.00	1.7609	0.02055	-0.2245	1.5749	0.03134	-0.1957
9.00	1.8100	0.02320	-0.2129	1.6266	0.03530	-0.1878
10.00	1.8476	0.02704	-0.2007	1.6707	0.04031	-0.1803
11.00	1.8651	0.03288	-0.1878	1.7064	0.04658	-0.1734
12.00	1.8508	0.04270	-0.1748	1.7341	0.05440	-0.1675
13.00	1.8171	0.05659	-0.1650	1.7518	0.06406	-0.1627
14.00	1.7629	0.07505	-0.1590	1.7572	0.07570	-0.1589
15.00	1.7293	0.09272	-0.1571	1.7284	0.09272	-0.1569
16.00	1.6969	0.11138	-0.1581			
17.00	1.6573	0.13182	-0.1621			
18.00	1.6202	0.15301	-0.1691			
19.00	1.5987	0.17165	-0.1766			

$R = 0.50 \times 10^6$

PROFIL00	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-11.00	-0.106	0.015533	-0.2825	-0.094	0.019766	-0.2836
-10.00	0.003	0.013480	-0.2848	0.015	0.017433	-0.2861
-9.00	0.116	0.012200	-0.2875	0.125	0.016846	-0.2885
-8.00	0.230	0.011432	-0.2904	0.234	0.016489	-0.2909
-7.00	0.341	0.011090	-0.2930	0.343	0.016279	-0.2932
-6.00	0.452	0.010954	-0.2945	0.452	0.016218	-0.2946
-5.00	0.562	0.011084	-0.2968	0.561	0.016300	-0.2967
-4.00	0.671	0.011223	-0.2989	0.670	0.016511	-0.2988
-3.00	0.780	0.011251	-0.3010	0.779	0.016862	-0.3008
-2.00	0.889	0.011538	-0.3030	0.888	0.017345	-0.3027
-1.00	0.998	0.012002	-0.3049	0.997	0.017911	-0.3045
0.00	1.107	0.012525	-0.3067	1.105	0.018653	-0.3062
1.00	1.216	0.013242	-0.3083	1.214	0.019548	-0.3078
2.00	1.324	0.014078	-0.3099	1.322	0.020594	-0.3093
2.23				1.347	0.020858	-0.3097
3.00	1.433	0.015126	-0.3114			
4.00	1.541	0.016399	-0.3128			
5.00	1.649	0.017764	-0.3140			
5.40	1.692	0.018459	-0.3144			

XFOIL 6.94	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-8.00	-0.0795	0.01335	-0.2168	-0.1024	0.01915	-0.2033
-7.00	0.0886	0.01180	-0.2299	0.0506	0.01753	-0.2160
-6.00	0.2633	0.01049	-0.2440	0.1924	0.01669	-0.2246
-5.00	0.4178	0.00991	-0.2532	0.3252	0.01632	-0.2302
-4.00	0.5421	0.00998	-0.2555	0.4526	0.01621	-0.2341
-3.00	0.6641	0.01013	-0.2572	0.5759	0.01628	-0.2369
-2.00	0.7838	0.01027	-0.2585	0.6959	0.01650	-0.2388
-1.00	0.9005	0.01059	-0.2590	0.8125	0.01685	-0.2399
0.00	1.0158	0.01097	-0.2591	0.9256	0.01733	-0.2401
1.00	1.1290	0.01137	-0.2589	1.0349	0.01794	-0.2395
2.00	1.2390	0.01193	-0.2579	1.1391	0.01870	-0.2379
3.00	1.3462	0.01259	-0.2563	1.2369	0.01960	-0.2349
4.00	1.4498	0.01334	-0.2540	1.3274	0.02069	-0.2305
5.00	1.5478	0.01429	-0.2506	1.4043	0.02205	-0.2235
6.00	1.6411	0.01534	-0.2463	1.4796	0.02374	-0.2165
7.00	1.7169	0.01692	-0.2386	1.5497	0.02588	-0.2092
8.00	1.7758	0.01895	-0.2279	1.6122	0.02857	-0.2012
9.00	1.8258	0.02191	-0.2165	1.6677	0.03196	-0.1931
10.00	1.8588	0.02612	-0.2035	1.7167	0.03626	-0.1853
11.00	1.8510	0.03398	-0.1875	1.7565	0.04177	-0.1778
12.00	1.8255	0.04524	-0.1742	1.7879	0.04869	-0.1711
13.00	1.7930	0.05968	-0.1653	1.7899	0.05969	-0.1645
14.00	1.7760	0.07399	-0.1604	1.7726	0.07402	-0.1598
15.00	1.7567	0.08965	-0.1582	1.7534	0.08960	-0.1575
16.00	1.7271	0.10767	-0.1586			
17.00	1.6919	0.12709	-0.1615			
18.00	1.6628	0.14624	-0.1667			
19.00	1.6378	0.16557	-0.1742			
20.00	1.6246	0.18315	-0.1824			

$R = 0.70 \times 10^6$

PROFIL00	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-11.00	-0.106	0.013345	-0.2823	-0.093	0.017728	-0.2836
-10.00	0.006	0.011912	-0.2850	0.016	0.016292	-0.2861
-9.00	0.121	0.010811	-0.2880	0.125	0.015808	-0.2885
-8.00	0.233	0.010158	-0.2907	0.235	0.015510	-0.2909
-7.00	0.343	0.009951	-0.2924	0.344	0.015344	-0.2932
-6.00	0.453	0.009852	-0.2948	0.453	0.015312	-0.2947
-5.00	0.562	0.009865	-0.2970	0.562	0.015406	-0.2969
-4.00	0.672	0.009936	-0.2991	0.671	0.015620	-0.2989
-3.00	0.781	0.010016	-0.3012	0.780	0.015971	-0.3009
-2.00	0.890	0.010292	-0.3032	0.888	0.016435	-0.3028
-1.00	0.999	0.010681	-0.3051	0.997	0.016970	-0.3047
0.00	1.108	0.011214	-0.3069	1.106	0.017683	-0.3064
1.00	1.217	0.011931	-0.3086	1.214	0.018517	-0.3080
2.00	1.325	0.012781	-0.3102	1.323	0.019502	-0.3095
2.41				1.367	0.019999	-0.3101
3.00	1.434	0.013753	-0.3117			
4.00	1.542	0.014870	-0.3130			
5.00	1.650	0.016165	-0.3143			
5.40	1.693	0.016772	-0.3147			

XFOIL 6.94	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-8.00	-0.0463	0.01131	-0.2241	-0.0679	0.01712	-0.2137
-7.00	0.1369	0.00978	-0.2406	0.0794	0.01592	-0.2241
-6.00	0.2998	0.00896	-0.2520	0.2151	0.01539	-0.2306
-5.00	0.4283	0.00898	-0.2552	0.3449	0.01514	-0.2351
-4.00	0.5517	0.00896	-0.2575	0.4704	0.01509	-0.2385
-3.00	0.6720	0.00909	-0.2589	0.5928	0.01519	-0.2409
-2.00	0.7893	0.00937	-0.2596	0.7123	0.01541	-0.2426
-1.00	0.9069	0.00961	-0.2603	0.8289	0.01575	-0.2435
0.00	1.0222	0.00994	-0.2605	0.9424	0.01621	-0.2437
1.00	1.1349	0.01039	-0.2601	1.0524	0.01679	-0.2432
2.00	1.2458	0.01089	-0.2594	1.1583	0.01748	-0.2418
3.00	1.3534	0.01150	-0.2580	1.2579	0.01831	-0.2391
4.00	1.4575	0.01227	-0.2558	1.3514	0.01930	-0.2352
5.00	1.5581	0.01311	-0.2530	1.4372	0.02048	-0.2299
6.00	1.6529	0.01413	-0.2490	1.5077	0.02200	-0.2216
7.00	1.7307	0.01584	-0.2419	1.5814	0.02387	-0.2146
8.00	1.7891	0.01809	-0.2310	1.6473	0.02621	-0.2067
9.00	1.8353	0.02130	-0.2189	1.7054	0.02915	-0.1983
10.00	1.8478	0.02679	-0.2027	1.7568	0.03294	-0.1900
11.00	1.8273	0.03593	-0.1856	1.8007	0.03776	-0.1821
12.00	1.8150	0.04642	-0.1741	1.8083	0.04659	-0.1727
13.00	1.8205	0.05679	-0.1671	1.8151	0.05686	-0.1660
14.00	1.8104	0.07010	-0.1621	1.8051	0.07013	-0.1609
15.00	1.7867	0.08596	-0.1591			
16.00	1.7530	0.10434	-0.1588			
17.00	1.7155	0.12393	-0.1613			
18.00	1.6809	0.14373	-0.1663			
19.00	1.6532	0.16327	-0.1735			
20.00	1.6354	0.18167	-0.1820			

$R = 1.00 \times 10^6$

PROFIL00	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-11.00	-0.105	0.011822	-0.2823	-0.092	0.016277	-0.2837
-10.00	0.012	0.010641	-0.2856	0.017	0.015198	-0.2862
-9.00	0.124	0.009795	-0.2884	0.126	0.014801	-0.2886
-8.00	0.235	0.009417	-0.2909	0.235	0.014553	-0.2910
-7.00	0.344	0.009193	-0.2927	0.344	0.014425	-0.2927
-6.00	0.454	0.009027	-0.2950	0.453	0.014419	-0.2949
-5.00	0.563	0.008963	-0.2972	0.563	0.014524	-0.2970
-4.00	0.672	0.008977	-0.2993	0.671	0.014741	-0.2991
-3.00	0.782	0.009152	-0.3014	0.780	0.015074	-0.3011
-2.00	0.891	0.009402	-0.3034	0.889	0.015481	-0.3030
-1.00	1.000	0.009743	-0.3053	0.998	0.016033	-0.3048
0.00	1.109	0.010294	-0.3071	1.107	0.016704	-0.3066
1.00	1.218	0.010897	-0.3088	1.215	0.017488	-0.3082
2.00	1.326	0.011643	-0.3104	1.323	0.018462	-0.3097
2.60				1.388	0.019085	-0.3106
3.00	1.435	0.012526	-0.3119			
4.00	1.543	0.013545	-0.3133			
5.00	1.651	0.014748	-0.3145			
5.40	1.695	0.015258	-0.3150			

XFOIL 6.94	Transition Free			Transition Fixed		
α, deg	c_l	c_d	c_m	c_l	c_d	c_m
-8.00	-0.0068	0.00947	-0.2332	-0.0349	0.01529	-0.2234
-7.00	0.1789	0.00834	-0.2501	0.1040	0.01455	-0.2309
-6.00	0.3145	0.00815	-0.2551	0.2354	0.01420	-0.2359
-5.00	0.4372	0.00817	-0.2572	0.3626	0.01406	-0.2396
-4.00	0.5595	0.00816	-0.2592	0.4869	0.01405	-0.2424
-3.00	0.6776	0.00838	-0.2601	0.6085	0.01418	-0.2446
-2.00	0.7972	0.00850	-0.2614	0.7276	0.01440	-0.2461
-1.00	0.9150	0.00870	-0.2622	0.8443	0.01473	-0.2469
0.00	1.0299	0.00906	-0.2622	0.9581	0.01516	-0.2471
1.00	1.1438	0.00943	-0.2622	1.0689	0.01570	-0.2467
2.00	1.2555	0.00989	-0.2616	1.1763	0.01633	-0.2456
3.00	1.3643	0.01049	-0.2603	1.2780	0.01709	-0.2432
4.00	1.4706	0.01117	-0.2587	1.3744	0.01799	-0.2398
5.00	1.5726	0.01201	-0.2562	1.4637	0.01904	-0.2351
6.00	1.6649	0.01330	-0.2518	1.5376	0.02037	-0.2273
7.00	1.7477	0.01491	-0.2457	1.6124	0.02200	-0.2200
8.00	1.8031	0.01742	-0.2343	1.6805	0.02406	-0.2121
9.00	1.8261	0.02183	-0.2179	1.7416	0.02664	-0.2037
10.00	1.8174	0.02881	-0.1989	1.7967	0.02987	-0.1952
11.00	1.8261	0.03602	-0.1858	1.8174	0.03627	-0.1839
12.00	1.8441	0.04363	-0.1765	1.8364	0.04378	-0.1748
13.00	1.8453	0.05421	-0.1686	1.8372	0.05443	-0.1670
14.00	1.8428	0.06629	-0.1632	1.8359	0.06640	-0.1618
15.00	1.8242	0.08118	-0.1596			
16.00	1.7933	0.09881	-0.1585			
17.00	1.7549	0.11833	-0.1602			
18.00	1.7138	0.13869	-0.1646			
19.00	1.6841	0.15809	-0.1711			
20.00	1.6617	0.17681	-0.1792			

REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 2003	Subcontractor report: July 11, 2002 – October 31, 2002

4. TITLE AND SUBTITLE
Theoretical Aerodynamic Analyses of Six Airfoils for Use on Small Wind Turbines

5. FUNDING NUMBERS
WER3.1830

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Airfoils, Inc.
122 Rose Drive
Port Matilda, Pennsylvania 16870-9483

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NREL/SR-500-33295

11. SUPPLEMENTARY NOTES
NREL Technical Monitor: P.G. Migliore

12a. DISTRIBUTION/AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Theoretical analyses of six airfoils—the E 387, FX 63-137, S822, S834, SD2030, and SH3055—have been performed for Reynolds numbers from 0.10×10^6 to 1.00×10^6 using the Eppler Airfoil Design and Analysis Code and the XFOIL code. The results from both codes exhibit the typical Reynolds number and roughness effects. Comparisons of the results from the two codes generally show good agreement, particularly for Reynolds numbers greater than 0.10×10^6. The maximum lift coefficient predicted by the XFOIL code is about 0.2 higher, and the Reynolds number and roughness effects are larger. The magnitudes of the zero-lift angle and pitching-moment coefficients predicted by the Eppler code are greater.

14. SUBJECT TERMS
wind energy; airfoils; Reynolds numbers; Eppler code; XFOIL code

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL