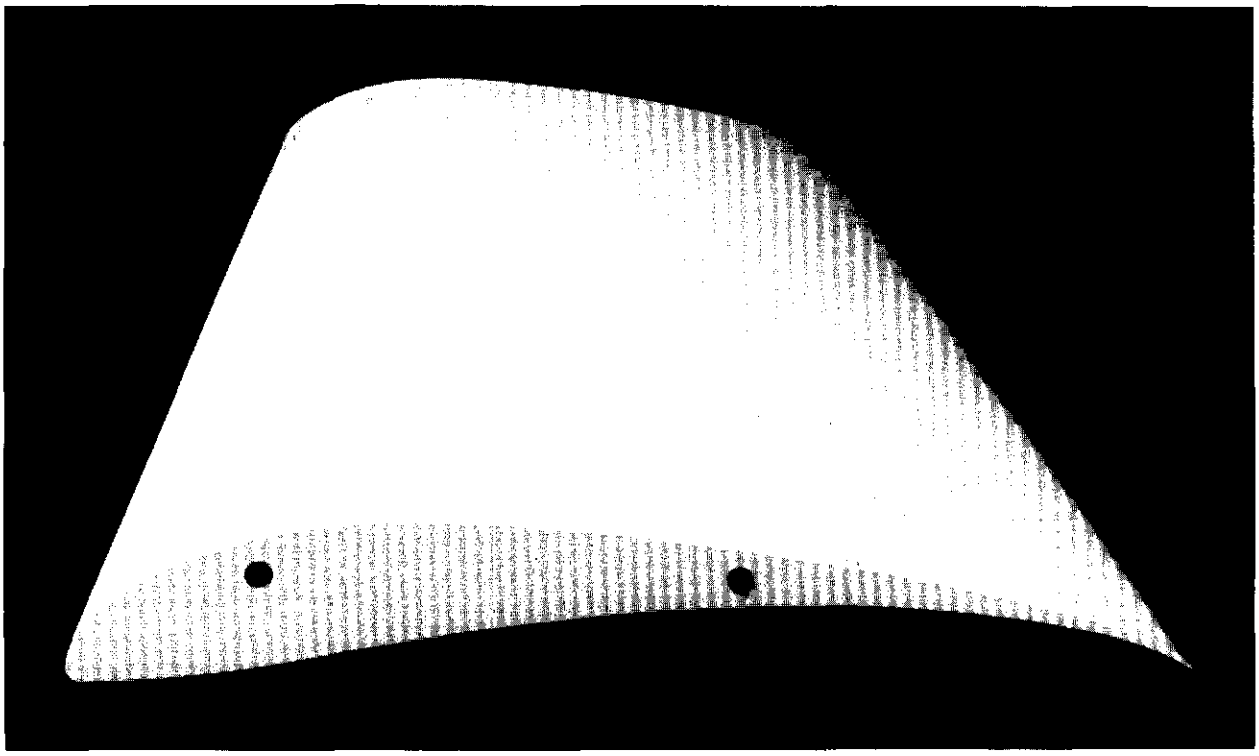
# Summary of Low-Speed Airfoil Data

**Michael S. Selig, James J. Guglielmo, Andy P. Broeren and Philippe Giguère**



**Volume 1**

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**Volume 1**

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# Preface

A reader just discovering airfoil aerodynamics will find it helpful to reference the companion book *Airfoils at Low Speeds* (by Selig, Donovan and Fraser), which was first published as SoarTech 8 in 1989. The book presents the results of wind-tunnel tests conducted at Princeton University on over 60 airfoils for model aircraft (mostly radio controlled sailplanes), and it also introduces the terminology and jargon used here in discussing airfoils at low speeds, specifically, airfoils at low Reynolds numbers.

When the wind-tunnel tests were completed at Princeton in January 1989, no continuation of that effort was planned. In the hope that the tests could be later continued, however, the experimental apparatus and the assorted wind-tunnel models were put in safe storage. Michael Selig continued his graduate studies at Penn State (Ph.D. in Aerospace Engineering) and John Donovan (Ph.D. from Princeton) accepted a position at McDonnell Douglas in St. Louis. Sadly, David Fraser died in an aircraft icing accident in January 1992.

As this book reveals, the opportunity to continue the low-speed airfoil test effort has emerged. In August 1992, Selig joined the faculty in the Department of Aeronautical and Astronautical Engineering at the University of Illinois at Urbana-Champaign. In brief chronological order, re-establishing the airfoil test capability was initiated with the help of two graduate students—Jim Guglielmo (M.S.) and Tony Balow (M.S.). Support from modelers was solicited in December 1993, and the test program was named the UIUC Low-Speed Airfoil Tests. (The tremendous generosity of all those who have contributed to the project is discussed in the acknowledgments.) Preliminary tests were performed in April 1994. Andy Broeren (M.S.) volunteered to join the test team in May 1994. Philippe Giguère (Ph.D.) volunteered to start work on the project in August 1994. The extensive data collection effort mounted for this book took place over a one month period from mid-December 1994 to mid-January 1995. More recently, Cameron Ninham (M.S.) and Ashok Gopalarathnam (Ph.D.) have offered to play a role in future testing. To date, only Jim Guglielmo has been supported (since July 1994) on funds donated by modelers.

## This Book and Its Organization

*Summary of Low-Speed Airfoil Data* is only the first in what should be a series of volumes that document the ongoing low Reynolds number airfoil tests at the University of Illinois at Urbana-Champaign. In this volume, the airfoils tested cover a broad spectrum that includes airfoils for free flight model aircraft, heavy lift R/C aircraft and, of course, R/C sailplanes, to name just a few. As an overview, the 34 airfoils tested are briefly introduced in Chapter 1.

Chapter 2 is devoted to a discussion of the wind-tunnel test facility and the experimental procedures. This chapter can be skipped by those less interested in the myriad of issues that arise in wind-tunnel testing. Of course, the importance of the methods used in taking and reducing the data cannot be over-emphasized. Although the data collection effort was performed in little more than a month, nearly two and a half years were spent in preparation for the tests. Fortunately, future tests will not require as much preparation time.

This book is primarily designed to be used as a reference for low Reynolds number airfoil data. In Chapter 3, a discussion of all the airfoils is given first; then the figures (airfoil plots and performance data) are presented in Chapter 4. The discussion is organized according to the application (i.e., free flight model airfoils are first discussed, then F3B airfoils and so on for each category). The figures in Chapter 4, however, are organized alphabetically by the airfoil name. For quick referencing of the figures in Chapter 4, the airfoil name is listed in the margin below the page number. Finally, the tabulated airfoil coordinates and performance data (available on diskette) are given in Appendices A and B. Appendix C contains the UIUC Low-Speed Airfoil Tests Manifesto that outlines the scope and purpose of this work.

# Acknowledgments

The airfoil testing effort would not have been possible without the support of a large number of people. *To each of them we are indebted.* In particular, for monetary contributions that were used for equipment and a graduate student research assistantship, we are especially grateful to the following organizations, clubs, businesses, individuals and t-shirt patrons. Shown in parentheses for each category is that category's fraction of the total support received. Note that some people are listed more than once since they have helped in different capacities.

- *Organizations (10%):* Academy of Model Aeronautics (with special appreciation to Bob Underwood and others), ISF-International R/C Soaring Forum (with special appreciation to Rolf Girsberger), National Association of Rocketry (Mark Bundick), and National Free Flight Society (with special appreciation to Bob Waterman).

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  (* denotes wind-tunnel models under construction or built after the completion of the most recent wind-tunnel tests)

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# Airfoil Data Distribution

All of the airfoil coordinates and performance data presented in this book (see Chapter 4) are available on IBM and Macintosh compatible diskettes through SoarTech Publications. SoarTech will be returning a portion of the proceeds from all disk and book sales to help support the continuation of these airfoil wind tunnel tests. For more information, write to

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The data is also available on the Internet from the host **opus.aae.uiuc.edu** using anonymous FTP. See the file `/pub/lsat/AIRFOIL.DATA` for directions on which files to copy.

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If you find the airfoil performance data useful, **please send a donation** to support our work. If you have already made a donation, we hope that you will consider renewing your commitment. Your tax deductible donations (see Appendix C) can be mailed to

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# List of Symbols

| | |
|---|---|
| $A_{ts}$ | test section area |
| $b$ | model span |
| $c$ | airfoil chord |
| $C_l$ | airfoil lift coefficient, $l/\frac{1}{2}\rho V_\infty^2 c$ |
| $C_L$ | aircraft lift coefficient |
| $C_{l_{max}}$ | maximum lift coefficient |
| $\Delta C_{l_{sc}}$ | change in lift coefficient due to streamline curvature |
| $C_d$ | airfoil drag coefficient, $d/\frac{1}{2}\rho V_\infty^2 c$ |
| $C_D$ | aircraft drag coefficient |
| $C_{d_o}$ | zero-lift drag coefficient |
| $C_{d_u}$ | uncorrected drag coefficient |
| $C_{m,c/4}$ | airfoil pitching moment about the quarter-chord point |
| $d$ | drag per unit span |
| $h$ | trip height or Gurney flap height |
| $h_{ts}$ | test section height |
| $K_1$ | wind-tunnel correction constant for solid blockage effects (0.74) |
| $K_{vel}$ | ratio of upstream velocity to velocity at model quarter-chord point |
| $l$ | lift per unit span |
| $L/D$ | aircraft lift-to-drag ratio |
| $M_v$ | model volume |
| $q_\infty$ | freestream dynamic pressure |
| $P_{atm}$ | atmospheric pressure |
| $P_0$ | total pressure |
| $P_{0,1}$ | wake total pressure |
| $P_{0,\infty}$ | freestream total pressure |
| $P_s$ | static pressure |
| $P_{s,1}$ | wake static pressure |
| $P_{s,\infty}$ | freestream static pressure |
| $\Delta P_0$ | total pressure difference between freestream and wake |
| $R$ | ideal gas constant for air |
| $Re$ | Reynolds number, $\rho V_\infty\, c/\mu$ |
| $\mathcal{R}$ | reduced Reynolds number |
| $S$ | Sutherland's constant or wing area |
| $T$ | temperature |
| $T_0$ | reference temperature |
| $u_1$ | streamwise velocity in wake |
| $V$ | inviscid local velocity on airfoil surface |
| $V_c$ | corrected velocity |
| $V_u$ | uncorrected velocity |
| $V_\infty$ | freestream velocity |

| | |
|---|---|
| $W$ | aircraft weight |
| $x$ | distance along airfoil chord or along model span |
| $y$ | vertical distance |
| $\alpha$ | angle of attack |
| $\alpha_u$ | uncorrected angle of attack |
| $\Delta\alpha_{sc}$ | change in angle of attack due to streamline curvature |
| $\varepsilon_b$ | total blockage correction factor (solid and wake) |
| $\varepsilon_{sb}$ | solid blockage correction factor |
| $\varepsilon_{wb}$ | wake blockage correction factor |
| $\sigma$ | wind-tunnel correction parameter, $(\pi^2/48)(c/h)^2$ |
| $\mu$ | fluid viscosity |
| $\mu_0$ | reference fluid viscosity |
| $\rho$ | fluid density |
| FF | free flight |
| HLG | hand-launch glider |
| MSL | mean sea level |
| VG's | vortex generators |

# Chapter 1

# The Airfoils Tested

This volume of SoarTech presents the performance characteristics of 34 airfoils (36 wind tunnel models), most of which are intended primarily for model aircraft, although the airfoils and data are expected to have wider application. Figure 1.1 shows by category the collection of airfoils that were tested. The myriad of airfoils depicted reflects the variety of airfoil design requirements that differ widely from one application to the next. These differences are highlighted in the pages that follow.

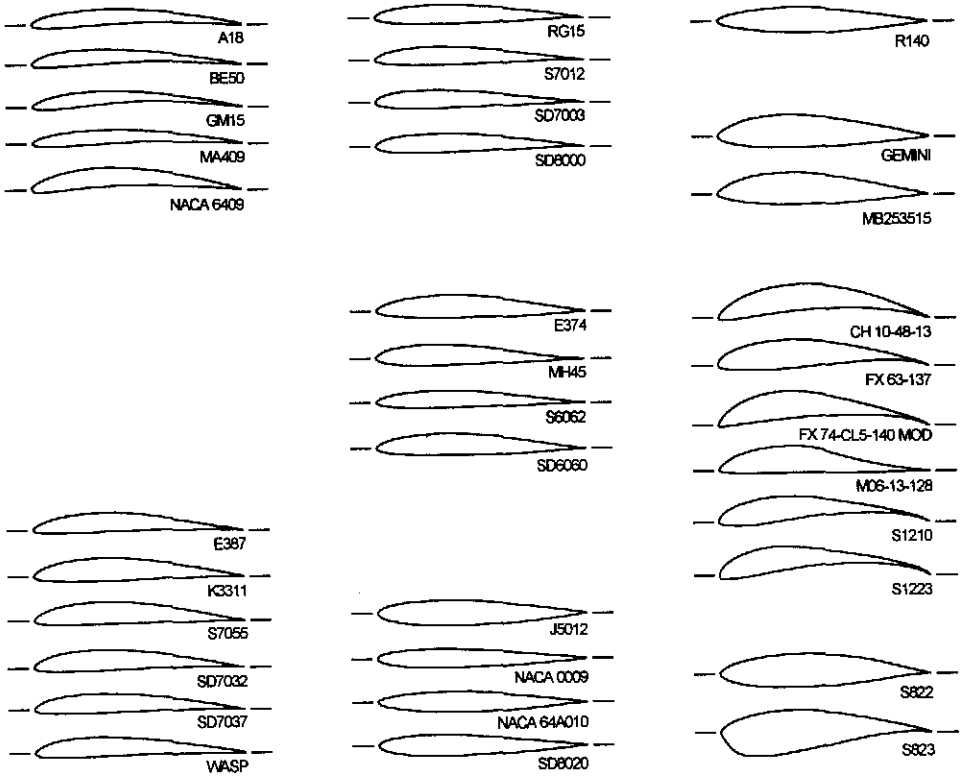



**Fig. 1.1** The collection of airfoils tested during Phase I of the UIUC Low-Speed Airfoil Tests (January 1995).

# Chapter 2

# Wind-Tunnel Facility and Measurement Techniques

All experiments were performed in the UIUC Department of Aeronautical and Astronautical Engineering Subsonic Aerodynamics Laboratory. Detailed descriptions of the low-speed wind tunnel, lift and drag measurement techniques, data acquisition equipment, and data reduction procedures are presented in this chapter and in Ref. 1.

## 2.1 Experimental Facility

Research was conducted in the UIUC low-turbulence subsonic wind tunnel shown in Fig. 2.1. The wind tunnel is an open-return type with a 7.5:1 contraction ratio. The rectangular test section is nominally $2.8 \times 4.0$ ft in cross section and 8 ft long. Over the length of the test section, the width increases by approximately 0.5 in to account for boundary-layer growth along the tunnel side walls. Test-section speeds are variable up to 160 mph via a 125 horsepower alternating current electric motor connected to a five-bladed fan. For a Reynolds number of 500,000 based on the airfoil chord, the resulting test-section speed was 80 ft/sec (55 mph). Additional photographs of the wind-tunnel inlet, test section and fan are presented in Figs. 2.2–2.4.

Since low Reynolds number airfoil performance is highly dependent on the behavior of the laminar boundary layer, low turbulence levels within the wind tunnel are necessary to ensure that laminar flow does not prematurely transition to turbulent flow over the airfoil surface. In order to ensure good flow quality in the test section, the wind-tunnel settling chamber contains a 4 in thick honeycomb and four anti-turbulence screens, which can be partially removed for cleaning. The turbulence intensity has been measured to be less than 0.1%,[2] which is sufficient for low Reynolds number airfoil measurements.

The experimental setup is depicted in Fig. 2.5. For the current tests, the airfoil models were mounted horizontally between two 3/8 in thick, 6 ft long Plexiglas endplates (not shown in Fig. 2.5 for clarity) to isolate the ends of the model from the tunnel side-wall boundary layers and the support hardware. Gaps between the model and Plexiglas were nominally 0.05 in. One side of the

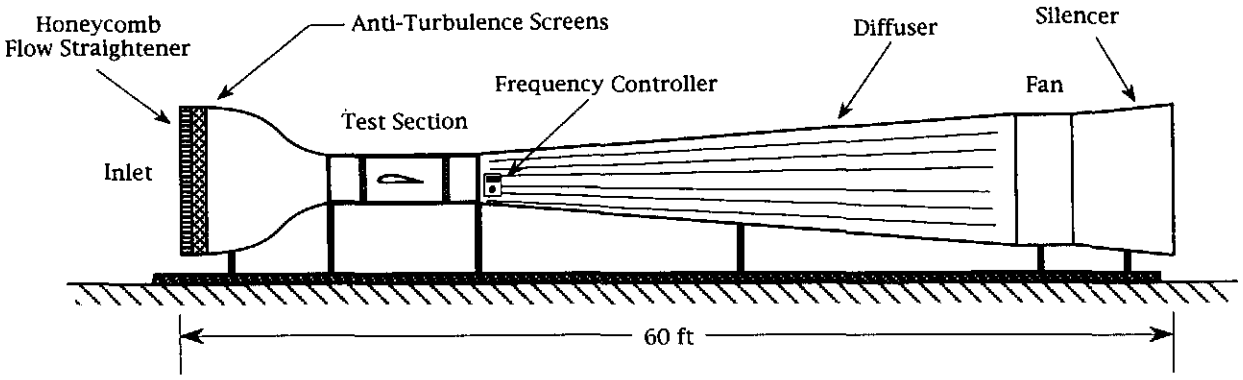



**Fig. 2.1** UIUC low-speed subsonic wind tunnel. (not to scale)

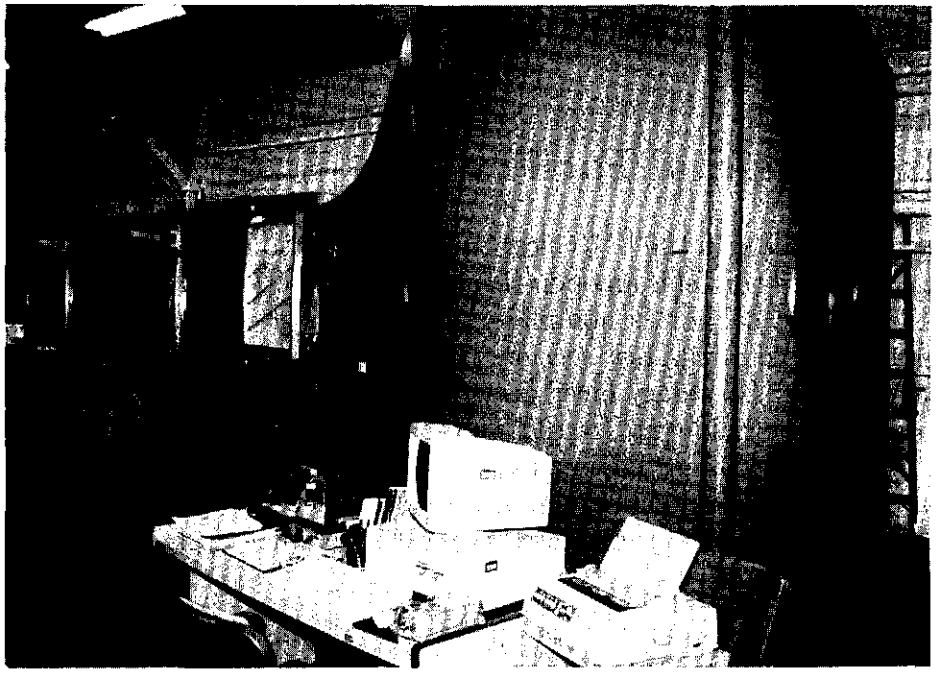


**Fig. 2.2** Photograph of wind-tunnel inlet.

airfoil was free to pivot (far side of Fig. 2.5). At this location, the angle of attack was measured using a linear transformer. The other side of the airfoil model was connected to the lift carriage through two steel wing rods that passed through the wing-rod fixture and were anchored to the model through two set screws. At this side, the airfoil model was free to move vertically on a precision ground shaft, but not free to rotate. A feedback-controlled force balance, however, restrained the motion of the model, as discussed later. Linear and spherical ball bearings within the lift carriage helped to minimize any frictional effects.

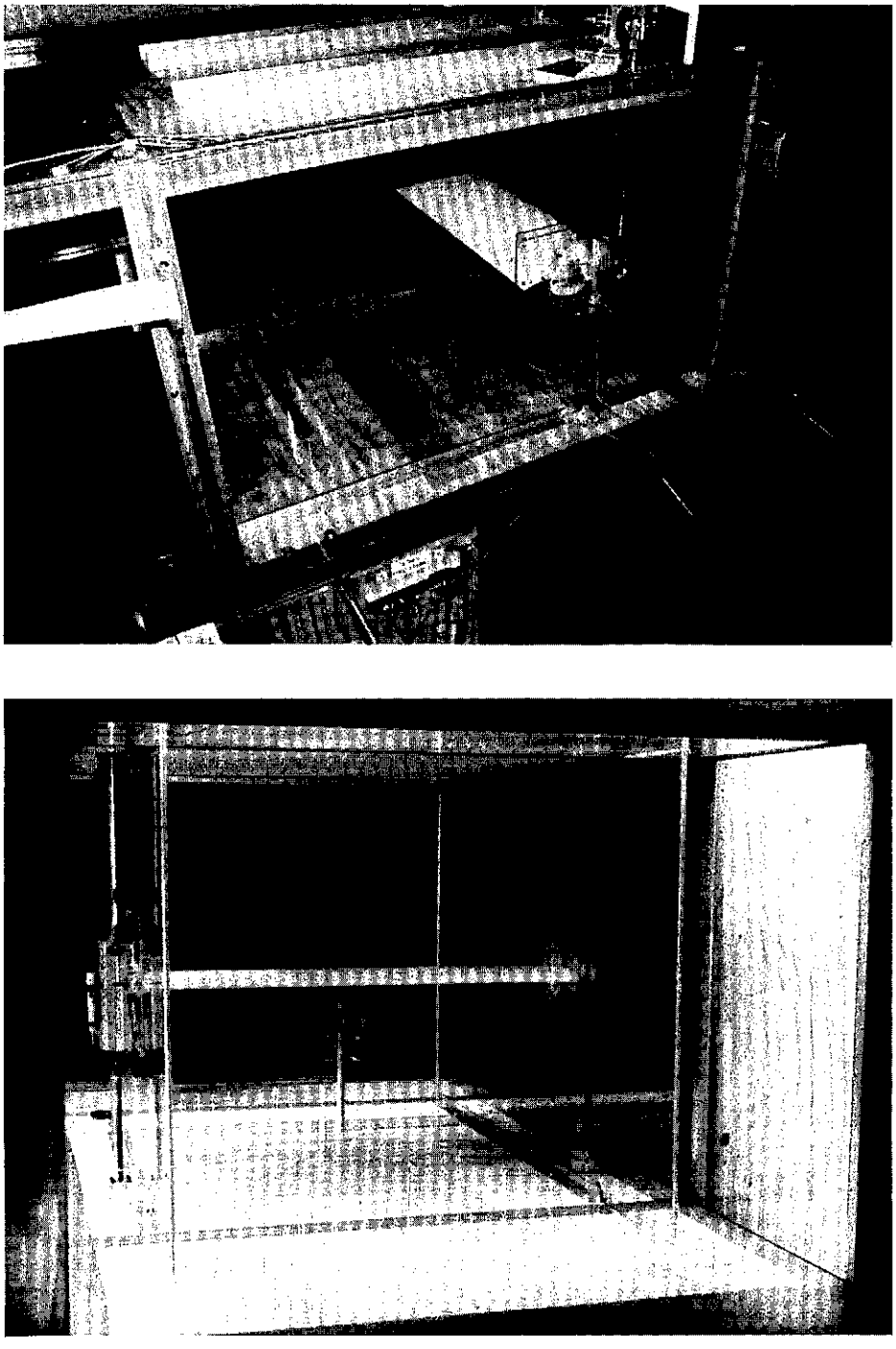


**Fig. 2.3** Photographs of wind-tunnel test section.

The two-axis traverser designed and built by the late David Fraser is depicted in Fig. 2.6. Two side-by-side pitot probes (spaced 3.96 in apart in the spanwise $x$-direction) were connected to the main center post that extended vertically

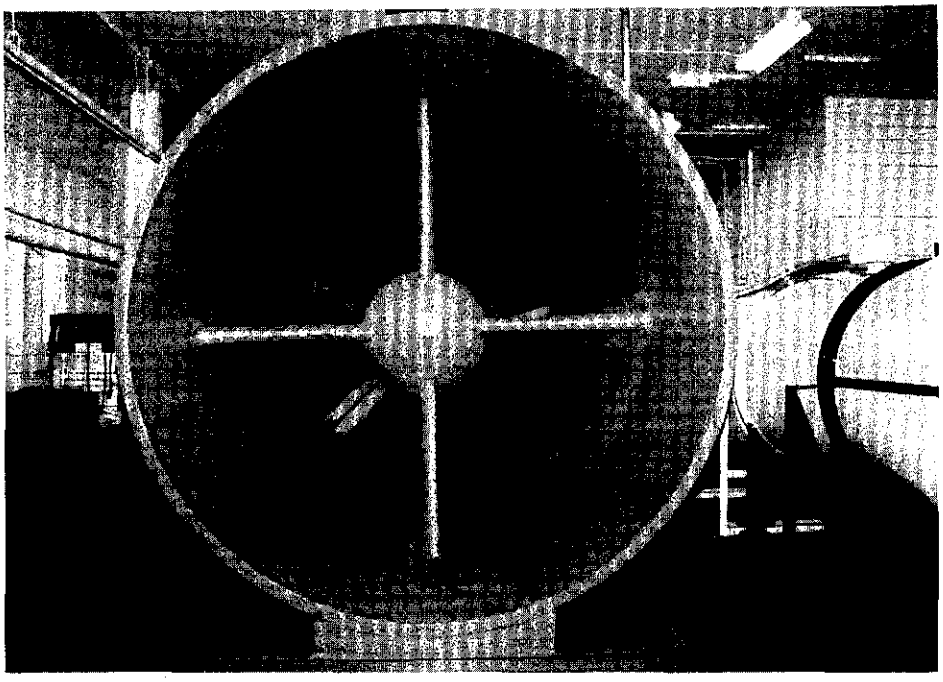


**Fig. 2.4** Photograph of wind-tunnel fan.

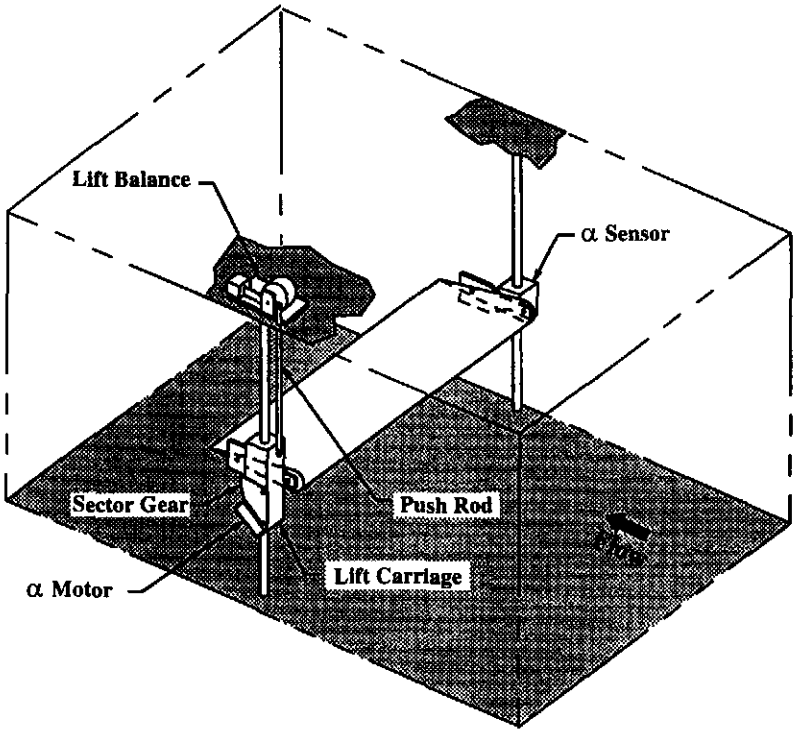



**Fig. 2.5** Experimental setup. (Plexiglas endplates and traverser not shown for clarity)

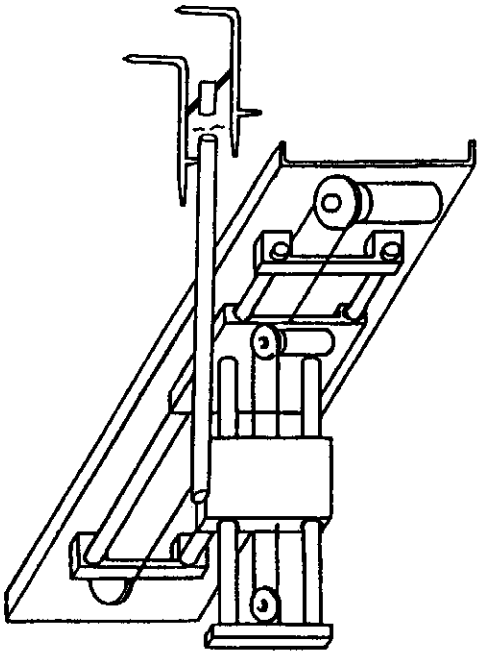


**Fig. 2.6** The $x$-$y$ traverser system.

through the tunnel test-section floor. The whole traversing system was located within a pressure-sealed box underneath the tunnel test section. The resolution and setability of the traverser are less than 0.001 and 0.005 in, respectively, in both the spanwise and vertical directions. Readout accuracy in the spanwise and vertical directions are 0.020 and 0.002 in, respectively.

All wind-tunnel models have a nominal 12 in chord and 33 5/8 in span ($\pm$ 1/64 in tolerances), and two brass tubes on each end of the model for mounting. Figure 2.7 depicts the general construction specifications and dimensions of the airfoil models.

## 2.2 Measurement Techniques

All analog data was recorded on an AT&T 386 computer through a Data Translation DT2836 16-bit analog-to-digital data acquisition board. The DT2836 has a resolution of 0.0015% of full-scale reading, eight differential input channels, and two 16-bit digital-to-analog output channels. Set for a full-scale range of $\pm$ 10 volts, the 16-bit resolution of the board provided an accuracy of $\pm$ 0.305 mV.

At the low speeds required for low Reynolds number tests, there were small time-dependent fluctuations in tunnel speed due to the inertia of both the drive system and the air. Thus, all quantities (dynamic pressure, total pressure, lift, angle of attack, $x$-position, $y$-position, and temperature) were measured simultaneously through a computer controlled data acquisition system. Once a run started, the entire data acquisition process was completely automated, including

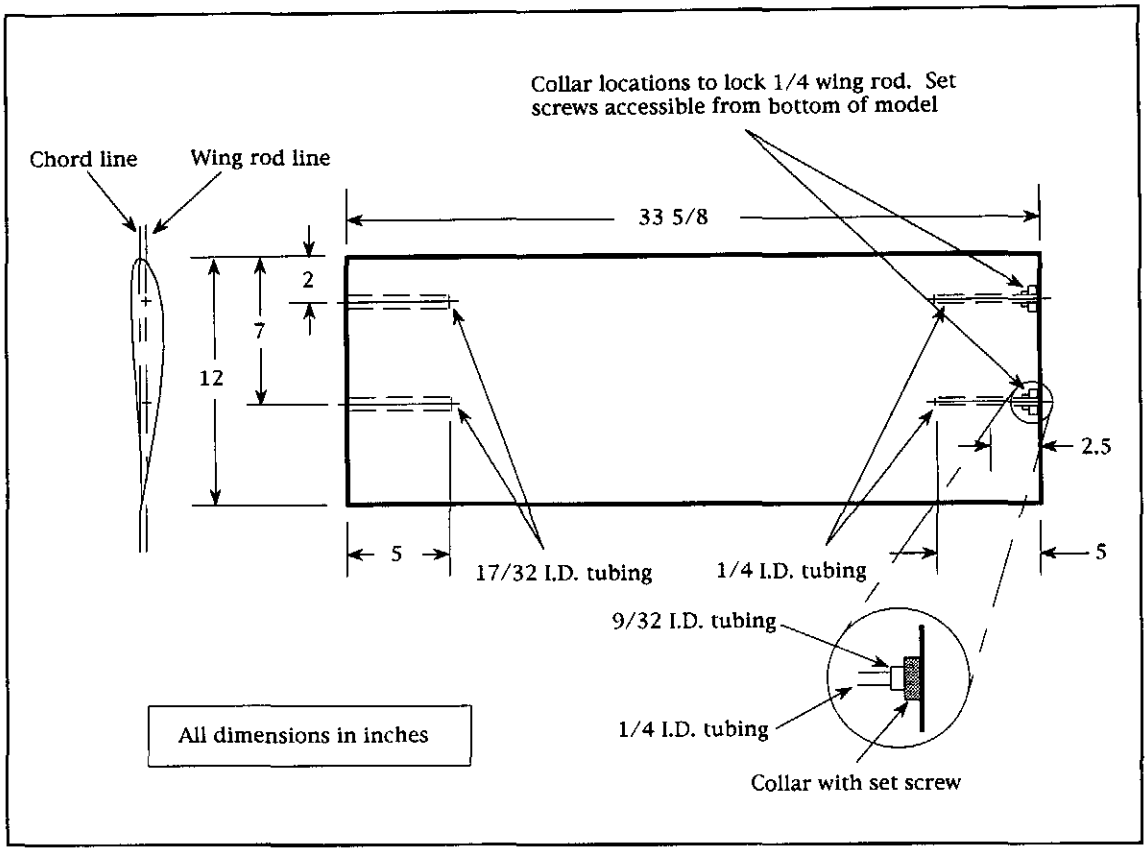



**Fig. 2.7** General wind-tunnel model construction specifications.

setting and maintaining a constant Reynolds number within the test section, acquiring data, and plotting raw data graphically to the computer screen and numerically to a printer. All data was also saved to a separate output file for later in-depth data reduction.

### 2.2.1 Lift Force Measurements

The wind-tunnel model was connected to the lift balance (or force transducer) through a pushrod attached to the lift carriage, as shown in Fig. 2.5. The force transducer was a servo balance rather than a standard strain gauge or load cell. Similar to a standard beam balance, the dead weight of the airfoil and support structure were counter-balanced with weights. The remaining forces (lift and residual imbalance) were then balanced by the torque from a brushless DC torque motor mounted on the beam axis. Any angular displacement from a reference zero was sensed by a linear transformer, and the error signal was used to drive the torque motor until the error was removed.

In general, acquiring only lift data was a relatively quick process. Since no wake measurements were taken, it was possible to cover a full angle of attack

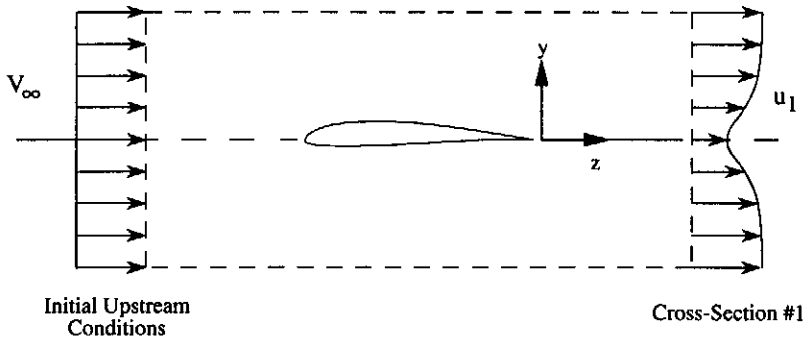



**Fig. 2.8** Control volume for the 2-D momentum deficit method to determine the profile drag.

range past stall in a short amount of time. (For example, angle of attack values from −8 deg to 16 deg to −8 deg with increments of 0.5 deg took approximately 15 minutes). Both increasing and decreasing angles of attack were covered to document any aerodynamic hysteresis.

### 2.2.2 Drag Force Measurements

While the lift force on airfoils at low Reynolds numbers can be obtained with acceptable accuracy through a lift balance, drag forces are often a magnitude less than their lift counterparts. As a result, profile drag is often best obtained by the momentum method instead of a force balance. For the current tests, the profile drag was determined through the method developed by Jones[3] (taken from Schlichting[4]).

After application of the two-dimensional momentum and continuity equations to a control volume shown in Fig. 2.8, the drag force per unit span can be calculated from

$$d = \rho \int_{-\infty}^{\infty} u_1(V_\infty - u_1)dy \tag{2.1}$$

Assuming that the location in which the measurements are performed is located sufficiently far enough behind the airfoil such that the static pressure has returned to upstream tunnel static pressure (i.e., $P_{s,1} = P_{s,\infty} = P_s$) and that the downstream flow outside the airfoil wake proceeds without losses (i.e., the total pressure remains constant along every streamline), the total pressure relationships from Bernoulli's equation are

$$P_s + \frac{1}{2}\rho {u_1}^2 = P_{0,1} \tag{2.2}$$

$$P_s + \frac{1}{2}\rho V_\infty^2 = P_{0,\infty} \tag{2.3}$$

Application of the above relationships to Eq. (2.1) and simplifying

$$d = 2\int_{-\infty}^{\infty} \left\{\sqrt{P_{0,1} - P_s}\sqrt{q_\infty - P_s} - (P_{0,1} - P_s)\right\} dy \tag{2.4}$$

$$P_{0,1} - P_s = P_{0,1} - P_s - P_{0,\infty} + P_{0,\infty} = q_\infty - \Delta P_0 \tag{2.5}$$

$$d = 2\int_{-\infty}^{\infty} \sqrt{q_\infty - \Delta P_0}\left(\sqrt{q_\infty} - \sqrt{q_\infty - \Delta P_0}\right) dy \tag{2.6}$$

To ensure that the wake had relaxed to tunnel static pressure, the wake measurements were performed 14.8 in (approximately 1.25 chord lengths) downstream of the trailing edge of the airfoil. Each vertical wake traverse consisted of between 20 and 80 total-head pressure measurements (depending on wake thickness) with points nominally spaced 0.08 in apart. No measurements were taken in stall due to the size and unsteadiness of the wake.

Pressure measurements within the wake were made using MKS Baratron Model 220 variable-capacitance differential pressure transducers with a full-scale range of 1 mm Hg (0.02 psia), resolution of 0.01% of full-scale reading, and an accuracy of 0.15% of reading.

In order to obtain an accurate value for the drag coefficient, wake profile measurements were taken at four spanwise locations spaced 4 in apart over the center 12 in of the airfoil. The resulting four drag coefficients were then averaged to obtain the drag at a given angle of attack. This average drag coefficient is presented in Chapter 4 and Appendix B. Figure 2.9 depicts a typical variation in the spanwise drag coefficient at Reynolds numbers from 60,000 to 300,000. For the *Re* of 60,000 case, the variation could be called "scatter," which is due partly to the unsteadiness in the wake and the difficulty in resolving such small pressure differences. At the higher *Re*'s, however, an intrinsic steady-state variation is present. For the interested reader, a thorough documentation of this phenomenon is presented in Refs. 5 and 6.

It should be noted that for the *Re*'s of 60,000 and 100,000 the spanwise drag coefficient for approximately $x = 5.5$ in was often higher than the other three locations. (For reference, the center of the tunnel was $x = 0$ in and the endplates are $\pm$ 16.86 in.) The higher spanwise drag value may be related to corner vortices developing at the juncture between the model and endplates, but this is only speculation. While it may be correct to discard this value, it was still included for the average drag coefficient results presented in this book.

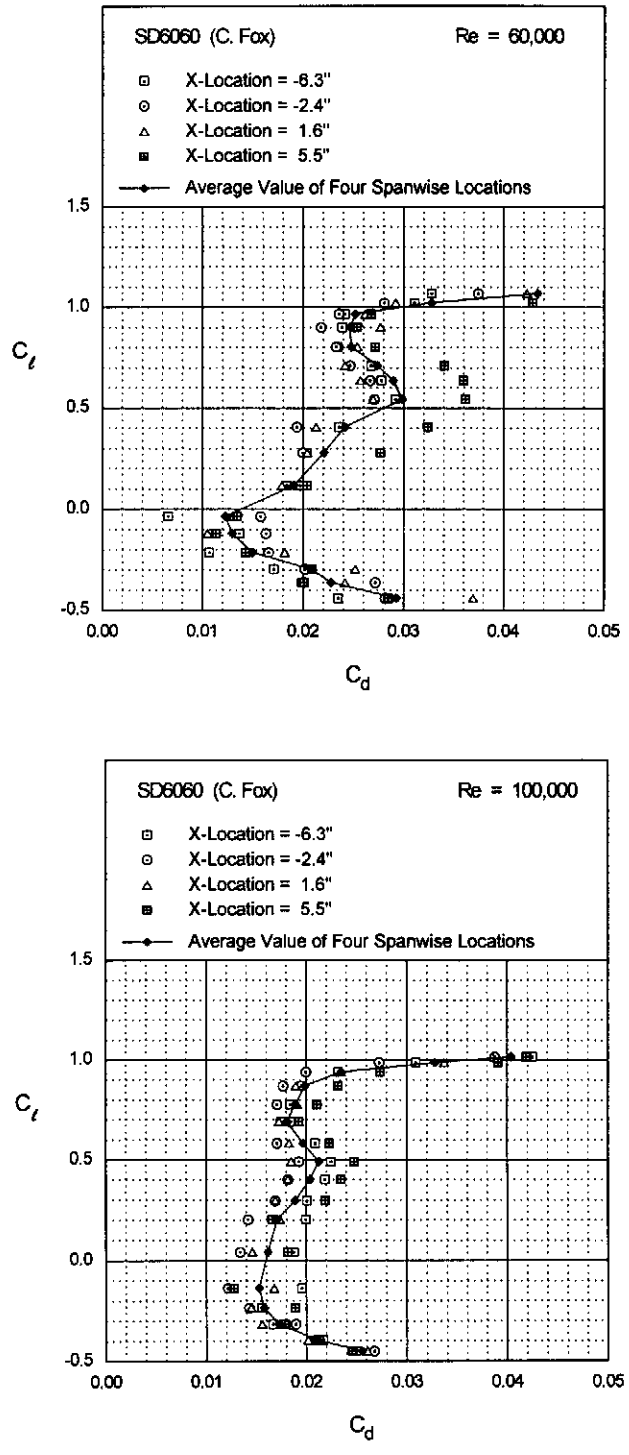
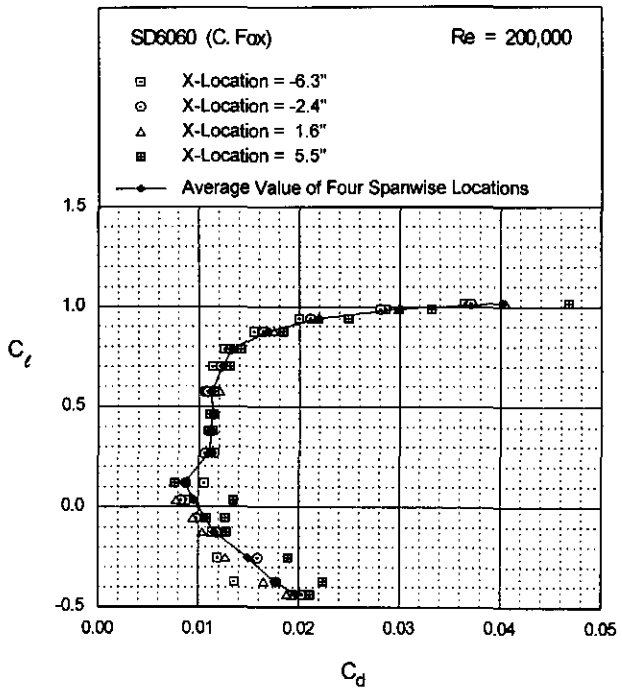



**Fig. 2.9** Drag results for the SD6060 airfoil depicting typical spanwise drag variations for the four spanwise stations for $Re$ = 60,000, 100,000, 200,000 and 300,000.

(figure continues)



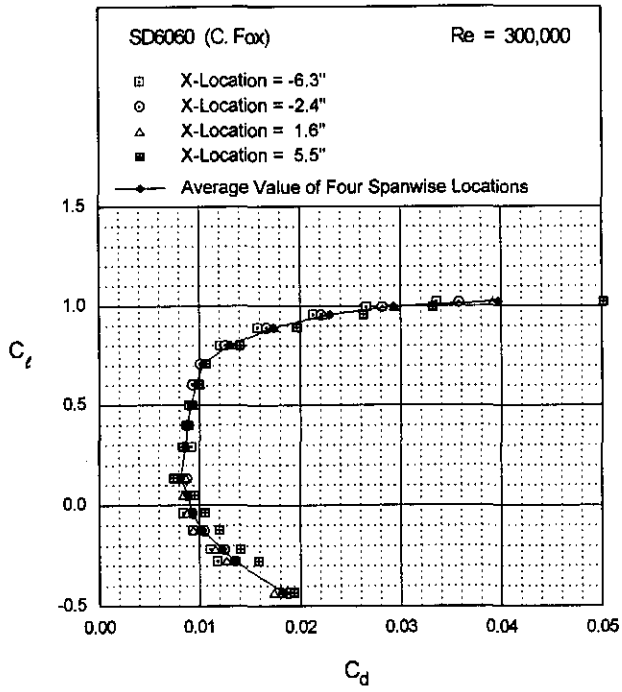




**Fig. 2.9** Continued.

For the spanwise drag measurements, primary emphasis was placed on resolving the spanwise profile drag variations, and as a result, detailed vertical ($y$-direction) surveys through the wake were made at spanwise stations nominally spaced 0.25 in apart. On average, a typical run involving 57 spanwise stations required 2 hours of continuous wind-tunnel operation.

### 2.2.3 Airfoil Model Accuracy Measurements

In order to determine the accuracy of the wind-tunnel models, each model was digitized using a Brown & Sharpe coordinate measuring machine (CMM) to determine the actual airfoil shape. Approximately 80 points were taken around the airfoil. The spacing was more or less proportional to the local curvature; near the leading and trailing edges the spacing was relatively small, while over the central section it was as large as 0.7 in. Due to constraints on the model/CMM arrangement, the S823, S1223, CH 10-48-13 and FX 74-CL5-140 MOD wind-tunnel models were measured on the left (angle of attack) side of the model. All other models coordinates were measured in the middle of the model.

Section profiles and model accuracy plots are presented Chapter 4. The profiles include both the true airfoil as designed (solid line) compared with the actual digitized model coordinates (dotted line). The model accuracy plots depict the differences between the true airfoil and actual airfoil coordinates for the upper surface (solid line) and lower surface (dotted line) of the airfoil. A displacement above or below the axis means that the model surface lies above or below the nominal, respectively. For instance, the actual SD6060 wind-tunnel model was thinner than the true SD6060 by approximately 0.008 in over the majority of the chord.

### 2.2.4 Freestream Velocity Measurements

Since the wind-tunnel model was mounted between endplates, the amount of flow (or spillage) between the endplates and the side walls of the test section could not be easily determined. Consequently, measurement of the freestream ahead of the endplates could not be used to determine the true freestream experienced by the model. Rather, the upstream dynamic pressure was measured between the two endplates 15.9 in ahead of the quarter-chord point of the airfoil models, and 5.2 in above the test section floor. Since the upstream pitot-static probe was close to the leading edge of the airfoil, the measured velocity was corrected for circulation effects, as discussed in Section 2.3.2. In order to convert the upstream dynamic pressure into velocity, the air density was calculated from the ideal gas law

$$\rho = \frac{P_{atm}}{RT} \tag{2.7}$$

with ambient temperature obtained from an Omega thermocouple (accurate to within 1 deg Rankine) located next to the wind tunnel. The velocity was then calculated from

$$V_\infty = \sqrt{\frac{2q_\infty}{\rho}} \tag{2.8}$$

The Reynolds number based on the airfoil chord is given by

$$Re = \frac{\rho V_\infty c}{\mu} \tag{2.9}$$

where $\mu$ for air was calculated using Sutherland viscosity law[7] expressed as

$$\frac{\mu}{\mu_0} = \left(\frac{T}{T_0}\right)^{3/2} \left(\frac{T_0 + S}{T + S}\right) \tag{2.10}$$

## 2.3 Data Reduction

The physical boundaries of a closed test section restrict the flow and, as a result, produce extraneous forces on the model that must be subtracted out. These extraneous aerodynamic forces occur mainly from the fact that the velocity of the air increases as it flows over the model due to the restraining effect of the wind-tunnel boundaries combined with the physical presence of the model and its wake. This effect is minimized when the model is small compared to the size of the test section. Unfortunately, smaller models are more difficult to build accurately. Since experienced model airplane enthusiasts were solicited to build the airfoil models instead of a machine shop, a larger 12 in chord model was selected as a compromise even though it required measuring smaller forces and a more complicated data reduction process.

In the following three sections, only an overview of the two-dimensional wind-tunnel corrections and their causes is presented. A more detailed discussion can be found in a separate report.[8]

### 2.3.1 Wind-Tunnel Boundary Corrections

The presence of the wind-tunnel walls increase the measured lift, drag and pitching moment due to an increase in velocity at the model. More specifically, the lateral boundaries in a two-dimensional testing context cause four phenomena to occur.

- **Buoyancy:** Buoyancy is an additional drag force that results from a decrease in static pressure along the test section due to the growth of the boundary layer at the walls. Even though buoyancy effects are usually insignificant even for airfoils tested within test sections of constant area,[9] the main effect of buoyancy was taken into account directly in the corrections of the freestream velocity.
- **Solid Blockage:** The physical presence of a model within a test section is known as solid blockage, which produces a decrease in the effective area. From the continuity and Bernoulli's equation, the velocity of the air must increase as it flows over the model, increasing all aerodynamic forces and moments at a given angle of attack. Solid blockage is a function of the model size and test section dimensions.

$$\varepsilon_{sb} = \frac{K_1 M_v}{A_a^{3/2}} \tag{2.11}$$

- **Wake Blockage:** The second type of blockage is known as wake blockage, which results from a lower velocity within the airfoil wake compared to the freestream velocity. For closed test sections, in order to satisfy the continuity equation the velocity at the model (outside of the wake) must increase. The effect of wake blockage is proportional to the wake size and thus to the measured drag force on the model.

$$\varepsilon_{wb} = \left(\frac{c}{2\,h_{ts}}\right) C_{d_u} \tag{2.12}$$

- **Streamline Curvature:** Due to the physical constraints of the tunnel boundaries, the normal curvature of the free air as it passes over a lifting body (such as an airfoil) is altered, increasing the airfoil effective camber as the streamlines are "squeezed" together. For closed wind-tunnel sections, the increase in camber results in an increase in lift, pitching moment about the quarter-chord point, and angle of attack, while the drag is unaffected. Since no pitching moment measurements were taken, corrections for only lift and angle of attack are presented below.

$$\Delta C_{l_{sc}} = \sigma C_l \tag{2.13}$$

$$\Delta \alpha_{sc} = \frac{57.3\,\sigma}{2\pi}(C_l + 4\,C_{m,c/4}) \tag{2.14}$$

where

$$\sigma = \frac{\pi^2}{48}\left(\frac{c}{h_{ts}}\right)^2 \tag{2.15}$$

### 2.3.2 Additional Velocity Corrections

In the case of the UIUC LSATs, the velocity must not only be corrected for solid and wake blockage, but also for other factors which are particular to the present setup. As previously mentioned, the model was mounted between two endplates within the test section. This arrangement minimized the effects of boundary-layer growth (and thus buoyancy) by generating fresh boundary layers at the leading edge of the endplates, isolated the model from the support hardware, but also required the upstream velocity to be measured between the endplates. Since the upstream pitot-static probe was close to the airfoil leading edge, the circulation about the airfoil induced a velocity component that effected the pitot-static probe reading. This circulation effect was directly related to the generation of lift by the model—the higher the lift, the larger the induced velocity. Since all aerodynamic coefficients were normalized by a velocity term, it was important to have an accurate freestream velocity measurement and thus to correct for the circulation effects.

To obtain a mathematical expression to account for the circulation effects, the airfoil was modeled as a single vortex at the quarter-chord point, and the tunnel walls were simulated by an image system. The induced velocity components were then computed at the location of the velocity measuring probe. Since the circulation is also function of the freestream velocity, an iterative method was used to converge on a solution.

Finally, the velocity was also corrected to account for the boundary-layer growth along the tunnel walls, which resulted in a slightly higher-than-freestream velocity at the model. By using a second velocity measuring probe at the model quarter-chord point with the model removed, and measuring the upstream and downstream velocities simultaneously over the full chord Reynolds number range, a calibration curve was obtained. Thus, for a measured upstream velocity, the actual velocity at the model could be calculated.

### 2.3.3 Corrections to Measured Quantities

The measured quantities that must be corrected can be subdivided into two categories: stream and model quantities. The most important stream quantity is the velocity at the model. This velocity was obtained from the freestream velocity measurements and by applying the proper corrections to account for solid

and wake blockage as well as boundary-layer growth. Combining the velocity corrections in a single expression:

$$V_c = V_u K_{vel}(1 + \varepsilon_{sb} + \varepsilon_{wb}) \tag{2.15}$$

Other stream quantities, such as the Reynolds number and dynamic pressure, were then obtained directly from the corrected value of the velocity.

The model quantities of interest are the lift, drag and the angle of attack, which were corrected in their non-dimensional form to account for solid and wake blockage as well as streamline curvature.

$$C_l = C_{l_u} \frac{1 - \sigma}{(1 + \varepsilon_b)^2} \tag{2.16}$$

$$C_d = C_{d_u} \frac{1 - \varepsilon_{sb}}{(1 + \varepsilon_b)^2} \tag{2.17}$$

$$\alpha = \alpha_u - \frac{57.3\sigma}{2\pi}(C_l + 4C_{m,c/4}) \tag{2.18}$$

It is important to note that drag coefficient data was necessary to correct the model quantities since wake blockage is proportional to the measured drag coefficient. For the lift runs, however, drag was not measured, which has an effect on the lift data reduction. For the lift curves, the wake blockage correction was computed using a constant value for the drag coefficient of 0.04, which was representative for conditions close to maximum lift. This method ensured more accurate values for the maximum lift coefficients even though it over-corrected lift coefficient values in the linear region of the lift curves. This "over-correction" was not significant as can be seen by comparing lift data taken from a lift run with that from a drag run.

A final note concerning these wind-tunnel corrections is that even though the current setup does not provide pitching moment data, airfoil moment coefficients have been determined computationally using either the Eppler,[10,11] ISES[12,13] orXFOIL[14] code. These moments are representative over the low drag range and were used to correct the angle of attack measurements. Since quarter-chord pitching moments are relatively constant with angle of attack and since the effect on the wind-tunnel corrections was small, a constant $C_{m,c/4}$ was used for each airfoil. The values used are listed in Chapter 3.

## 2.4 Calibrations and Uncertainty Analysis

By applying the general uncertainty analysis presented in Coleman & Steele,[15] the uncertainties in the velocity, lift coefficient, and drag coefficient were found in a relatively straight forward manner. Further details describing the uncertainty analysis are presented in Ref. 6.

First, consider the case of measuring the upstream velocity, which is used to normalize the lift and drag forces. The highest uncertainty in the pressure readings due to fluctuations in flow angle is 1%, resulting in a freestream-velocity uncertainty within 0.5%. If no errors related to the probes are included, the uncertainty in pressure readings and the velocity measurements reduce to less than approximately 0.5% and 0.3%, respectively. The lift balance was calibrated over a range that depended on the loads expected for a given run—the higher the Reynolds number, the larger the range. The lift balance calibration slopes over the 1 1/2 month testing period varied by approximately 4%. Of course, this drift did not affect the accuracy of the measurements since the lift balance was repeatedly calibrated. Overall uncertainty in the lift coefficient is estimated to be 1.5%. The accuracy of the lift calibrations was the main contribution to this small error. The drag measurement error comes from three sources: accuracy of the data acquisition instruments, repeatability of the measurements, and the selection of the particular four wake profiles used to determine the average drag coefficient. Based partly on the error analysis method presented in McGhee[16] and Coleman & Steele,[15] the uncertainty due to the instruments and measurement repeatablity are less than 1% and 1.5%, respectively. Based on a statistical analysis (for a 95% confidence interval) of the spanwise drag results for the E374 airfoil at $\alpha = 4$ deg (which is representative of the middle range of the drag polars), the uncertainties due to the spanwise variations are estimated at 3% for $Re = 100,000$ and reduce to approximately 1.5% at and above $Re = 200,000$. At $Re = 60,000$ and below, the flow is dominated by laminar separation bubbles that produce large variations in profile drag that make it difficult to confidently assign a measure of accuracy. A more detail discussion of this issue is presented in Ref. 6. For the angle of attack sensor, calibration measurements were taken at six different angles of attack incremented from 0 to 25 deg in 5 deg steps. Overall uncertainty in the angle of attack is estimated at 0.08 deg, based on the calibration results.

## 2.5 Comparison with Other Facilities

For comparison, drag polar results for the E387 airfoil from tests at NASA-Langley LTPT,[16] Delft,[16] Stuttgart,[17] and UIUC are presented in Fig. 2.10. It should be noted, however, that the E387 from the UIUC tests was slightly decambered and warped at the trailing edge, which has an effect on the results. Drag polar results for the the same E374 airfoil model tested both at the Princeton[1] and UIUC wind tunnels are presented in Fig. 2.11. The agreement between the Princeton and UIUC data is quite good, even at a Reynolds number of 60,000.

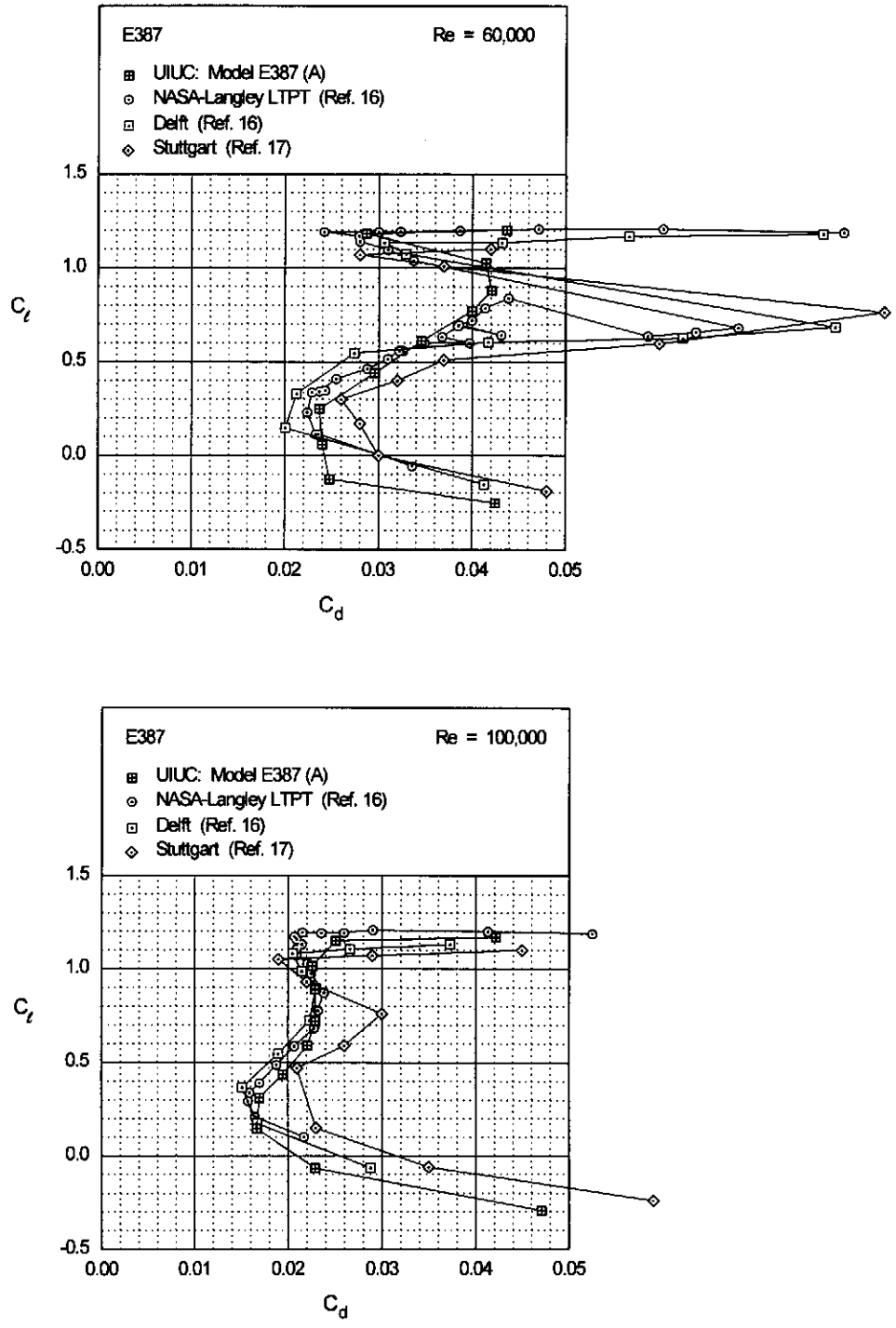
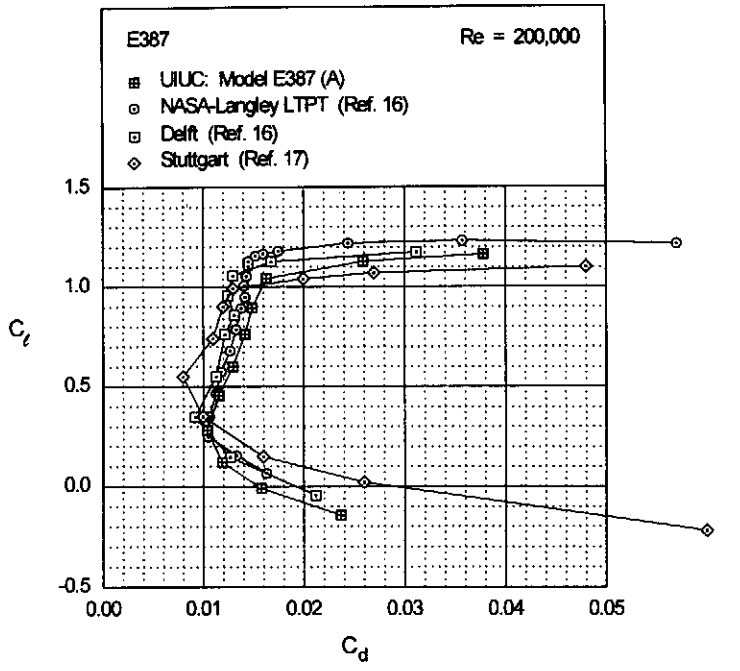



**Fig. 2.10** Comparison of drag data for the E387 airfoil from various wind-tunnel facilities for $Re$ = 60,000, 100,000, 200,000 and 300,000.

(figure continues)



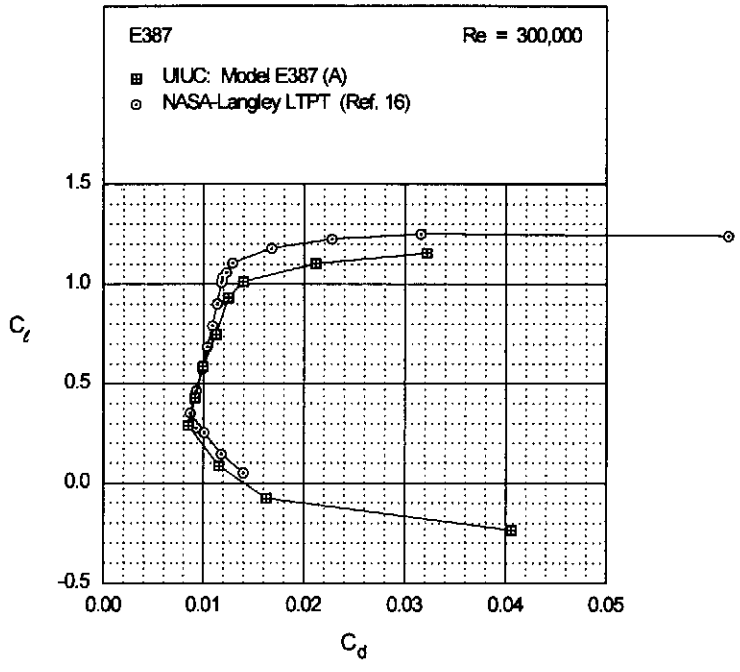




**Fig. 2.10** Continued.

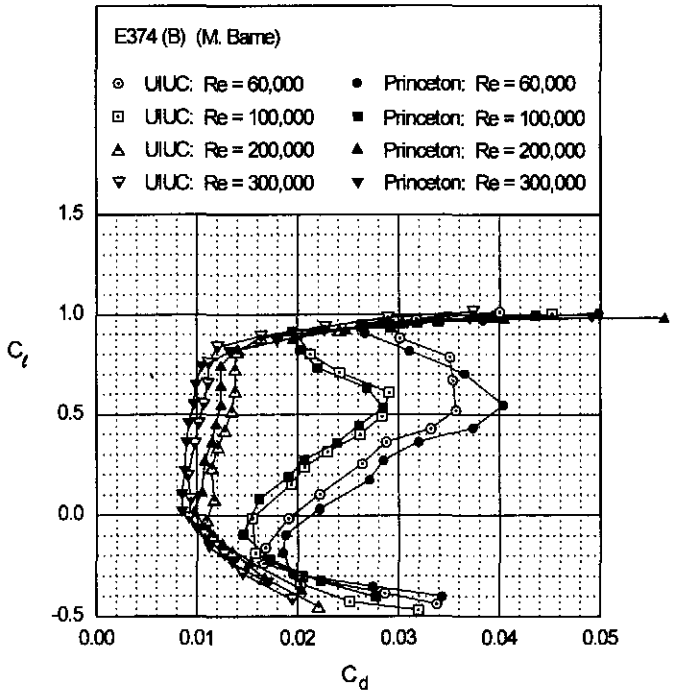



**Fig. 2.11** Comparison of drag data for the E374 airfoil from the Princeton and UIUC wind-tunnel facilities.

# Chapter 3

# Summary of Airfoil Data

In this chapter, the airfoil performance characteristics are discussed. To aid in the navigation of the data, the airfoils are grouped and discussed by category, e.g., airfoils for free flight models, airfoils for thermal soaring, and so on. The categories in order of discussion are listed in Table 3.1 along with the associated airfoils. Also, for reference, Table 3.1 lists the thickness, camber and pitching moment for the true airfoils, as well as the wind-tunnel model construction method, model accuracy and model builder.

Within each category, the discussion is organized according to how the airfoils relate to each other in terms of performance. Tables are included that list each airfoil in the category. For each airfoil, the table then lists the profile plot, the lift and drag data, the configuration of the model (e.g., clean, with boundary-layer trips, etc.), any special data, and the figures and pages pertaining to the data. Occasionally embedded within the discussion of the airfoils are sections on more general but related topics. These special sections are typeset between centered horizontal rules.

Following the discussion of the airfoils by category in this chapter, all of the figures (airfoil profile and performance plots) are included separately in Chapter 4. The figures are organized alphabetically by airfoil name for quick indexing.

As shown in Table 3.1, many of the airfoils listed were previously tested at Princeton.[1] The tests were repeated for several reasons. First, comparisons of the airfoil data from the two facilities can be used to gauge what differences might be expected if those remaining airfoils were tested again at Illinois. Second, the data can also be used in an attempt to ascertain any gross differences in wind-tunnel flow quality. And finally, since data taken on identical airfoils in different wind tunnels can vary, several of the widely used airfoils were re-tested to provide a complete and consistent data set.

Some general comments apply to the data and discussion.

- In *Airfoils at Low Speeds*,[1] the designation "-PT" (for Princeton Tests) was used after the names of the actual airfoils tested to distinguish them from the true airfoils. In this book, no special designation is applied to the airfoil name to make this distinction between the actual and true airfoil. It is important to note, however, that the discussion of each airfoil is based on the actual

**Table 3.1: Airfoils Sorted by Category**

| Airfoils for: | Airfoil | % Thickness | % Camber | $C_{m,c/4}$ |
|---|---|---|---|---|
| Free Flight Models | A18 | 7.26 | 3.84 | −0.126 |
| | BE50 | 7.31 | 3.96 | −0.114 |
| | GM15 | 6.70 | 4.76 | −0.154 |
| | MA409 | 6.69 | 3.33 | −0.115 |
| | NACA 6409† | 9.00 | 6.00 | −0.163 |
| Thermal Duration | E387 (A)† | 9.06 | 3.90 | −0.082 |
| Sailplanes | K3311 | 11.03 | 3.23 | −0.085 |
| | S7055‡ | 10.50 | 3.55 | −0.068 |
| | SD7032 (D)† | 9.95 | 3.66 | −0.099 |
| | SD7032 (E) | 9.95 | 3.66 | −0.099 |
| | SD7037 (A)† | 9.20 | 3.02 | −0.085 |
| | SD7037 (B) | 9.20 | 3.02 | −0.085 |
| | WASP | 9.35 | 2.98 | −0.074 |
| F3B Sailplanes | RG15 (B) | 8.92 | 1.76 | −0.058 |
| | S7012‡ | 8.75 | 2.02 | −0.068 |
| | SD7003† | 8.51 | 1.46 | −0.035 |
| | SD8000† | 8.86 | 1.71 | −0.049 |
| Slope Racers | E374 (B)† | 10.91 | 2.24 | −0.056 |
| | MH45 | 9.84 | 1.64 | −0.006 |
| | S6062 | 7.95 | 1.59 | −0.040 |
| | SD6060† | 10.37 | 1.84 | −0.039 |
| Tail Sections | J5012† | 12.00 | 0.00 | 0.000 |
| | NACA 0009† | 9.00 | 0.00 | 0.000 |
| | NACA 64A010† | 10.00 | 0.00 | 0.000 |
| | SD8020† | 10.10 | 0.00 | 0.000 |
| Quickie 500 Racers | R140 (A) | 12.04 | 0.45 | −0.012 |
| Sport Planes | GEMINI | 15.38 | 2.20 | −0.048 |
| | MB253515† | 14.96 | 2.43 | −0.050 |
| Heavy Lift | CH 10-48-13 | 12.75 | 10.20 | −0.230 |
| Cargo Planes | FX 63-137 (B) | 13.59 | 5.94 | −0.170 |
| | FX 74-CL5-140 MOD | 13.01 | 9.72 | −0.250 |
| | M06-13-128 (B) | 12.81 | 5.16 | 0.004 |
| | S1210‡ | 11.87 | 7.20 | −0.250 |
| | S1223‡ | 11.93 | 8.67 | −0.290 |
| Small Wind Turbines | S822 | 16.00 | 1.89 | −0.070 |
| | S823 | 21.00 | 2.49 | −0.150 |

† Wind-tunnel models tested previously at Princeton[1]

‡ New airfoils designed and built for the current test phase

**Table 3.1: continued**

| Airfoil | Surface Finish | Avg. Difference (in) | Builder |
|---|---|---|---|
| A18 | smooth | 0.0105 | Cooney |
| BE50 | smooth | 0.0159 | Cooney |
| GM15 | monokote over balsa | 0.0028* | Morris |
| MA409 | smooth | 0.0195 | Cooney |
| NACA 6409 | open bay | 0.0107 | Halsey |
| E387 (A) | smooth | 0.0106 | Champine |
| K3311 | monokote over balsa | 0.0032* | Kincaid |
| S7055 | smooth | 0.0160 | Jones |
| SD7032 (D) | smooth | 0.0057 | Watson |
| SD7032 (E) | smooth | 0.0152 | Michaelis |
| SD7037 (A) | fiberglass over balsa | 0.0119 | Michaelis |
| SD7037 (B) | smooth | 0.0081 | Thompson |
| WASP | smooth | 0.0018* | M. Fox |
| RG15 (B) | paint over obechi | 0.0049 | Champine |
| S7012 | smooth | 0.0077 | Lachowski |
| SD7003 | smooth | 0.0065 | Allen |
| SD8000 | smooth | 0.0073 | Wagner/Olsen |
| E374 (B) | smooth | 0.0083 | Bame |
| MH45 | smooth | 0.0384 | C. Fox |
| S6062 | varnish over balsa | 0.0125 | Matheson |
| SD6060 | smooth | 0.0088 | C. Fox |
| J5012 | smooth | 0.0130 | Raskin |
| NACA 0009 | smooth | 0.0105 | Nankivil |
| NACA 64A010 | varnish over obechi | 0.0062 | Champine |
| SD8020 | smooth | 0.0041 | Wagner/Olsen |
| R140 (A) | smooth | 0.0230 | Friedlander |
| GEMINI | open bay | 0.0052* | Bates |
| MB253515 | smooth | 0.0046 | Bame |
| CH 10-48-13 | smooth | 0.0017* | Hollinger |
| FX 63-137 (B) | smooth | 0.0093 | Allen |
| FX 74-CL5-140 MOD | smooth | 0.0038* | Hollinger |
| M06-13-128 (B) | smooth | 0.0112 | Allen |
| S1210 | smooth | 0.0037 | Allen |
| S1223 | molded, smooth | 0.0100 | Tinel |
| S822 | smooth | 0.0054 | Allen |
| S823 | smooth | 0.0073 | Allen |

* Smoothed model coordinates were taken as true coordinates

contour shape of the model. If the average difference between the actual and true airfoil coordinates is large (greater than approximately 0.010 in, depending on the model), then interpretation of the true airfoil performance from the wind-tunnel test data might be difficult. The accuracy of the lower surface is not as critical as that of the leading and trailing edges, and the upper surface. The useful lift range is most affected by differences at the trailing edge, while inaccuracies along the upper surface contour influence pressure (bubble) drag.

- The suffixes "(A)", "(B)", etc. on the airfoil names refer to multiple models of the particular airfoil. If only one version of the airfoil was built for the Princeton Tests and another one was built for the current tests, the models are designated here as versions "(A)" and "(B)" as in the case of the SD7037.
- Coordinates for the airfoils are tabulated in Appendix A. The performance characteristics are tabulated in Appendix B and ordered according to the airfoil name and figure. This data is available in various forms as mentioned in the Section "Airfoil Data Distribution."
- For some airfoils, the wind-tunnel model coordinates were mathematically smoothed (using the computer program AFSMO[18]) and taken as the true airfoil since no "as designed" airfoil coordinates were available. In such cases, the smoothed wind-tunnel model coordinates were then compared with the actual model coordinates as measured. These airfoils are identified in Table 3.1 by the notation "*" in the column for accuracy. As the comparison plots reveal (see Chapter 4), the differences between the smoothed and actual coordinates is nominally 0.003 in, which is in some sense a measure of the surface waviness.
- The nominal Reynolds number is listed in the figures while the actual Reynolds number is listed in the tabulated data in Appendix B.
- If a model was tested with a boundary-layer trip or modified in some other way (e.g., plain flap, Gurney flap), the configuration of the model is listed in the data summary table and drawn on the related figures.
- The airfoil moment coefficients listed in Table 3.1 were determined computationally using either the Eppler,[10] ISES[12,13] or XFOIL[19] code. The value given is representative of that over the low drag range.
- In Table 3.1, in the column for surface finish, "smooth" indicates that the model finish was produced by either vacuum bagging fiberglass over foam or painted or both.
- Although the airfoils are categorized by application, the airfoils, of course, can have a wider application. For example, some airfoils might fit equally well into two groups. For instance, the GEMINI and MB253515 airfoils were first used on R/C sailplanes but are listed here as airfoils for sport planes.

Also, the MH45 was developed for flying wings, but it is included with the airfoils for slope soaring.

- For airfoils that were previously tested at Princeton, the discussion is sometimes brief, in which case a more thorough discussion of the airfoil can be found in *Airfoils at Low Speeds.*[1]
- Velocity distributions for the true airfoils as predicted by the Eppler code[10] are included with the airfoil polars, lift plots, etc. It should be noted that these velocity distributions do not include the effects of the laminar separation bubble; only the inviscid flow is modeled. Nevertheless, with experience, much can be gleaned from this information to help interpret the airfoil polars and lift curves. As can be seen, subtle differences in airfoil shapes can yield significant differences in the velocity distributions.
- For the lift plots, increasing and decreasing angles of attack are denoted by solid-triangle and open-circle symbols, respectively.

## 3.1 Airfoils for Free Flight Models

As listed in Table 3.2, five free flight (FF) airfoils were tested. The first four airfoils (A18, BE50, GM15 and MA409) are used by leading flyers in F1C competition ("FAI power"). The NACA 6409 airfoil, as described by the builder Harlan I. Halsey, is used on old-timer FF, R/C (SAM) and electric FF.

Prior to discussing the wind-tunnel test results of the F1C airfoils, background information on the airfoils is given as provided by Gilbert Morris (see acknowledgments):

- **A18** The A18 airfoil was designed by Randy Archer (Scottsdale, Arizona) — the current F1C World Champion. The A18 was named after his model 18 used in the 1993 World Championship contest in which he successfully defended his title. As compared with the A15 that was used on his model 15 to win the 1991 title,[19] the A18 is very similar but has slightly less camber. Model 18 has a higher climb but does not glide as well as model 15. In terms of total performance (climb and glide), both models are essentially equal.
- **BE50** The BE50 airfoil was designed by Eugene Verbitsky (Ukraine) — former F1C World Champion. Verbitsky is considered to be one of the most influential F1C designers worldwide. The BE50 was named after his first model employing this airfoil. In 1980, the Russian team unveiled their new F1C design embodying much of the work of Verbitsky—high aspect ratio, thin, undercambered, low dihedral, aluminum foil covered wing, long tail boom, small stab, folding propeller, brake, VIT (variable incidence tail) and the revolutionary "bunt transition."[n1]

**Table 3.2: Summary of Airfoil Data for Free Flight Models**

| Airfoil | Data | Configuration | Figure/Page |
|---|---|---|---|
| A18 | Velocity Dist. | | Fig. 4.1/p. 62 |
| | Profile | | Fig. 4.2/p. 62 |
| | Drag Polar | Clean | Fig. 4.3/p. 63 |
| | Lift Curves | Clean | Fig. 4.4/p. 64 |
| BE50 | Velocity Dist. | | Fig. 4.5/p. 68 |
| | Profile | | Fig. 4.6/p. 68 |
| | Drag Polar | Clean | Fig. 4.7/p. 69 |
| | Lift Curves | Clean | Fig. 4.8/p. 70 |
| GM15 | Velocity Dist. | | Fig. 4.34/p. 104 |
| | Profile | | Fig. 4.35/p. 104 |
| | Drag Polar | Clean | Fig. 4.36/p. 105 |
| | Lift Curves | Clean | Fig. 4.37/p. 106 |
| | Profile | Clean, Reflexed | Fig. 4.35/p. 104 |
| | Drag Polar | Clean, Reflexed | Fig. 4.38/p. 108 |
| | Lift Curves | Clean, Reflexed | Fig. 4.39/p. 109 |
| MA409 | Velocity Dist. | | Fig. 4.51/p. 126 |
| | Profile | | Fig. 4.52/p. 126 |
| | Drag Polar | Clean | Fig. 4.53/p. 127 |
| | Lift Curves | Clean | Fig. 4.54/p. 128 |
| NACA 6409 | Velocity Dist. | | Fig. 4.65/p. 144 |
| | Profile | | Fig. 4.66/p. 144 |
| | Drag Polar | Clean | Fig. 4.67/p. 145 |
| | Lift Curves | Clean | Fig. 4.68/p. 146 |
| | Planform | | Fig. 4.69/p. 147 |
| | Spanwise Drag | Clean | Fig. 4.69/p. 147 |

- **GM15** The GM15 airfoil was designed by Gilbert Morris (Columbus, Ohio) and named after his model that won the 1994 F1C US Team Selection Finals. Of the six "flapper airfoils" designed by Morris over the past eight years, the GM15 has proven the best to date in giving balance between climb, glide and total endurance. The airfoils was designed by combining three logarithmic spirals: 7% top, 7% undercamber and 2% Phillips entry.
- **MA409** The MA409 airfoil was designed by Michael Achterberg (Sacramento, California) — former US F1C Team Member. This airfoil was designated by his initials followed by maximum camber of "4.09%." (It actually has 3.33% camber.) The MA409 has proven itself in numerous unlimited flyoffs for fast climb and good glide endurance. It is currently being used by an increasing number of F1C flyers. Achterberg won a team position at the 1994 F1C US Team Selection Finals using this airfoil.

In general, this type of anecdotal background information and personal experience and observations are needed to complement and interpret the wind tunnel test data. The degree to which this information is useful, however, depends on the accuracy of the observations and also the accuracy of the wind-tunnel models. With respect to the latter, the A18, BE50, and MA409 models all had significantly less camber than their respective true airfoils. Thus, for these airfoils, the usefulness of correlating the comments of Gilbert Morris to wind-tunnel data is limited. Therefore, the following comments only pertain to the wind-tunnel model airfoils.

**A18 & MA409** Of the four F1C airfoils tested, the A18 and MA409 are quite similar both in shape and in performance as shown in Figs. 4.1–4.4 and 4.51–4.54. A significant difference, however, is that the MA409 has less camber and consequently the polar is shifted downward as compared with the A18. The lower overall lift of the MA409 is probably advantageous for the near vertical climb phase (power condition) during which the $C_l$ is close to zero and the $Re$ is in the range 250k–300k. Thus, low drag at zero $C_l$ and high $Re$ is important for this type of model. From the polars, the $C_{d_o}$ (zero lift $C_d$) of the MA409 is lower than the A18. In fact, the MA409 had the lowest $C_{d_o}$ of all the F1C airfoils tested.

In F1C competition, there is a tradeoff between the climb and glide: a mediocre climb can be offset by an excellent glide and vice versa. Although the A18 might not launch as high as the MA409 (with all else equal), the A18 probably makes up for this climb handicap in glide performance. The process of finding the best airfoil that optimizes the tradeoff between climb and glide is best determined through flight tests combined with computer simulations that use the wind-tunnel data.

**BE50** The performance of the BE50 differs significantly from both the A18 and the MA409. As compared with the A18 at $Re$ of 60k, the drag is lower in the mid-range of the polar. This same trend is observed at 100k. For all $Re$'s, the polars show a smooth increase in drag over the $C_l$ range from 0.5 to 1. Airfoils with this type of behavior typically offer the best endurance over a fairly broad $C_l$ range, which corresponds to a broad speed range. Thus, the BE50 might be less sensitive to trim changes in glide as compared with the A18 and MA409 airfoils, which exhibit a more "peaky" performance.

**GM15** Since climb and glide are the primary flight conditions of importance in F1C competition, one strategy is to use a "flapper airfoil"—an airfoil with a plain flap that is reflexed (low camber) in climb and unflapped (high camber) in glide. The GM15 is an example of such an airfoil. As shown in Fig. 4.36, the unflapped GM15 has the highest $C_l$ of all the F1C airfoils. In this condition, the glide performance probably equals or exceeds that of the other airfoils. With the 33%-chord trailing-edge flap reflexed by approximately −8 1/2 deg for climb (see Fig. 4.38), the effects of the flap are apparent. The polar is shifted downward

and the $C_{d_o}$ is reduced. There is, however, added drag owing to the disturbed flow around the hinge line. Nevertheless, as compared with the other airfoils, the added drag is small for the zero-$C_l$ condition for climb.

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*R/C Hand Launch Airfoils* Although these airfoils are currently used for F1C, they are probably applicable to R/C hand-launch gliders (R/C HLG). The launch is somewhat similar to the climb/bunt maneuver in F1C. Upon release the glider is put into a steep climb, and then at the top a relatively quick push-over maneuver is performed. At the beginning of the climb, the *Re*'s are in the 300k range, and then for thermaling the *Re*'s are in the 80k–100k range. Between R/C HLG and F1C, there is an important difference in the flying mode. R/C HLGs must repeatedly be able to thermal and then cruise to the next thermal. This need to cruise places more emphasis on low drag in the mid-$C_l$ range. In this range, all of the F1C airfoils presented have good performance.

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**NACA 6409** The NACA 6409 model, which was built originally for the Princeton Tests, had an open-bay construction from the leading edge to trailing edge. As depicted in Fig. 4.69, 1/8 in thick primary ribs were spaced every 3 in (25% chord). In addition, 1/8 in thick leading-edge secondary ribs were located between the main ribs and used on the forward 27% chord. The sagging of the covering was about 0.025 in (0.2%) worst case, and generally much less—0.005 to 0.015 in. Due to the lack of torsional rigidity, data was taken only up to 200k.

The polar and lift curves presented in Fig. 4.67 and Figs. 4.68, respectively, show the effects of a laminar separation bubble at *Re* of 60k. At an angle of attack near 4 deg, the bubble detaches from the airfoil and the airfoil effectively stalls. At an angle of attack of near 11 deg, however, the bubble reattaches, the airfoil unstalls and the lift reaches a level consistent with that at *Re* of 100k and 200k. There exists a small hysteresis loop[n2] between 9 and 11 deg. Just beyond 11 deg, the airfoil exhibits a mild stall.

Detailed spanwise drag measurements were taken to examine the effects of the ribs on the downstream wake profiles, which are used to determine the drag. Since the geometry of the model with ribs is non-uniform, specifically, three-dimensional and periodic, it can be anticipated that a periodic variation will appear in the wake profile drag. Indeed, at an angle of attack of 1.5 deg, downstream of the primary ribs, the drag is highest, while between the primary ribs the drag is lowest. At an angle of attack of 7.5 deg, a similar trend is seen; however, the secondary ribs located midway between the primary ribs also appear to produce on a smaller scale the same peak and valley effect. Also shown in Fig. 4.69 are the four spanwise stations at which measurements were taken to determine the drag presented in Fig. 4.67. It cannot be inferred from this result

that the ribs cause high drag since the profiles were measured approximately 1.25 chord lengths downstream. It is merely an observation (albeit interesting) that the drag is periodic with the rib spacing and highest downstream of the primary ribs. The variation in the drag found downstream is most likely due to the evolution of the three-dimensional wake that is affected by the periodic spatial change of the geometry of the model.

Clearly, for a model with open-bay construction (or some other spanwise variation), if an accurate $C_d$ value is desired, detailed spanwise surveys through the wake should be made. Unfortunately, such extensive surveys are very time consuming. For instance, the data shown in Fig. 4.69 required approximately 3.5 hours of wind-tunnel test time.

## 3.2 Airfoils for Thermal Duration Sailplanes

Of the seventeen Selig-Donovan airfoils presented in *Airfoils at Low Speeds*,[1] the SD7037 has become the favorite for R/C soaring thermal duration competition. Due to its popularity, the SD7037 will be discussed first and used as a benchmark for comparison with similar thermal duration airfoils listed in Table 3.3.

**SD7037** Two models of the SD7037 were tested. Version A was built for the Princeton Tests and tested again for comparison. Owing to improvements in the wind-tunnel data-acquisition and correction techniques (see Chapter 2), the maximum lift at the lower *Re*'s is slightly increased as compared with the Princeton data. Also, the drag is somewhat higher, which indicates that the UIUC wind tunnel has lower turbulence levels. This trend—higher $C_{l_{max}}$ at lower Reynolds numbers and higher drag overall—is observed in much of the data presented.

Version B is more accurate than version A, which has a slightly reflexed trailing edge and too little thickness on the forward upper surface. The reflexed trailing edge of version A will reduce the overall lift of the airfoil. Moreover, the deviation on the forward upper surface can be expected to reduce the high-lift performance (see the DF101/102/103 airfoil discussion in *Airfoils at Low Speeds*[1]). Indeed, as seen in the polars, version A is not as efficient as version B at high lift coefficients. From the polars alone, one would anticipate a substantial difference in $C_{l_{max}}$ between versions A and B. From the lift curves, however, the difference in $C_{l_{max}}$ is only 0.05.

The drag data of versions A and B at *Re* of 60k (see Figs. 4.133 and 4.137) reveals some of the challenges and mysteries in taking data at low Reynolds numbers. For several angles of attack, the spanwise drag station at $x$ of 5.5 in on the SD7037 (B) yielded values that were far above the average of the other three stations. If this station at $x$ of 5.5 in were ignored, then the average of

**Table 3.3: Summary of Airfoil Data for Thermal Duration Sailplanes**

| Airfoil | Data | Configuration | Figure/Page |
|---|---|---|---|
| E387 | Velocity Dist. | | Fig. 4.17/p. 84 |
| | Profile | | Fig. 4.18/p. 84 |
| | Drag Polar | Clean | Fig. 4.19/p. 85 |
| | Lift Curves | Clean | Fig. 4.20/p. 86 |
| K3311 | Velocity Dist. | | Fig. 4.43/p. 116 |
| | Profile | | Fig. 4.44/p. 116 |
| | Drag Polar | Clean | Fig. 4.45/p. 117 |
| | Lift Curves | Clean | Fig. 4.46/p. 118 |
| S7055 | Velocity Dist. | | Fig. 4.111/p. 198 |
| | Profile | | Fig. 4.112/p. 198 |
| | Drag Polar | Clean | Fig. 4.113/p. 199 |
| | Lift Curves | Clean | Fig. 4.114/p. 200 |
| SD7032 (D) | Velocity Dist. | | Fig. 4.123/p. 210 |
| | Profile | | Fig. 4.124/p. 210 |
| | Drag Polar | Clean | Fig. 4.125/p. 211 |
| | Lift Curves | Clean | Fig. 4.126/p. 212 |
| SD7032 (E) | Velocity Dist. | | Fig. 4.127/p. 214 |
| | Profile | | Fig. 4.128/p. 214 |
| | Drag Polar | Clean | Fig. 4.129/p. 215 |
| | Lift Curves | Clean | Fig. 4.130/p. 215 |
| SD7037 (A) | Velocity Dist. | | Fig. 4.131/p. 216 |
| | Profile | | Fig. 4.132/p. 216 |
| | Drag Polar | Clean | Fig. 4.133/p. 217 |
| | Lift Curves | Clean | Fig. 4.134/p. 218 |
| SD7037 (B) | Velocity Dist. | | Fig. 4.135/p. 220 |
| | Profile | | Fig. 4.136/p. 220 |
| | Drag Polar | Clean | Fig. 4.137/p. 221 |
| | Lift Curves | Clean | Fig. 4.138/p. 222 |
| WASP | Velocity Dist. | | Fig. 4.150/p. 240 |
| | Profile | | Fig. 4.151/p. 240 |
| | Drag Polar | Clean | Fig. 4.152/p. 241 |
| | Lift Curves | Clean | Fig. 4.153/p. 242 |

the remaining three would produce results similar to those of the SD7037 (A). A discussion of this dilemma, its possible causes, the frequency of occurrence, and a strategy to deal with the problem is discussed in Section 2.2.2. For $Re$ above 100k, any bias, if present, was negligible.

The SD7037 is favored for R/C thermal soaring because of its working lift range (the lift range over the low drag region) that begins near a $C_l$ of 0.2 and extends to near $C_l$ of 1.0 where the drag begins to increase more rapidly. Its other attributes include low drag and good flap/aileron response, the latter of which will be quantified during the next series of tests.

**WASP** The WASP airfoil built and designed by Mike Fox is quite similar to the SD7037 in performance and shape. In many respects, the performance appears to be a mixture of the SD7037 (A) and SD7037 (B). Although Mike Fox uses the airfoil for R/C HLG, it is included here since it has much in common with the SD7037.

**K3311** The K3311 airfoil was designed by Leon C. Kincaid and used on his HEAT SEEKER design that placed 1st in Sportsman Multi-Task at the 1992 and 1993 LSF Championships. Leon Kincaid, a retired Model Builder/Machinist for the NACA (now NASA), used his skills to measure the K3311 coordinates off his original wind-tunnel model with a dial indicator with a 1 in throw, mounted on a surface gauge. These original coordinates were mathematically smoothed using AFSMO,[18] from which 79 coordinates (based on a standard $x/c$ data set) were determined. The airfoil differs from the previous two airfoils discussed in that the high-lift (low-speed) corner of the polar is improved at 100k. As a result, the K3311 should have better thermal performance. This advantage is balanced by slightly worse performance at low lift (cruise). It should also be noted that the stall of the K3311 is milder than the SD7037.

**E387** Version A of the E387 built by Bob Champine and originally tested at Princeton is included here since it shares much in common with the K3311. It should, however, be noted that this wind-tunnel model had a spanwise twist of approximately 0.22 deg/ft. Also, the overall camber of the model was less than the true E387. Thus, the results do not accurately represent the performance of the true E387.

**S7055** Newcomers and casual pilots favor simplicity, which often leads to the choice of a flat-bottomed airfoil. Unfortunately, the selection of flat-bottomed airfoils is limited. Also, few flat-bottomed airfoils have been recently designed with a view toward reducing the bubble drag. The idea to change this situation was motivated through discussions with Tim Renaud of Airtronics who felt that a 10–11% flat-bottomed airfoil (flat past the spar) was needed for thermal soaring. In addition, he recommended that the new airfoil be designed with more lift than the S3021 or E205, which "build up speed too quickly for beginners." As a result, the new S7055 (10.5%) was designed to fill this niche.

The wind-tunnel results show that the flat-bottomed S7055 does not perform as well as the SD7037, WASP, E387 and K3311—airfoils that are not constrained to be flat. In particular, at low lift, there is a noticeable performance loss.

Nevertheless, the high-lift thermal performance compares well with the other airfoils, and the airfoil has a mild stall.

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*Flat Bottomed Airfoils* The S7055 in comparison with the SD7037 serves to illustrate that when an airfoil is required to be flat bottomed, there is an associated performance penalty. More generally, when the geometry of any portion of the airfoil is constrained, some performance loss can be anticipated because that part of the airfoil cannot be optimized for best aerodynamic performance. The airfoil, however, can be tailored so that the performance loss occurs in less important regions of the polar.

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**SD7032** The SD7032 is a high-lift variant of the SD7037. As in Figs. 4.123–4.126 (version D), the polar as compared with the SD7037 is shifted upward by a $\Delta C_l$ of 0.15. This increment in $C_l$ is enough to substantially improve the thermal performance. The trade-off is reduced $L/D$ performance, which in light-wind conditions is acceptable. Version E of the SD7032 is less accurate than version D, but the performance characteristics are similar.

## 3.3 Airfoils for F3B Sailplanes

**RG15** For F3B flying, the RG15 designed by Rolf Girsberger has become a standard. As compared with the previous group of thermal duration airfoils, the lower lift of the RG15 makes it more ideal for F3B where the distance ($L/D$ performance) and speed tasks are more important than the duration task (thermal performance). Some pilots, however, prefer the RG15 for thermal duration competition, particular in geographical regions noted for having strong thermals in windy conditions. Under such circumstances, the $L/D$ performance is the design driver that favors the RG15 or, more generally, all airfoils in this category.

**SD7003** This airfoil designed and tested at Princeton was used by Joe Wurts and Daryl Perkins on their F3B EAGLE models that placed 1st and 2nd, respectively, in the 1991 F3B World Championship. Since that time, interest has shifted away from the SD7003 toward the RG15, which has an advantage in the duration task. Although thermal performance is secondary, this is the key factor that reportedly sets the two airfoils apart. From the polars, little difference is observed at high lift. The high-lift performance shown in the polars is, however, for zero flap deflection. In F3B competition, camber-changing flaps are used in all three tasks. For the duration task, the positive flap settings that are used must improve the performance of the RG15 over the SD7003. To see this effect, these airfoils should be tested with flaps.

**Table 3.4: Summary of Airfoil Data for F3B Sailplanes**

| Airfoil | Data | Configuration | Figure/Page |
|---|---|---|---|
| RG15 (B) | Velocity Dist. | | Fig. 4.78/p. 158 |
| | Profile | | Fig. 4.79/p. 158 |
| | Drag Polar | Clean | Fig. 4.80/p. 159 |
| | Lift Curves | Clean | Fig. 4.81/p. 160 |
| S7012 | Velocity Dist. | | Fig. 4.107/p. 194 |
| | Profile | | Fig. 4.108/p. 194 |
| | Drag Polar | Clean | Fig. 4.109/p. 195 |
| | Lift Curves | Clean | Fig. 4.110/p. 196 |
| SD7003 | Velocity Dist. | | Fig. 4.119/p. 206 |
| | Profile | | Fig. 4.120/p. 206 |
| | Drag Polar | Clean | Fig. 4.121/p. 207 |
| | Lift Curves | Clean | Fig. 4.122/p. 208 |
| SD8000 | Velocity Dist. | | Fig. 4.139/p. 224 |
| | Profile | | Fig. 4.140/p. 224 |
| | Drag Polar | Clean | Fig. 4.141/p. 225 |
| | Lift Curves | Clean | Fig. 4.142/p. 226 |

**SD8000** The SD8000 has a working lift range similar to both the RG15 and SD7003, and it has been used successfully in F3B competition, although without such illustrious results. The thermal performance is known to be better than, but similar to, the SD7003.

**S7012** The S7012 is a new F3B airfoil designed to be an improvement over the RG15. Clearly, the RG15 for F3B competition can be classified as an "optimum" airfoil in the sense that it seems that no airfoil can be designed with lower drag everywhere. Therefore, one is left with making tradeoffs. The question then becomes what are the best compromises to make. In particular, where does the RG15 have good performance that can be sacrificed for better performance elsewhere, or in conceptual terms where can the drag be increased for lower drag elsewhere? The strategy taken in the design of the S7012 was to give up performance between the best distance speed and the best thermal speed in exchange for improvements primarily in the speed and thermal tasks. As the following discussion reveals, these goals were achieved at the expense of some performance in the distance task.

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*Judging Polars Based on Constant Reynolds Numbers* Before discussing the S7012 further, a word about interpreting airfoil polars is in order. Judging aircraft performance based on airfoil data for constant $Re$ polars can be difficult. The aircraft $Re$ changes with the flight speed, and therefore it does not follow a constant $Re$ line on the traditional polar. Plotting the performance of the airfoil

as it "flies" through the constant $Re$ polars is much more helpful since it takes into account the change in aircraft speed (and hence $Re$) with lift coefficient. This aircraft $Re$ that changes with the lift coefficient is called the "reduced Reynolds number," $\mathcal{R}.^{n3}$

Another difficulty in judging aircraft performance based on airfoil data is that the fuselage, tail and induced drag components, which make up a significant contribution to the overall aircraft drag, are not included in the airfoil polar plots. As a result of this additional drag, the $(C_L/C_D)_{max}$ and $(C_L^{3/2}/C_D)_{max}$ for the whole aircraft will not correspond to the same flight condition as the $(C_l/C_d)_{max}$ and $(C_l^{3/2}/C_d)_{max}$ read directly from the airfoil drag polars. For the interested reader, the basics of understanding airfoil polars can be found in Ref. 20.

Seeing the full effect of this additional drag together with the airfoil drag greatly helps in the airfoil selection process. With respect to the design of the S7012, including this additional drag with the airfoil drag helps to determine what tradeoffs are the best ones to make.

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Figure 3.1 shows the performance of the S7012 as compared with the RG15 for $\mathcal{R}$ of 120k, which is typical for F3B ships with wing loadings near 12 oz/ft$^2$. The SD7003 airfoil data is shown for reference and will be discussed last. Figures 3.2 and 3.3 show two key performance parameters plotted vs. the sailplane lift coefficient, $C_L$. These performance parameter curves correspond to a typical F3B glider (in particular, one with an aspect ratio of 12.5, a wing span of 112 in and a combined fuselage and tail drag coefficient of approximately 0.003).

The first parameter is the aircraft $L/D$ (sailplane glide slope), where the drag coefficient does include all drag components. As seen, there is clearly a tradeoff. The S7012 is better than the RG15 below a $C_L$ of approximately 0.27—the crossover point. Thus, if the F3B distance run is done below this point, the S7012 will be better, and if above it will be worse. Typically, for sailplanes with the RG15, the distance run is done near a $C_L$ of 0.40 or lower—the lower the $C_L$, the greater the number of laps in the working time. The benefit of the S7012 will depend on the course conditions: the stronger the lift on course, the lower the $C_L$, and the better the S7012 relative to the RG15.

The second performance parameter shown in Fig. 3.3 is the aircraft endurance parameter $(C_L^{3/2}/C_D)$. A 5% improvement in the endurance parameter translates into a 5% improvement in duration time. As seen in the figure, the S7012 peak value for the endurance parameter is nearly 2% higher than the RG15. An additional improvement is that the best endurance occurs at a higher lift coefficient, so the best thermal speed is slower and thermal turns can be made tighter.

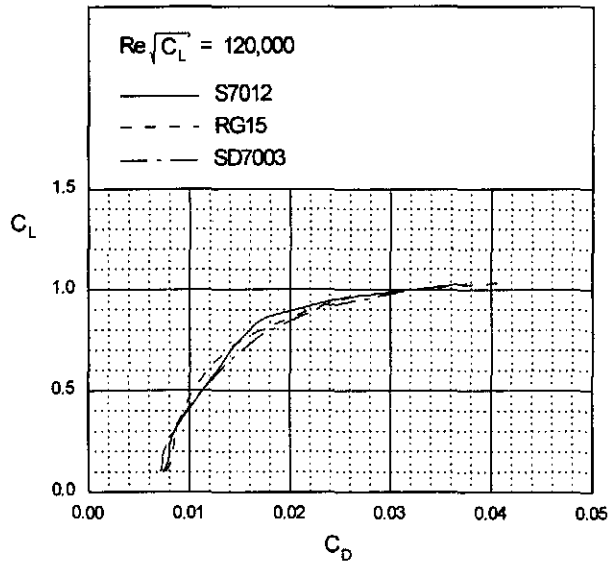


**Fig. 3.1** Performance characteristics of the S7012 compared with the RG15 and SD7003 for $\mathcal{R}$ of 120k.

For the F3B speed task, the differences between the S7012 and RG15 are hard to deduce from Figs. 3.2 and 3.3. From the airfoil polars, however, the S7012 has 3% lower drag at a $C_L$ of 0.1, which is close to that for speed task. Thus, the new airfoil should be slightly faster in a straight run. For turn performance during the speed and distance task, the $L/D$ performance is best compared; whereas, for turns in the duration task the endurance performance should be used for comparison. Unfortunately, the comparison in these areas requires testing the airfoils with flaps—tests which have not yet been done.

It is important to emphasize that the S7012 is only better than the RG15 in certain areas of the $C_l$ range, which translate to certain aircraft speeds. The best thermal speed only occurs over a fairly narrow $C_l$ range, so if the speed is not carefully controlled the benefits of the new airfoil will hardly be noticed. If the distance task is flown too slowly, again the benefits will be hard to detect, or worse, there will be no benefit.

Another characteristic of the S7012 should also be mentioned. The thermal performance improves gradually with increasing lift coefficient, but only up to a certain point. Beyond this point, the performance degrades rather quickly, which should send a clear signal to the pilot. Several Eppler airfoils have this characteristic, and it seems to be favored as it provides clear cues to the pilot.

The SD7003 is known for its good high-speed performance and marginal thermal performance. The S7012 is an improvement above a $C_L$ of 0.4 and worse below, which again illustrates that compromises must be made when the performance is near an optimum.

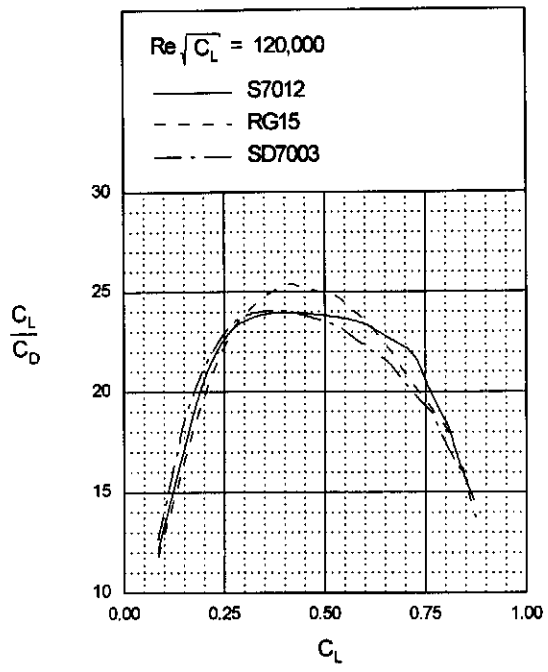


**Fig. 3.2** $L/D$'s for sailplanes based on the S7012, RG15 and SD7003 for $\mathcal{R}$ of 120k.

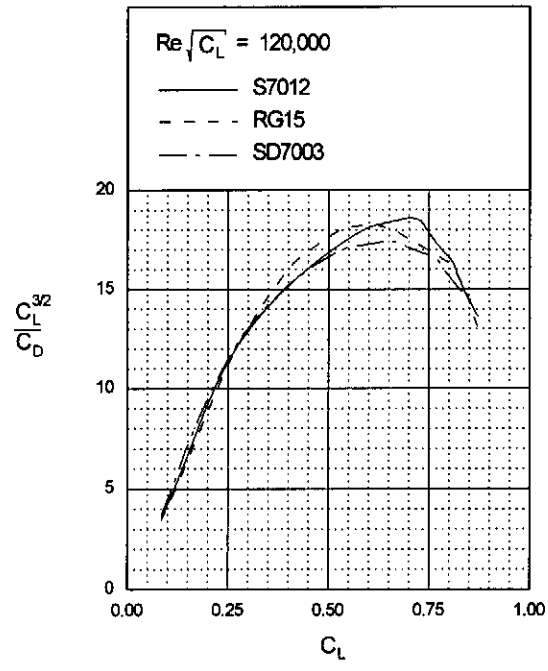


**Fig. 3.3** Endurance parameters for sailplanes based on the S7012, RG15 and SD7003 for $\mathcal{R}$ of 120k.

## 3.4 Airfoils for Slope Racers

**Table 3.5: Summary of Airfoil Data for Slope Racers**

| Airfoil | Data | Configuration | Figure/Page |
|---|---|---|---|
| E374 (B) | Velocity Dist. | | Fig. 4.13/p. 80 |
| | Profile | | Fig. 4.14/p. 80 |
| | Drag Polar | Clean | Fig. 4.15/p. 81 |
| | Lift Curves | Clean | Fig. 4.16/p. 82 |
| MH45 | Velocity Dist. | | Fig. 4.58/p. 136 |
| | Profile | | Fig. 4.59/p. 136 |
| | Drag Polar | Clean | Fig. 4.60/p. 137 |
| | Lift Curves | Clean | Fig. 4.61/p. 138 |
| S6062 | Velocity Dist. | | Fig. 4.103/p. 190 |
| | Profile | | Fig. 4.104/p. 190 |
| | Drag Polar | Clean | Fig. 4.105/p. 191 |
| | Lift Curves | Clean | Fig. 4.106/p. 192 |
| SD6060 | Velocity Dist. | | Fig. 4.115/p. 202 |
| | Profile | | Fig. 4.116/p. 202 |
| | Drag Polar | Clean | Fig. 4.117/p. 203 |
| | Lift Curves | Clean | Fig. 4.118/p. 204 |

**E374 & SD6060** An extensive discussion of the design philosophy behind the SD6060 was given in *Airfoils at Low Speeds*[1] and also Ref. 21. Briefly, the SD6060 was designed to be an improvement over the E374. The approach was to incorporate into the SD6060 design bubble ramps that were similar to, but longer than, the E374. The effect of these longer ramps was to reduce the drag produced by the laminar separation bubble. As seen in Figs. 4.15 and 4.117, almost everywhere the drag of the SD6060 is lower than the E374. When the drag polars are used to generate data for a constant reduced Reynolds number, $\mathcal{R}$, the performance is better than the E374 under most R/C slope-soaring conditions.

The performance envelope of these two airfoils is typical of slope-soaring airfoils. The straight-line high-speed performance requires that slope-soaring airfoils have low drag at low lift. Thus, the working range of the polar must extend to zero lift and below to accommodate gusts. The high-lift end of the polar is determined partly by turn performance, but perhaps more importantly by climb performance. Climb is important because the slope racers are allowed a fixed amount of time to gain altitude before entering the course—the higher the start height, the better the speed on course.

The specific amount of high-lift performance, that is, the upper end of the working range, is most easily determined by inspection of the SD6060 and E374 polars, which are very similar to the F3B airfoils previously discussed. Conse-

quently, F3B airfoils are equally applicable to slope racing. For instance, the S7012 as a slope-soaring airfoil is better than the SD6060 in most areas of the performance envelope.

Although these two airfoils are categorized here as airfoils for slope soaring, the E374 and likewise the SD6060 have been used effectively on cross-country sailplanes where the *Re*'s can be in the 400k–800k range.

**S6062** The S6062 is a 8% version of the SD6060 (10.37%) optimized for speed as evidenced by its minimum drag coefficient, which is the lowest of all the airfoils tested. Efficient turn performance will require the use of camber-changing flaps. Interestingly, the S6062 has nearly the same maximum lift coefficient as the SD6060. The S6062 is recommended for use as a tip airfoil in combination with the SD6060 at the root.

**MH45** The slightly-reflexed 9.84% thick MH45 was designed by Martin Hepperle for use on flying wings, but it is included in this category since it has much in common with slope soaring airfoils. The airfoil has a wide usable lift range, including good performance at negative lift coefficients required for inverted flight. The generous thickness, wide lift range and predictable stall characteristics make the MH45 a good all-purpose slope airfoil. The true characteristics of the MH45, however, are difficult to ascertain from the polars since the wind-tunnel model was too thick.

## 3.5 Airfoils for Tail Sections

**J5012, NACA 0009, NACA 64A010 & SD8020** These four airfoils were all tested at Princeton[1] and showed to varying degrees nonlinearities in the lift curve about 0 deg. A much more dramatic case of this effect (which gives the airfoil a "deadband" in relative terms) was found by Mueller & Batill on the NACA $66_3$-018 airfoil.[22] For this airfoil at *Re* of 130k the lift curve through zero angle of attack actually changed sign over a 3 deg range, that is, an increase in angle of attack produced a decrease in lift. Of the current airfoils tested, the NACA 64A010 exhibited the most pronounced case of this nonlinearity. When such an airfoil is used as a full-flying stabilator, it can adversely impact the aircraft handling qualities, particularly when the *Re*'s are low and the airfoil operates about zero lift. Consider a special case of a hand-launch glider that uses the NACA 64A010 at a *Re* of 30k. When the tail surface is deflected 2 deg (in magnitude), the $C_l$ reaches 0.1. A 4 deg deflection, however, produces a $C_l$ of 0.4. This nonlinear $C_l$-$\alpha$ characteristic will produce a nonlinear control response that is undesirable. (Note that the difference in the lift coefficient for increasing and decreasing angles of attack for *Re* of 30k is due to transducer and mechanical hysteresis.)

**Table 3.6: Summary of Airfoil Data for Tail Sections**

| Airfoil | Data | Configuration | Figure/Page |
|---|---|---|---|
| J5012 | Velocity Dist. | | Fig. 4.40/p. 112 |
| | Profile | | Fig. 4.41/p. 112 |
| | Lift Curves | Clean | Fig. 4.42/p. 113 |
| NACA 0009 | Velocity Dist. | | Fig. 4.62/p. 140 |
| | Profile | | Fig. 4.63/p. 140 |
| | Lift Curves | Clean | Fig. 4.64/p. 141 |
| NACA 64A010 | Velocity Dist. | | Fig. 4.70/p. 148 |
| | Profile | | Fig. 4.71/p. 148 |
| | Drag Polar | Clean | Fig. 4.72/p. 149 |
| | Lift Curves | Clean | Fig. 4.73/p. 150 |
| SD8020 | Velocity Dist. | | Fig. 4.143/p. 228 |
| | Profile | | Fig. 4.144/p. 228 |
| | Drag Polar | Clean | Fig. 4.145/p. 229 |
| | Lift Curves | Clean | Fig. 4.146/p. 230 |
| | Lift Curves | Tripped | Fig. 4.147/p. 234 |
| | Drag Polar | Clean | Fig. 4.148/p. 237 |
| | Lift Curves | Tripped | Fig. 4.149/p. 238 |

As compared with the Princeton data, the current results show larger deadband regions. In fact, the SD8020 when tested at Princeton appeared to have no significant deadband; whereas, the current results show that the SD8020 is not an exception after all. (Its lift characteristics are, however, the most linear of the four airfoils). The main cause of the peculiar lift characteristics is related to the interplay between the upper and lower surface laminar separation bubbles. Furthermore, it is known that larger turbulence levels produce smaller laminar separation bubbles and their associated effects, which for these symmetrical airfoils includes the extent of the deadband region. Thus, from the nonlinear behavior of the lift curves, it is clear that the turbulence levels of the current tunnel are lower than they were at Princeton.

Trips can sometimes be used to "repair" otherwise poorly performing airfoils known to be afflicted adversely by bubbles. This axiom was applied in an attempt to improve the characteristics of the SD8020, particularly in regard to the lift characteristics. First, one zig-zag trip type B shown in Fig. 4.147 was placed on both the upper and lower surfaces. The leading edge of the trip was located at 25% chord. As seen in Fig. 4.147, the nonlinearity (deadband) is reduced up to $Re$ of 80k, after which it is completely eliminated. Second, two layers of the zig-zag trip were used, and the effects of the bubbles were eliminated between 60k and 100k (see Fig. 4.149). At 40k, although there is still some nonlinear behavior, the lift characteristics are greatly improved over the baseline case without trips.

It is reasonable to assume that the other three airfoils would likewise benefit in this way from the use of trips. Of course, the drag at the higher *Re*'s will be increased (see Fig. 4.148).

## 3.6 Airfoils for Quickie 500 Pylon Racers

**Table 3.7: Summary of Airfoil Data for Quickie 500 Pylon Racers**

| Airfoil | Data | Configuration | Figure/Page |
|---|---|---|---|
| R140 (A) | Velocity Dist. | | Fig. 4.74/p. 154 |
| | Profile | | Fig. 4.75/p. 154 |
| | Drag Polar | Clean | Fig. 4.76/p. 155 |
| | Lift Curves | Clean | Fig. 4.77/p. 156 |
| S8052 | Velocity Dist. | | Fig. 3.4/p. 43 |
| | Profile | | Fig. 3.4/p. 43 |
| | Drag Polar | Clean | Fig. 3.5/p. 44 |

**R140 (A) & S8052** The R140 has been used for Quickie 500 (Q-500) pylon racing. The airfoil thickness is 12.04%, which is close to that required by Q-500 rules (11.88%). Under typical race conditions, the *Re*'s can reach $1 \times 10^6$ (1000k), which is beyond the current wind-tunnel test capability. In order to gain a measure of the performance in this relatively high *Re* regime, the XFOIL airfoil code[14] (version 6.5) was used to predict the performance at 300k, 600k and 1000k. The results afford a comparison between predictions and experimental results for the *Re* of 300k. Over the mid-lift range the agreement is relatively good, while at the limits of the polar discrepancies exist. In these regions, the higher drag found in the wind-tunnel tests indicates that transition takes place sooner than predicted. (For reference, the computational results were performed with a turbulence amplification factor, $n$, of 9—a value consistent with the wind-tunnel turbulence level.)

From the wind-tunnel data, the airfoil operates well at moderately negative lift coefficients, but performance in this range may not be required. Negative lift coefficients are used for inverted flight as encountered in aerobatic maneuvers. Also, in steady level upright flight, gusts can cause the airfoil to operate in the negative range. At high speeds, however, gust effects are reduced and consequently so too is the need for good negative lift performance. Pilot control excursions could cause the model to operate at negative $g$'s (negative lift coefficients), but top competition pilots flying smooth laps usually keep positive $g$'s (positive lift coefficients) on the aircraft. In F3B competition, the speed task is somewhat like Q-500 pylon racing and one could assume that the airfoil requirements will be somewhat similar. As deduced partly through trial and error, optimum airfoils for F3B do not have much negative lift performance. The ev-

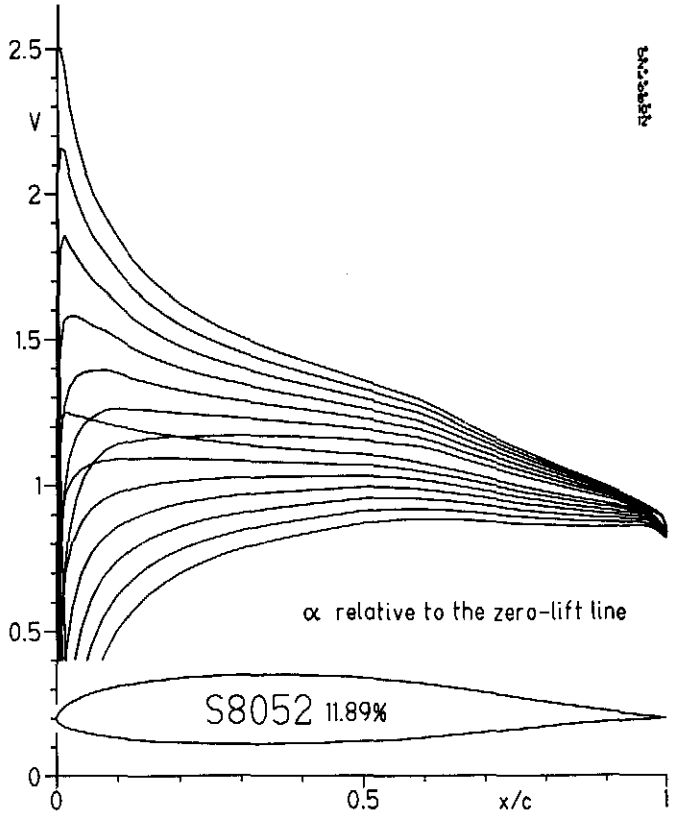


**Fig. 3.4** Velocity distributions for the S8052.

idence indicates that very little negative lift performance is required for Q-500 models.

In light of the aforementioned comments related to setting the airfoil design requirements for Q-500 models, a new airfoil, the S8052 shown in Fig. 3.4, was designed for Q-500 pylon racing. Since wind-tunnel tests have not yet been performed, Fig. 3.5 shows the performance predicted by XFOIL. As seen, the new airfoil has less negative lift performance and nearly the same minimum drag coefficient as compared with the R140. The upper limit of the low-drag range is extended to improve turn performance. Camber-changing flaps are not required, but, as has been found useful in F3B competition, camber-changing flaps will prove to be quite beneficial for rapid turn performance. For reference, the airfoil zero-lift angle of attack and pitching moment are approximately $-1.5$ deg and $-0.031$, respectively.

## 3.7 Airfoils for Sport Planes

**GEMINI & MB253515** Both of these semi-symmetrical airfoils were originally used for R/C sailplanes, but they are included here since they have application to powered sport models. The GEMINI airfoil used on the GEMINI

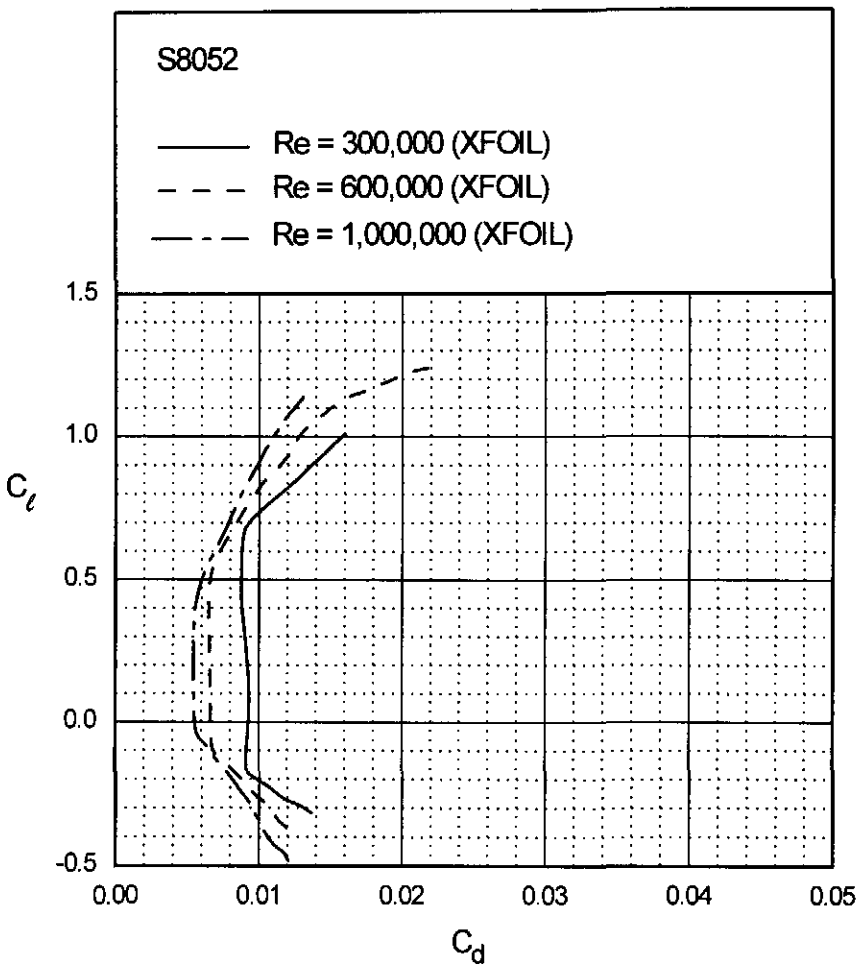


**Fig. 3.5** Predicted performance characteristics for the S8052.

**Table 3.8: Summary of Airfoil Data for Sport Planes**

| Airfoil | Data | Configuration | Figure/Page |
|---|---|---|---|
| GEMINI | Velocity Dist. | | Fig. 4.29/p. 100 |
| | Profile | | Fig. 4.30/p. 100 |
| | Drag Polar | Clean | Fig. 4.31/p. 101 |
| | Lift Curves | Clean | Fig. 4.32/p. 102 |
| | Planform | | Fig. 4.33/p. 103 |
| | Spanwise Drag | Clean | Fig. 4.33/p. 103 |
| MB253515 | Velocity Dist. | | Fig. 4.55/p. 132 |
| | Profile | | Fig. 4.56/p. 132 |
| | Lift Curves | Clean | Fig. 4.57/p. 133 |

R/C sailplane is intended to be the same as the MB253515, but slight differences exist. Moreover, the GEMINI airfoil model had a D-tube/aft-open bay construction as shown in Fig. 4.33. The 9/32 in wide capstrips on the ribs were spaced every 3 1/8 in (26% chord). The sagging of the covering was between 0.032 and 0.090 in with an average of 0.062 in.

The MB253515 airfoil was tested primarily for comparison with the Princeton lift data. Once again, the effects of the laminar separation bubble are more apparent than at Princeton. The unusual bubble behavior results from the velocity distributions, which as shown in Fig. 4.55 are quite unlike those of all the other airfoils tested. Attempting to described the particular features in the velocity distributions that lead to the kink in the lift curve goes beyond the scope of this book.

As expected, the GEMINI airfoil has performance characteristics much like the MB253515, with some notable exceptions. The lift curve at $Re$ of 100k does not show a kink near 0 deg like the MB253515. Thus, the bubble on the GEMINI airfoil at this condition is probably smaller in size. This hypothesis is supported by the observation that the drag on the GEMINI airfoil is less at this condition. Another important difference is that the $C_{l_{max}}$ of the GEMINI airfoil is greater. These differences combined are probably caused by the sagging of the covering between the ribs.

Detailed spanwise measurements were taken on the GEMINI airfoil to quantify the degree of spanwise drag variation associated with the open-bay construction (see Fig. 4.33). As observed on the NACA 6409, the drag measured downstream of the ribs was higher than between the ribs for reasons that were discussed in Section 3.1.

## 3.8 Airfoils for Heavy-Lift Cargo Planes

As a result of heavy-lift cargo model competitions gaining popularity (e.g., the SAE Aero-Design Competition), there is a renewed interest in high-lift airfoils for such applications. Also, unmanned aerial vehicles (UAVs) are becoming increasingly important in both civilian (e.g., scientific, meteorology and mapping) and military (e.g., reconnaissance and electronic warfare) roles. Small model aircraft size UAVs are sometimes driven by the need to carry relatively heavy payloads for long periods of time.[23,24] For example, a mission may include a 24-hour endurance at an altitude at or below 100 ft mean sea level, with flight speeds ranging from 25–40 knots and payload requirements varying from 10–25 lb.[24] These objectives are best achieved through the use of efficient high-lift low Reynolds number wings, whose performance depends largely on the airfoils employed.

**Table 3.9: Summary of Airfoil Data for Heavy-Lift Cargo Planes**

| Airfoil | Data | Configuration | Figure/Page |
|---|---|---|---|
| CH 10-48-13 | Velocity Dist. | | Fig. 4.9/p. 74 |
| | Profile | | Fig. 4.10/p. 74 |
| | Drag Polar | Tripped | Fig. 4.11/p. 75 |
| | Lift Curves | Tripped | Fig. 4.12/p. 76 |
| FX 63-137 (B) | Velocity Dist. | | Fig. 4.21/p. 88 |
| | Profile | | Fig. 4.22/p. 88 |
| | Drag Polar | Clean | Fig. 4.23/p. 89 |
| | Lift Curves | Clean | Fig. 4.24/p. 90 |
| FX 74-CL5-140 MOD | Velocity Dist. | | Fig. 4.25/p. 94 |
| | Profile | | Fig. 4.26/p. 94 |
| | Drag Polar | Clean | Fig. 4.27/p. 95 |
| | Lift Curves | Clean | Fig. 4.28/p. 96 |
| M06-13-128 (B) | Velocity Dist. | | Fig. 4.47/p. 120 |
| | Profile | | Fig. 4.48/p. 120 |
| | Drag Polar | Clean | Fig. 4.49/p. 121 |
| | Lift Curves | Clean | Fig. 4.50/p. 122 |
| S1210 | Velocity Dist. | | Fig. 4.90/p. 170 |
| | Profile | | Fig. 4.91/p. 170 |
| | Drag Polar | Clean | Fig. 4.92/p. 171 |
| | Lift Curves | Clean | Fig. 4.93/p. 172 |
| S1223 | Velocity Dist. | | Fig. 4.94/p. 176 |
| | Profile | | Fig. 4.95/p. 176 |
| | Drag Polar | Clean | Fig. 4.96/p. 177 |
| | Lift Curves | Clean | Fig. 4.97/p. 178 |
| | Drag Polar | Vortex Generators | Fig. 4.98/p. 182 |
| | Lift Curves | Vortex Generators | Fig. 4.99/p. 183 |
| | Spanwise Drag | Vortex Generators | Fig. 4.100/p. 187 |
| | Drag Polar | Gurney Flap | Fig. 4.101/p. 188 |
| | Lift Curves | Gurney Flap | Fig. 4.102/p. 189 |

Although the existing "library" of low *Re*'s airfoils is extensive, to date only a few airfoils are suitable for high-lift low *Re* applications. Leading the list is often the Wortmann FX 63-137 airfoil, which will be discussed first.

**FX 63-137** Currently, the Wortmann FX 63-137 (see Figs. 4.21–4.24) is one of the most desirable airfoils for high-lift low *Re* models. The high-lift capability ($C_{l_{max}}$ near 1.7 at *Re* of 200k) and mild-stall characteristics seen in Figs. 4.24 are among its key attributes.

The FX 63-137 was tested down to *Re* of 60k to explore the limits of its capability. At *Re* of 60k, an indication of separation on the upper surface is already noticeable at an angle of attack of −2 deg. (Compare 60k data with 300k data). At 80k for increasing angles of attack, the airfoil is stalled at an angle of attack of near 11 deg, just beyond which the flow reattaches and $C_l$ dramatically increases. Trailing-edge stall eventually takes place near 16 deg. For decreasing angles of attack the airfoil unstalls at 16 deg, and then just past 8 deg the flow again separates and effectively stalls the airfoil. This complex stall behavior is shared by many of the high-lift airfoils in this group. At 90k, the hysteresis loop at low angles of attack is beginning to vanish, and only a small remnant is left at 100k, after which the airfoil is fairly well-behaved.

**M06-13-128** This airfoil designed by Miley[25] was intended for operation at its design *Re* of 600k. Nevertheless, it has been considered as a high-lift airfoil for application at *Re*'s below 600k. As seen in the polars for a *Re* of 300k, the $C_{l_{max}}$ is near 1.5, which is substantial in light of the low pitching-moment constraint. For practical applications, however, the M06-13-128 airfoil should not be be given serious consideration at *Re*'s below 300k owing to its high drag characteristics.

**FX 74-CL5-140 MOD** The actual wind-tunnel model tested is a modified version of the FX 74-CL5-140. As stated by the builder, Chuck Hollinger, the plot of the FX 74-CL5-140 found in a paper by Wortmann[26] on high-lift airfoils was enlarged in order to measure the coordinates. The airfoil was then reduced from 14% thickness to 13%, and the leading-edge nose radius was slightly increased. Other modifications can be deduced from Fig. 4.26.

Although the FX 74-CL5-140 was originally designed for *Re*'s between 1000k and 3000k, the modified FX 74-CL5-140 does perform well at lower *Re*'s. In fact, as seen in Fig. 4.28, a $C_{l_{max}}$ of near 2.0 is achieved at *Re* of 200k. In contrast to the FX 63-137, which was well-behaved at *Re* of 100k, the modified FX 74-CL5-140 must reach *Re* of near 175k to avoid inefficient operation within hysteresis loops.

It is interesting to note the unusual nature of the lift characteristics of the modified FX 74-CL5-140. For *Re* of 100k, the airfoil has a small but abrupt stall near 0 deg. Then at 20 deg the flow reattaches and the $C_l$ increases. This increase in $C_l$, however, does not occur as a result of fully-attached flow. As seen for *Re* of 175k, the airfoil at this high angle of attack condition is in the stalled region of the lift curve. As *Re* increases from 100k to 125k and then from 125k to 150k, the point at which the abrupt stall takes place increases to an angle of attack near 8 deg. For decreasing angles of attack at 175k, the flow first remains attached until 13 deg, then stalls, and reattaches near 1 deg to form a clockwise hysteresis loop in contrast the FX 63-137 that had a counter-clockwise hysteresis loop below the final stall angle of attack.

**CH 10-48-13** As described by the designer, Chuck Hollinger, this airfoil was formed by combining a 12.75% thick S4233 thickness distribution around an 10.2% mean camber line. A plain trip at 25% chord on the upper surface was added by Hollinger in an effort to improve the drag characteristics. Lift characteristics show that the airfoil achieves a $C_{l_{max}}$ of 1.95 at $Re$ of 200k. This airfoil also shows hysteresis characteristics much like the FX 74-CL5-140 MOD.

**S1223** As described in more detail at the end of this section, the design philosophy employed in the design of the S1223 airfoil involves combining the favorable effects of both a concave pressure recovery and aft loading to achieve maximum lift at a design Reynolds number of 200k.[24] The desired aerodynamic characteristics were achieved through the use of a suite of computational tools for airfoil design and analysis.[n4] As shown in Fig. 4.97, the $C_{l_{max}}$ at $Re$ of 200k is 2.11. Below this design $Re$, hysteresis in the lift curve characteristics appears. The single hysteresis loop is similar to the first hysteresis loop found on the Miley and FX 74-CL5-140 airfoils. This type of hysteresis is expected since the S1223 velocity distribution architecture is similar to the M06-13-128 and FX 74-CL5-140 airfoils.

In an effort to increase the $C_{l_{max}}$ above that of the baseline (clean) airfoil, the S1223 was tested with vortex generators (VGs) located on the airfoil upper surface at 17% chord. The VG geometry is shown in Fig. 4.95. As seen in Fig. 4.99 for $Re$ of 200k, the $C_{l_{max}}$ is increased to 2.19. This slight increase, however, occurs together with a sharp stall and a hysteresis loop, which taken together make the VGs not advantageous. As might be expected from work performed at Delft,[28] the VGs do produce a periodic spanwise drag variation downstream as seen in Fig. 4.100.

A 1.04% chord Gurney flap (shown in Fig. 4.95) on the S1223 was also examined, again, in an effort to improve the $C_{l_{max}}$ characteristics. This experiment did prove successful, yielding for $Re$ of 200k a $C_{l_{max}}$ of 2.21—the highest of all the airfoils tested. Although the airfoil was only tested for increasing angles of attack, hysteresis does not appear to be present. A discussion of the effects of Gurney flaps and the physical mechanism related to this simple and intriguing device can be found in Ref. 29.

**S1210** The S1210 was designed (before the S1223) to validate the design philosophy, which was later more fully exploited in the design of the S1223. A relatively conservative approach was taken as can be seen by comparing the velocity distributions of the S1210 with the S1223. Not only was the approach successfully validated, the resulting S1210 has performance comparable to the FX 63-137 (if not better). At $Re$ of 200k, the airfoil achieves a $C_{l_{max}}$ of 1.80 together with a surprisingly soft stall. Moreover, the airfoil maintains good performance down to $Re$ of 90k.

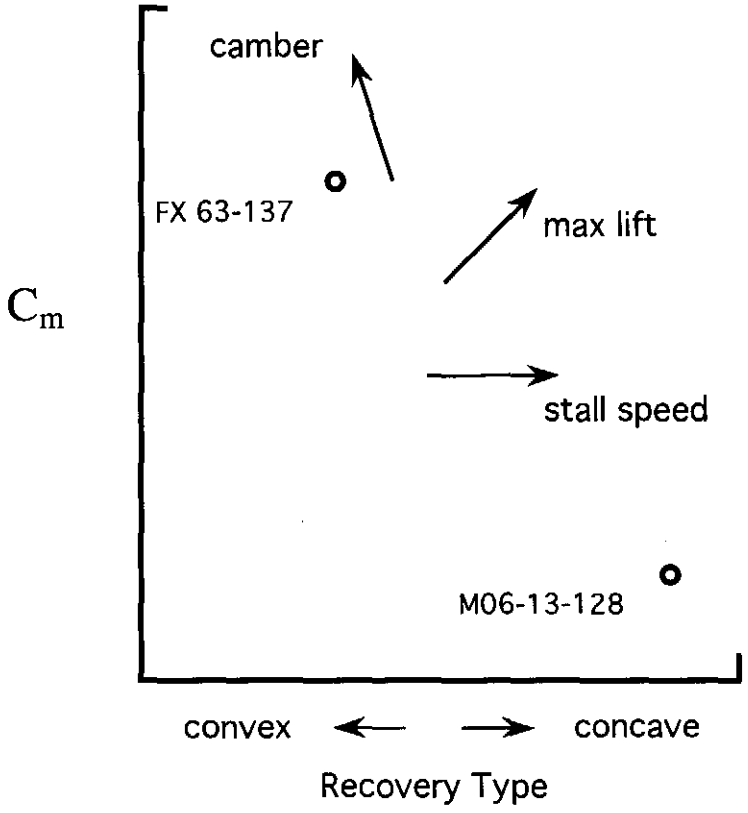


**Fig. 3.6** Low Reynolds number airfoil characteristics as a function of the recovery type and pitching moment.

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*High-Lift Low Reynolds Number Airfoil Design* The high-lift S1223 and S1210 were design based on a hypothesis developed from data on the FX 63-137 and M06-13-18 airfoils. These two airfoils can be classified by a number of characteristics as depicted in Fig. 3.6. In the figure, the pitching moment is plotted versus the upper-surface recovery type. Airfoils with concave Stratford-like pressure recoveries and low pitching moments would appear on the lower right, as for example, the M06-13-18 airfoil and some Liebeck airfoils.[30] The FX 63-137 with its relatively high pitching moment and convex pressure recovery appears to the upper left in Fig. 3.6.

Also shown in Fig. 3.6 are trend lines. One trend is that the airfoil typically becomes more cambered as the pitching moment increases and as the recovery becomes less concave/more convex. Another trend is that the trailing-edge stall becomes more abrupt as the pressure recovery becomes less convex/more concave.

"Trailing-edge stall speed" as denoted in the figure refers to the shape of the $C_l$-$\alpha$ curve at stall. The stall of the FX 63-137 is an example of a "slow" trailing-edge stall. The turbulent separation point slowly progresses forward as the angle of attack increases. This slow movement of the separation point produces a plateau in the $C_l$-$\alpha$ curve past the point of stall initiation (see Fig. 4.24). The stall of the M06-13-128 shown in Fig. 4.50 is an example of a relatively "fast" trailing-edge stall; the $C_l$-$\alpha$ curve peaks at $C_{l_{max}}$, then falls off more rapidly than the FX 63-137. This characteristic is indicative of a turbulent separation point that moves forward fairly rapidly with increasing angle of attack.

The last trend shown in Fig. 3.6 is that the maximum lift coefficient increases as the pitching moment increases and as the pressure recovery approaches a Stratford distribution. The FX 63-137 is a good example of increasing the $C_{l_{max}}$ primarily through added pitching moment. In contrast, Liebeck type airfoils (such as the M06-13-128) are good examples of increasing the $C_{l_{max}}$ mainly through the use of a Stratford pressure-recovery distribution.

Specifically, the Liebeck high-lift design philosophy[30] involves using a Stratford distribution to recover the most pressure without separation at $C_{l_{max}}$. Since separation is avoided completely, that is, up to trailing edge, the prototypical Liebeck airfoil is one with no aft loading, which gives a low pitching moment. The M06-13-128 serves as an example of applying the Liebeck design philosophy at low $Re$'s. Although the M06-13-128 has a high mid-range bubble drag at the off-design Reynolds numbers of 300k, the $C_{l_{max}}$ is 1.47. This value for $C_{l_{max}}$ is high, especially in light of the intrinsic low pitching-moment constraint.

Eppler[11] shows that to achieve maximum lift on an airfoil with concave Stratford-type recovery the low pitching-moment constraint should be relaxed. In particular, through a series of example airfoils, Eppler shows that the lift of an airfoil with a concave recovery can be improved through the use of aft loading. Such airfoils incorporate the favorable effects of both a concave recovery and aft loading to achieve high $C_{l_{max}}$ values. In Fig. 3.6, airfoils of this type would appear between the FX 63-137 and M06-13-128, but displaced in the direction of increased lift.

The high-lift design philosophy described by Eppler[11] was employed nearly two decades earlier by Wortmann[26] in the design of the FX 74-CL5-140 airfoil, which achieves a $C_{l_{max}}$ of 2.37 at a Reynolds number of 1000k. Figure 3.7 shows the $C_{l_{max}}$ characteristics of the FX 74-CL5-140 along with three other similar high-lift airfoils. In contrast, the FX 63-137 only achieves a $C_{l_{max}}$ of 1.6–1.7. The main difference in the maximum lift is not due to a Reynolds number effect as might be suggested by the figure. Rather, the difference is due to the shape of the recovery distribution—convex vs. concave (compare the inviscid velocity distributions shown in Figs. 4.21 and 4.25). Thus, the FX 63-137 should not be compared with the other airfoils since it is not in the same airfoil "family."

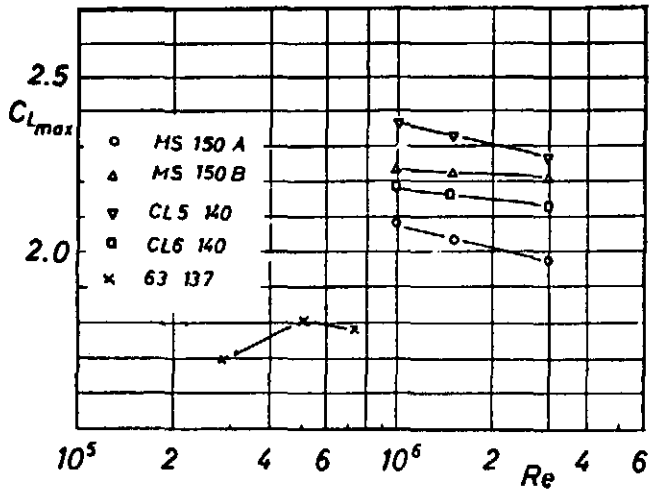


**Fig. 3.7** $C_{l_{max}}$ characteristics for five Wortmann airfoils (from Ref. 26).

Since the FX 63-137 should be excluded from consideration in Fig. 3.7, the low Reynolds number high-lift airfoil design problem has yet to be fully explored. The S1223 and S1210, however, are airfoils that fall into this category, that is, airfoils that employ both concave recoveries and aft loading designed for high lift at low *Re*'s.. As the S1223 demonstrates, lift coefficients on the order of 2 for *Re* of 200k are indeed possible. Moreover, the CH 10-48-13 and modified FX 74-CL5-140 confirm this fact as well. It is interesting to note that although the S1223, CH 10-48-13 and modified FX 74-CL5-140 achieve $C_{l_{max}}$ values near 2, the airfoils differ markedly in shape. Consequently, it can be speculated that future design optimization will lead to a single unique airfoil with an even greater $C_{l_{max}}$ performance.

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## 3.9 Airfoils for Small Wind Turbines

**Table 3.10: Summary of Airfoil Data for Small Wind Turbines**

| Airfoil | Data | Configuration | Figure/Page |
|---|---|---|---|
| S822 | Velocity Dist. | | Fig. 4.82/p. 162 |
| | Profile | | Fig. 4.83/p. 162 |
| | Drag Polar | Clean | Fig. 4.84/p. 163 |
| | Lift Curves | Clean | Fig. 4.85/p. 164 |
| S823 | Velocity Dist. | | Fig. 4.86/p. 166 |
| | Profile | | Fig. 4.87/p. 166 |
| | Drag Polar | Clean | Fig. 4.88/p. 167 |
| | Lift Curves | Clean | Fig. 4.89/p. 168 |

**S822 & S823** These airfoils,[31] developed under a joint effort between the National Renewable Energy Laboratory and Airfoils, Inc (D.M. Somers), were specially tailored for use on small horizontal-axis wind turbines, such as the variable-rpm Jacobs 17.5 kW machine. The airfoils have several advantages over those airfoils traditionally used on aircraft. First, the airfoils have a reduced roughness sensitivity for improved energy capture under dirty blade conditions owing to the accumulation of insect debris. Second, the increased section thickness of the root (S823–21%) and tip airfoils (S822–16%) allow for a lower blade weight, lower cost, increased stiffness and improved fatigue resistance. Finally, the restrained $C_{l_{max}}$ improves annual energy production and lower windfarm array losses when used on stall-regulated (fixed-rpm) wind turbines.

# Chapter 4

# Airfoil Profiles and Performance Plots

In this chapter, the airfoil profiles and performance plots are presented. For reference, the airfoil names are listed beneath the page numbers. Also presented is a table that lists all the data sets and associated figures and page numbers. In the table, a '¶' means that this lift data is not plotted to save space, but it is included with the data distribution disk. As a matter of record, the wind-tunnel run numbers are included in the table, and these also appear with the polar data in Appendix B and also in the data distribution files for cross reference.

| Model (Builder) Designer | Config. | Velocity & Profile | | Drag Data | | | | Lift Data | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fig. | p. | Fig. | p. | *Re* | Run | Fig. | p. | *Re* | Run |
| A18 (Cooney) Archer | Clean | 4.1 4.2 | 62 | 4.3 | 63 | 40,000 | 278 | 4.4 | 64 | 30,000 | 520 |
| | | | | | | 60,000 | 161 | | | 40,000 | 519 |
| | | | | | | 100,000 | 163 | | 65 | 60,000 | 160 |
| | | | | | | 200,000 | 165/521 | | | 100,000 | 162 |
| | | | | | | 300,000 | 167/522 | | 66 | 200,000 | 164 |
| | | | | | | | | | | 300,000 | 166 |
| BE50 (Cooney) Verbitsky | Clean | 4.5 4.6 | 68 | 4.7 | 69 | 60,000 | 570 | 4.8 | 70 | 30,000 | 567 |
| | | | | | | 100,000 | 572 | | | 40,000 | 568 |
| | | | | | | 200,000 | 574 | | 71 | 60,000 | 569 |
| | | | | | | 300,000 | 576 | | | 100,000 | 571 |
| | | | | | | | | | 72 | 200,000 | 573 |
| | | | | | | | | | | 300,000 | 575 |
| CH 10-48-13 (Hollinger) Hollinger | u.s.t. x/c = 40% h/c = 0.20% Plain | 4.9 4.10 | 74 | 4.11 | 75 | 200,000 | 156/560 | 4.12 | 76 | 100,000 | 340 |
| | | | | | | | | | | 100,000 | 556 |
| | | | | | | | | | 77 | 125,000 | 557 |
| | | | | | | | | | | 150,000 | 558 |
| | | | | | | | | | 78 | 175,000 | 559 |
| | | | | | | | | | | 200,000 | 155 |
| E374 (B) (Bame) Eppler | Clean | 4.13 4.14 | 80 | 4.15 | 81 | 60,000 | 69 | 4.16 | 82 | 60,000 | 361 |
| | | | | | | 100,000 | 67/503 | | | 100,000 | 363 |
| | | | | | | 150,000 | 502 | | ▮ | 150,000 | 501 |
| | | | | | | 200,000 | 65 | | 83 | 200,000 | 359 |
| | | | | | | 300,000 | 63 | | | 300,000 | 62 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| E387 (A)<br>(Champine)<br>Eppler | Clean | 4.17<br>4.18 | 84 | 4.19 | 85 | | | 4.20 | ▮<br>▮<br>▮<br>86<br><br>▮<br>87 | 30,000<br>40,000<br>50,000<br>60,000<br>100,000<br>150,000<br>200,000<br>300,000 | 296<br>294<br>295<br>208<br>210<br>554<br>212<br>214 |
| | | | | | | 60,000<br>100,000<br>150,000<br>200,000<br>300,000 | 209<br>211<br>555<br>213<br>215 | | | | |
| FX 63-137 (B)<br>(Allen)<br>Wortmann | Clean | 4.21<br>4.22 | 88 | 4.23 | 89 | | | 4.24 | 90<br><br>91<br><br>92<br><br>93 | 60,000<br>80,000<br>90,000<br>100,000<br>150,000<br>200,000<br>250,000<br>300,000 | 504<br>297<br>299<br>158<br>298<br>507<br>508<br>510 |
| | | | | | | 100,000<br>200,000<br>250,000<br>300,000 | 159<br>154<br>506<br>511 | | | | |
| FX 74-CL5-140<br>MOD<br>(Hollinger)<br>Hollinger | Clean | 4.25<br>4.26 | 94 | 4.27 | 95 | | | 4.28 | 96<br><br>97<br><br>98 | 100,000<br>125,000<br>150,000<br>175,000<br>200,000<br>300,000 | 302<br>304<br>303<br>305<br>579<br>578 |
| | | | | | | 200,000 | 185 | | | | |
| GEMINI<br>(Bates)<br>Bame | Clean | 4.29<br>4.30 | 100 | 4.31 | 101 | 100,000<br>200,000<br>300,000 | 217<br>219<br>221 | 4.32 | 102<br>▮ | 100,000<br>200,000<br>300,000 | 216<br>218<br>220 |
| | | | | 4.33 | 103 | 200,000 | | | | | |

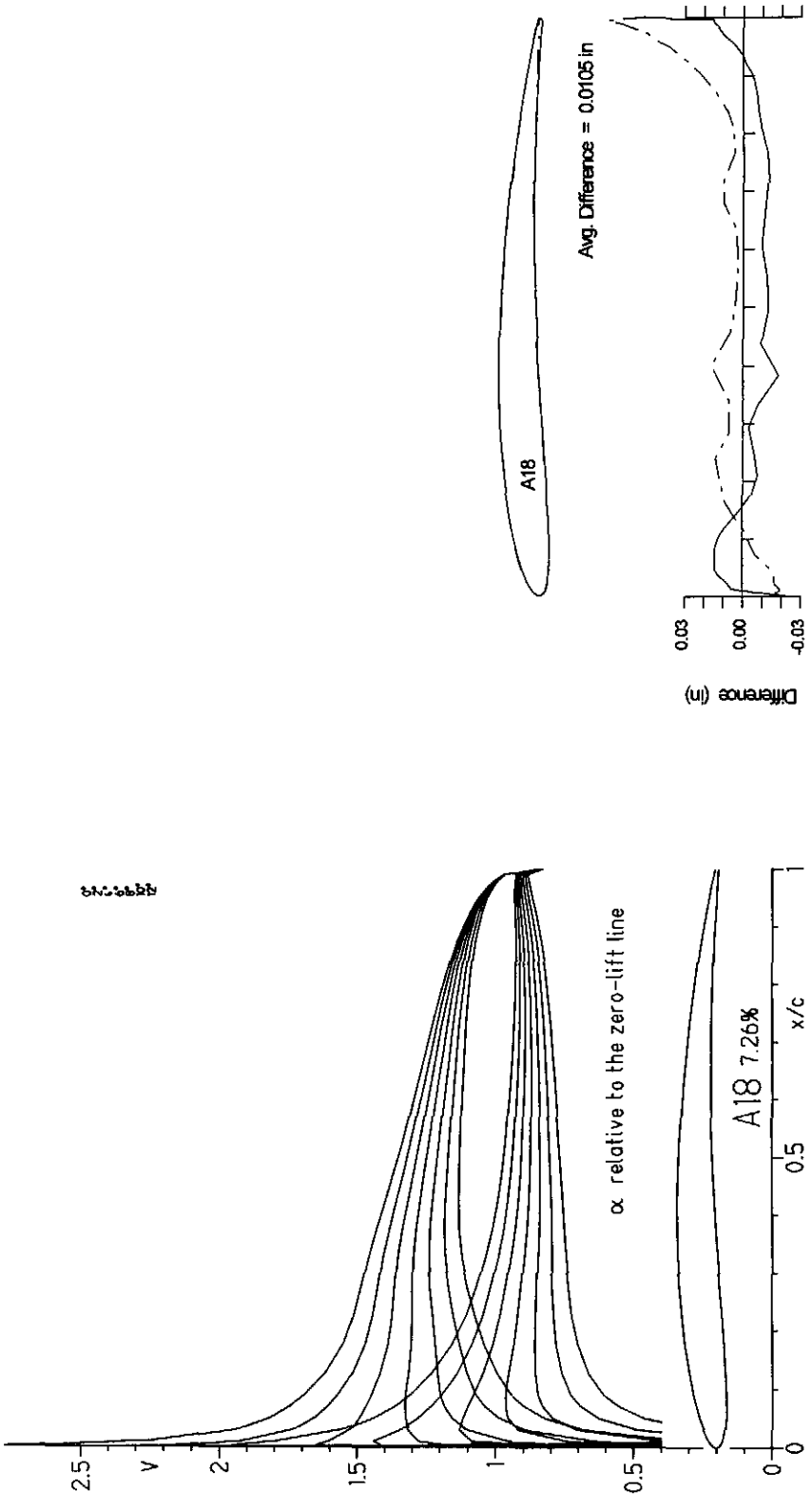
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R140 (A)<br>(Friedlander) | Clean | 4.74<br>4.75 | 154 | 4.76 | 155 | 100,000<br>200,000<br>300,000 | 203/531<br>205<br>207 | 4.77 | 156<br><br>157 | 100,000<br>200,000<br>300,000 | 202<br>204<br>206 |
| RG15 (B)<br>(Champine)<br>Grisberger | Clean | 4.78<br>4.79 | 158 | 4.80 | 159 | 60,000<br>100,000<br>150,000<br>200,000<br>300,000 | 85<br>83<br>550<br>81<br>79 | 4.81 | 160<br><br>▮<br>161 | 60,000<br>100,000<br>150,000<br>200,000<br>300,000 | 306<br>307<br>549<br>80<br>78 |
| S822<br>(Allen)<br>Somers | Clean | 4.82<br>4.83 | 162 | 4.84 | 163 | 100,000<br>200,000<br>300,000<br>400,000<br>500,000 | 416/417<br>419<br>437<br>435<br>420 to 433 | 4.85 | 164<br><br>165 | 100,000<br>200,000<br>300,000<br>400,000 | 415<br>418<br>438<br>434 |
| S823<br>(Allen)<br>Somers | Clean | 4.86<br>4.87 | 166 | 4.88 | 167 | 100,000<br>200,000<br>300,000<br>400,000<br>500,000 | 454<br>457/458<br>461/462/465<br>464<br>466 to 475,477 | 4.89 | 168<br><br>169 | 100,000<br>200,000<br>300,000<br>400,000 | 453<br>456<br>460<br>463 |
| S1210<br>(Allen)<br>Selig | Clean | 4.90<br>4.91 | 170 | 4.92 | 171 | <br><br><br>100,000<br>150,000<br>200,000<br>250,000<br>300,000 | <br><br><br>129/492<br>488<br>131<br>490/491<br>495 | 4.93 | 172<br><br>173<br><br>174<br><br>175 | 60,000<br>80,000<br>90,000<br>100,000<br>150,000<br>200,000<br>250,000<br>300,000 | 127<br>484<br>485<br>128<br>545<br>544<br>489<br>494 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S1223 (Tinel) Selig | Clean | 4.94 | 176 | 4.96 | 177 | | | 4.97 | 178 | 60,000 | 132 |
| | | 4.95 | | | | 100,000 | 134 | | | 100,000 | 133 |
| | | | | | | | | | 179 | 125,000 | 336 |
| | | | | | | 150,000 | 590/598 | | | 150,000 | 337 |
| | | | | | | | | | 180 | 175,000 | 338 |
| | | | | | | 200,000 | 136/588 | | | 200,000 | 339 |
| | | | | | | 250,000 | 594 | | 181 | 250,000 | 592 |
| | | | | | | 300,000 | 597 | | | 300,000 | 595 |
| | u.s. Vortex Generators x/c = 17% Type A | | | 4.98 | 182 | | | 4.99 | 183 | 60,000 | 354 |
| | | | | | | | | | | 80,000 | 353 |
| | | | | | | | | | 184 | 100,000 | 352 |
| | | | | | | | | | | 125,000 | 346 |
| | | | | | | | | | 185 | 150,000 | 350 |
| | | | | | | | | | | 175,000 | 351 |
| | | | | | | 200,000 | 370 | | 186 | 200,000 | 344 |
| | | | | 4.100 | 187 | 200,000 | | | | | |
| | Gurney Flap h/c = 1.04% | | | 4.101 | 188 | 200,000 | 517 | 4.102 | 189 | 200,000 | 515 |
| S6062 (Matheson) Selig | Clean | 4.103 | 190 | 4.105 | 191 | 100,000 | 142 | 4.106 | 192 | 100,000 | 141 |
| | | 4.104 | | | | 200,000 | 140/532 | | | 200,000 | 139 |
| | | | | | | 300,000 | 138 | | 193 | 300,000 | 137 |
| S7012 (Lachowski) Selig | Clean | 4.107 | 194 | 4.109 | 195 | 60,000 | 94 | 4.110 | 196 | 60,000 | 93 |
| | | 4.108 | | | | 100,000 | 92 | | | 100,000 | 91 |
| | | | | | | 150,000 | 565 | | ▮ | 150,000 | 564 |
| | | | | | | 200,000 | 90 | | 197 | 200,000 | 89 |
| | | | | | | 300,000 | 88 | | | 300,000 | 87 |
| S7055 (Jones) Selig | Clean | 4.111 | 198 | 4.113 | 199 | 60,000 | 152/547 | 4.114 | 200 | 60,000 | 151 |
| | | 4.112 | | | | 100,000 | 150 | | | 100,000 | 149 |
| | | | | | | 150,000 | 537 | | ▮ | 150,000 | 536 |
| | | | | | | 200,000 | 148/535/548 | | 201 | 200,000 | 147 |
| | | | | | | 300,000 | 146/534/577 | | | 300,000 | 145 |

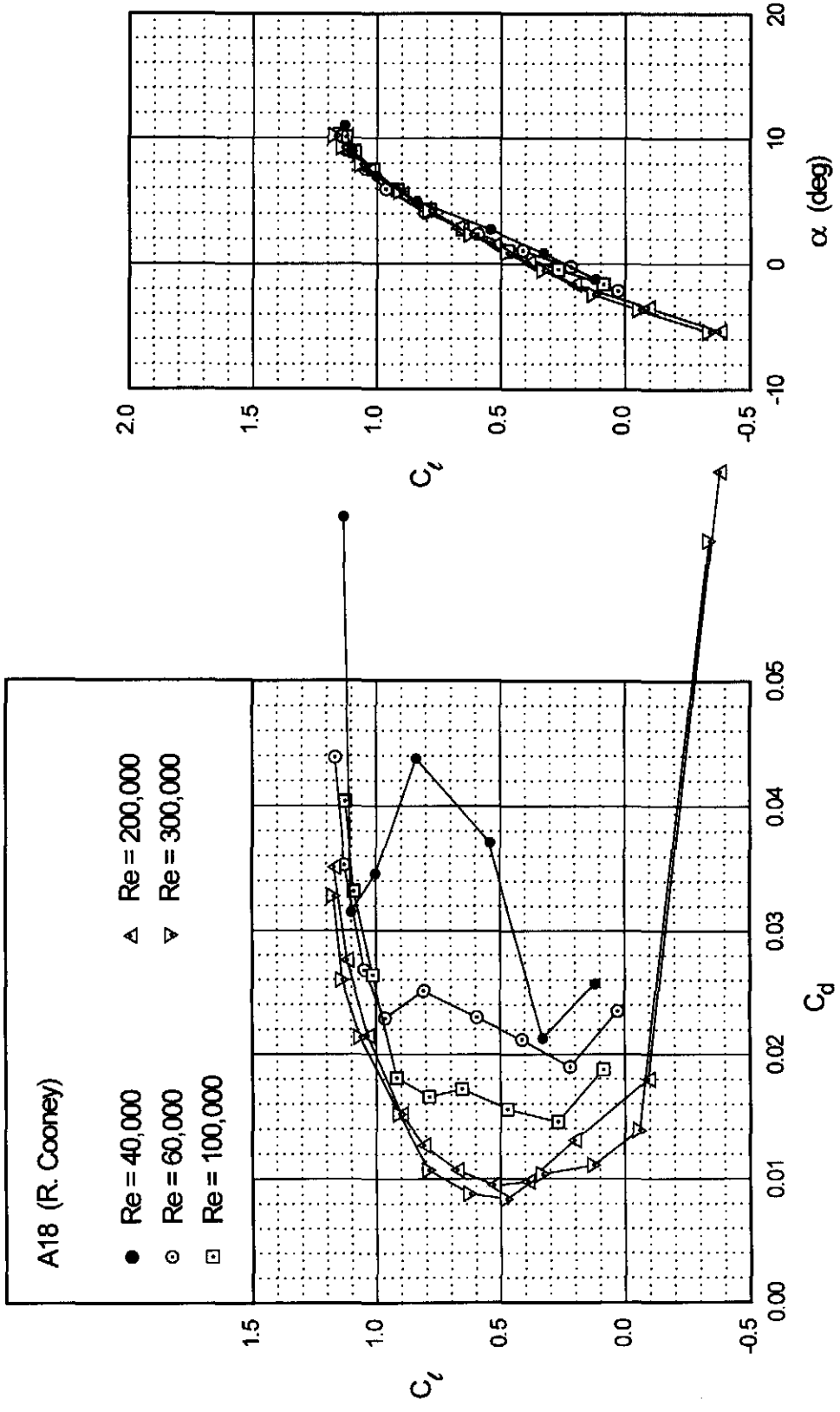
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SD6060 (C. Fox) Selig/Donovan | Clean | 4.115<br>4.116 | 202 | 4.117 | 203 | 60,000<br>100,000<br>150,000<br>200,000<br>300,000 | 77<br>75<br>540<br>73<br>71 | 4.118 | 204<br><br>205 | 60,000<br>100,000<br>150,000<br>200,000<br>300,000 | 312<br>314<br>539<br>72<br>70 |
| SD7003 (Allen) Selig/Donovan | Clean | 4.119<br>4.120 | 206 | 4.121 | 207 | 60,000<br>100,000<br>200,000<br>300,000 | 169<br>171<br>173<br>175/533 | 4.122 | 208<br><br>209 | 60,000<br>100,000<br>200,000<br>300,000 | 168<br>170<br>172<br>174 |
| SD7032 (D) (Watson) Selig/Donovan | Clean | 4.123<br>4.124 | 210 | 4.125 | 211 | 60,000<br>100,000<br>150,000<br>200,000<br>300,000 | 235<br>237<br>543<br>239<br>241 | 4.126 | 212<br><br>213 | 60,000<br>100,000<br>150,000<br>200,000<br>300,000 | 234<br>236<br>542<br>238<br>240 |
| SD7032 (E) (Michaelis) | Clean | 4.127<br>4.128 | 214 | 4.129 | 215 | 200,000 | 356 | 4.130 | 215 | 200,000 | 355 |
| SD7037 (A) (Michaelis) Selig/Donovan | Clean | 4.131<br>4.132 | 216 | 4.133 | 217 | 60,000<br>100,000<br>200,000<br>300,000 | 104<br>223<br>225<br>227 | 4.134 | 218<br><br>219 | 60,000<br>100,000<br>200,000<br>300,000 | 103<br>222<br>224<br>226 |
| SD7037 (B) (Thompson) Selig/Donovan | Clean | 4.135<br>4.136 | 220 | 4.137 | 221 | 60,000<br>100,000<br>150,000<br>200,000<br>300,000 | 102<br>100<br>582<br>98<br>96 | 4.138 | 222<br><br>223 | 60,000<br>100,000<br>150,000<br>200,000<br>300,000 | 580<br>99<br>581<br>97<br>95 |
| SD8000 (Wagner/ Olsen) Selig/Donovan | Clean | 4.139<br>4.140 | 224 | 4.141 | 225 | 60,000<br>100,000<br>200,000<br>300,000 | 325<br>327<br>329<br>331 | 4.142 | 226<br><br>227 | 60,000<br>100,000<br>200,000<br>300,000 | 324<br>326<br>328<br>330 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SD8020 (Wagner/ Olsen) Selig/Donovan | Clean | 4.143<br>4.144 | 228 | 4.145 | 229 | | | 4.146 | 230<br><br>231<br><br>232<br><br><br><br>233 | 30,000<br>40,000<br>50,000<br>60,000<br>80,000<br>100,000<br><br><br><br>200,000<br>300,000 | 262<br>259<br>260<br>261<br>263<br>264<br><br><br><br>255<br>257 |
| | | | | | | 60,000<br>100,000<br>200,000<br>300,000 | 252<br>254<br>256<br>258 | | | | |
| | u.s.t./l.s.t.<br>Zig-Zag<br>Type B<br>x/c = 25%<br>h/c = 0.16% | | | | | | | 4.147 | 234<br><br>235<br><br>236 | 30,000<br>40,000<br>50,000<br>60,000<br>80,000<br>100,000 | 271<br>272<br>273<br>274<br>275<br>276 |
| | u.s.t./l.s.t.<br>Zig-Zag<br>Type B<br>x/c = 25%<br>h/c = 0.32% | | | 4.148 | 237 | 60,000<br><br><br><br>200,000 | 287<br><br><br><br>289 | 4.149 | 238<br><br>239<br><br>[redacted] | 40,000<br>60,000<br>80,000<br>100,000<br>200,000 | 283<br>284<br>285<br>286<br>288 |
| WASP (M. Fox) M. Fox | Clean | 4.150<br>4.151 | 240 | 4.152 | 241 | 60,000<br>100,000<br>200,000<br>300,000 | 229<br>144<br>231<br>233 | 4.153 | 242<br><br>243 | 60,000<br>100,000<br>200,000<br>300,000 | 228<br>143<br>230<br>232 |

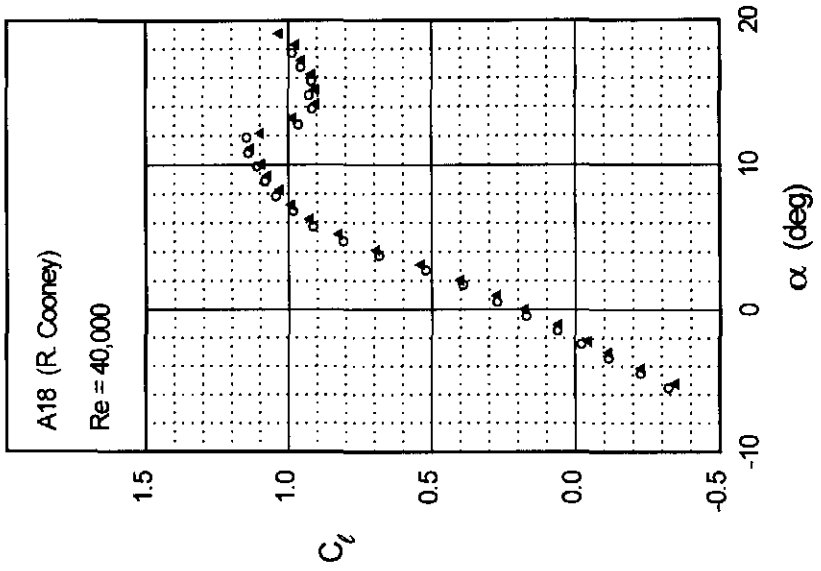
A18

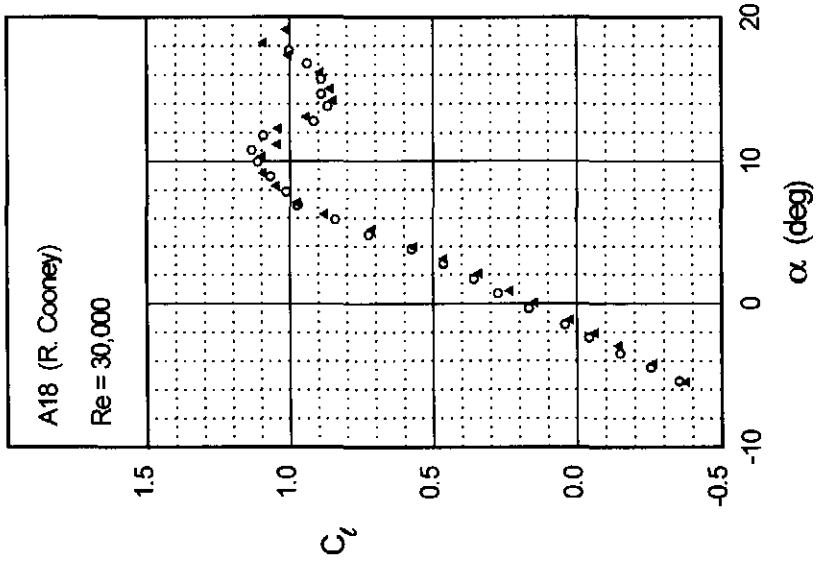

A18
Avg. Difference = 0.0105 in
0.03
0.00
-0.03
Difference (in)
2.5
2
1.5
1
0.5
V
α relative to the zero-lift line
A18 7.26%
0
0.5
1
x/c

A18

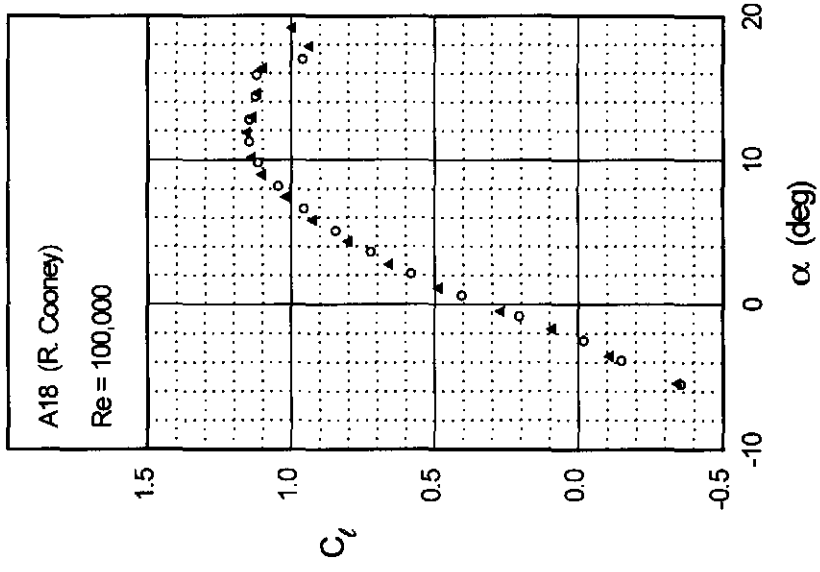

A18 (R. Cooney)
Re = 40,000
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)

A18


A18 (R. Cooney)
Re = 40,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


A18 (R. Cooney)
Re = 30,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

A18


A18 (R. Cooney)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
-10
0
10
20
α (deg)

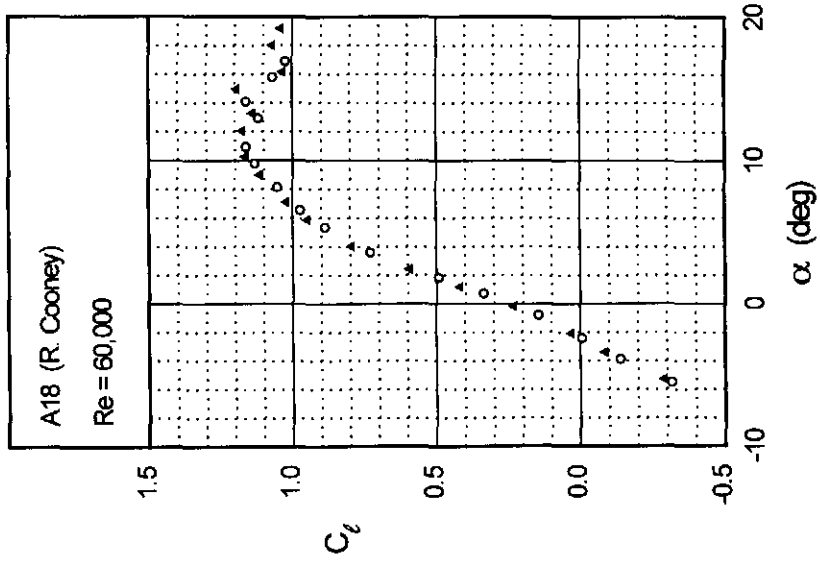
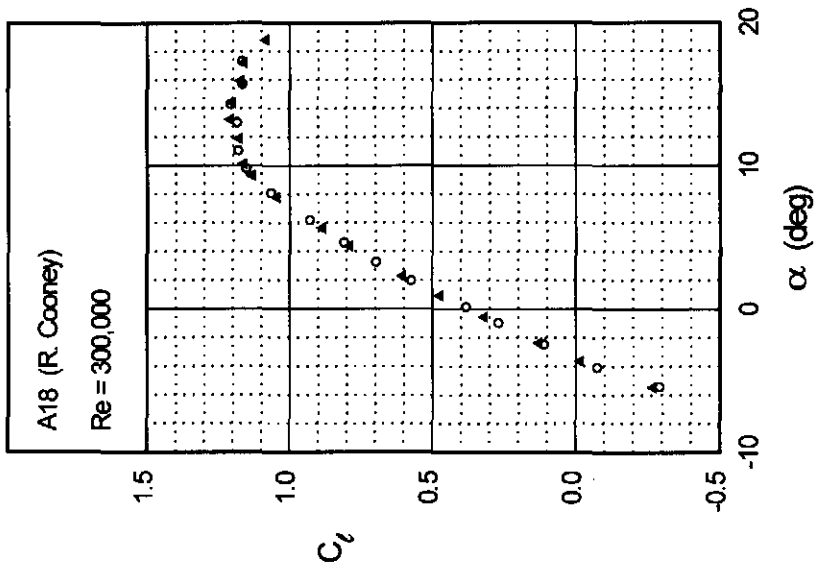
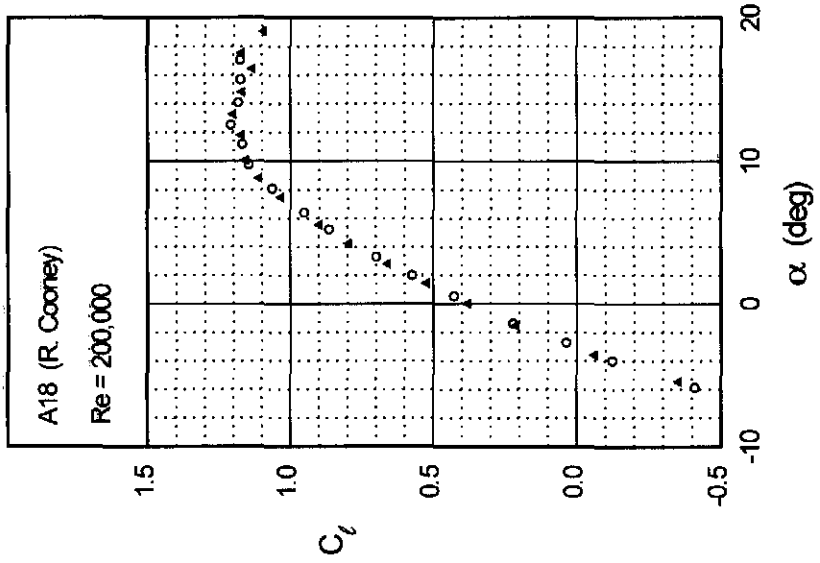

A18 (R. Cooney)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
-10
0
10
20
α (deg)

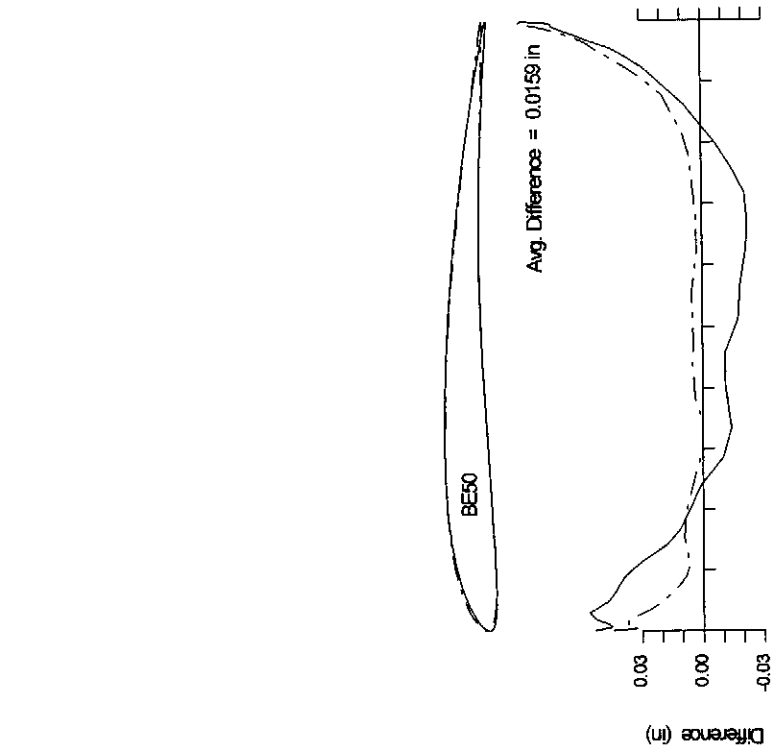
Fig. 4.4 (continued)

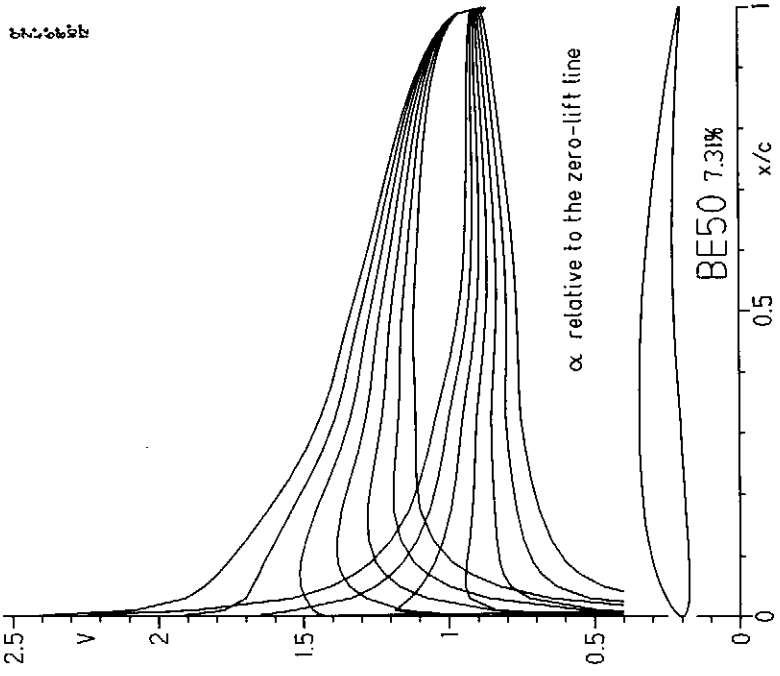
A18



BE50


BE50
Avg. Difference = 0.0159 in
0.03
0.00
-0.03
Difference (in)


2.5
2
1.5
1
0.5
V
α relative to the zero-lift line
BE50 7.31%
0
0.5
1
x/c

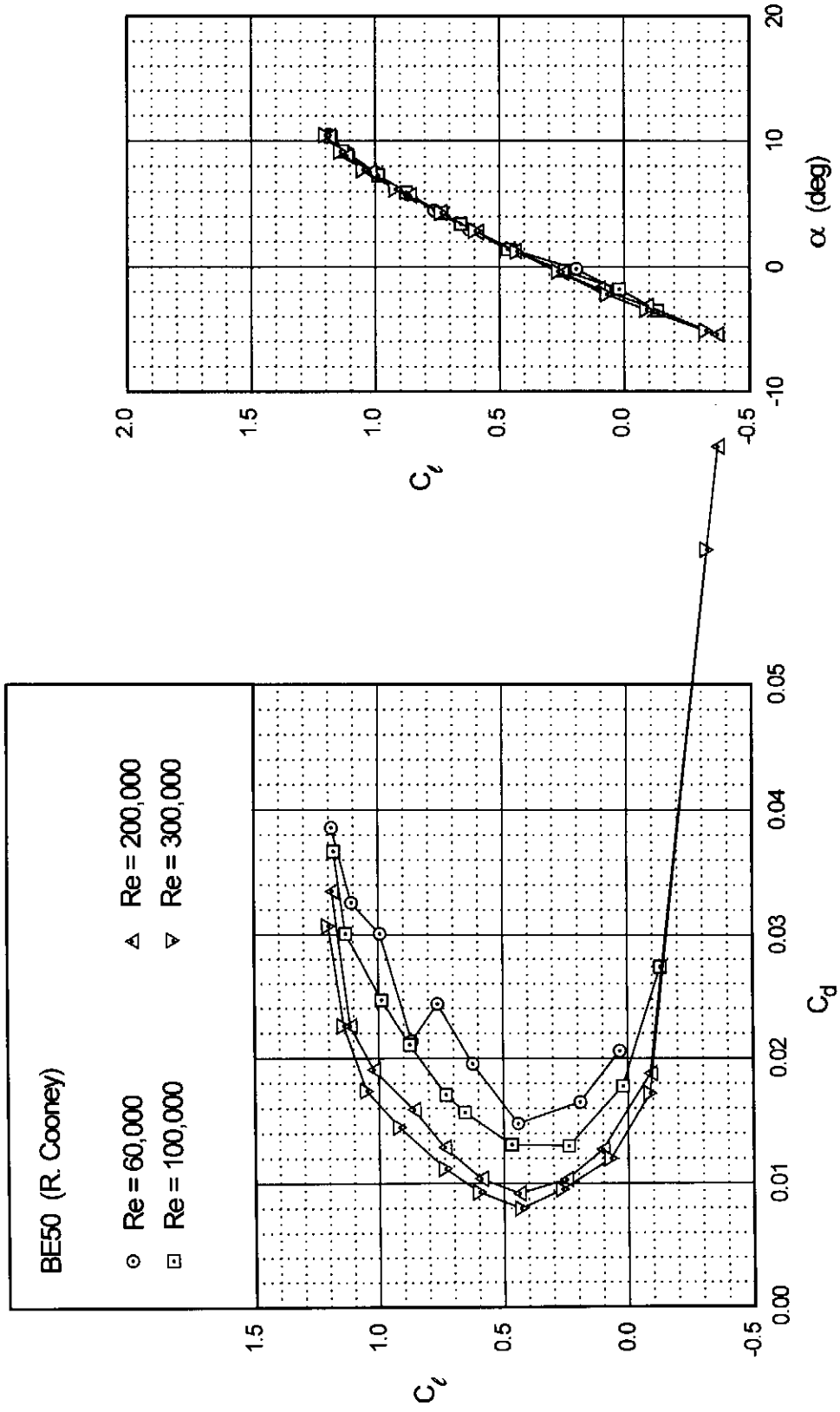
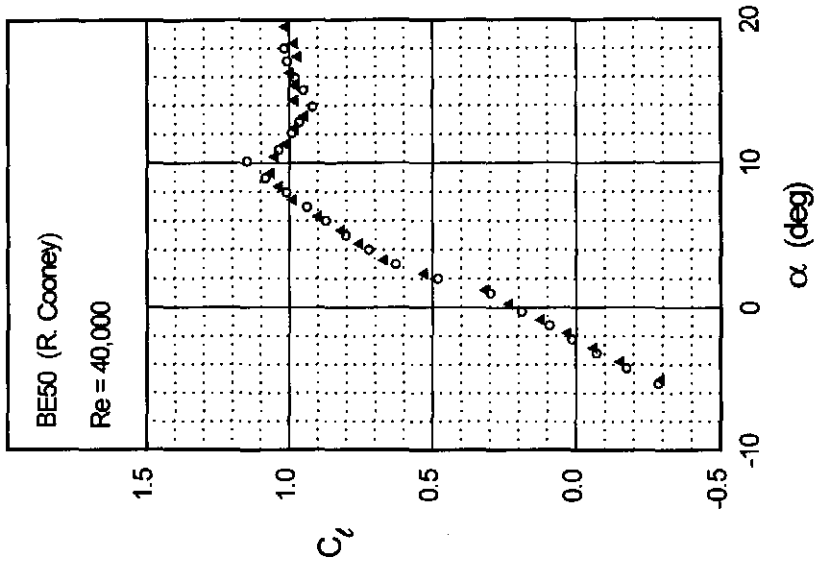
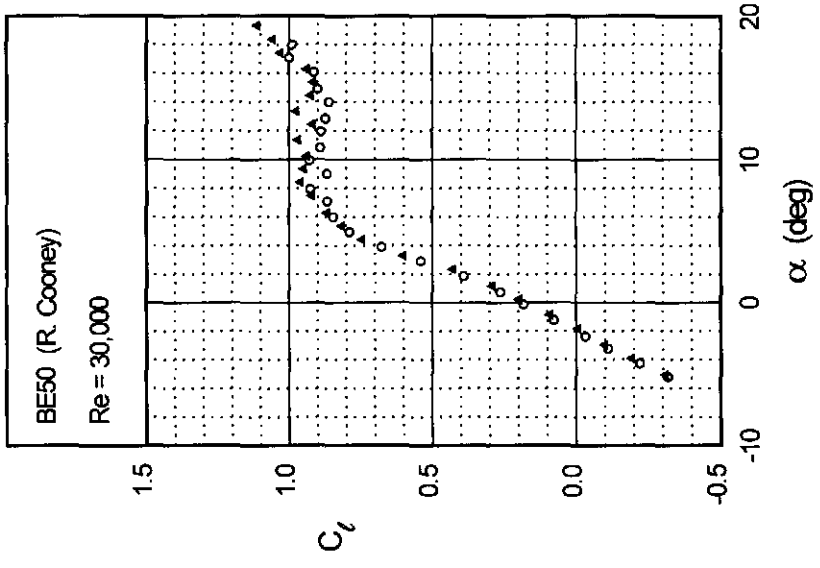
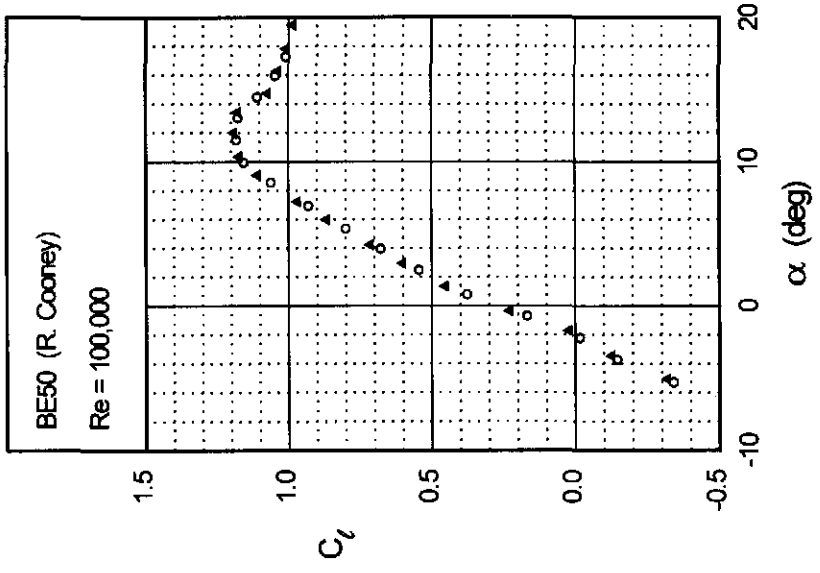

BE50
BE50 (R. Cooney)
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
$\alpha$ (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
-10
0
10
20
0.00
0.01
0.02
0.03
0.04
0.05

Fig. 4.8

BE50


BE50 (R. Cooney)
Re = 40,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


BE50 (R. Cooney)
Re = 30,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


BE50 (R Cooney)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

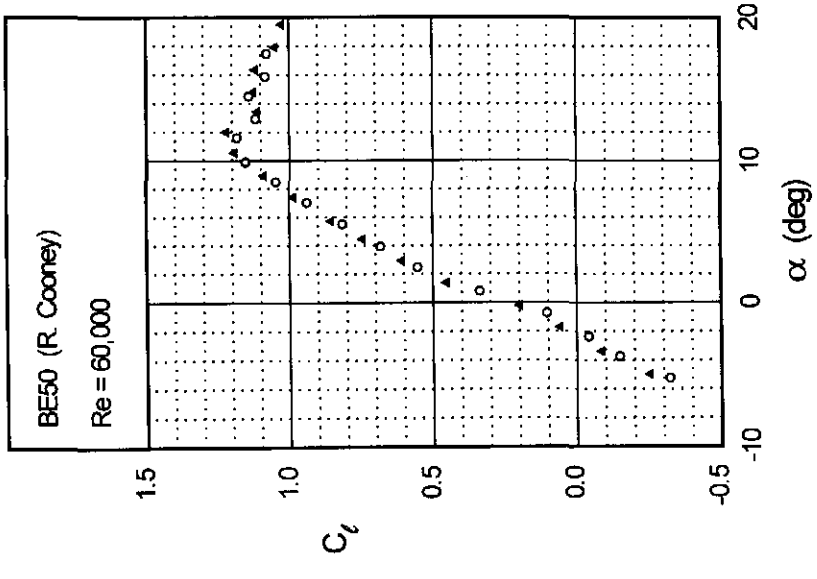
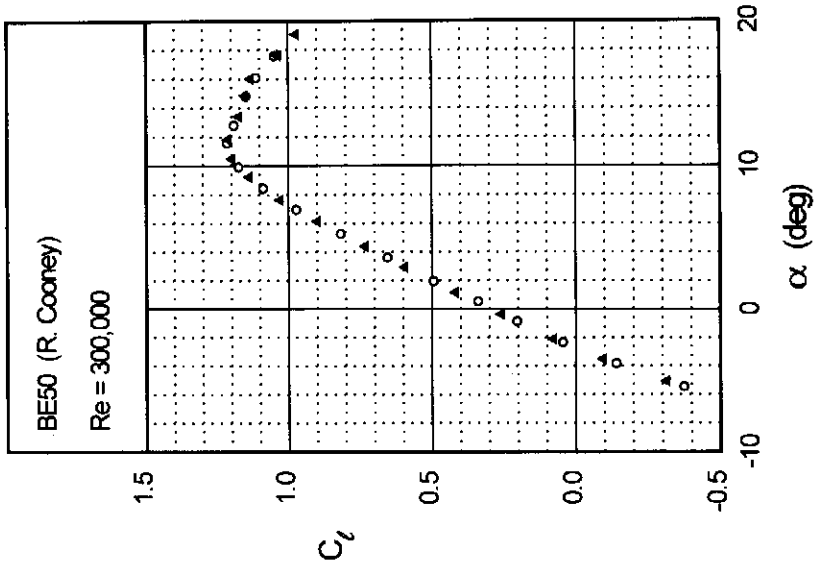
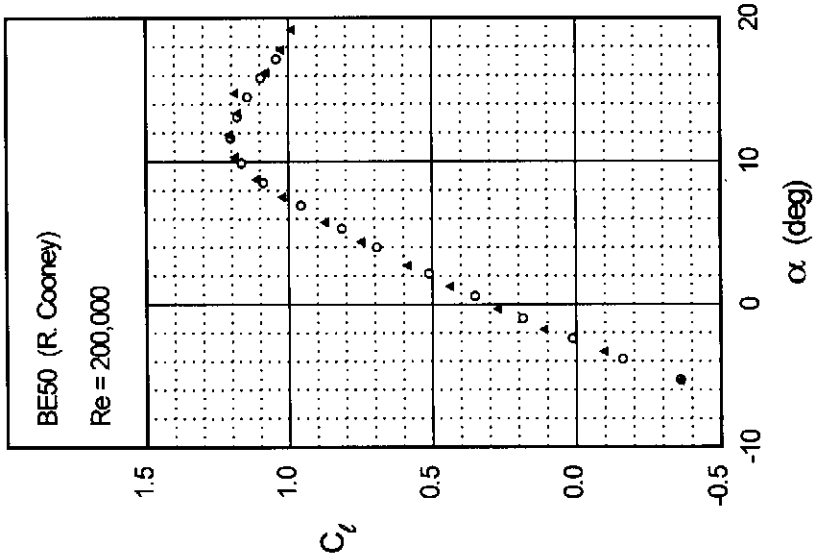

BE50 (R Cooney)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

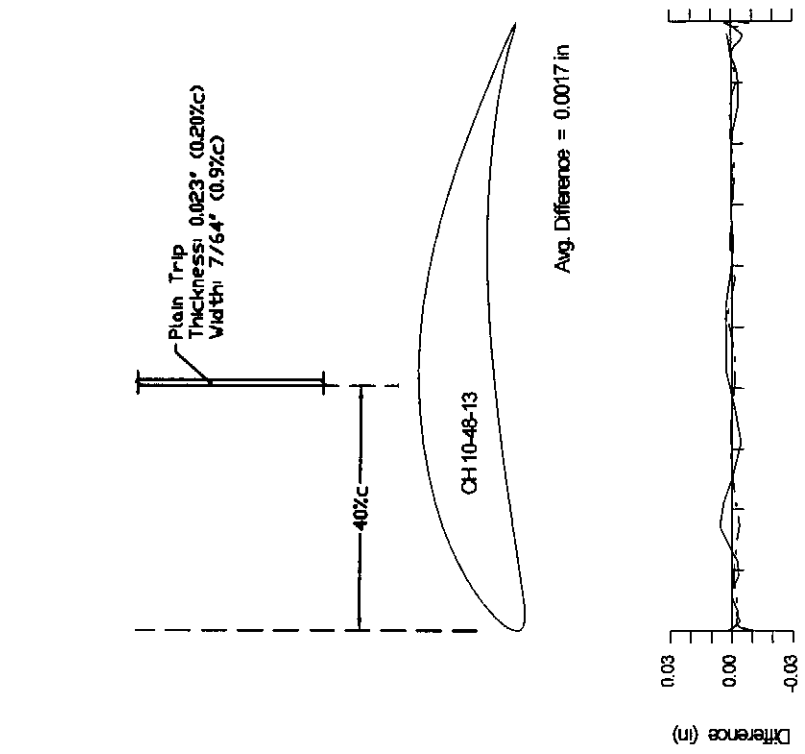
Fig. 4.8 (continued)

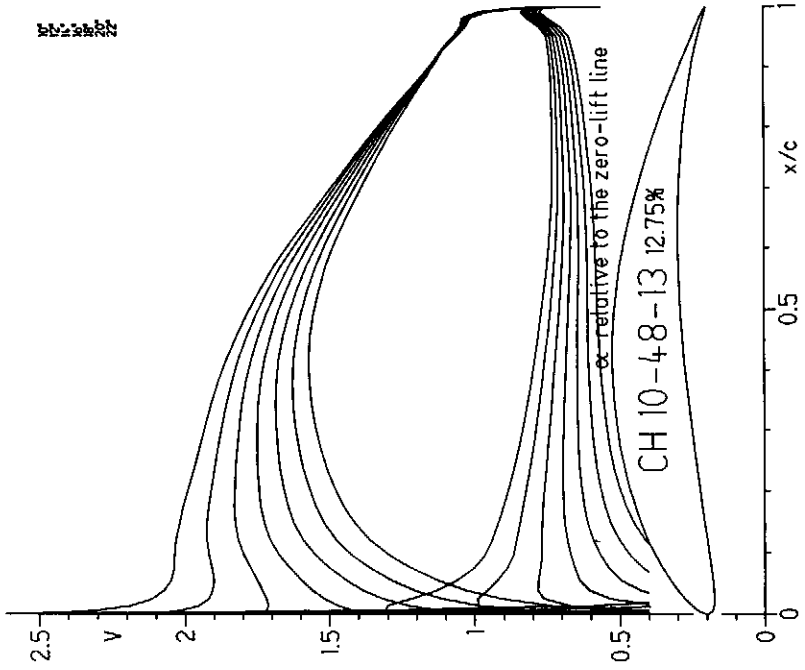
BE50



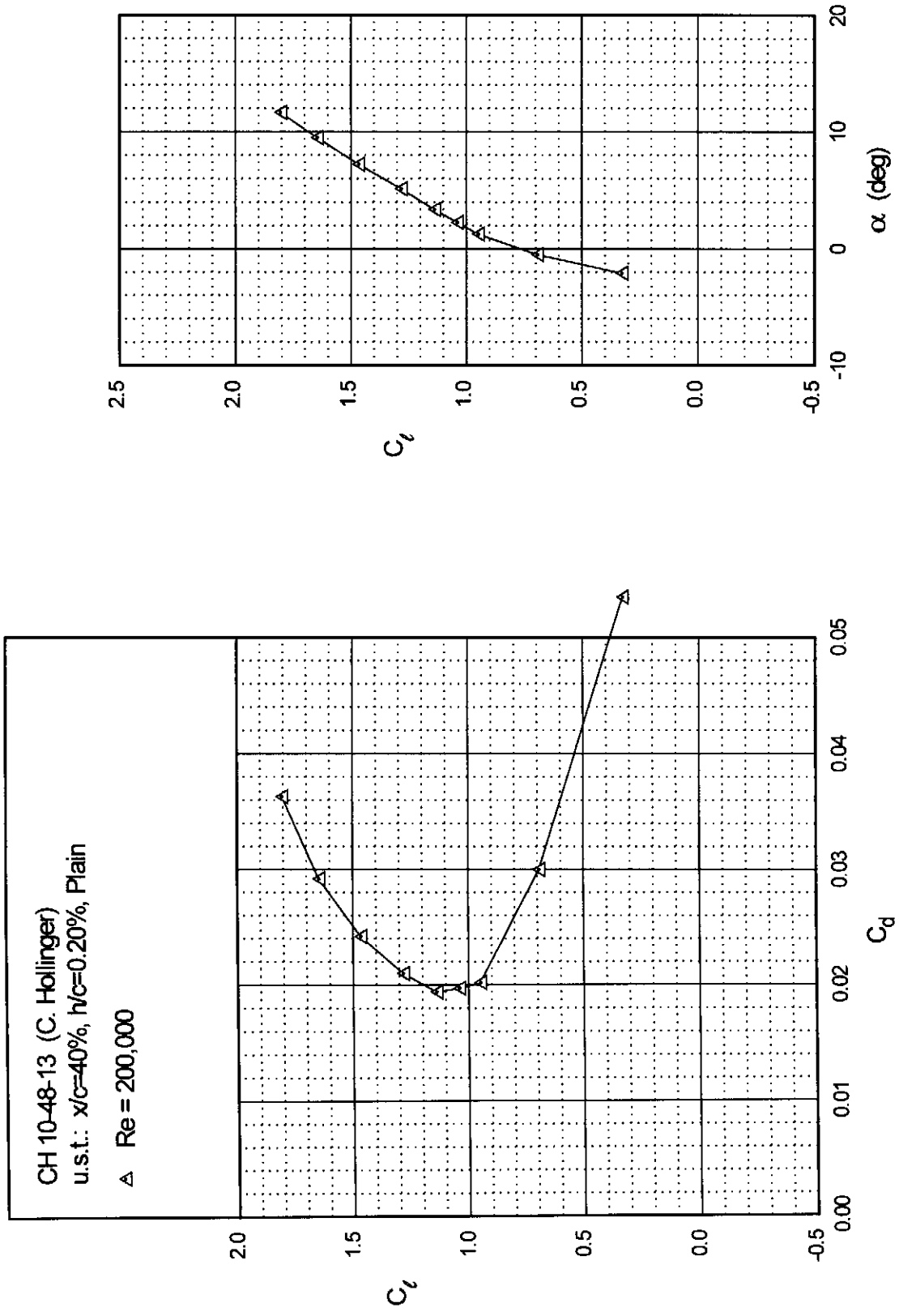



CH 10-48-13

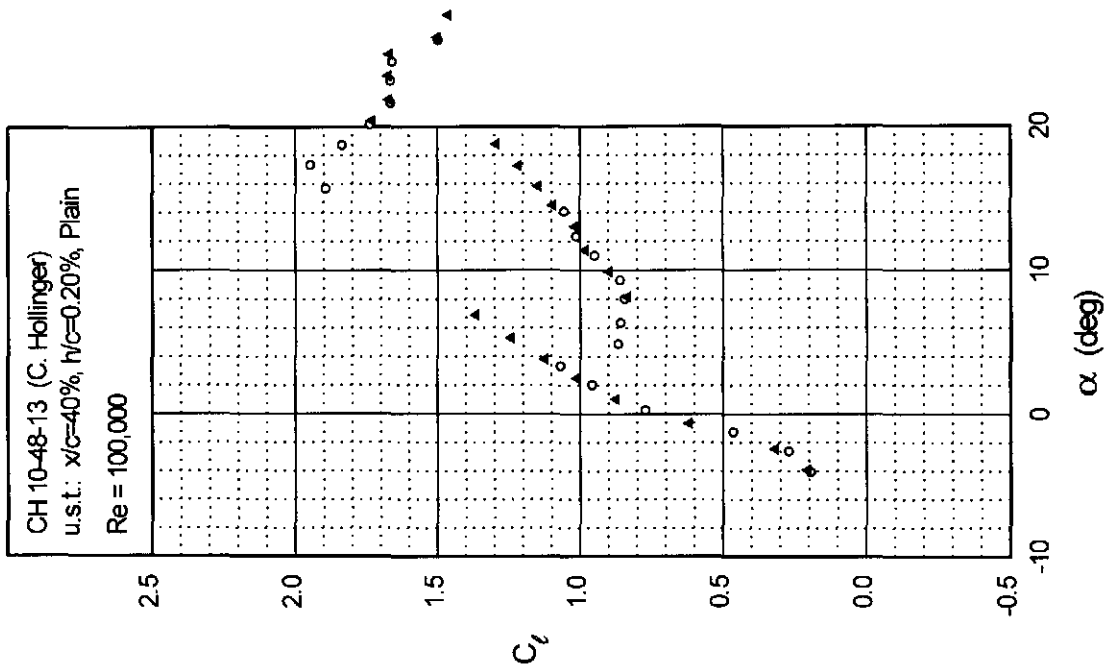

Plain Trip
Thickness: 0.023" (0.20%c)
Width: 7/64" (0.9%c)
40%c
CH 10-48-13
Avg. Difference = 0.0017 in
0.03
0.00
-0.03
Difference (in)

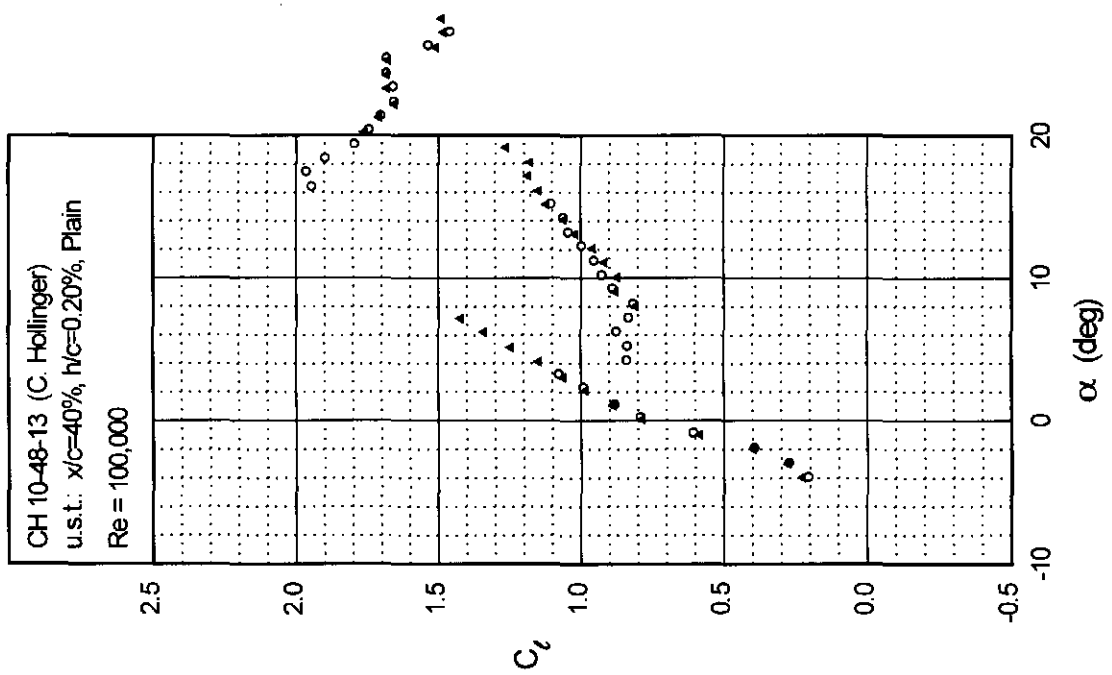

2.5
2
1.5
1
0.5
V
α relative to the zero-lift line
CH 10-48-13 12.75%
0
0.5
1
x/c

CH 10-48-13

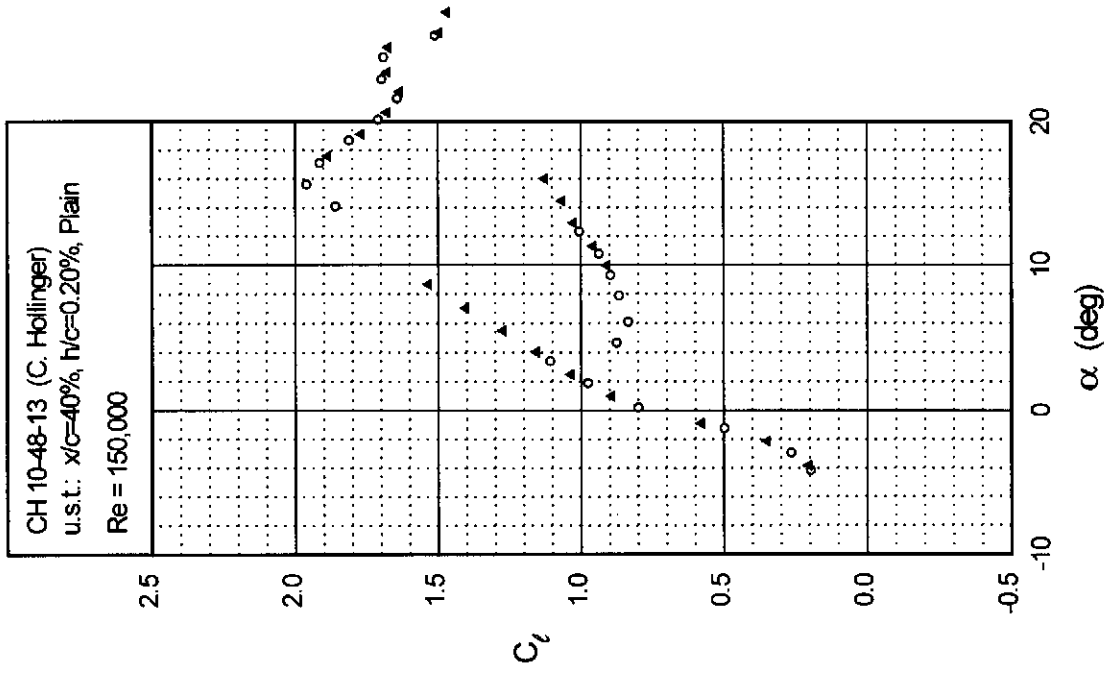

CH 10-48-13 (C. Hollinger)
u.s.t.: x/c=40%, h/c=0.20%, Plain
Re = 200,000
$C_l$
$C_d$
α (deg)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-10
0
10
20
0.00
0.01
0.02
0.03
0.04
0.05

CH 10-48-13


CH 10-48-13 (C. Hollinger)
u.s.t.: x/c=40%, h/c=0.20%, Plain
Re = 100,000
$C_l$
α (deg)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-10
0
10
20


CH 10-48-13 (C. Hollinger)
u.s.t.: x/c=40%, h/c=0.20%, Plain
Re = 100,000
$C_l$
α (deg)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-10
0
10
20

CH 10-48-13


CH 10-48-13 (C. Hollinger)
u.s.t.: x/c=40%, h/c=0.20%, Plain
Re = 150,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

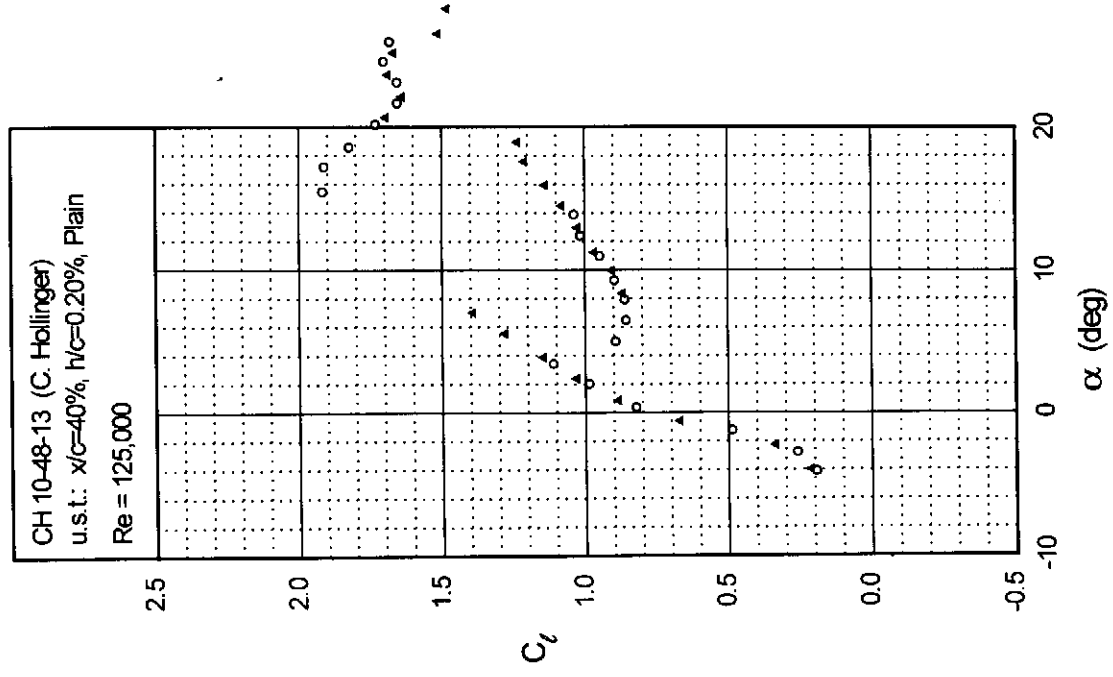
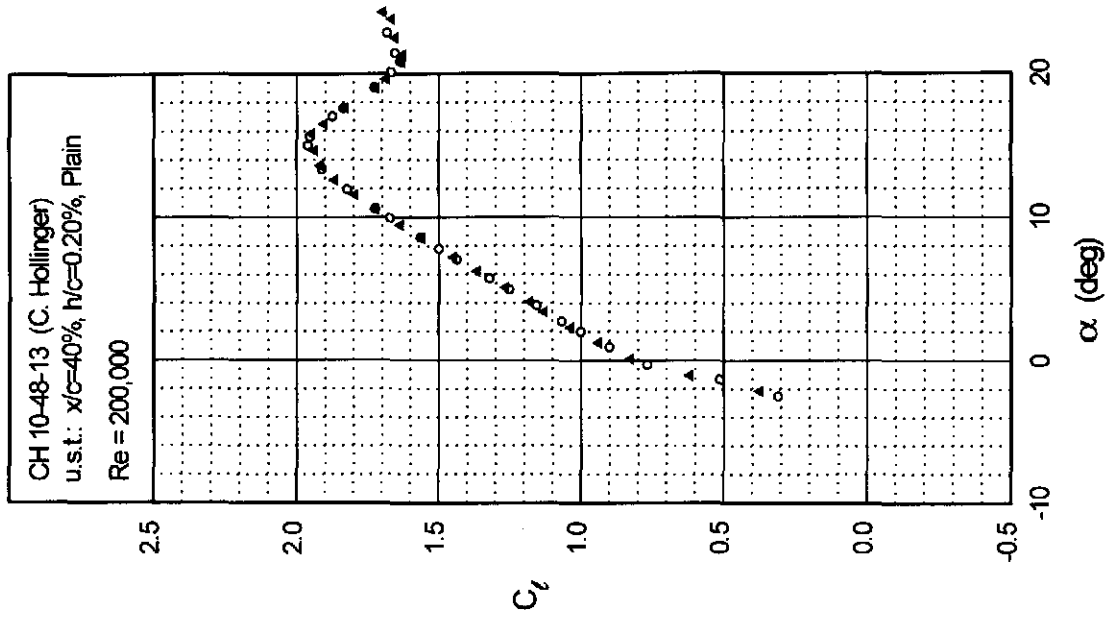
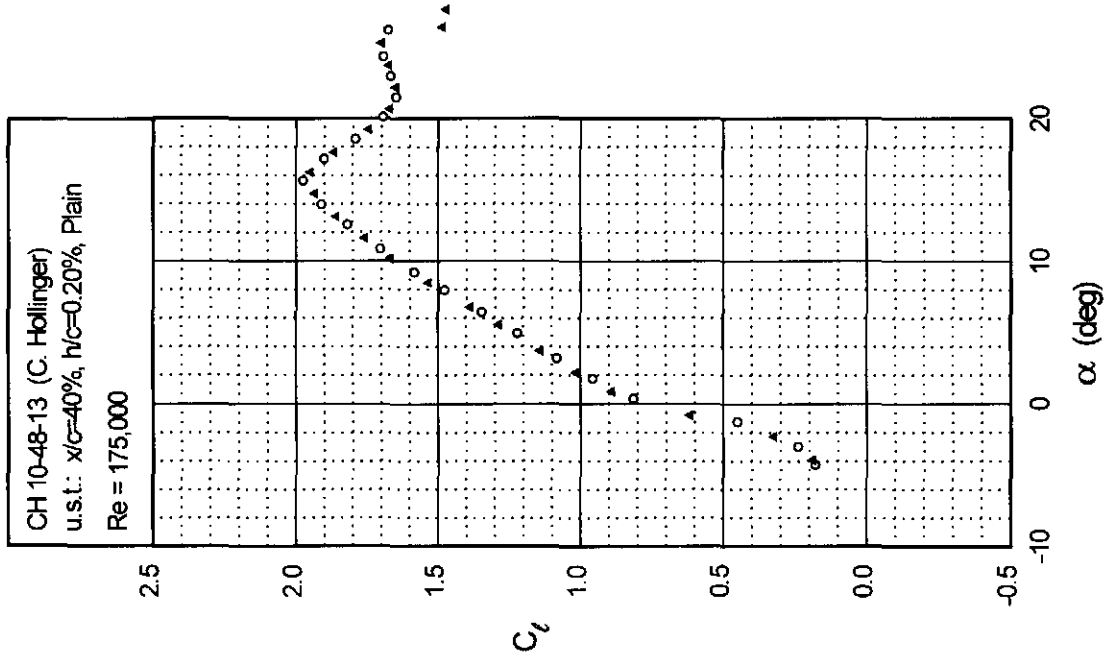

CH 10-48-13 (C. Hollinger)
u.s.t.: x/c=40%, h/c=0.20%, Plain
Re = 125,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

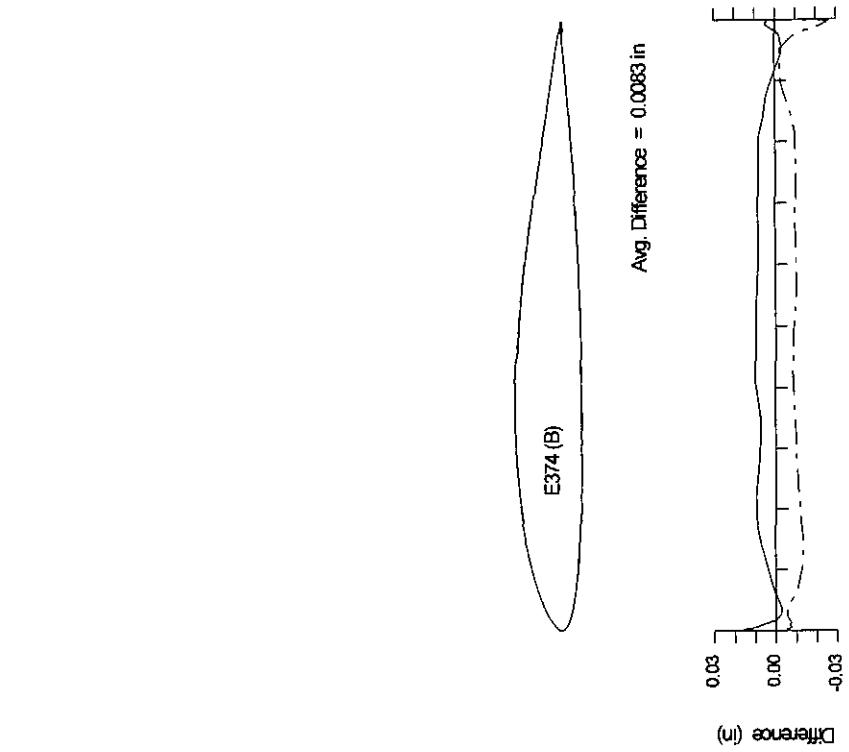
 Fig. 4.12 (continued)

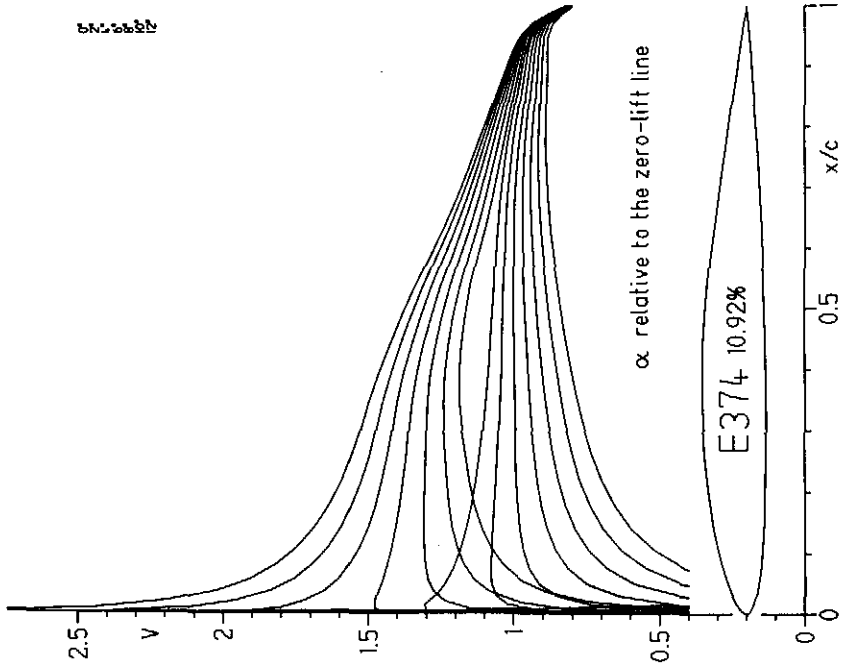
CH 10-48-13



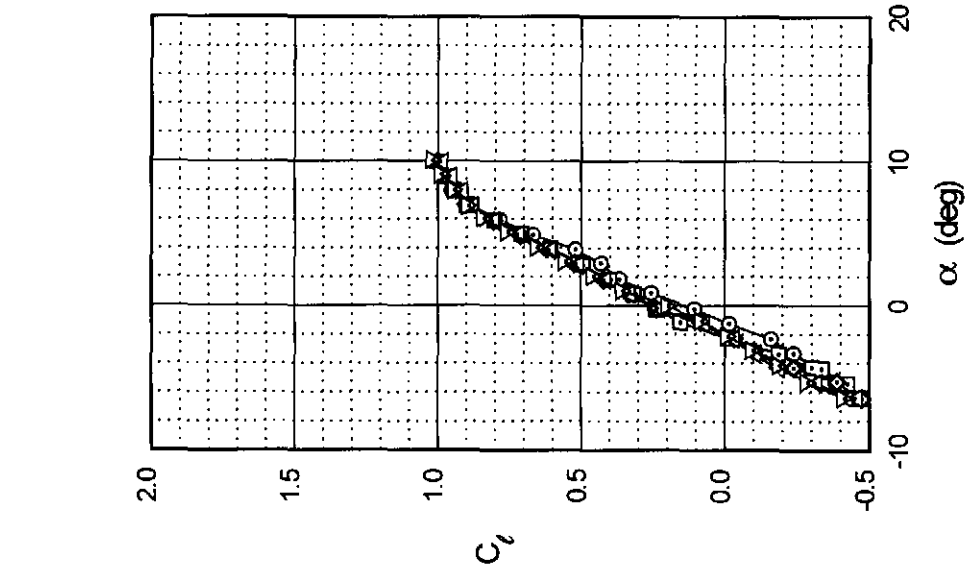



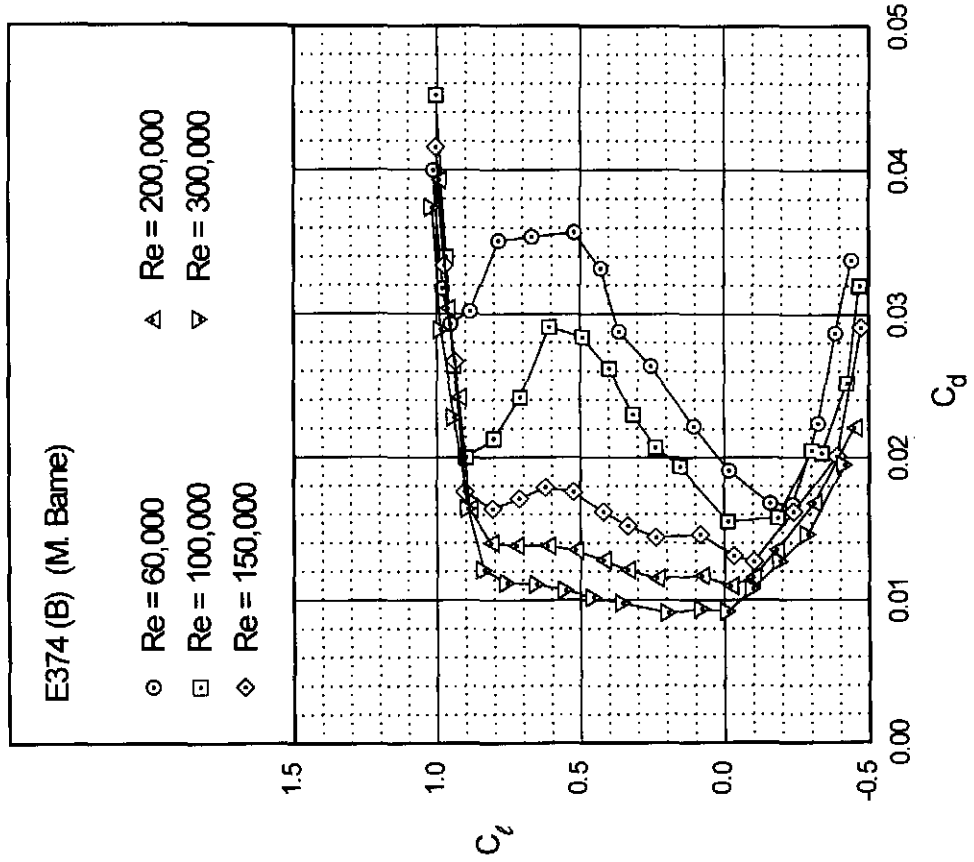
E374 (B)


E374 (B)
Avg. Difference = 0.0083 in
0.03
0.00
-0.03
Difference (in)

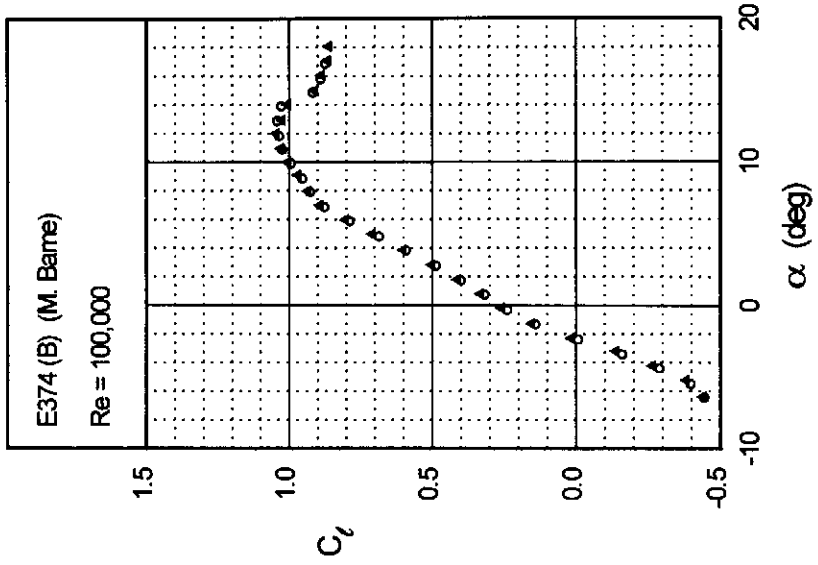

α relative to the zero-lift line
E374 10.92%
x/c
0
0.5
1
2.5
2
1.5
1
0.5
0

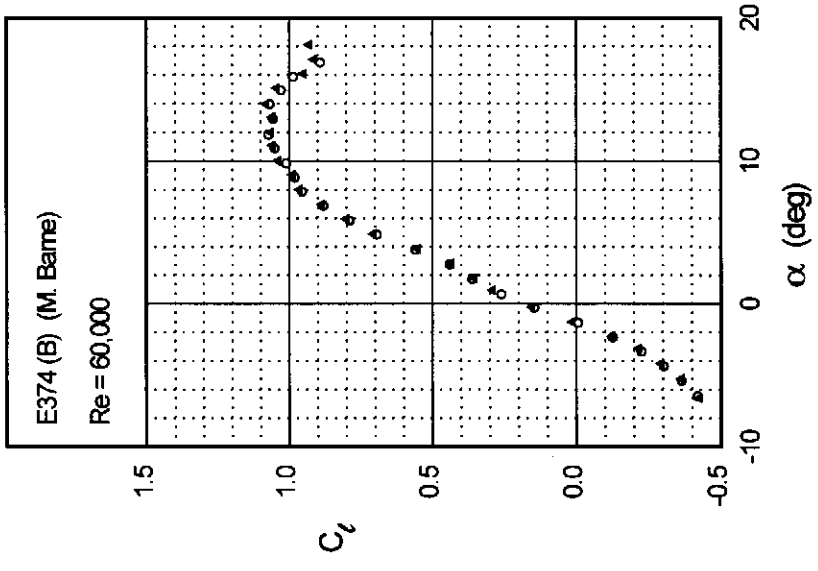
E374 (B)

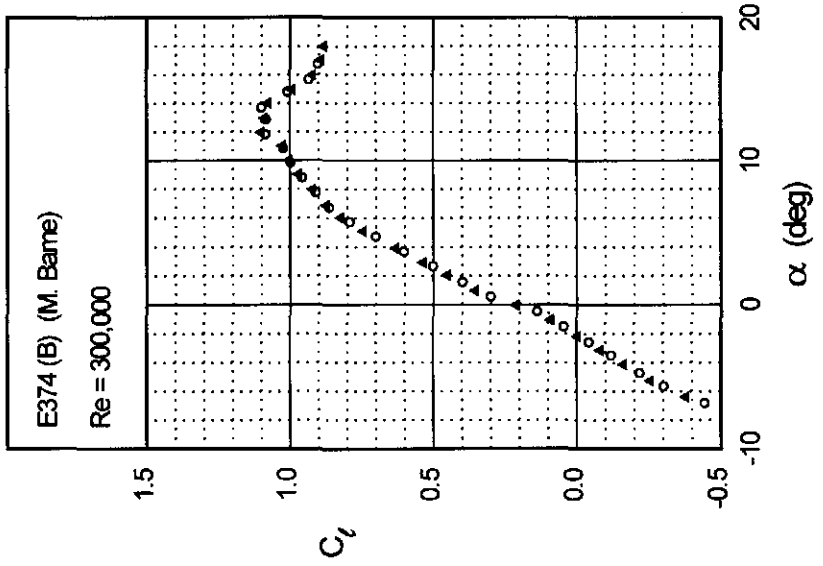

2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)

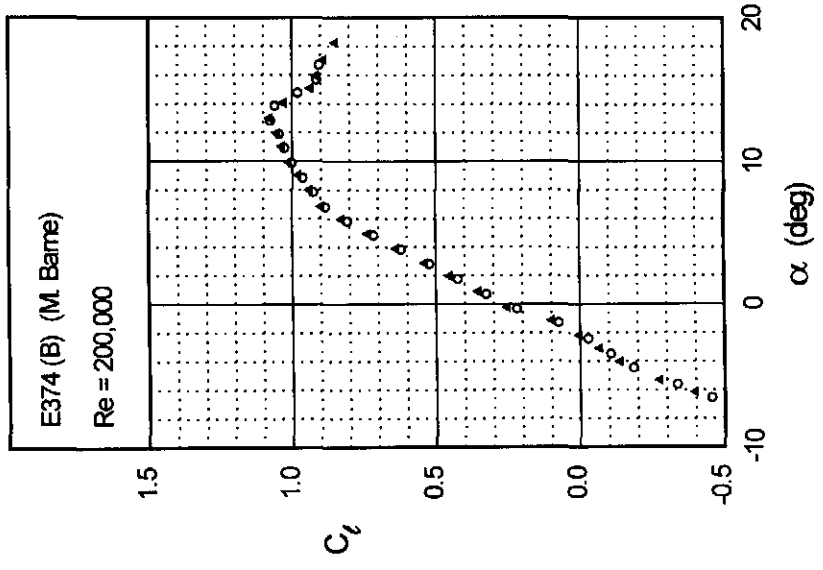

E374 (B) (M. Barne)
Re = 60,000
Re = 100,000
Re = 150,000
Re = 200,000
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
0.05
0.04
0.03
0.02
0.01
0.00
$C_d$

E374 (B)

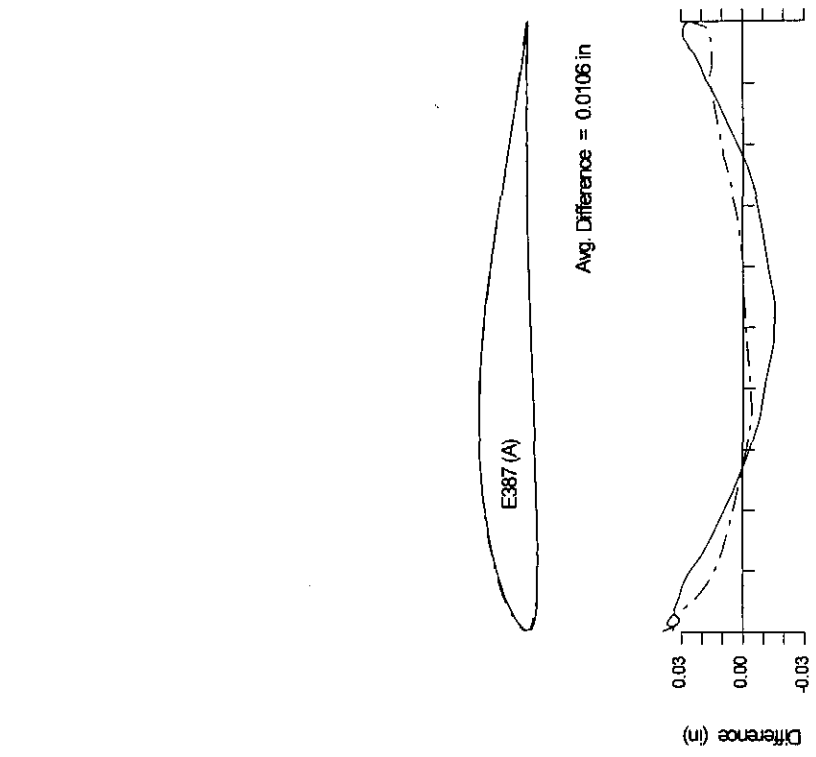

E374 (B) (M. Barne)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

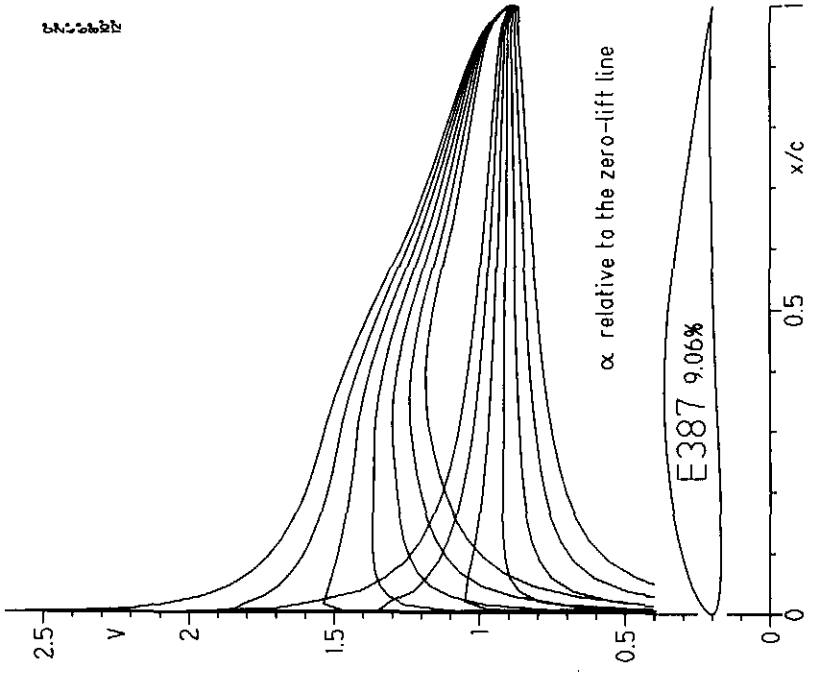

E374 (B) (M. Barne)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


E374 (B) (M. Barne)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)

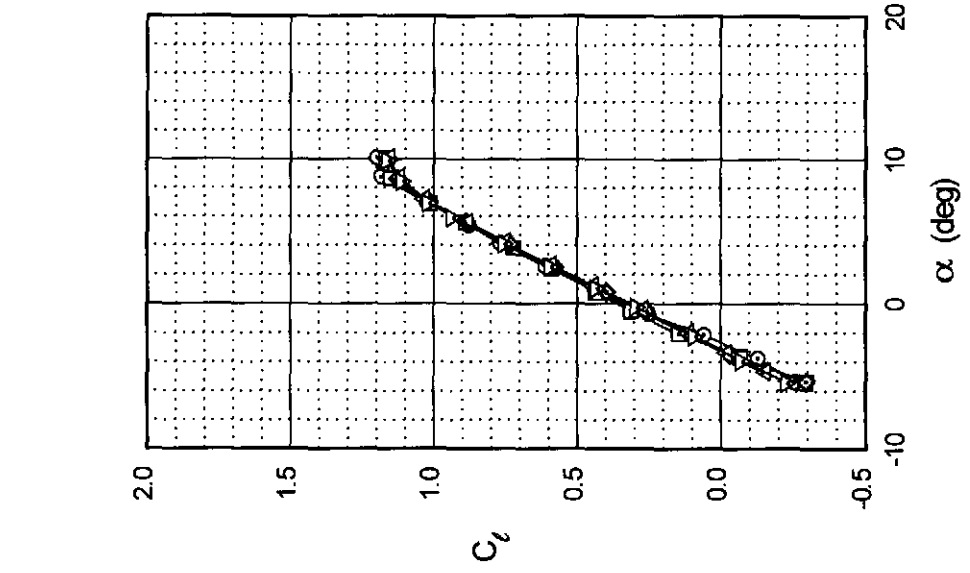

E374 (B) (M Barne)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)

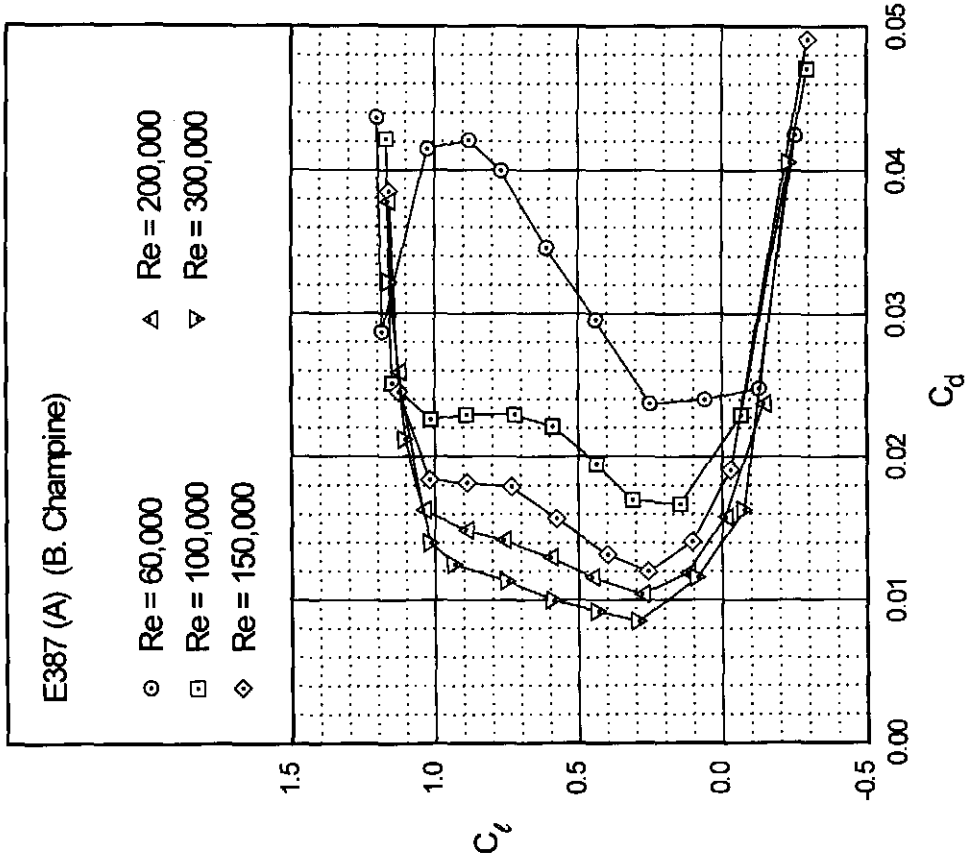
E387 (A)


E387 (A)
Avg. Difference = 0.0106 in
0.03
0.00
-0.03
Difference (in)

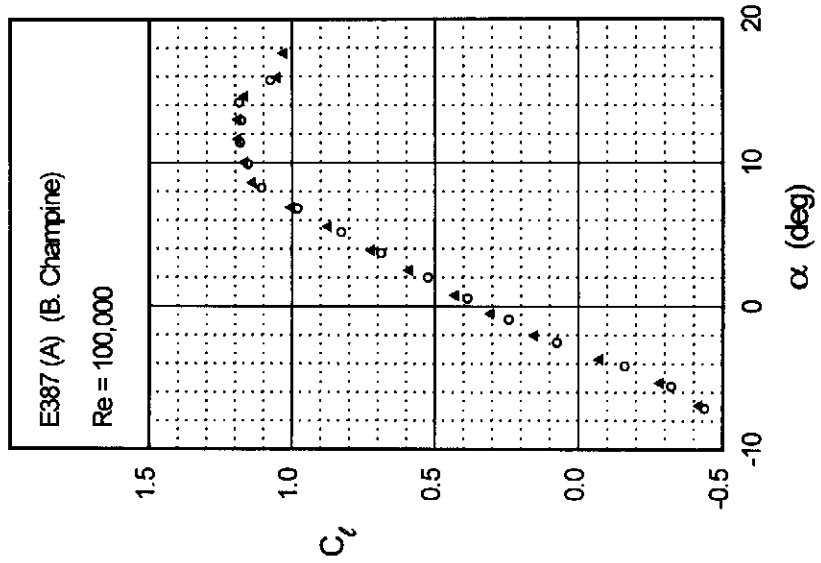

2.5
V
2
1.5
1
0.5
α relative to the zero-lift line
E387 9.06%
0
0.5
1
x/c

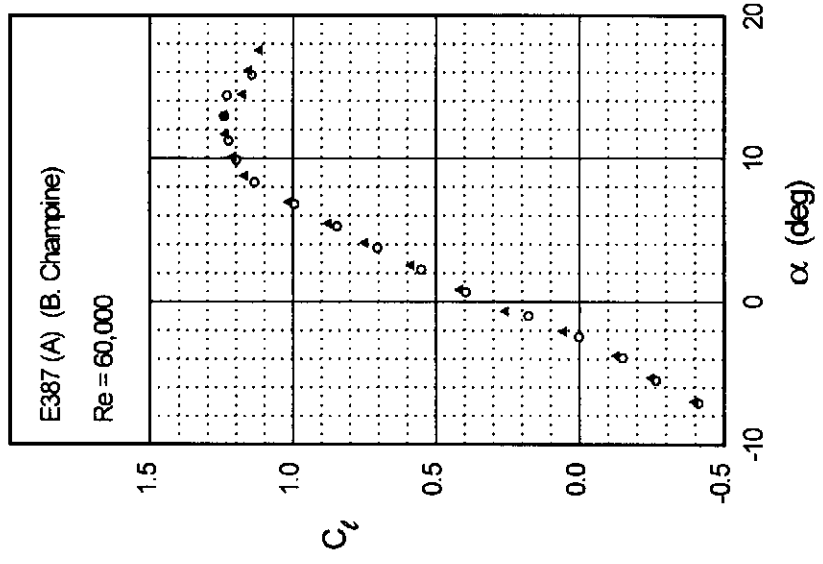
E387 (A)

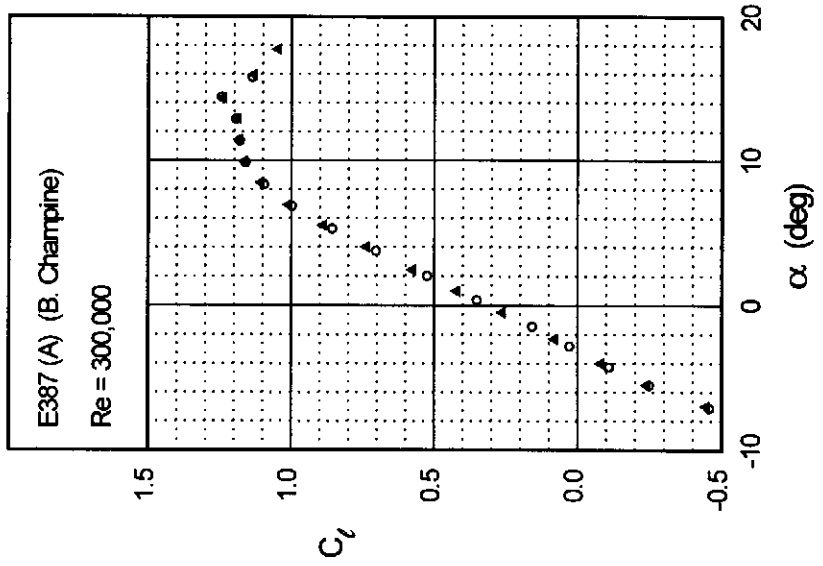

2.0
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
20
10
0
-10
α (deg)

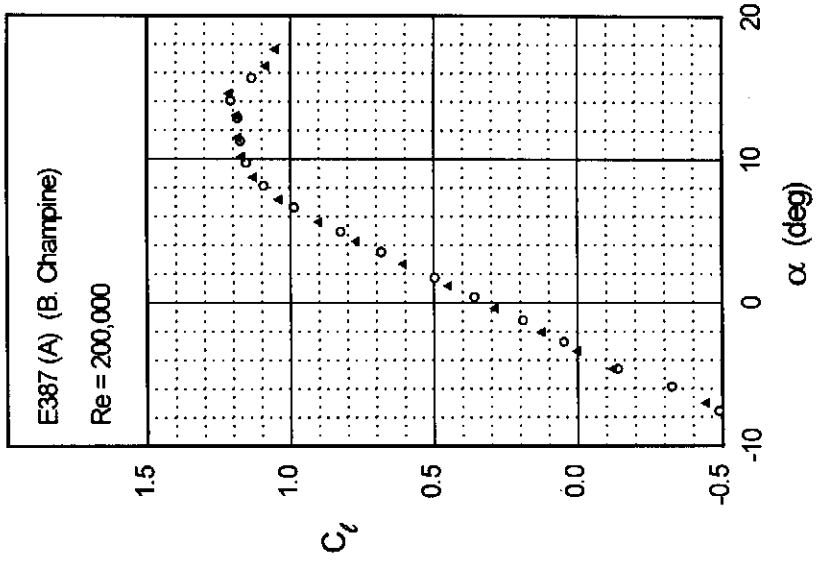

E387 (A) (B. Champine)
Re = 60,000
Re = 100,000
Re = 150,000
Re = 200,000
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
0.00
0.01
0.02
0.03
0.04
0.05
$C_d$

E387 (A)

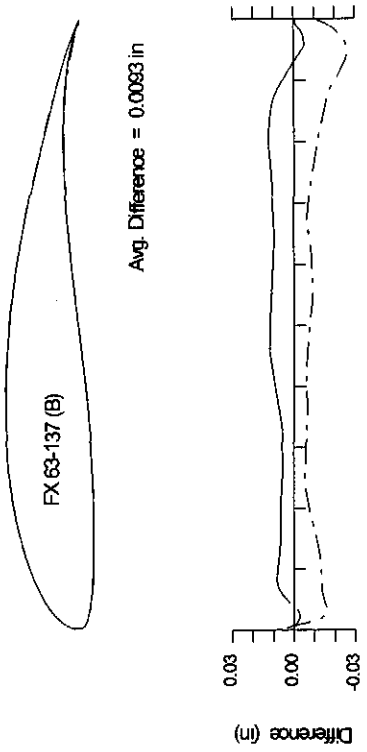

E387 (A) (B. Champine)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

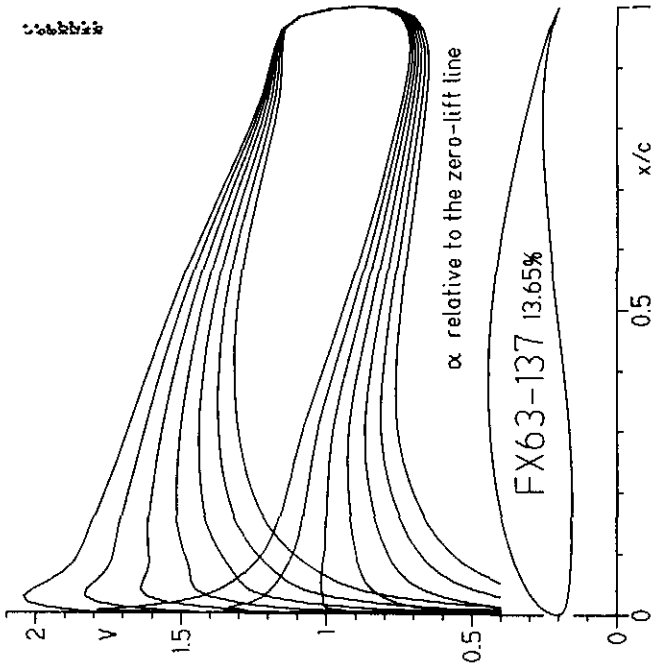

E387 (A) (B. Champine)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

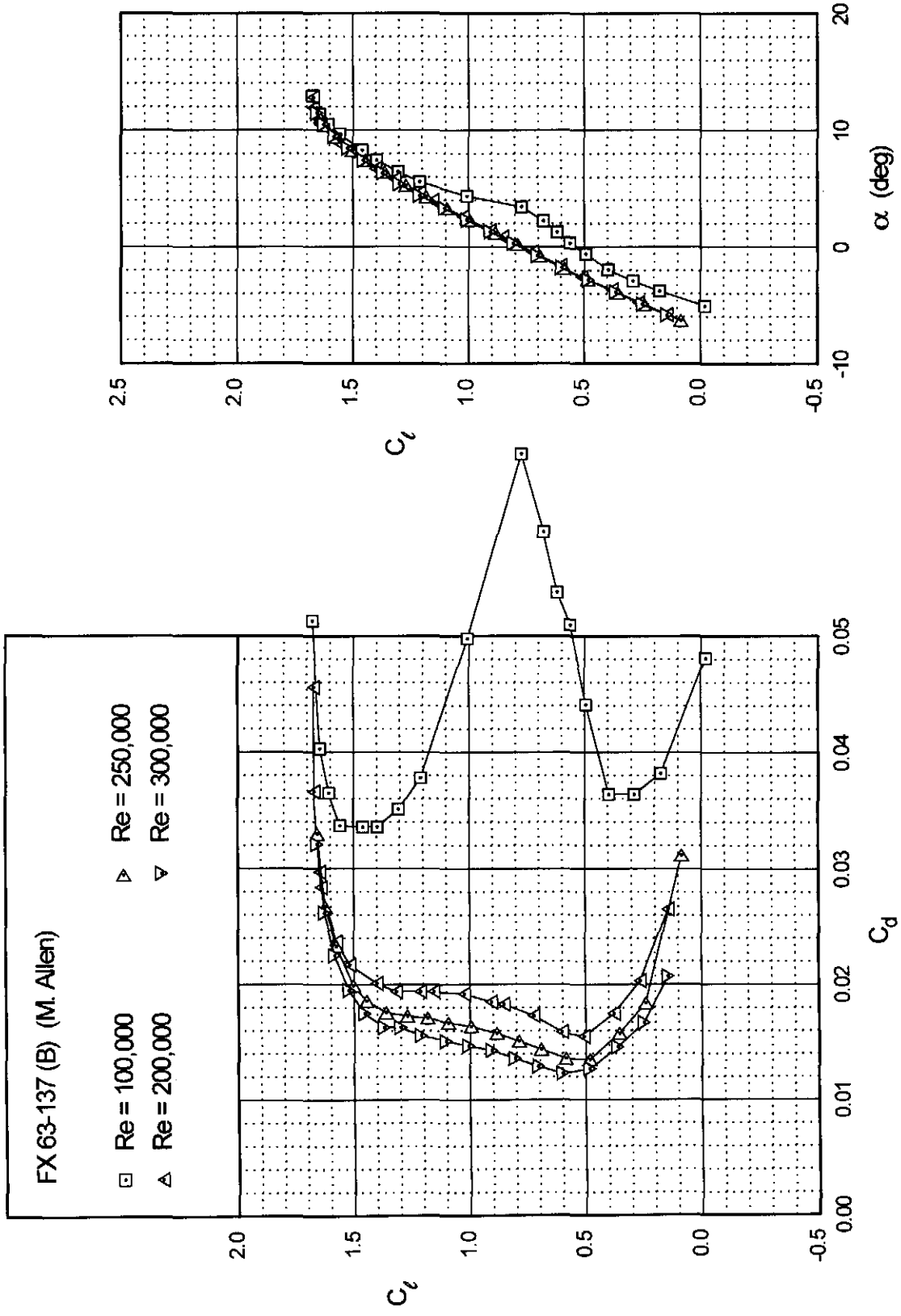

E387 (A) (B. Champine)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


E387 (A) (B. Champine)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

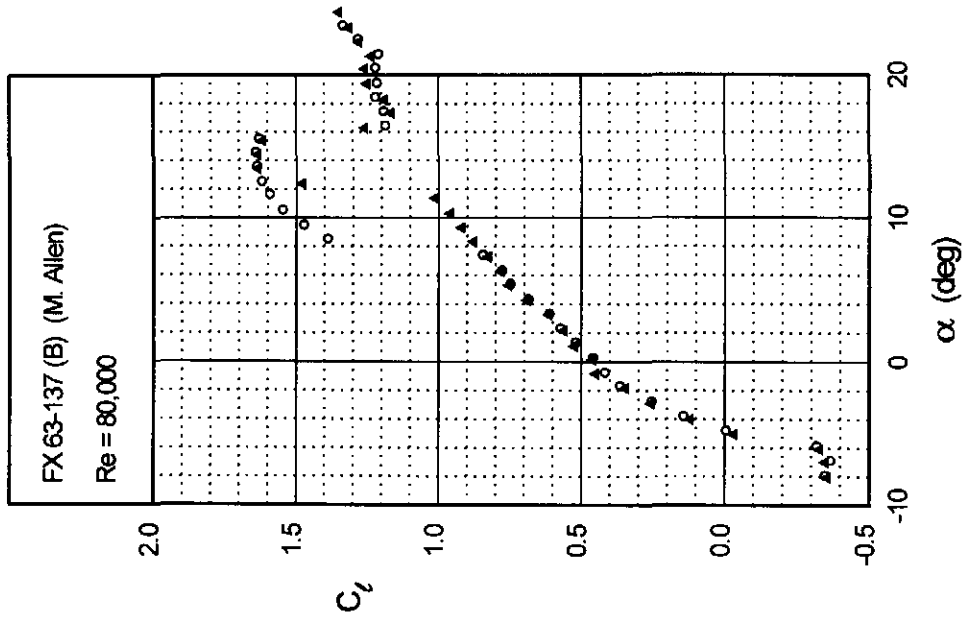
FX 63-137 (B)

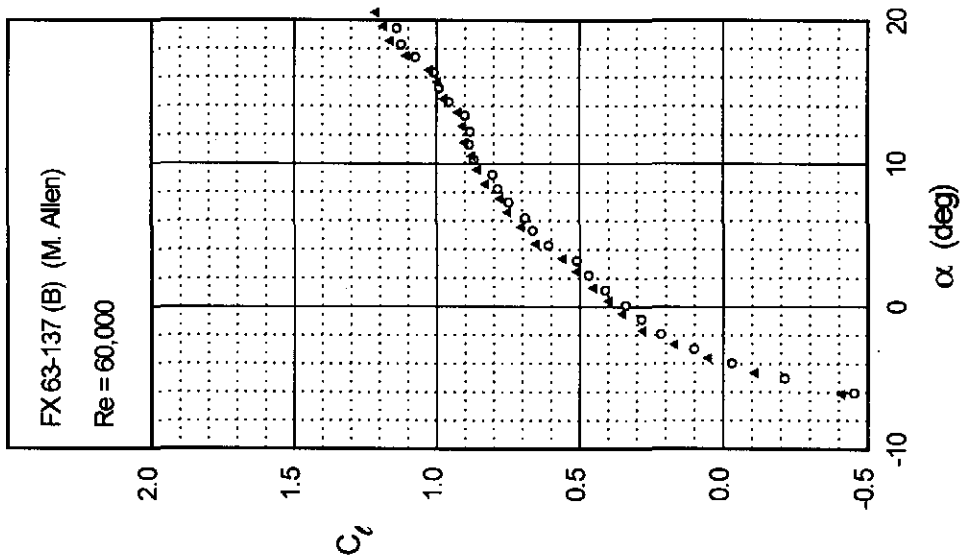

FX 63-137 (B)
Avg. Difference = 0.0093 in
0.03
0.00
-0.03
Difference (in)

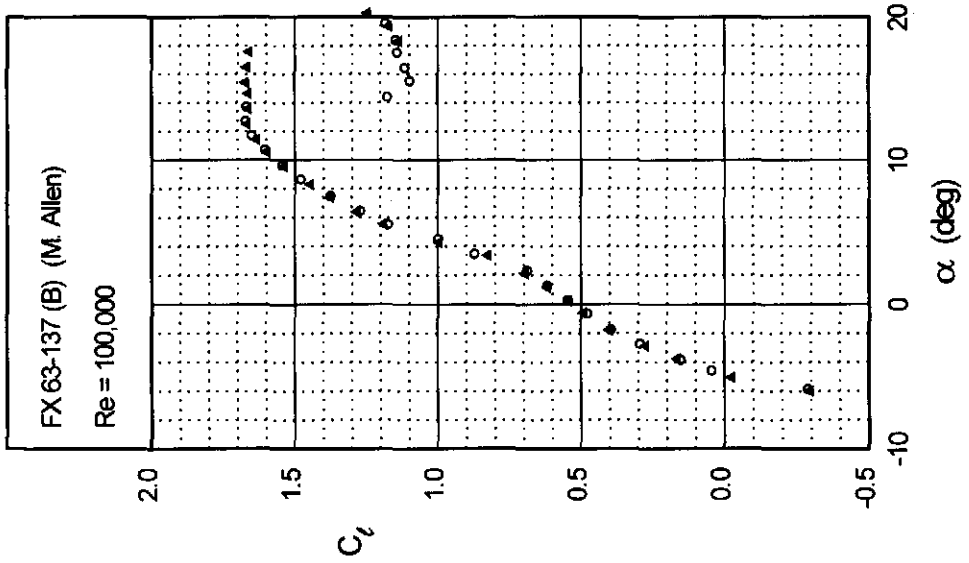

α relative to the zero-lift line
FX63-137 13.65%
2
1.5
1
0.5
V
0
0.5
1
x/c


FX 63-137 (B)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)
FX 63-137 (B) (M. Allen)
Re = 100,000
Re = 200,000
Re = 250,000
Re = 300,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
0.05
0.04
0.03
0.02
0.01
0.00
$C_d$

FX 63-137 (B)


FX 63-137 (B) (M. Allen)
Re = 80,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


FX 63-137 (B) (M. Allen)
Re = 60,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


FX 63-137 (B) (M. Allen)
Re = 100,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

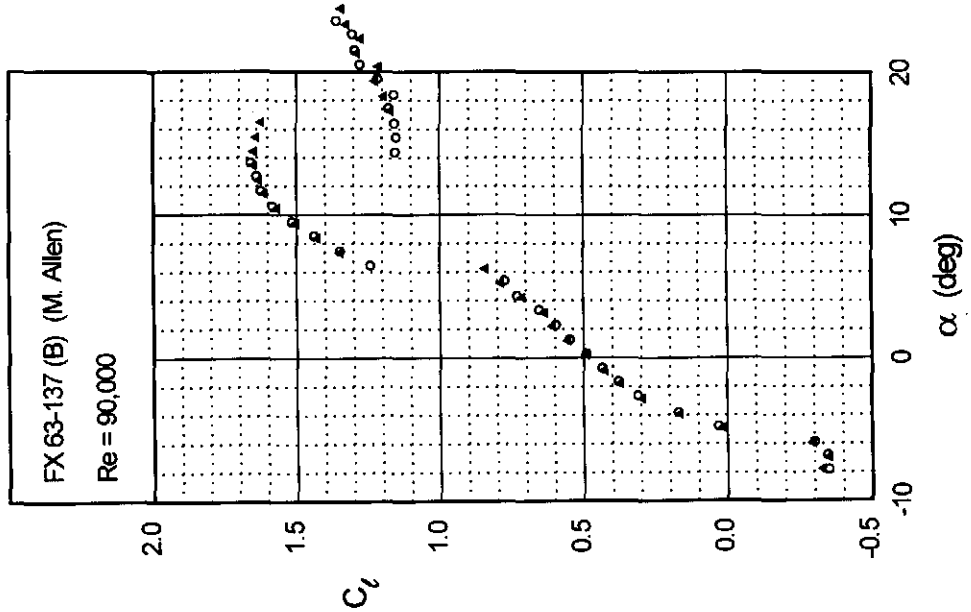
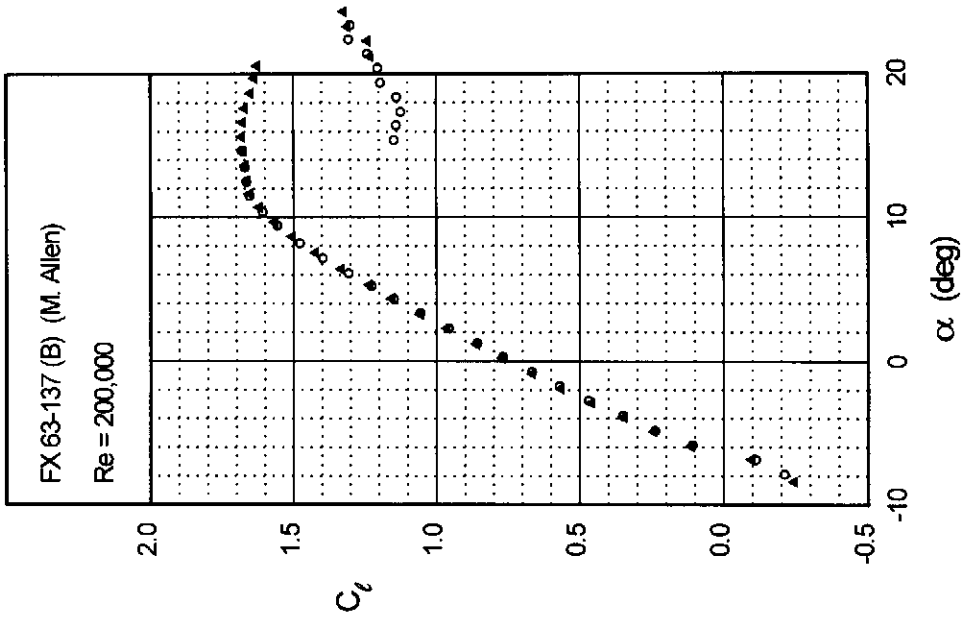
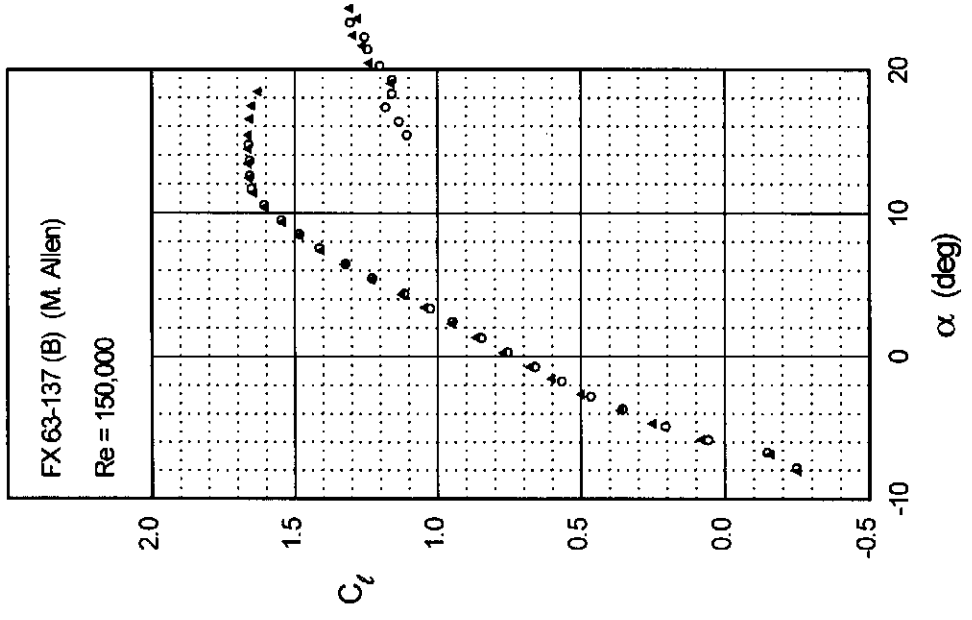
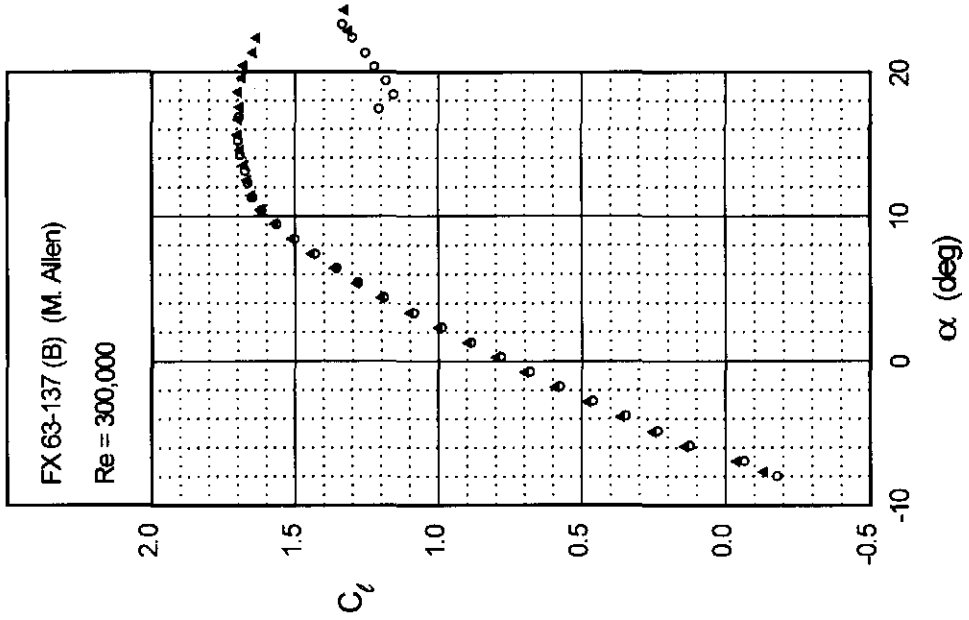

FX 63-137 (B) (M. Allen)
Re = 90,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

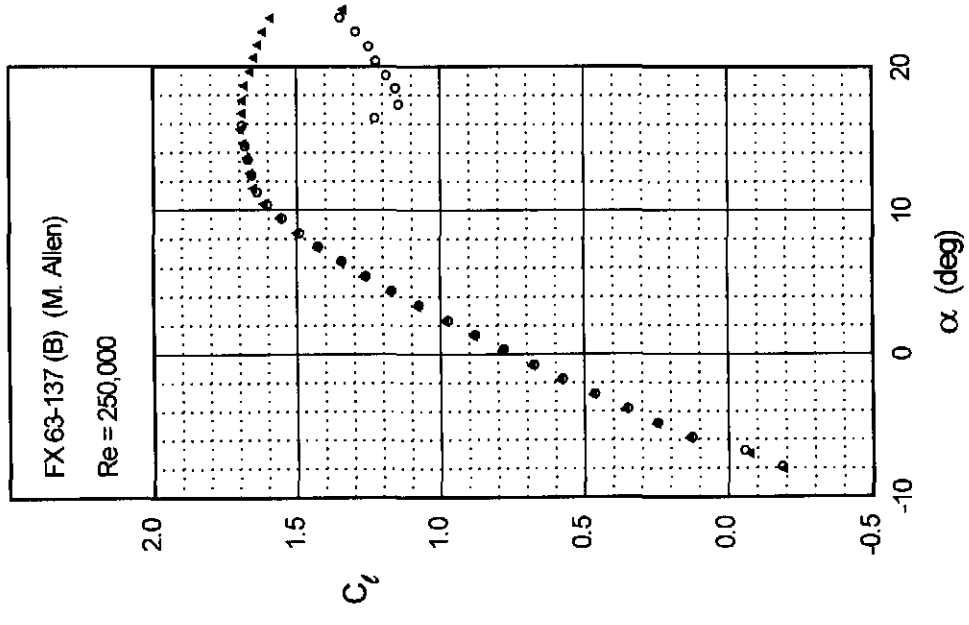
 Fig. 4.24 (continued)

FX 63-137 (B)

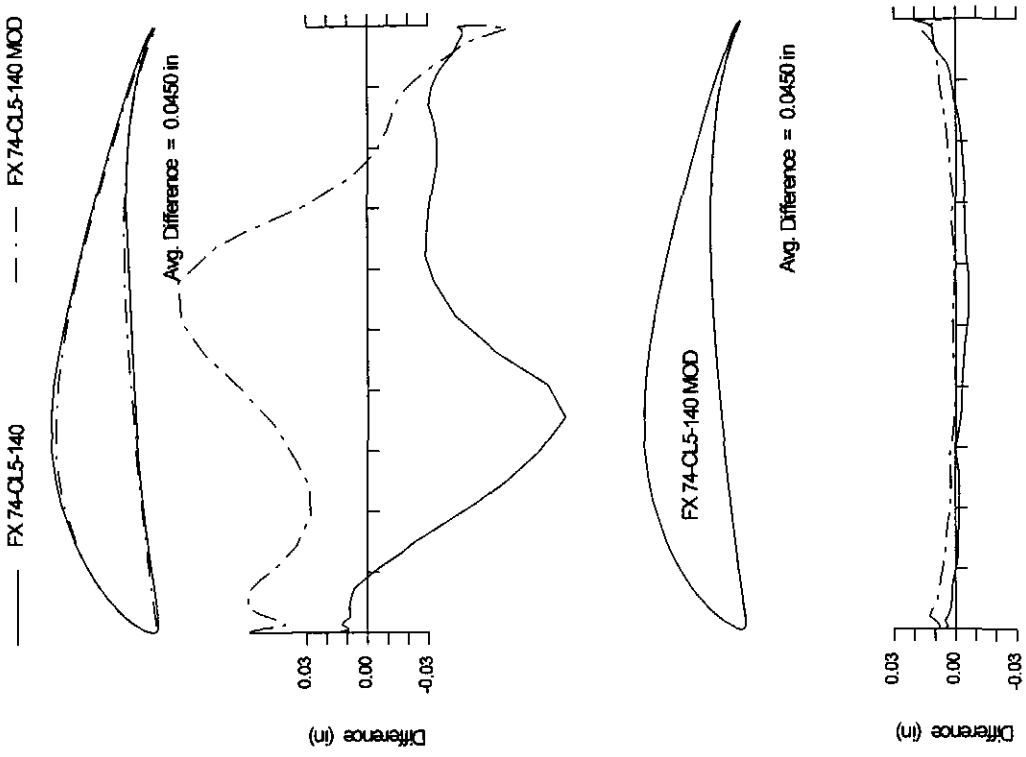


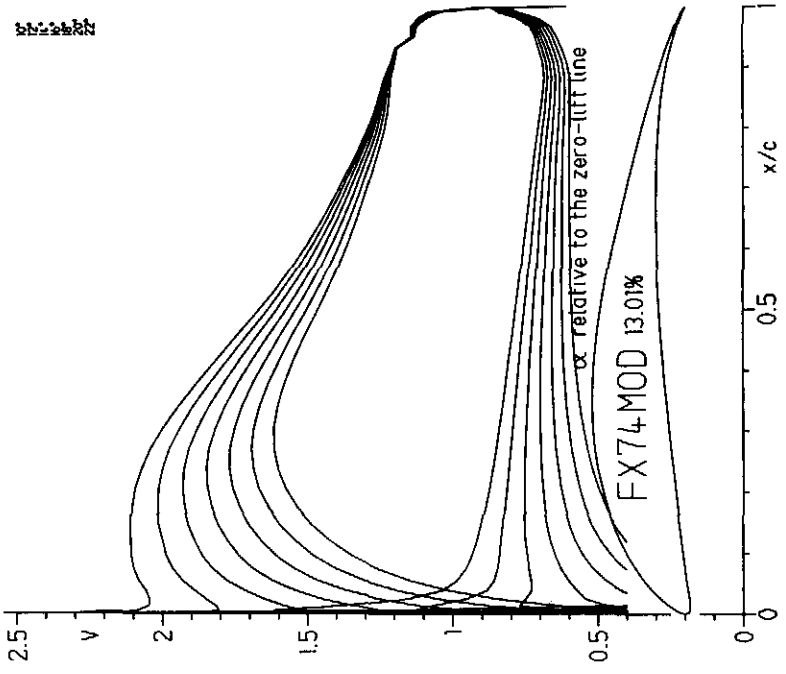




FX 63-137 (B) (M. Allen)
Re = 300,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

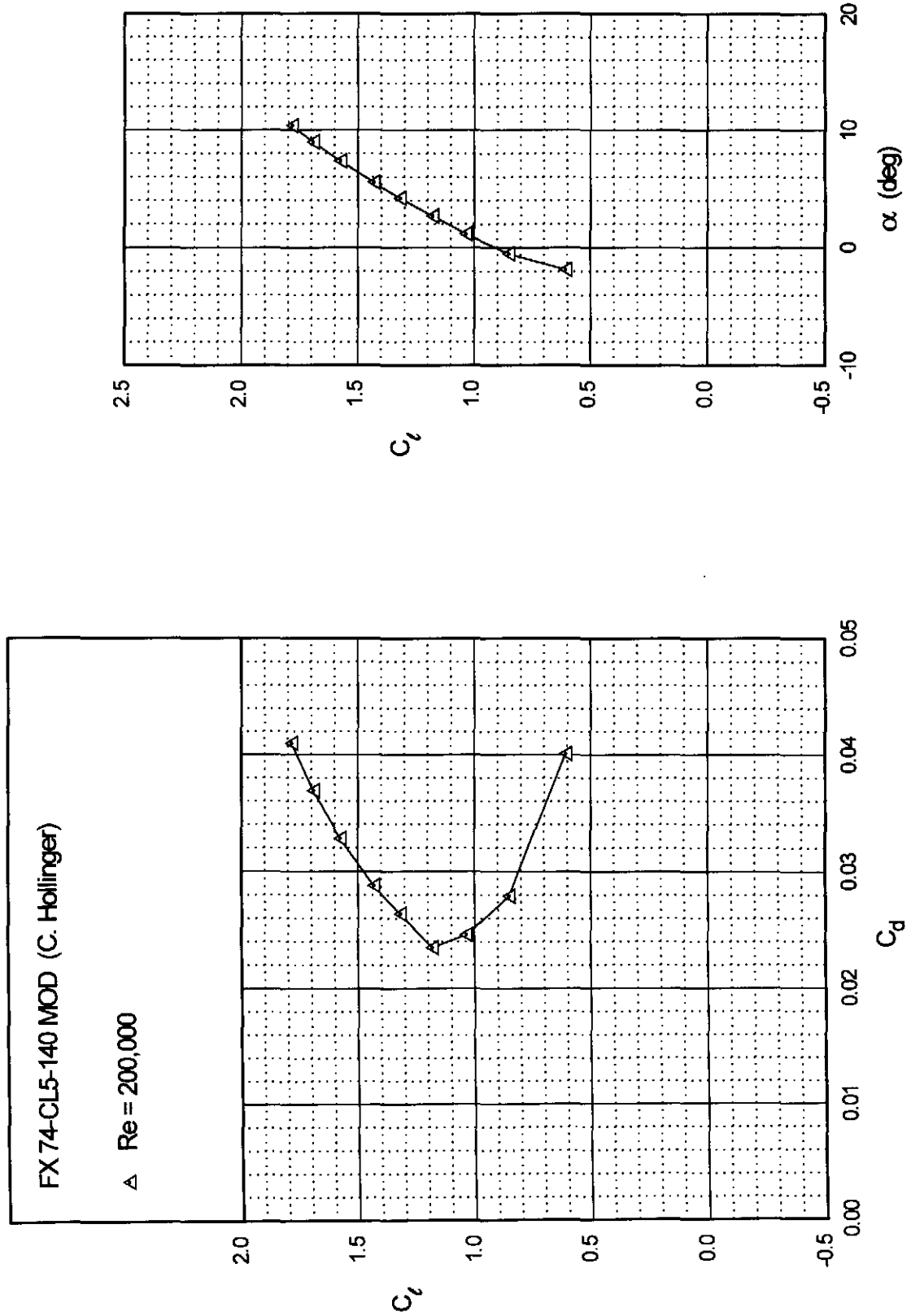

FX 63-137 (B) (M. Allen)
Re = 250,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

FX 74-CL5-140 MOD

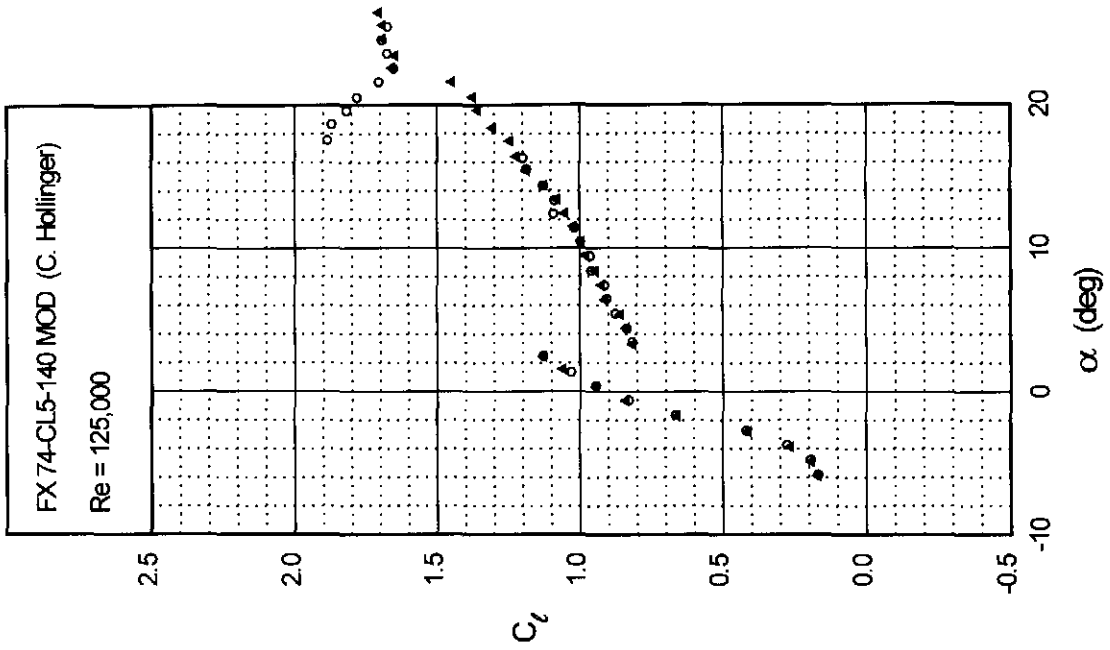


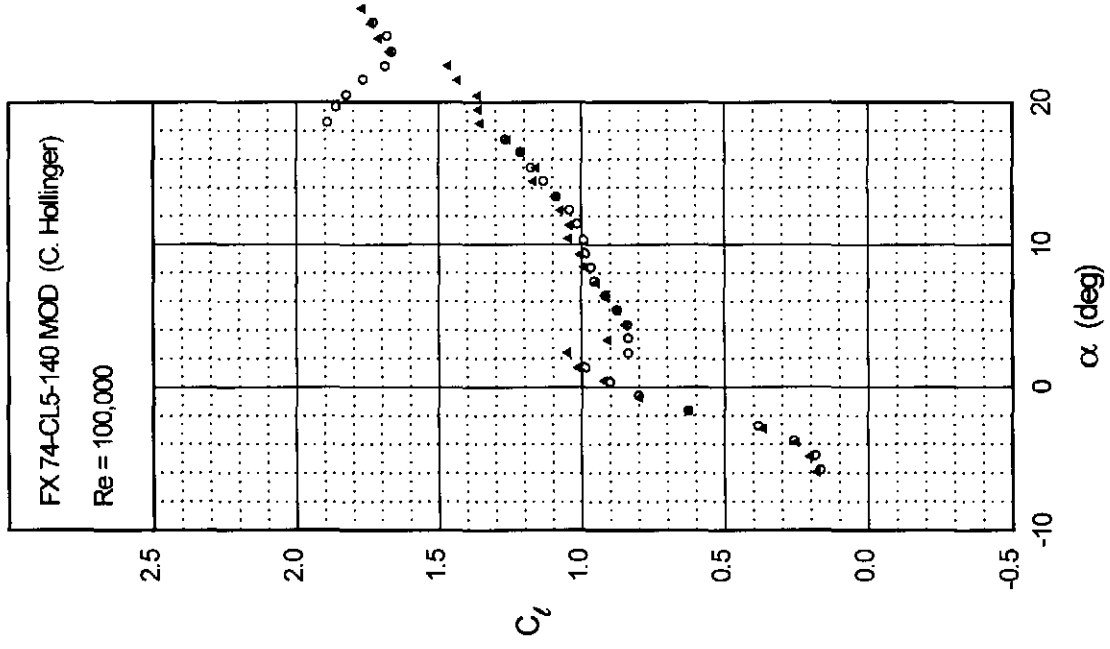



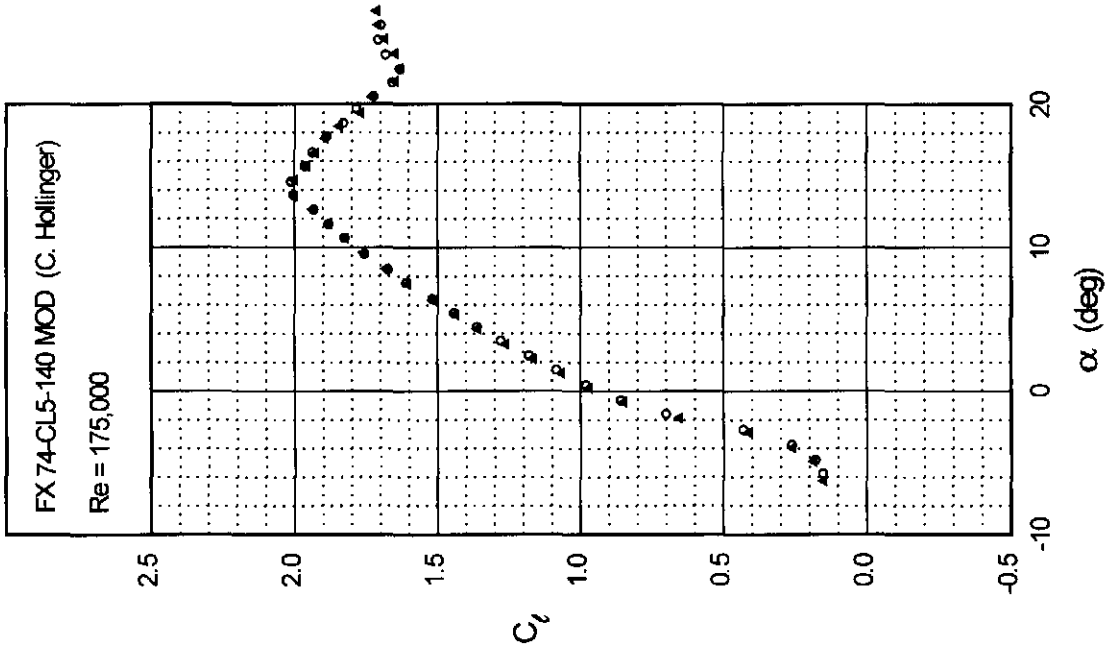
FX 74-CL5-140 MOD



FX 74-CL5-140 MOD




FX 74-CL5-140 MOD (C. Hollinger)
Re = 175,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)

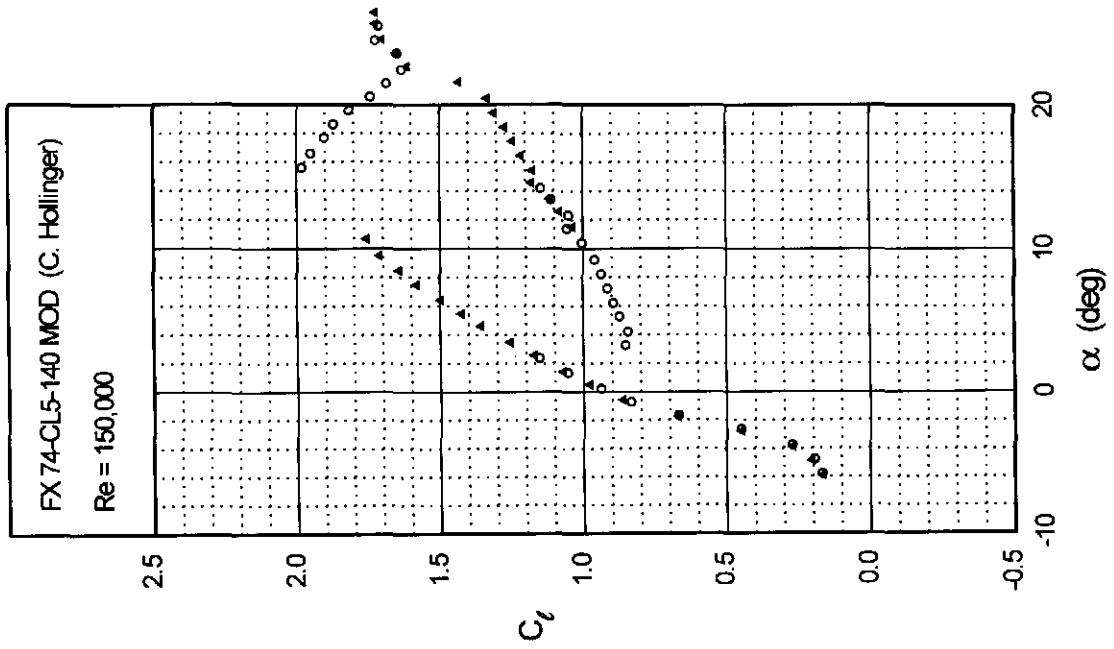
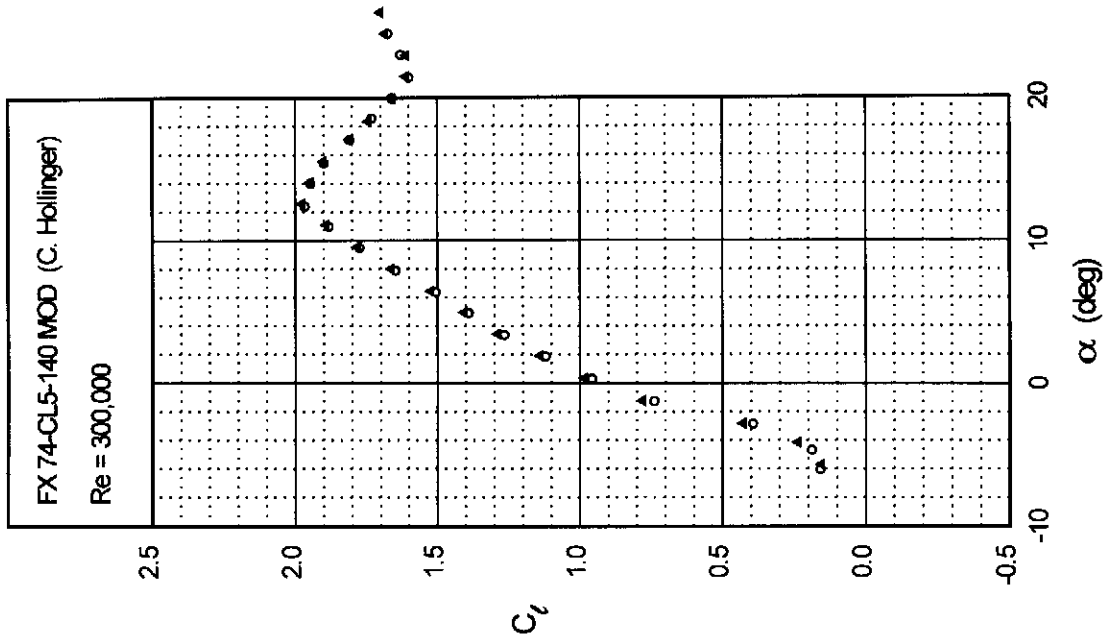
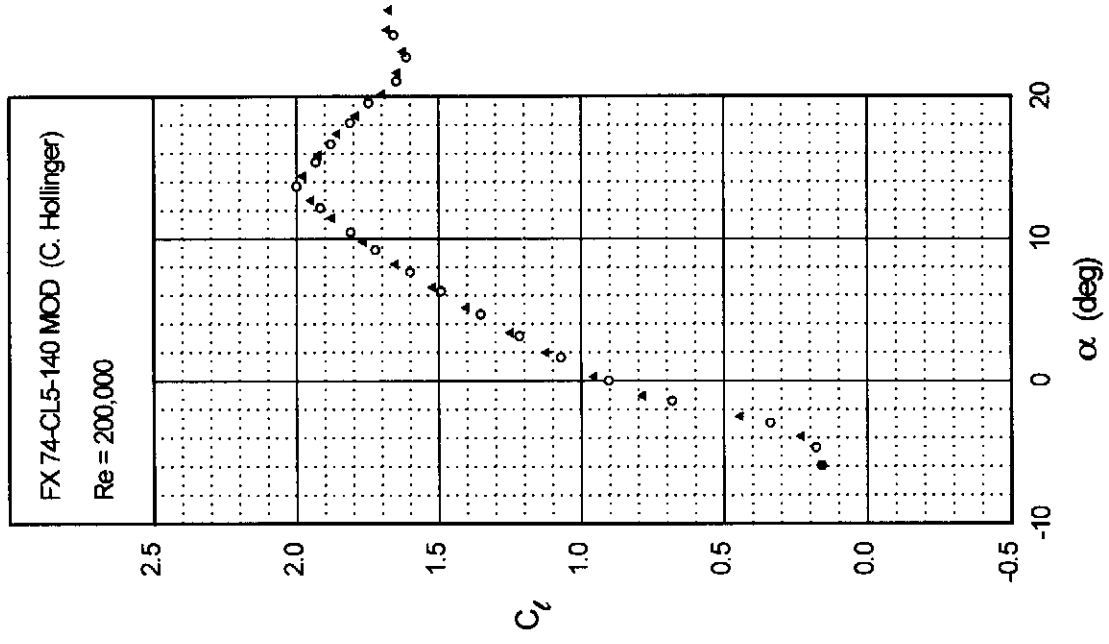

FX 74-CL5-140 MOD (C. Hollinger)
Re = 150,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)

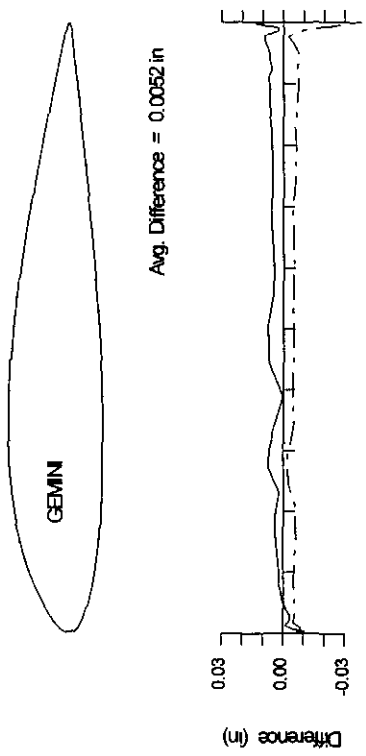
Fig. 4.28 (continued)

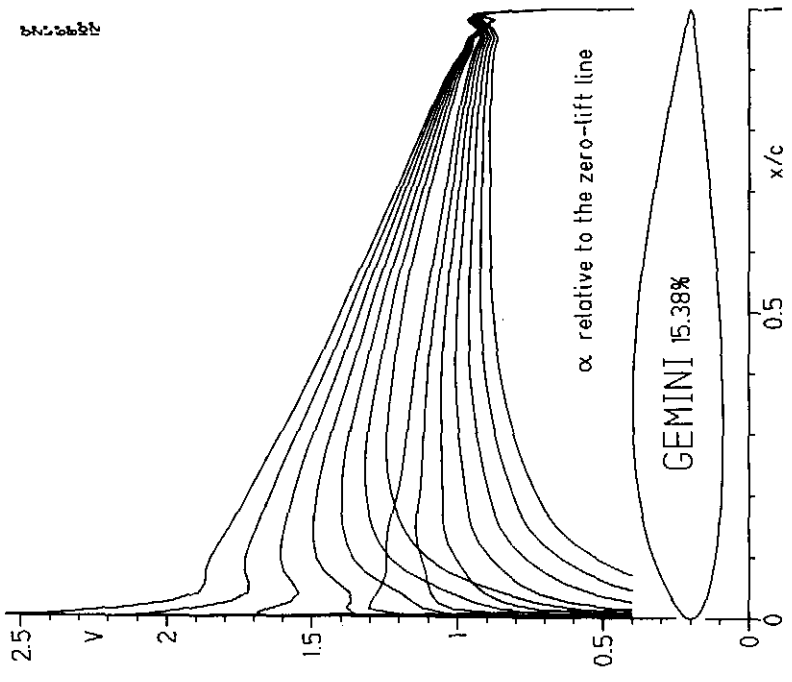
FX 74-CL5-140 MOD



GEMINI


GEMIN
Avg. Difference = 0.0052 in
0.03
0.00
-0.03
Difference (in)


α relative to the zero-lift line
GEMINI 15.38%
2.5
2
1.5
1
0.5
V
0
0.5
x/c

GEMINI

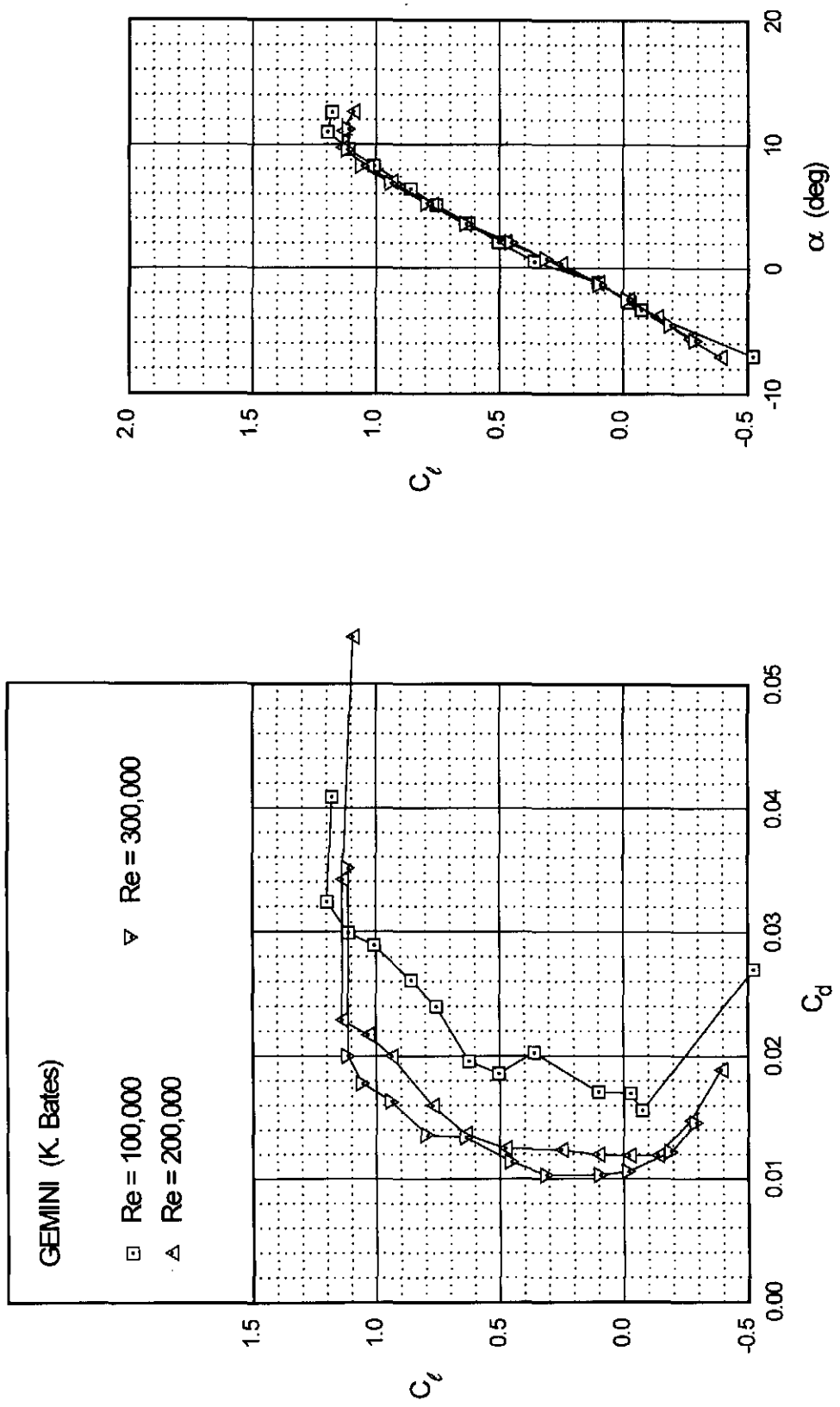
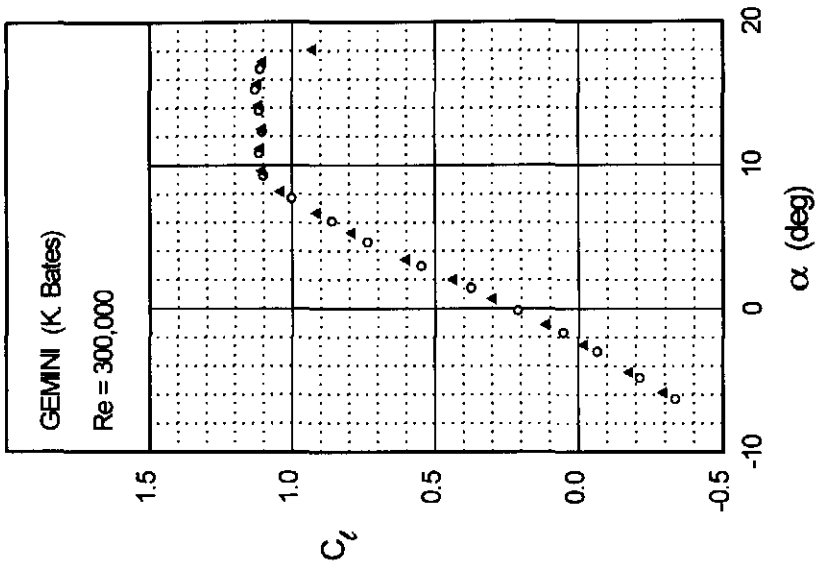
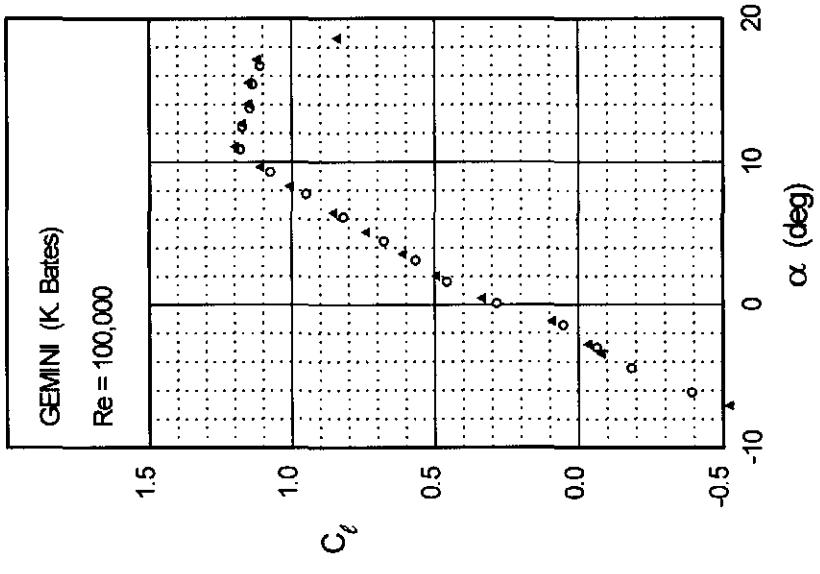

GEMINI (K. Bates)
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
20
10
0
-10
0.05
0.04
0.03
0.02
0.01
0.00

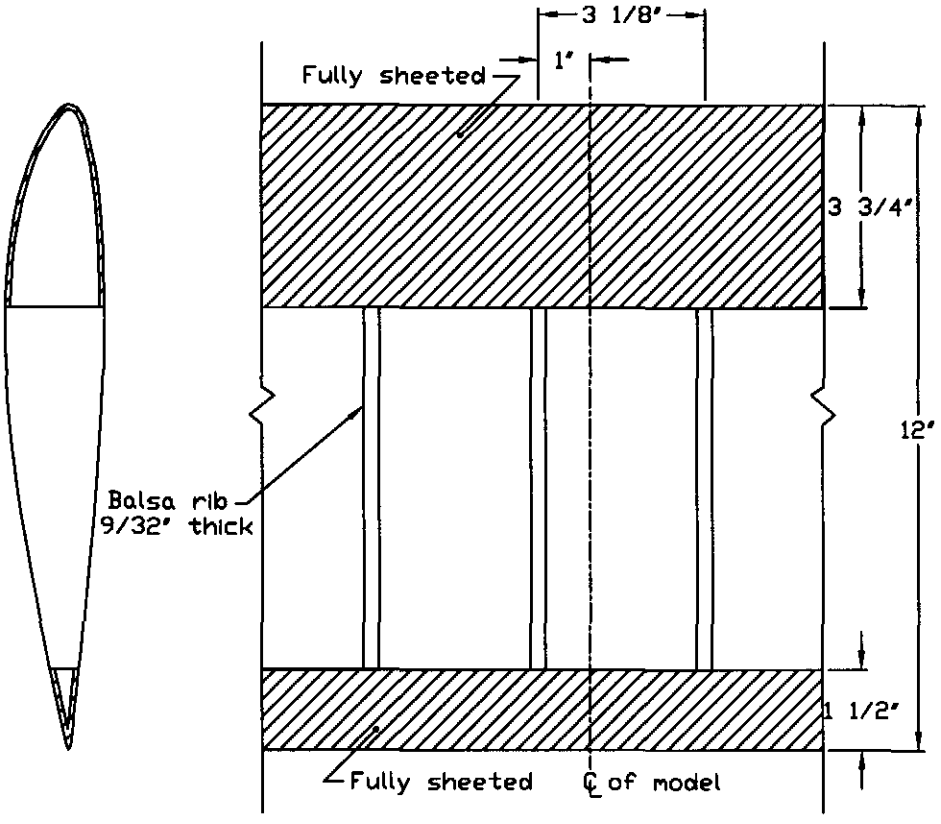
Fig. 4.32

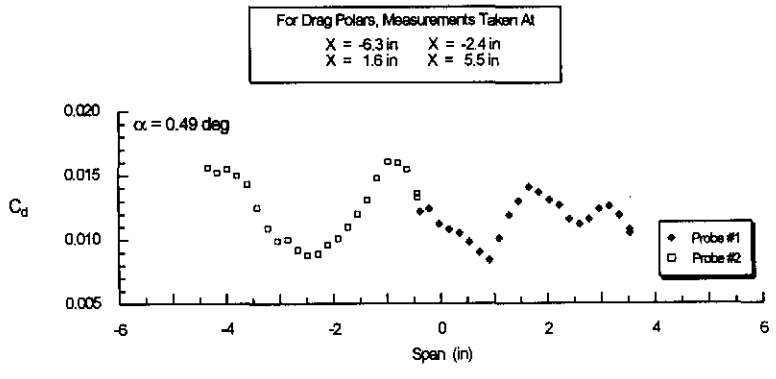
GEMINI



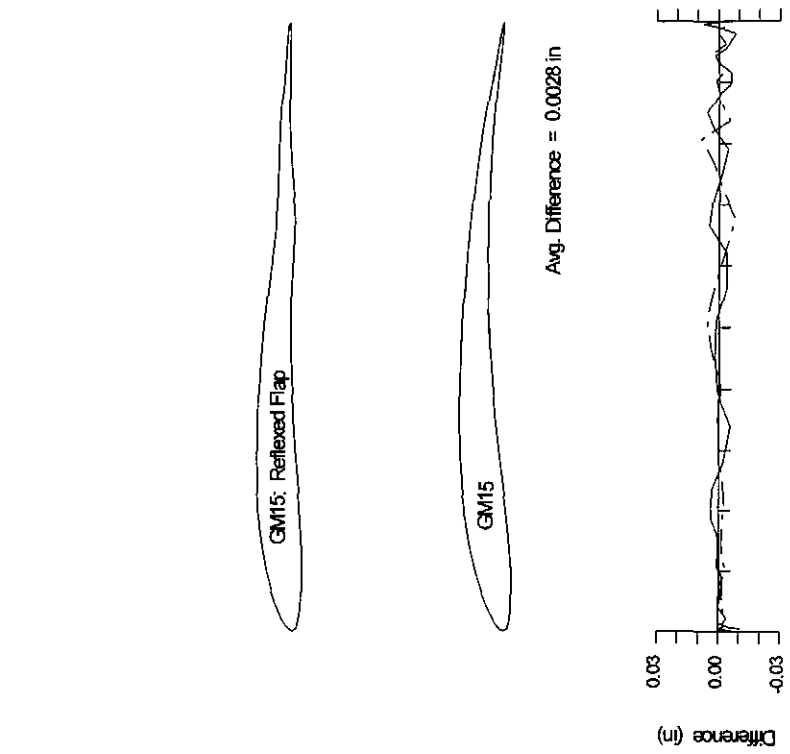



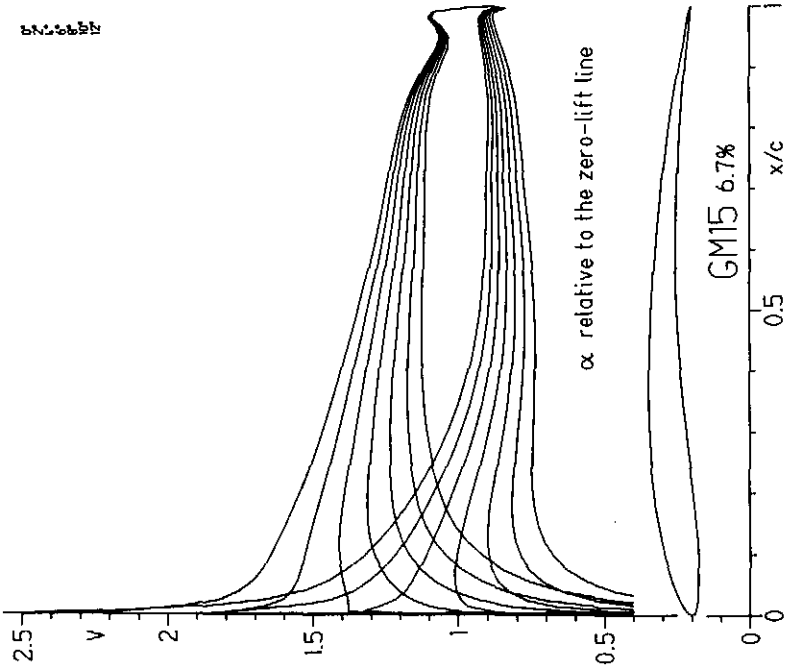
GEMINI


3 1/8"
1"
Fully sheeted
3 3/4"
12"
Balsa rib
9/32" thick
1 1/2"
Fully sheeted
℄ of model

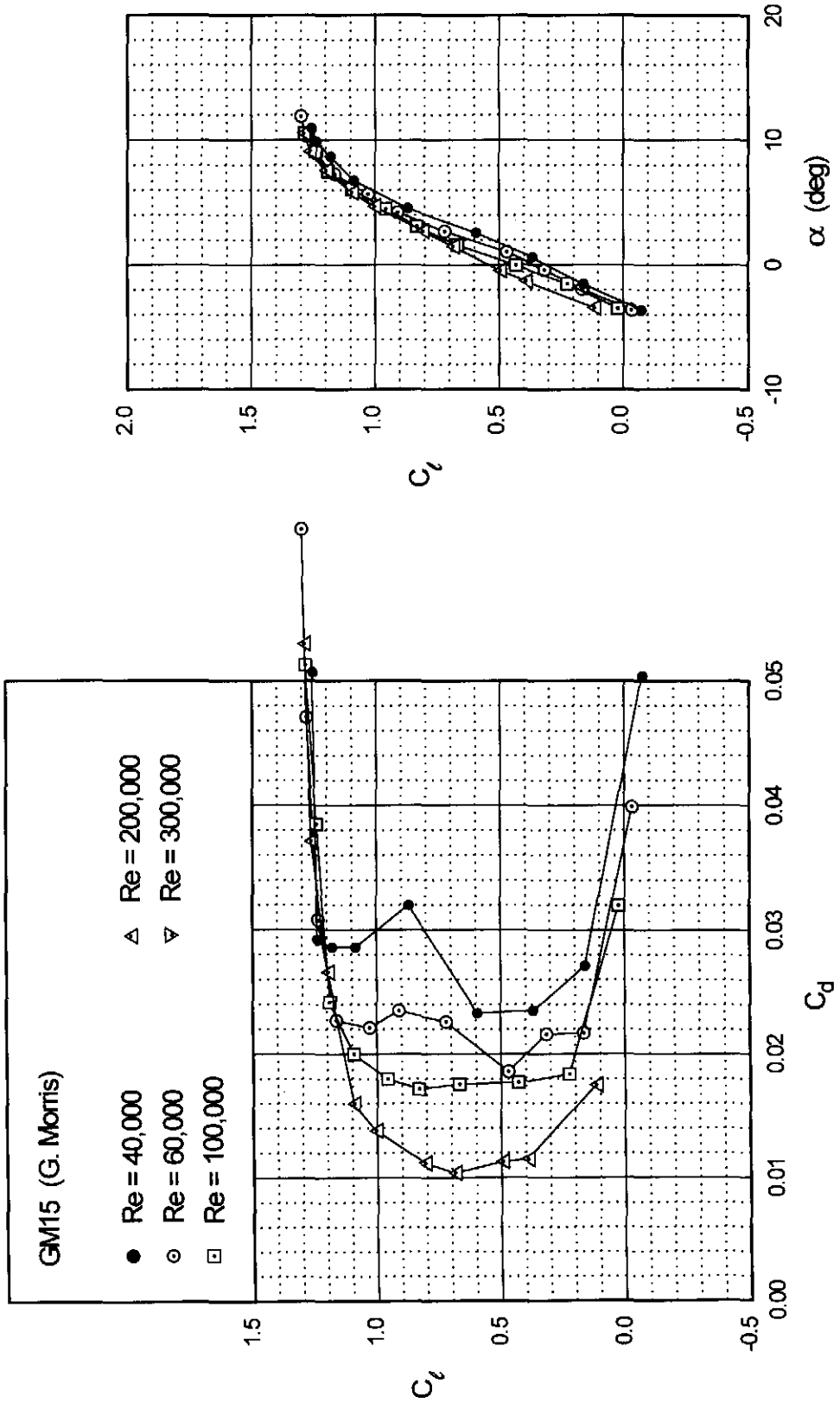

For Drag Polars, Measurements Taken At
X = -6.3 in X = -2.4 in
X = 1.6 in X = 5.5 in
α = 0.49 deg
$C_d$
0.020
0.015
0.010
0.005
-6
-4
-2
0
2
4
6
Span (in)
Probe #1
Probe #2

GM15

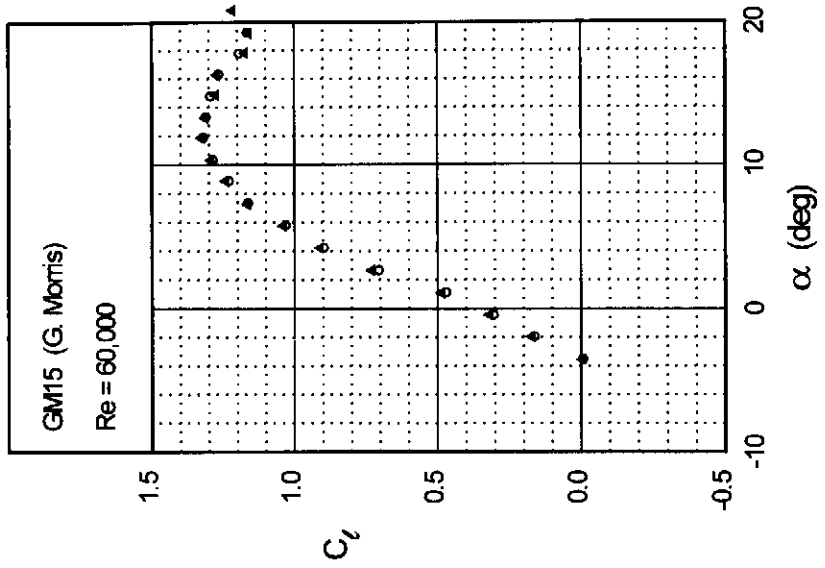

GM15: Reflexed Flap
GM15
Avg. Difference = 0.0028 in
0.03
0.00
-0.03
Difference (in)

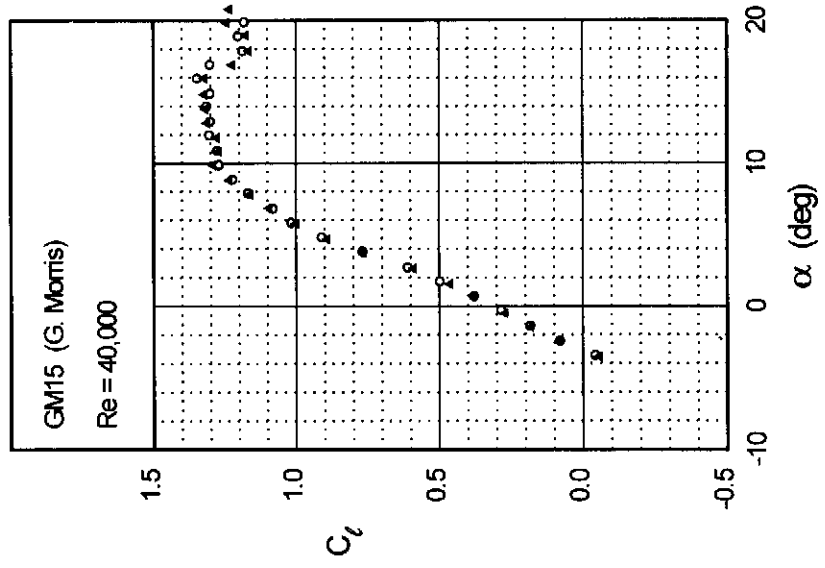

α relative to the zero-lift line
GM15 6.7%
x/c
0
0.5
1
0
0.5
1
1.5
2
2.5
v

GM15

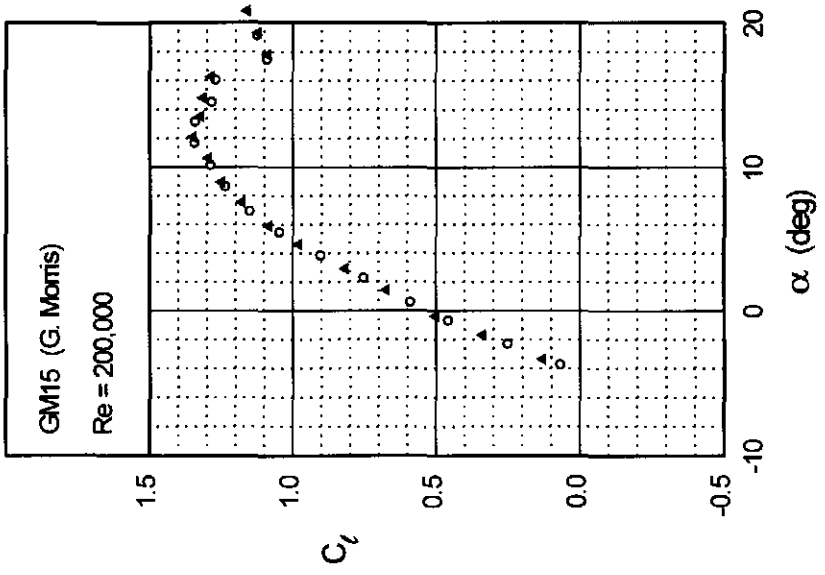

GM15 (G. Morris)
Re = 40,000
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
-10
0
10
20
0.00
0.01
0.02
0.03
0.04
0.05

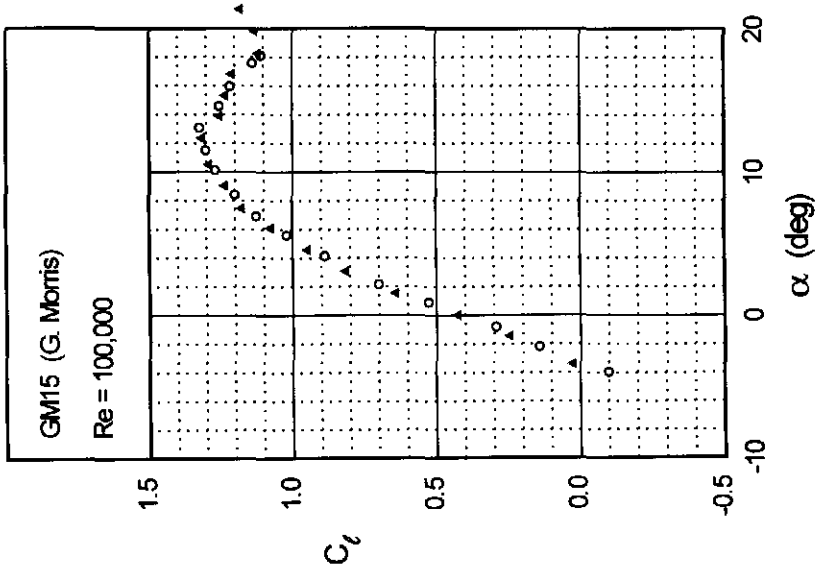
GM15


GM15 (G. Morris)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

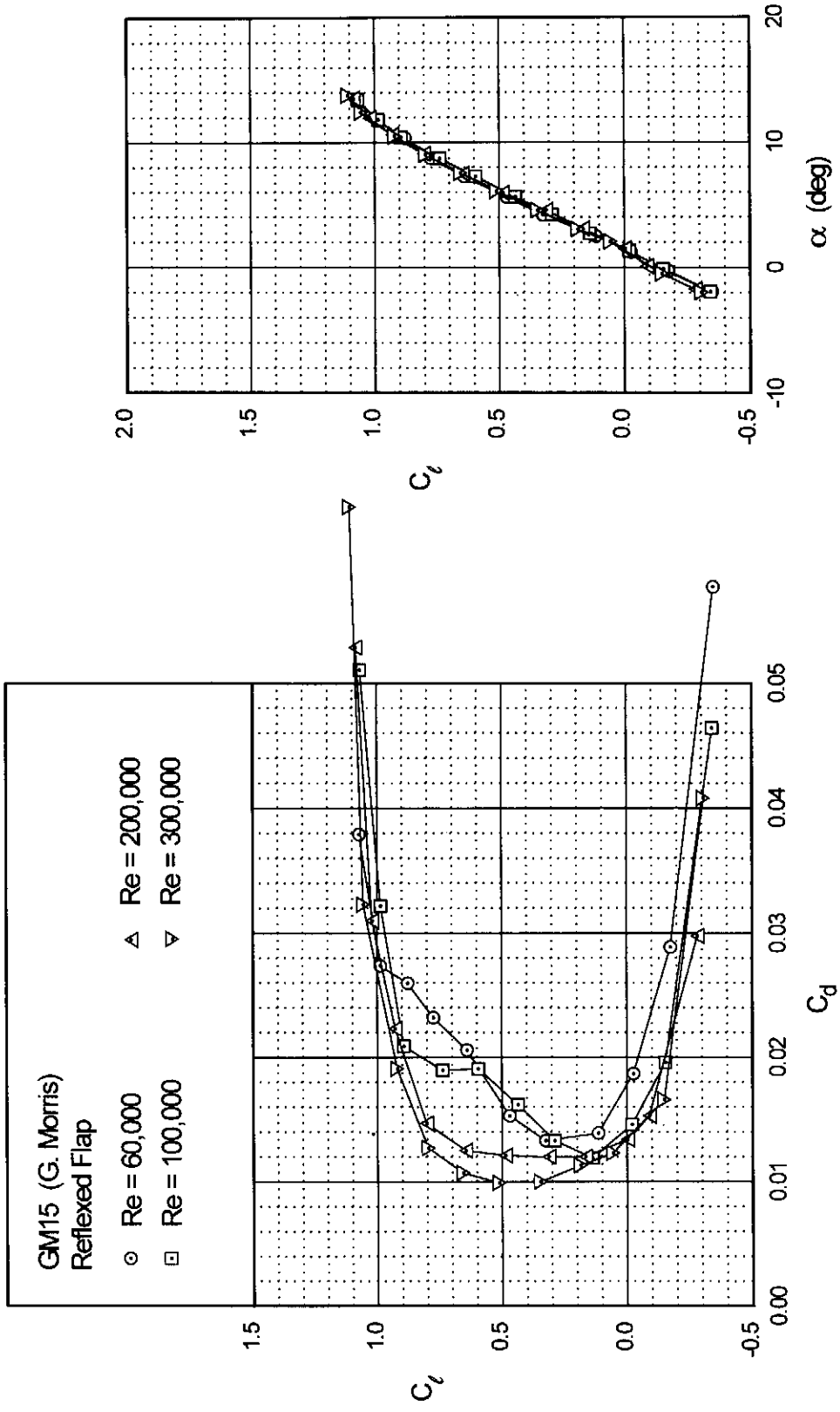

GM15 (G. Morris)
Re = 40,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

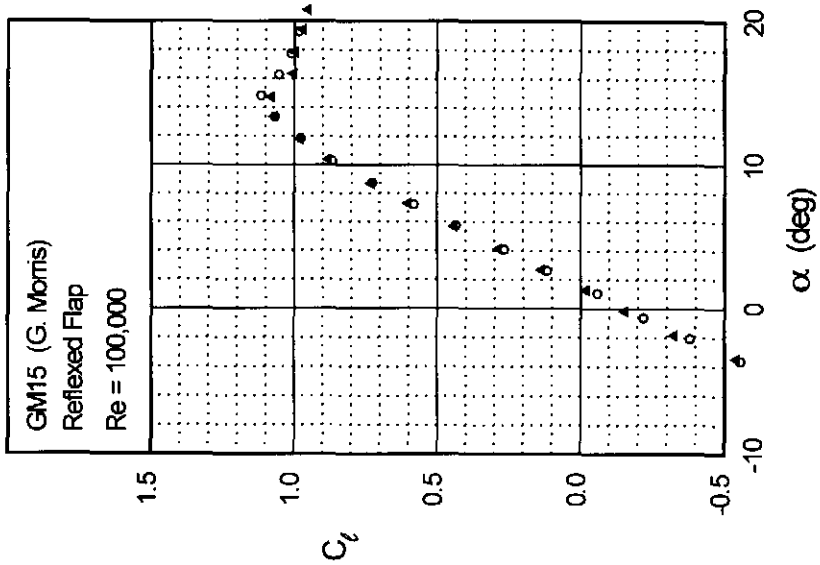
GM15

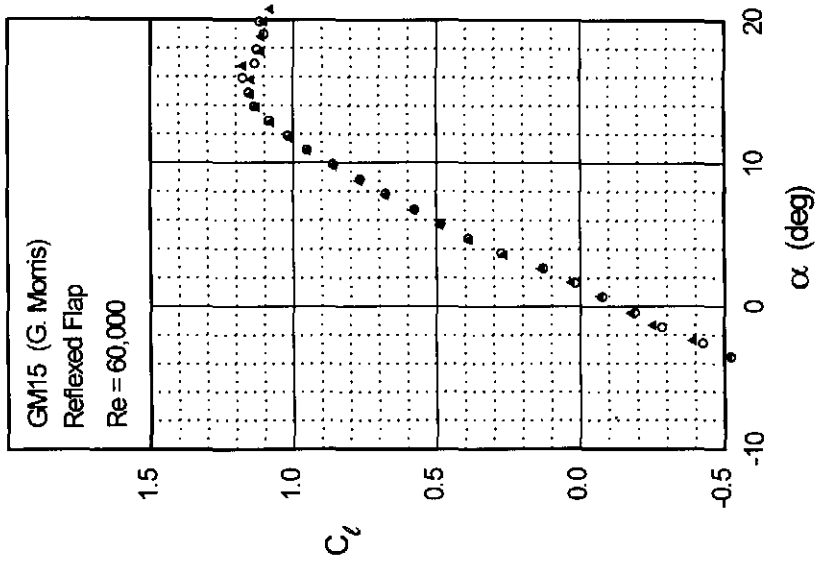

GM15 (G. Morris)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


GM15 (G. Morris)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

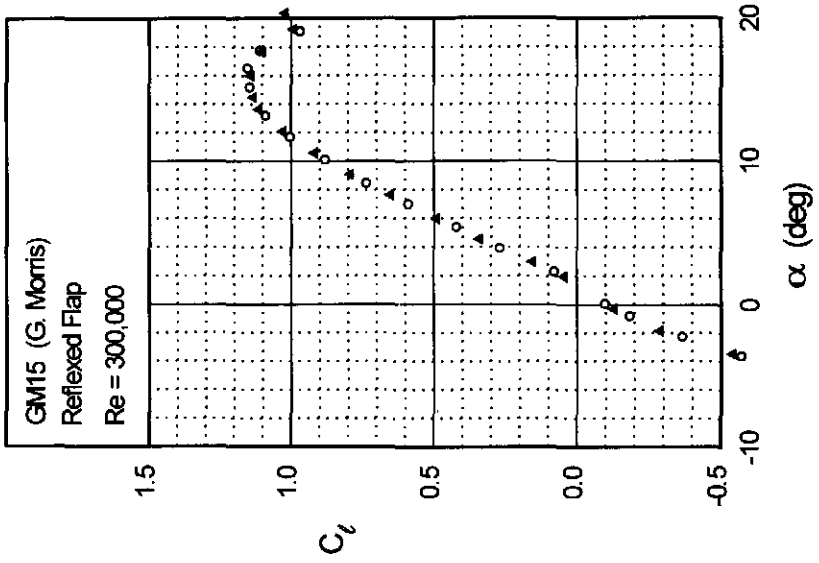
GM15

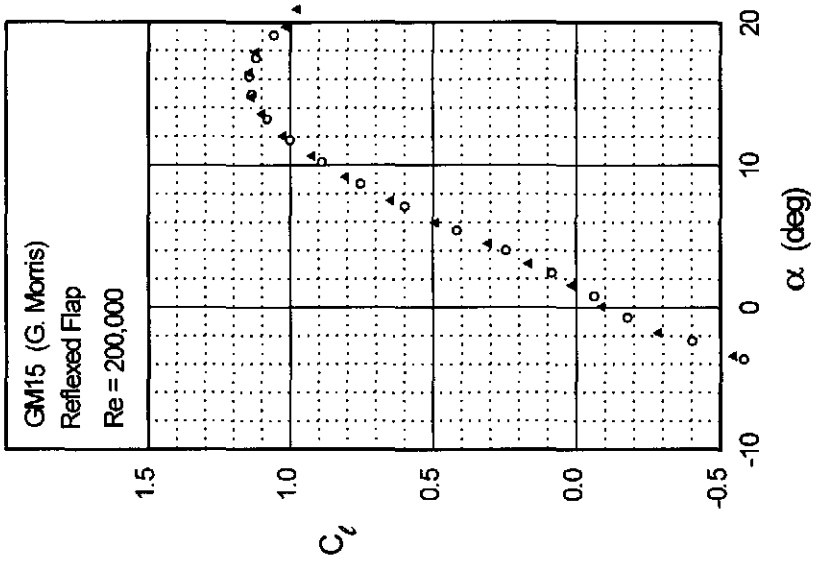

GM15 (G. Morris)
Reflexed Flap
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)


GM15 (G. Morris)
Reflexed Flap
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

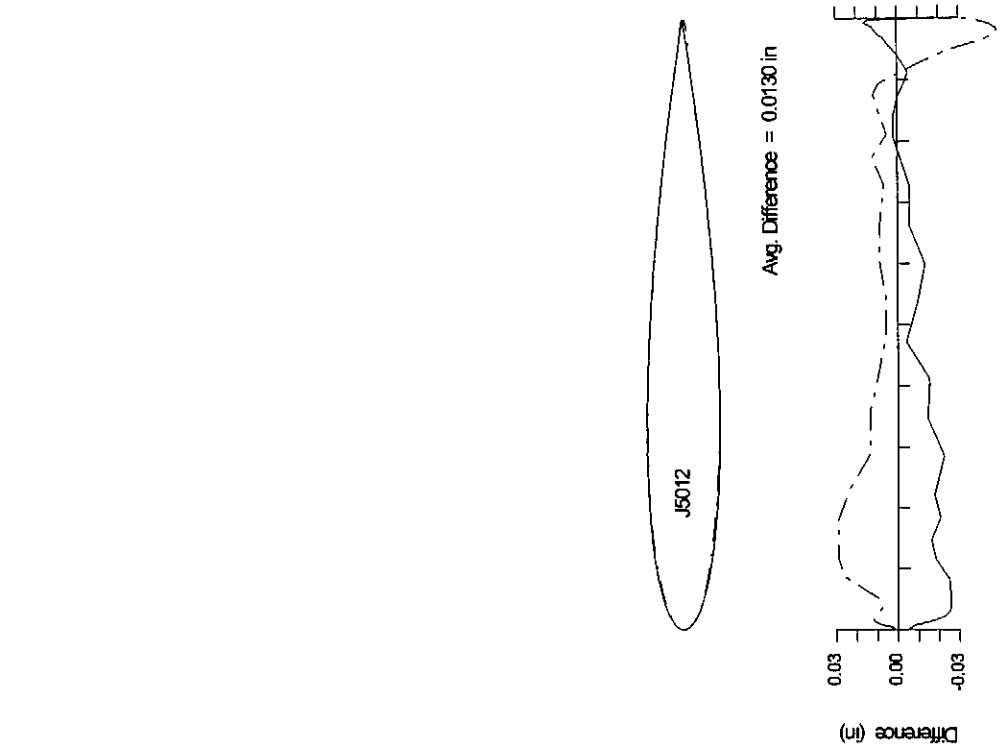

GM15 (G. Morris)
Reflexed Flap
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

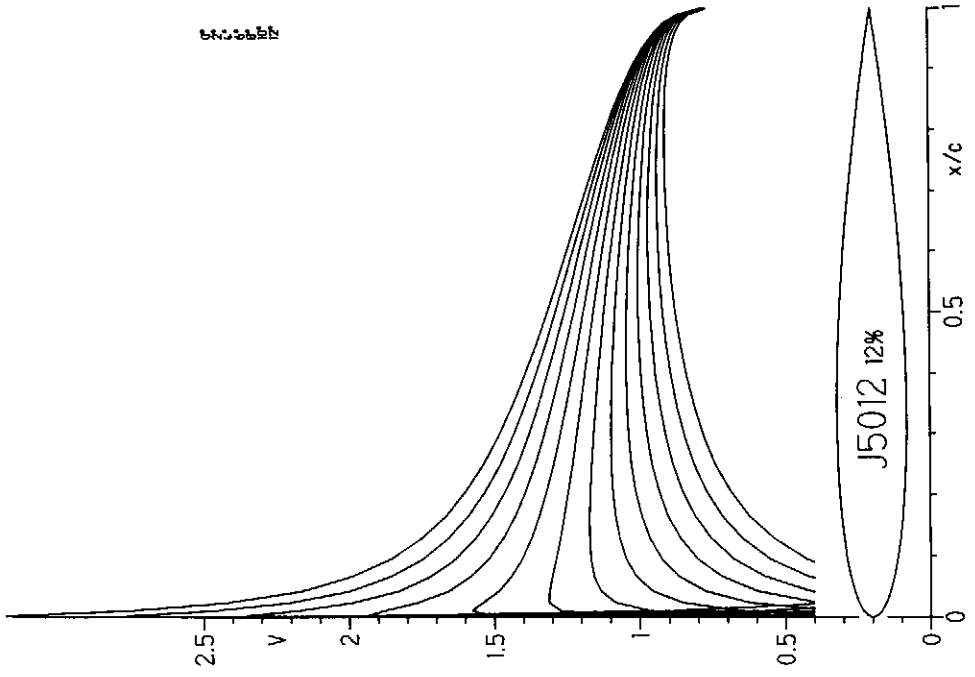
GM15


GM15 (G. Morris)
Reflexed Flap
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

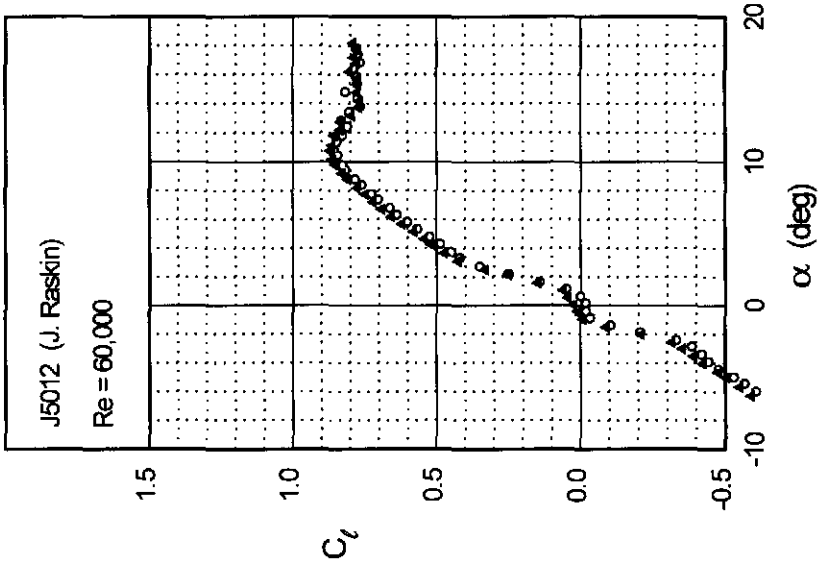

GM15 (G. Morris)
Reflexed Flap
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

J5012


J5012
Avg. Difference = 0.0130 in
0.03
0.00
-0.03
Difference (in)


2.5
V
2
1.5
1
0.5
J5012 12%
0
0.5
1
x/c

J5012


J5012 (J. Raskin)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

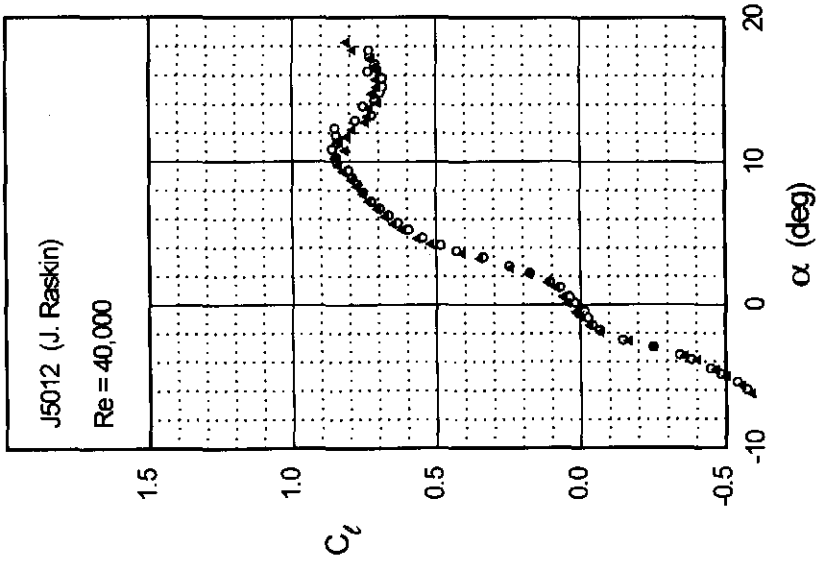
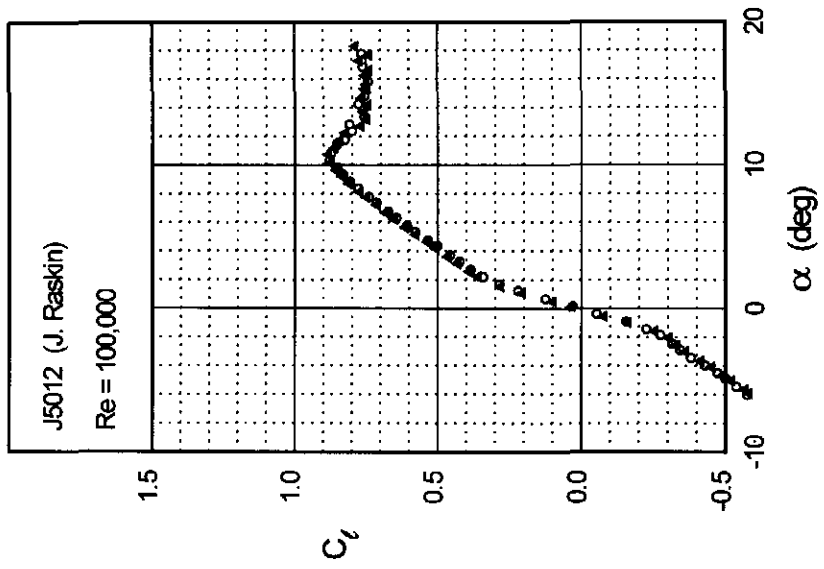
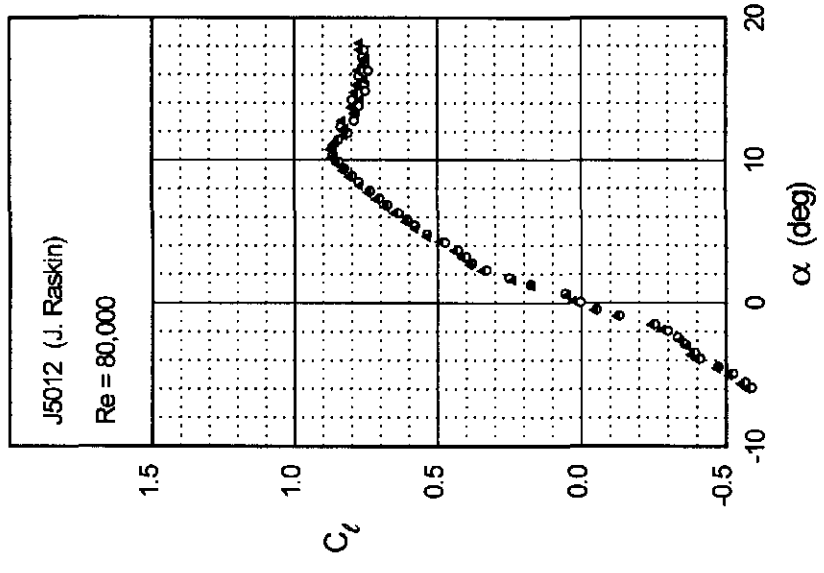

J5012 (J. Raskin)
Re = 40,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

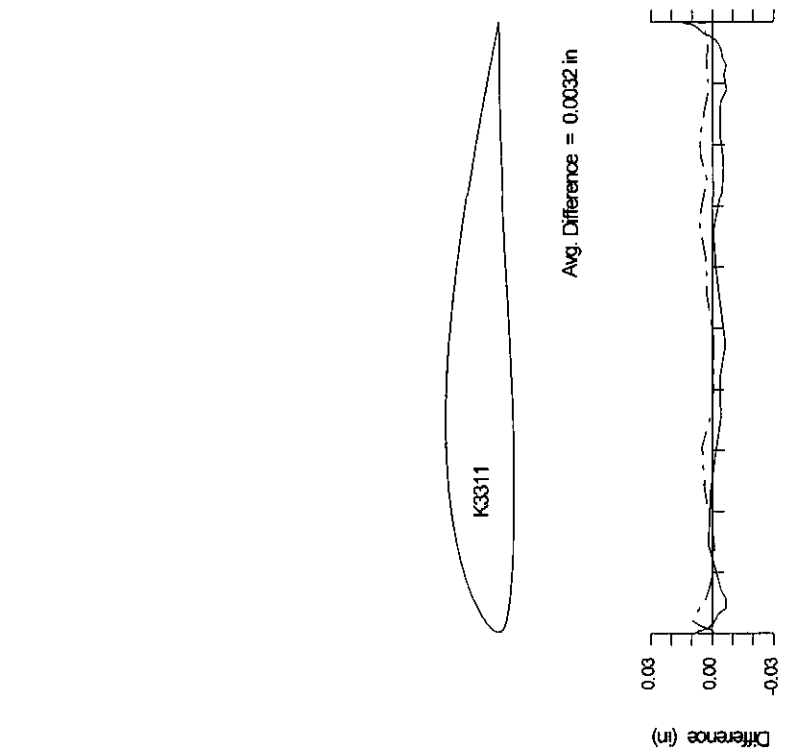
Fig. 4.42 (continued)

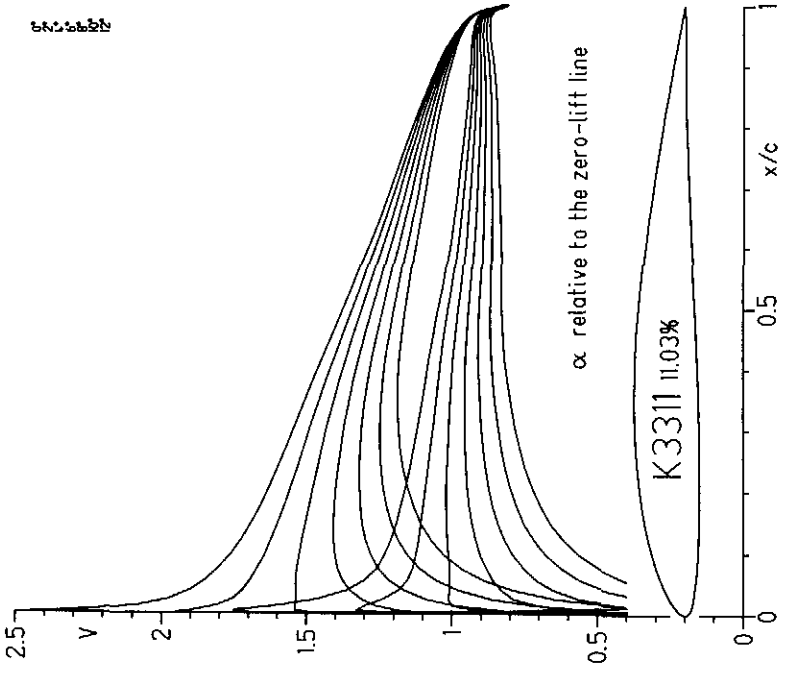
J5012



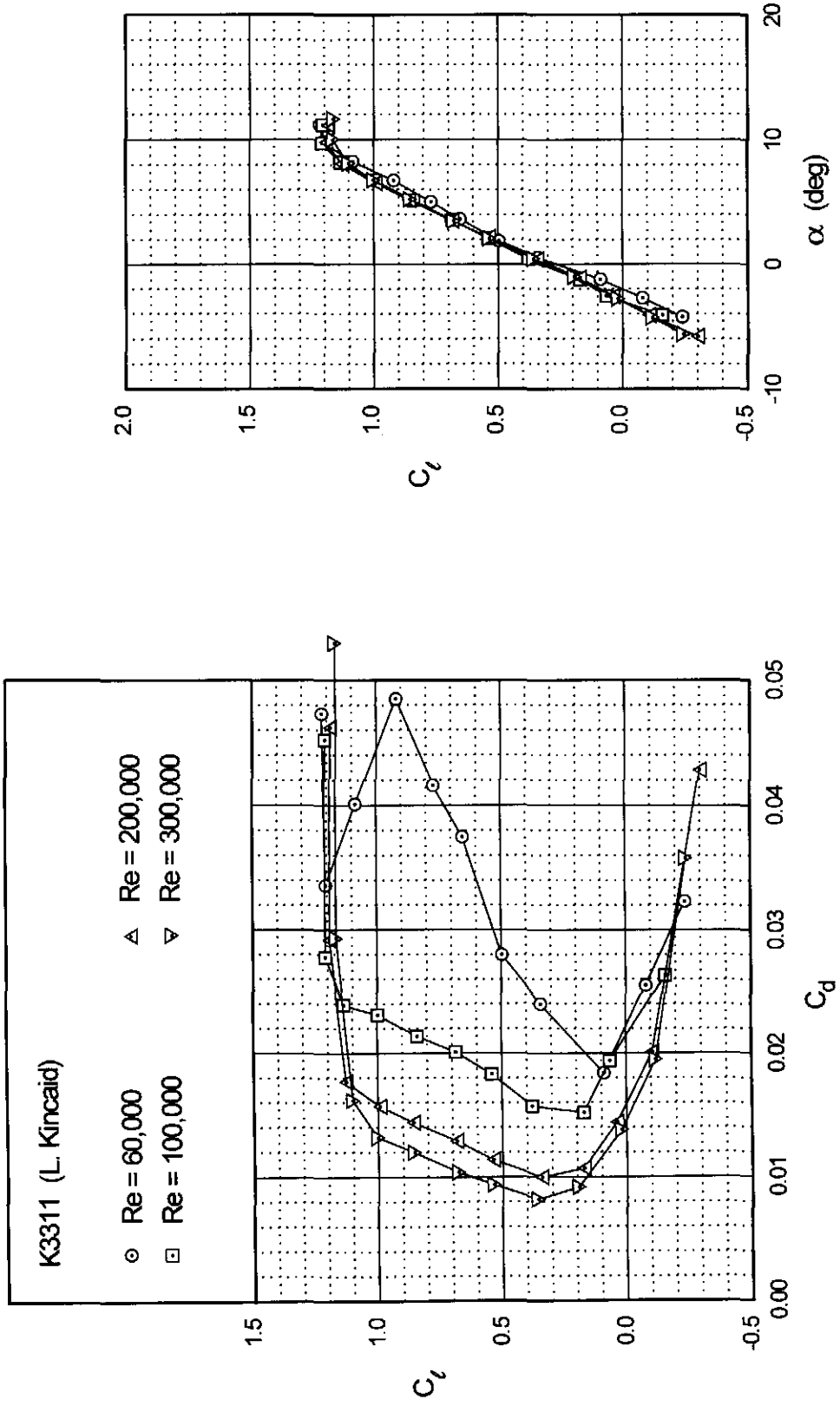



K3311

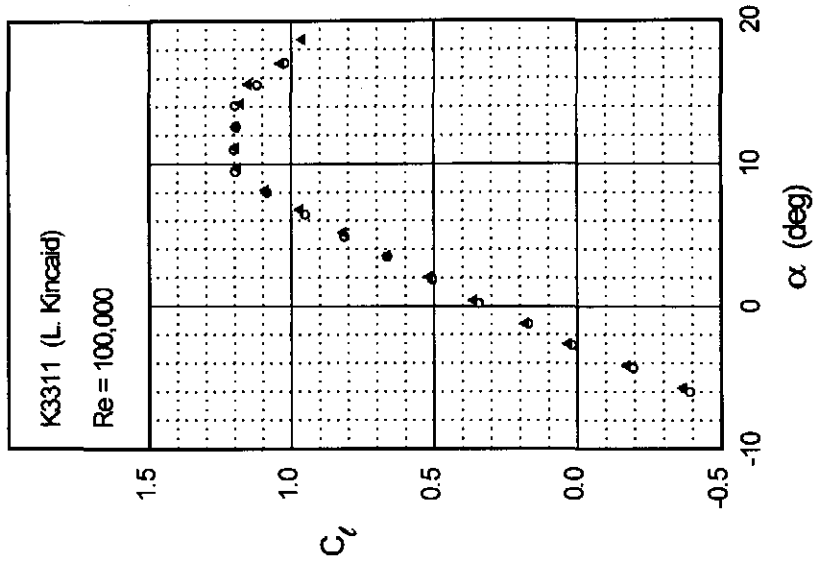

K3311
Avg. Difference = 0.0032 in
0.03
0.00
-0.03
Difference (in)

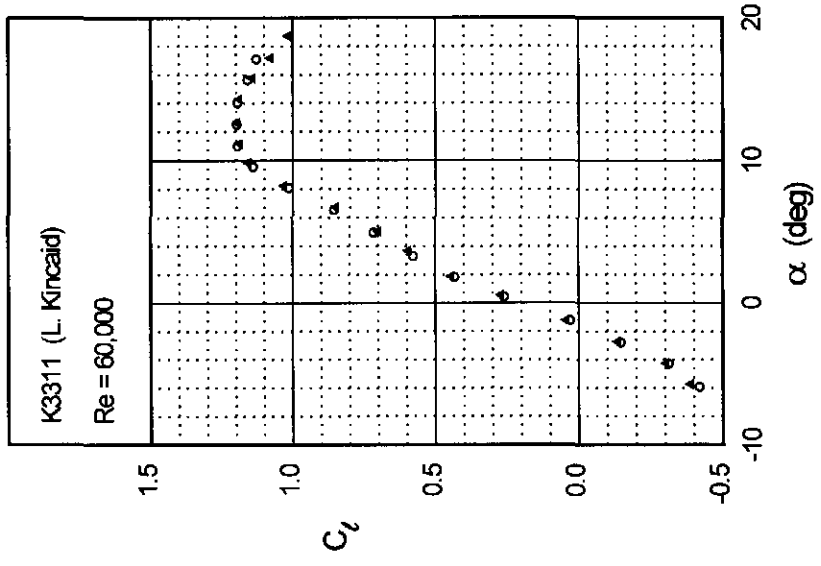

α relative to the zero-lift line
K3311 11.03%
2.5
2
1.5
1
0.5
V
0
0.5
1
x/c

K3311

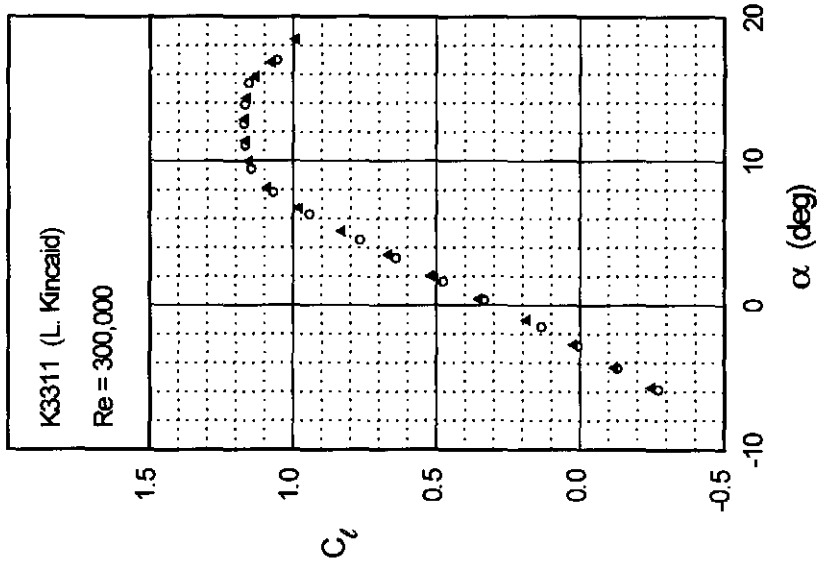

K3311 (L. Kincaid)
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
20
10
0
-10
0.05
0.04
0.03
0.02
0.01
0.00

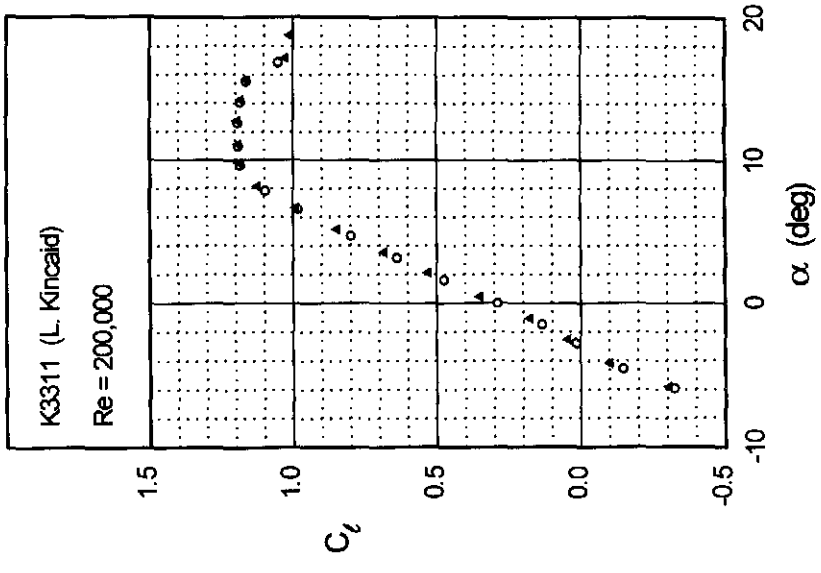
K3311


K3311 (L. Kincaid)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

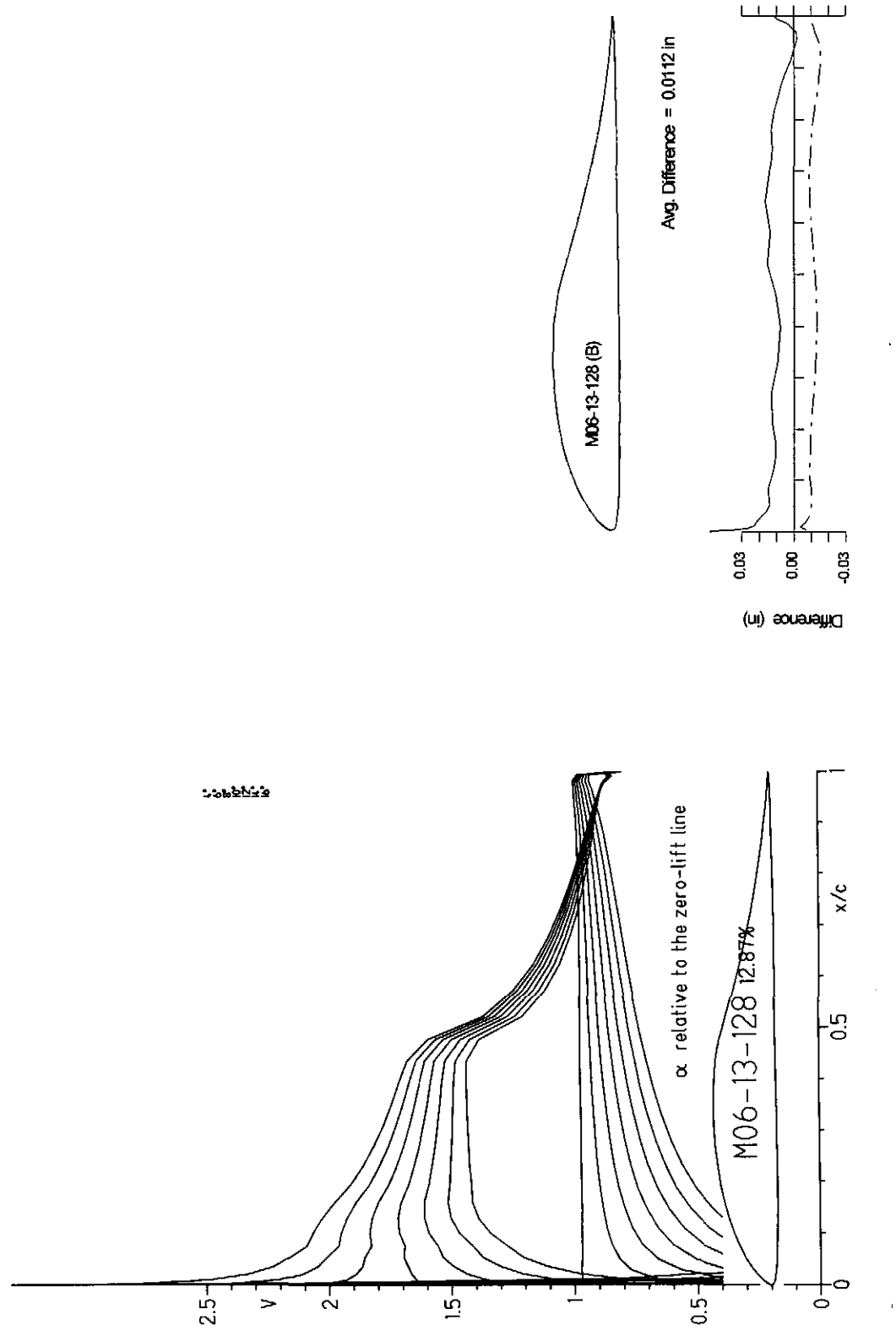

K3311 (L. Kincaid)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

K3311

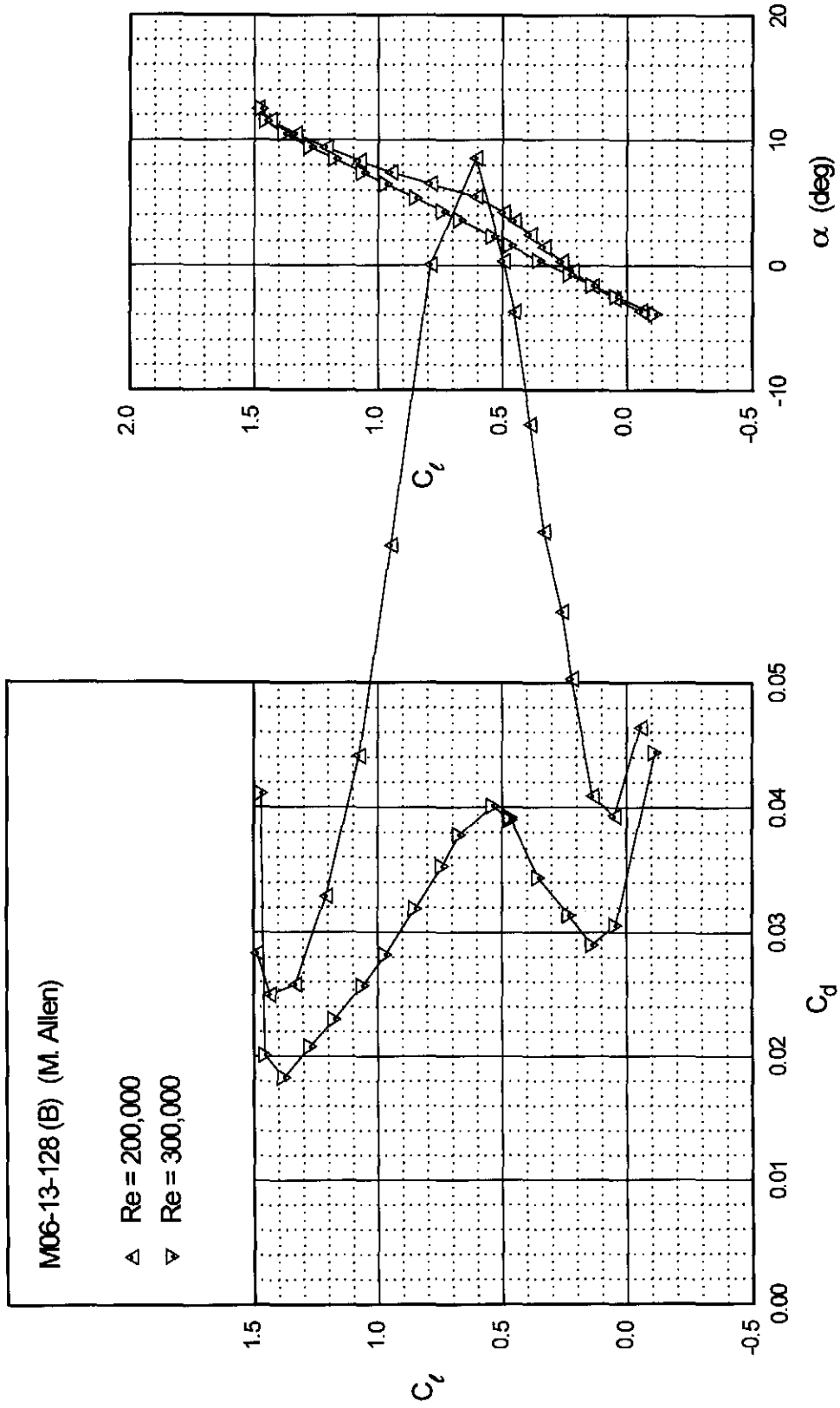

K3311 (L. Kincaid)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


K3311 (L. Kincaid)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

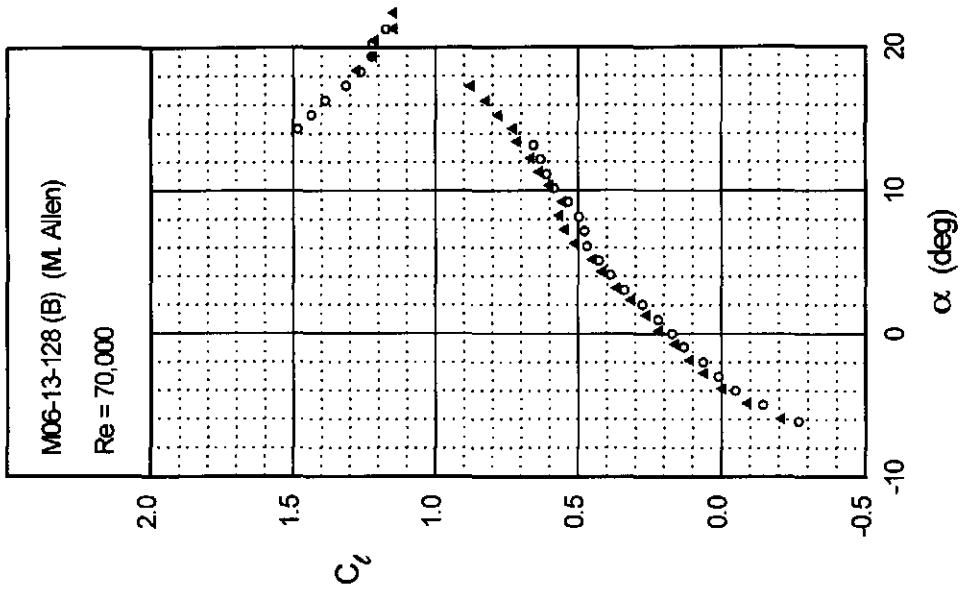
M06-13-128 (B)

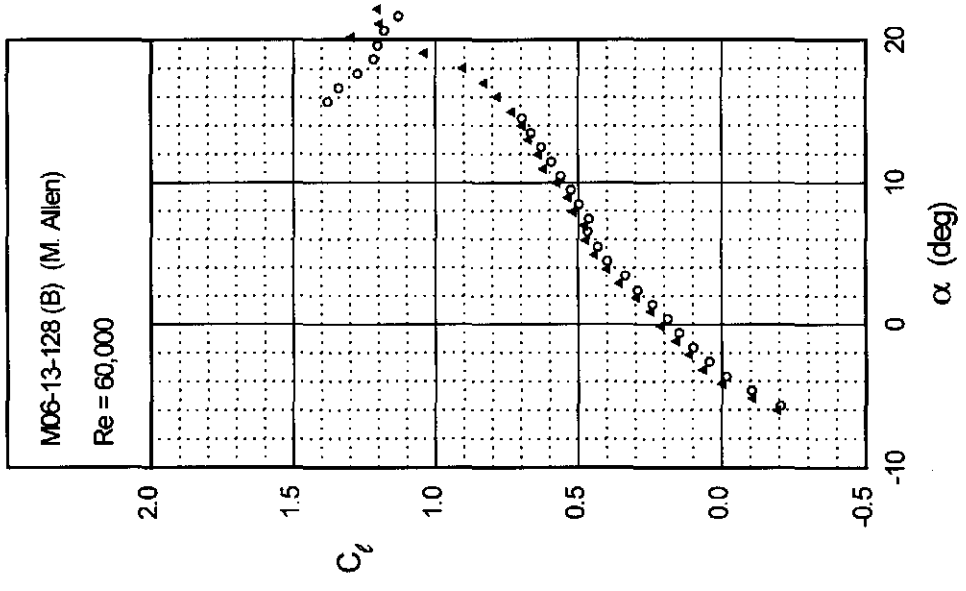

M06-13-128 (B)
Avg. Difference = 0.0112 in
0.03
0.00
-0.03
Difference (in)
α relative to the zero-lift line
M06-13-128 12.87%
2.5
2
1.5
1
0.5
V
0
0.5
1
x/c

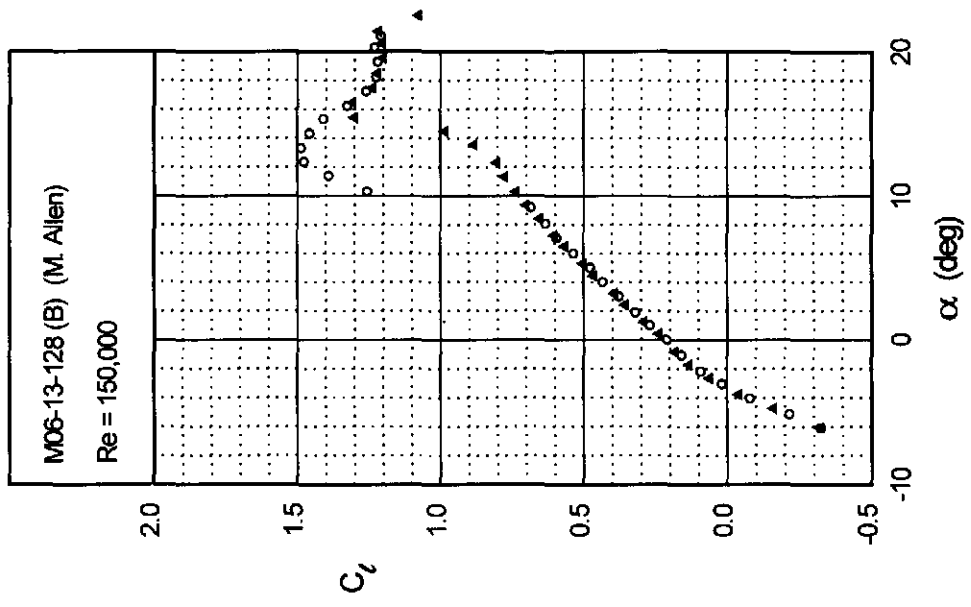
M06-13-128 (B)


M06-13-128 (B) (M. Allen)
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
0.05
0.04
0.03
0.02
0.01
0.00
20
10
0
-10

M06-13-128 (B)


M06-13-128 (B) (M. Allen)
Re = 70,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


M06-13-128 (B) (M. Allen)
Re = 60,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


M06-13-128 (B) (M. Allen)
Re = 150,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

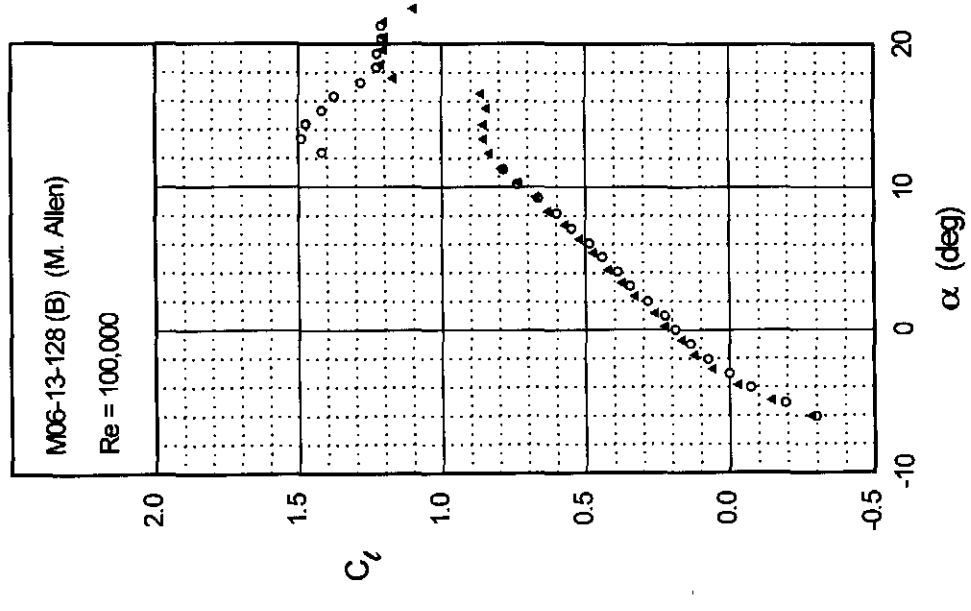
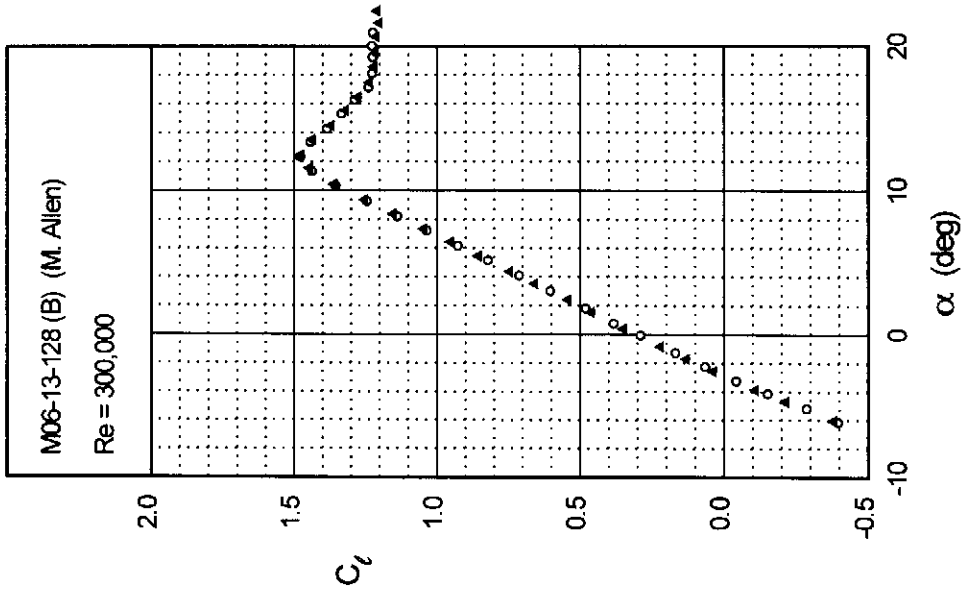
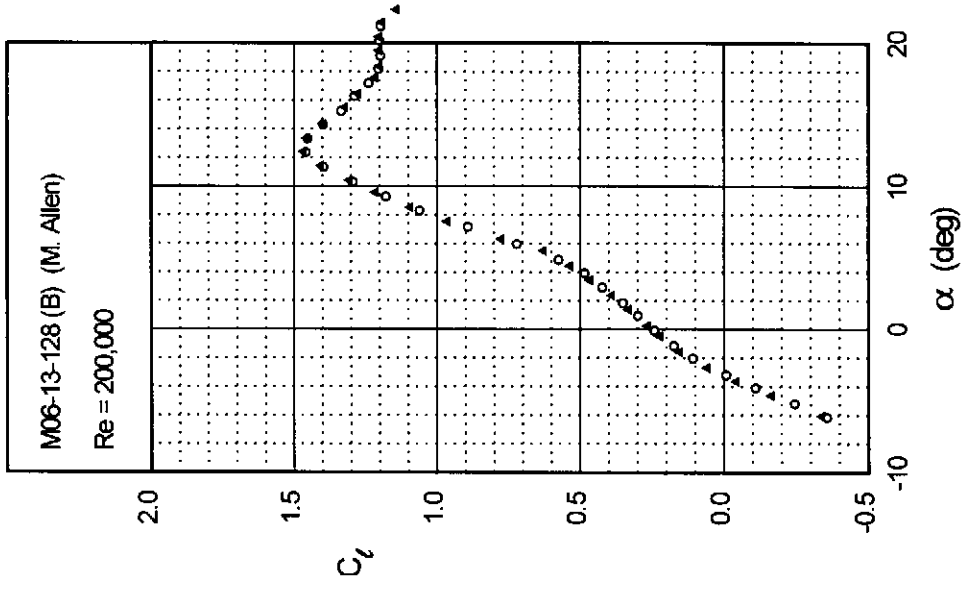

M06-13-128 (B) (M. Allen)
Re = 100,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

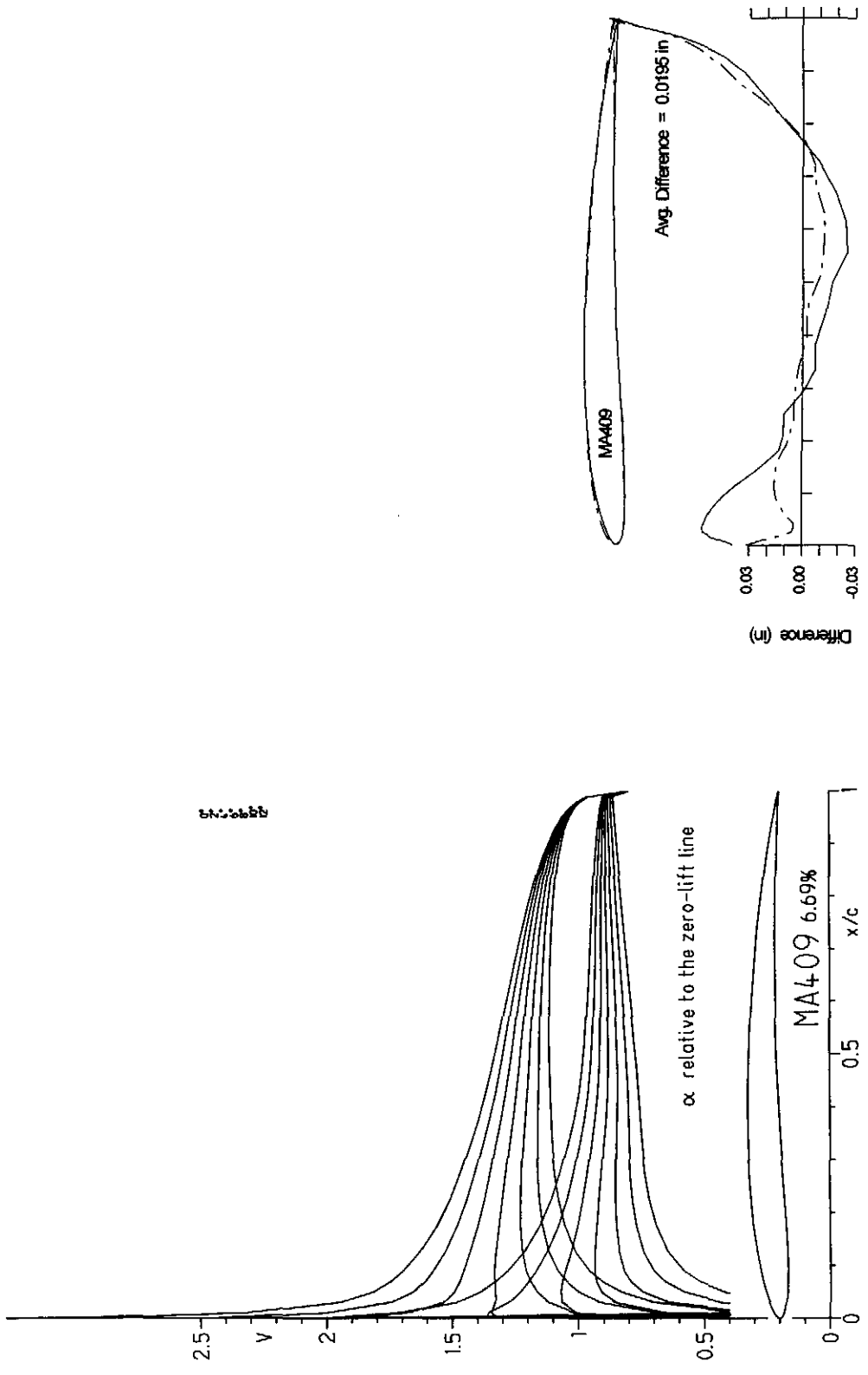
 Fig. 4.50 (continued)

M06-13-128 (B)

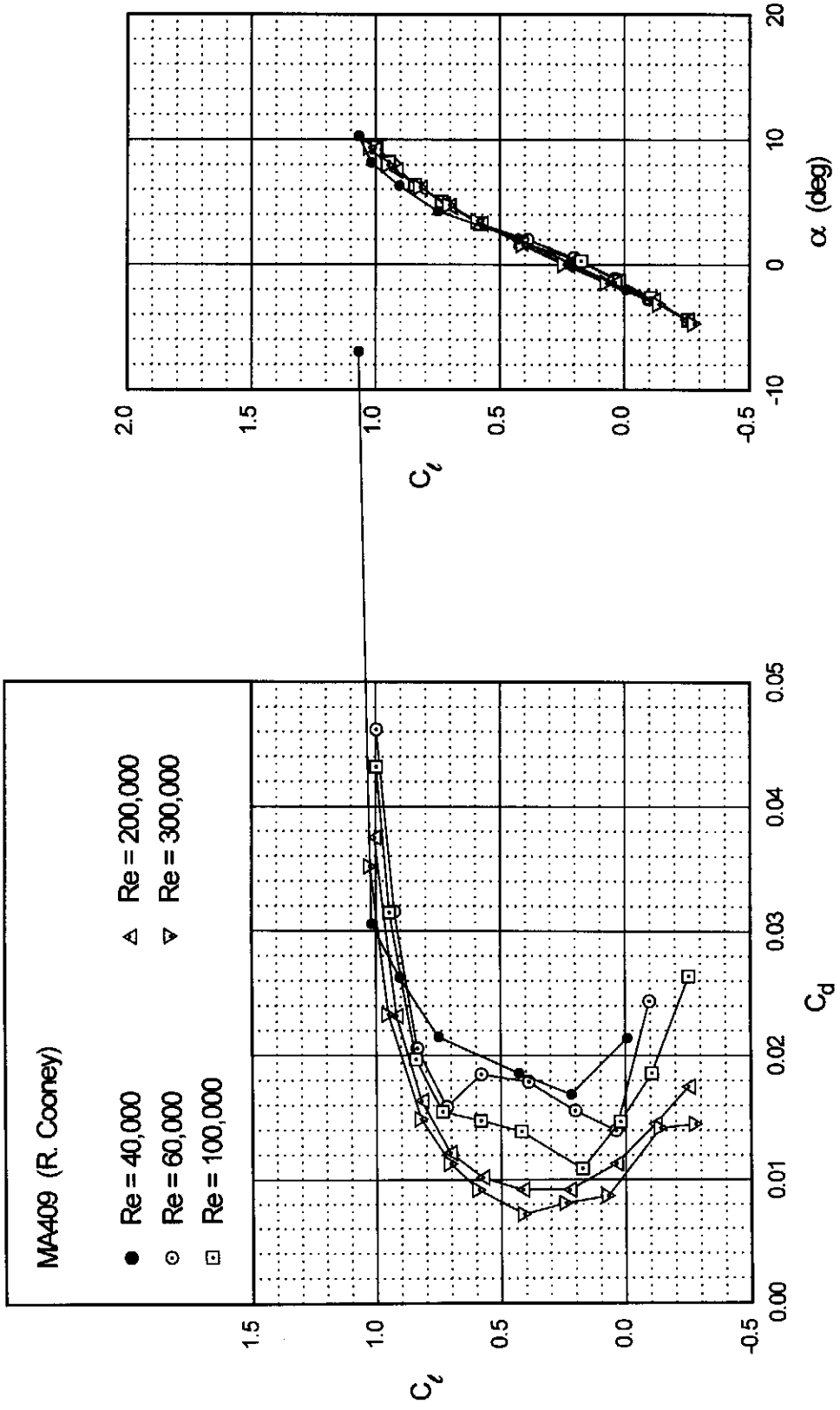


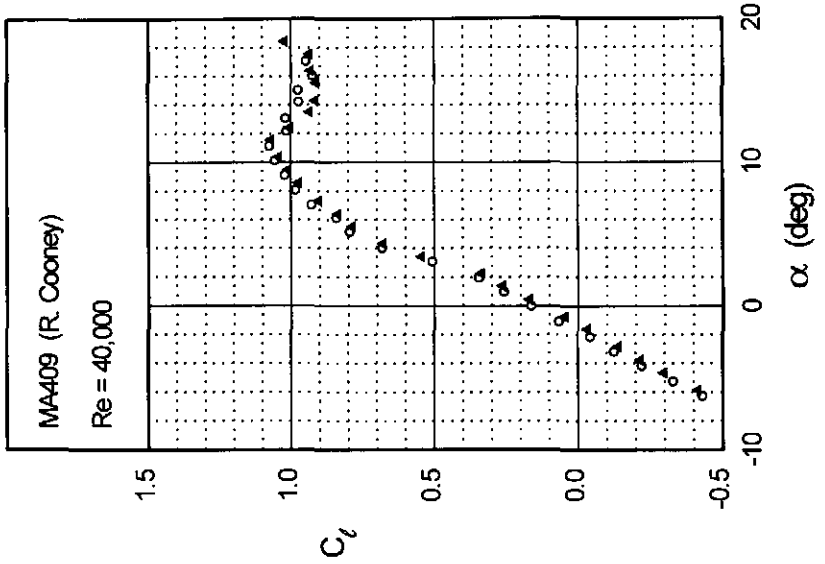
MA409

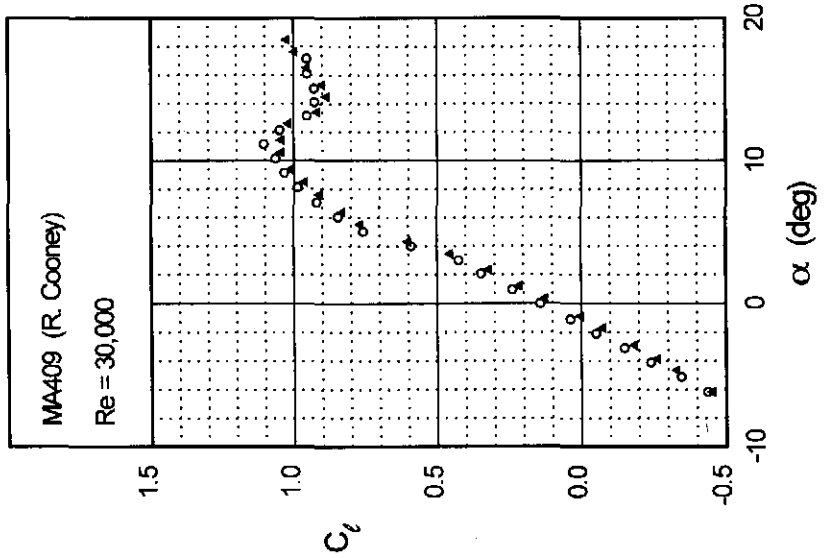

Avg. Difference = 0.0195 in
MA409
0.03
0.00
-0.03
Difference (in)
α relative to the zero-lift line
MA409 6.69%
x/c
0
0.5
1
2.5
2
1.5
1
0.5
0

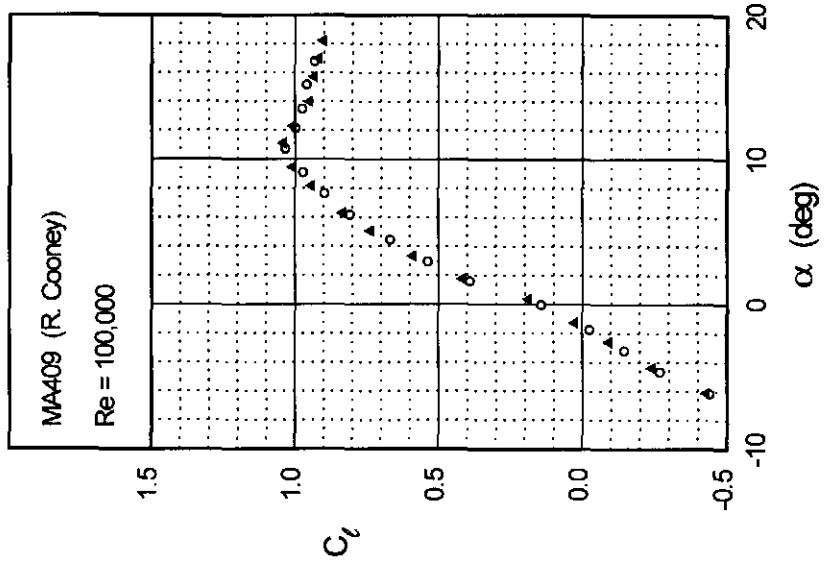
MA409


MA409 (R. Cooney)
Re = 40,000
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
$\alpha$ (deg)
1.5
1.0
0.5
0.0
-0.5
0.00
0.01
0.02
0.03
0.04
0.05
2.0
-10
0
10
20

MA409


MA409 (R. Cooney)
Re = 40,000
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
-10
0
10
20
α (deg)


MA409 (R. Cooney)
Re = 30,000
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
-10
0
10
20
α (deg)


MA409 (R. Cooney)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

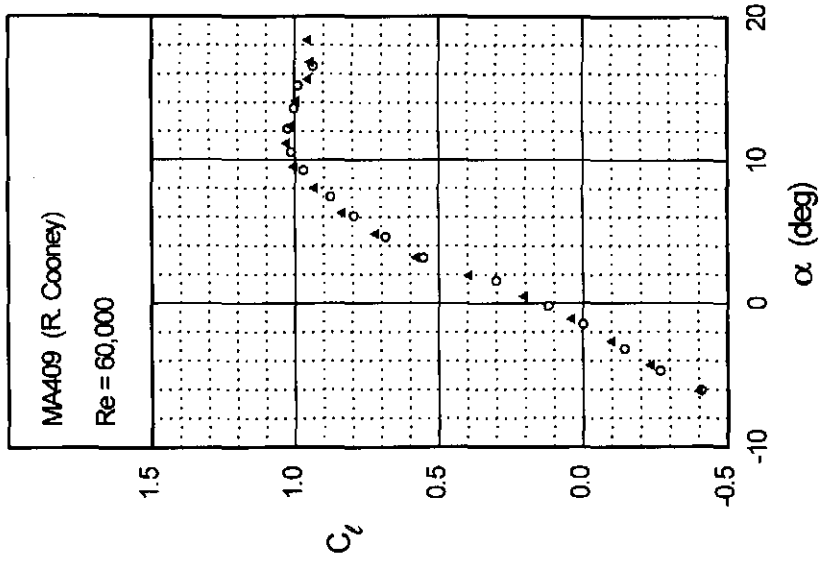
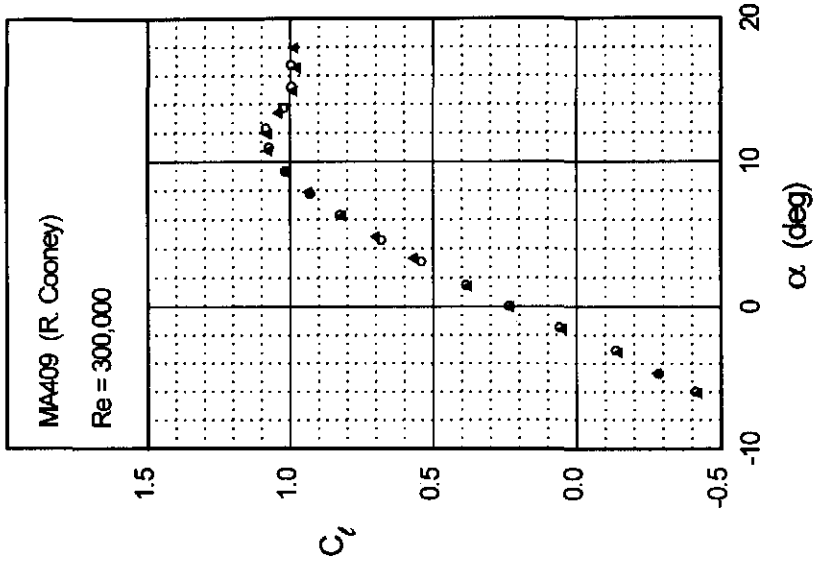
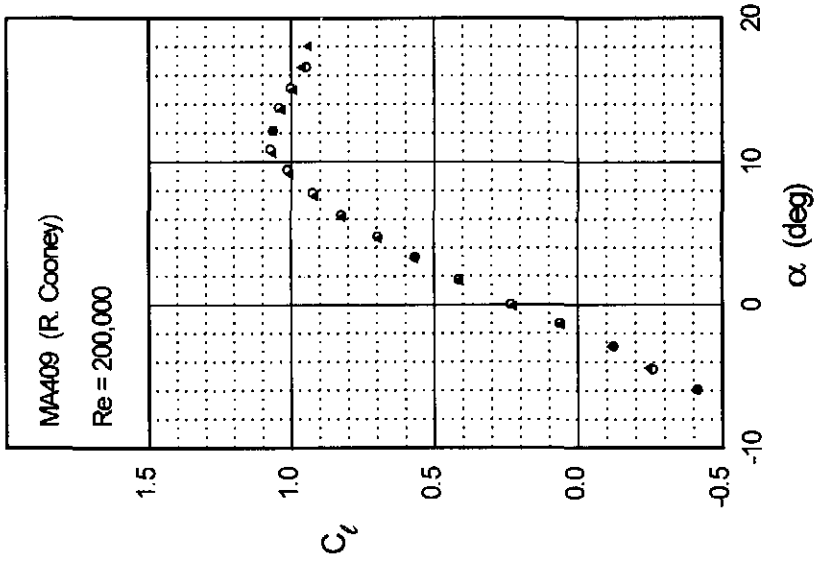

MA409 (R. Cooney)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

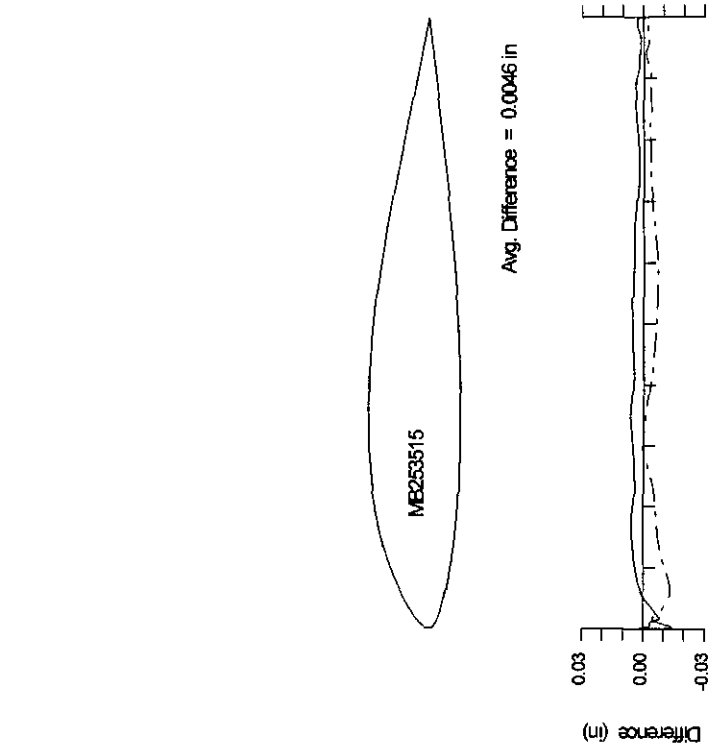
Fig. 4.54 (continued)

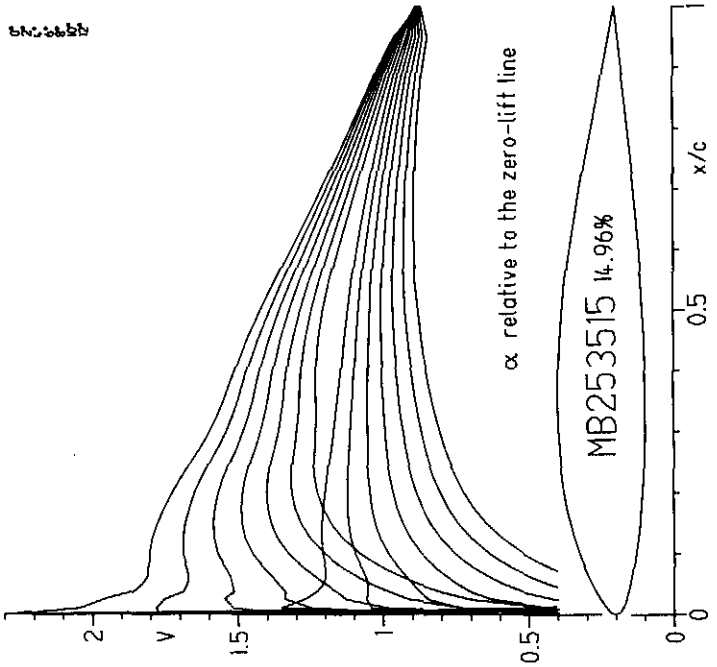
MA409

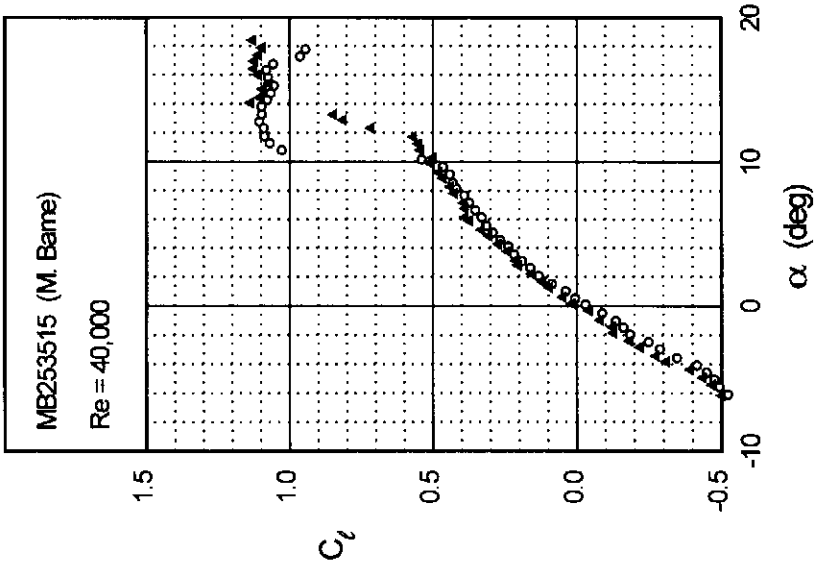


MB253515


MB253515
Avg. Difference = 0.0046 in
0.03
0.00
-0.03
Difference (in)


α relative to the zero-lift line
MB253515 14.96%
x/c
0
0.5
1
1.5
2
0
0.5


MB253515 (M. Bame)
Re = 40,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

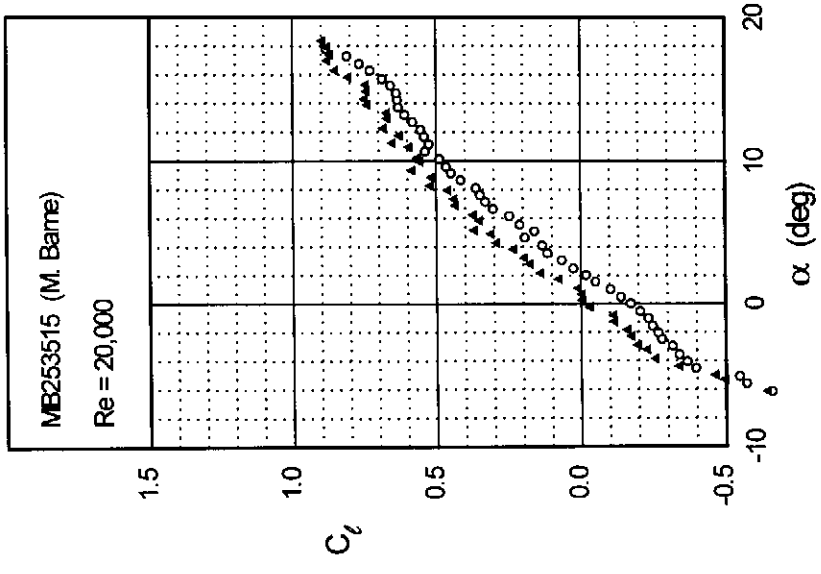
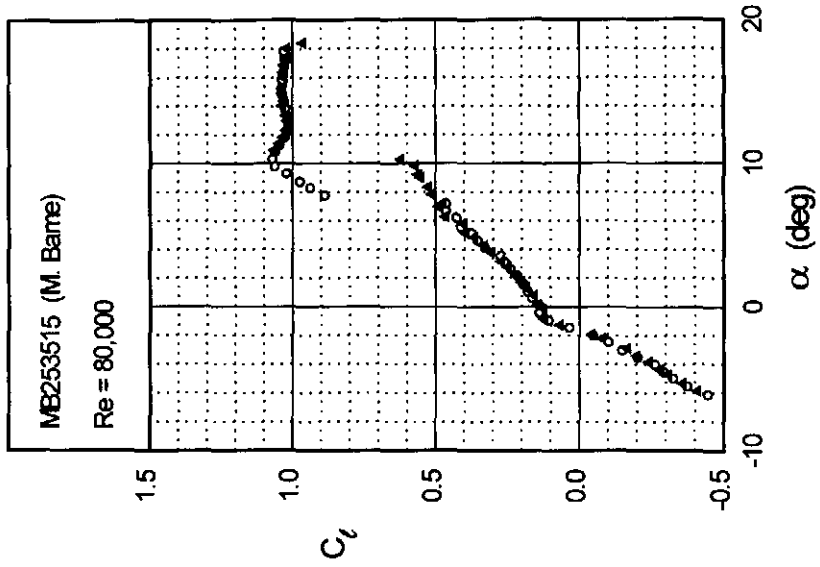
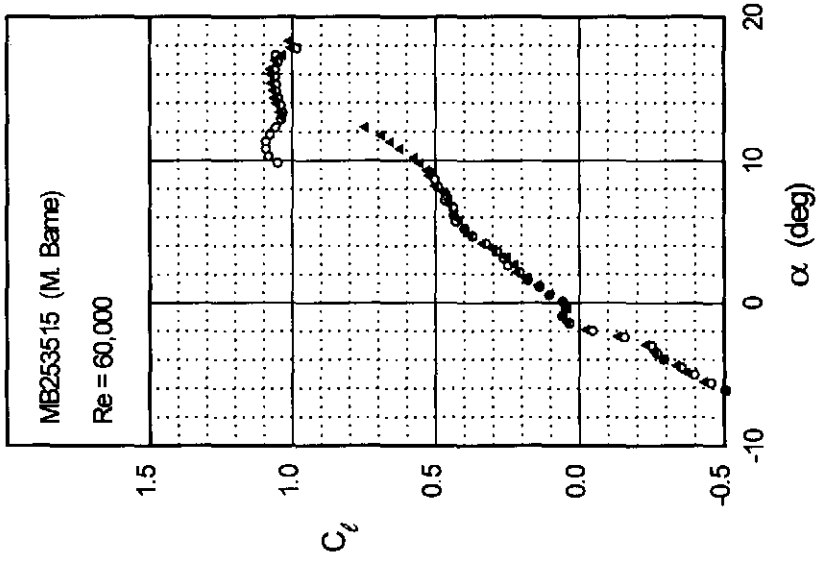
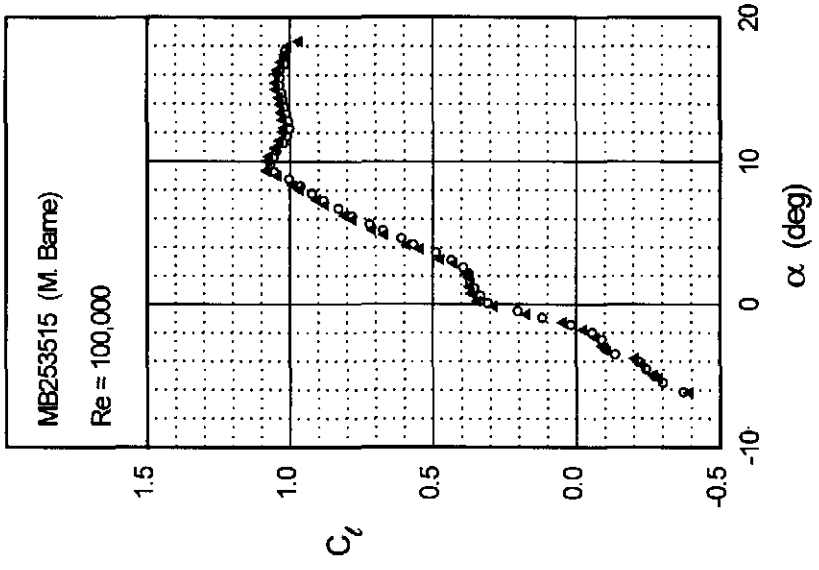

MB253515 (M. Bame)
Re = 20,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

Fig. 4.57 (continued)

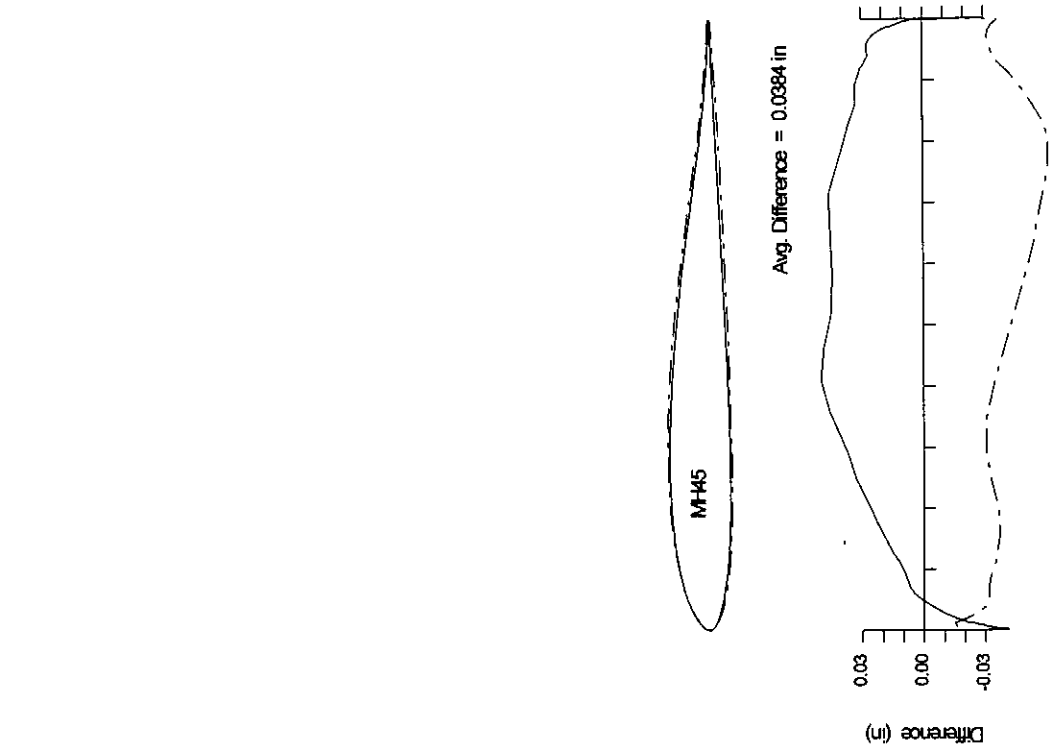
MB253515

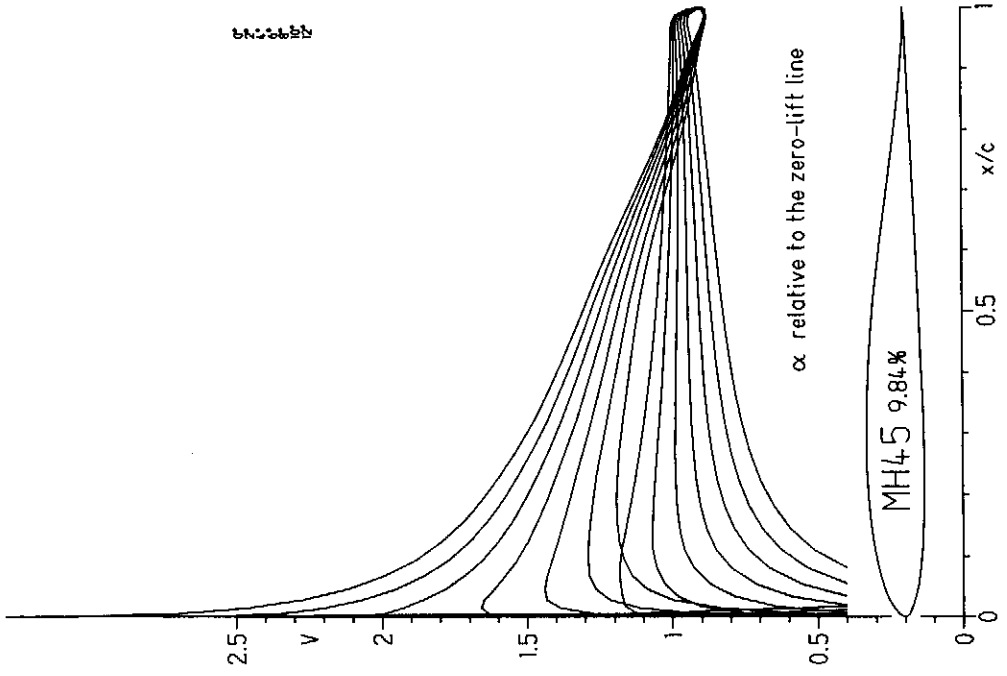


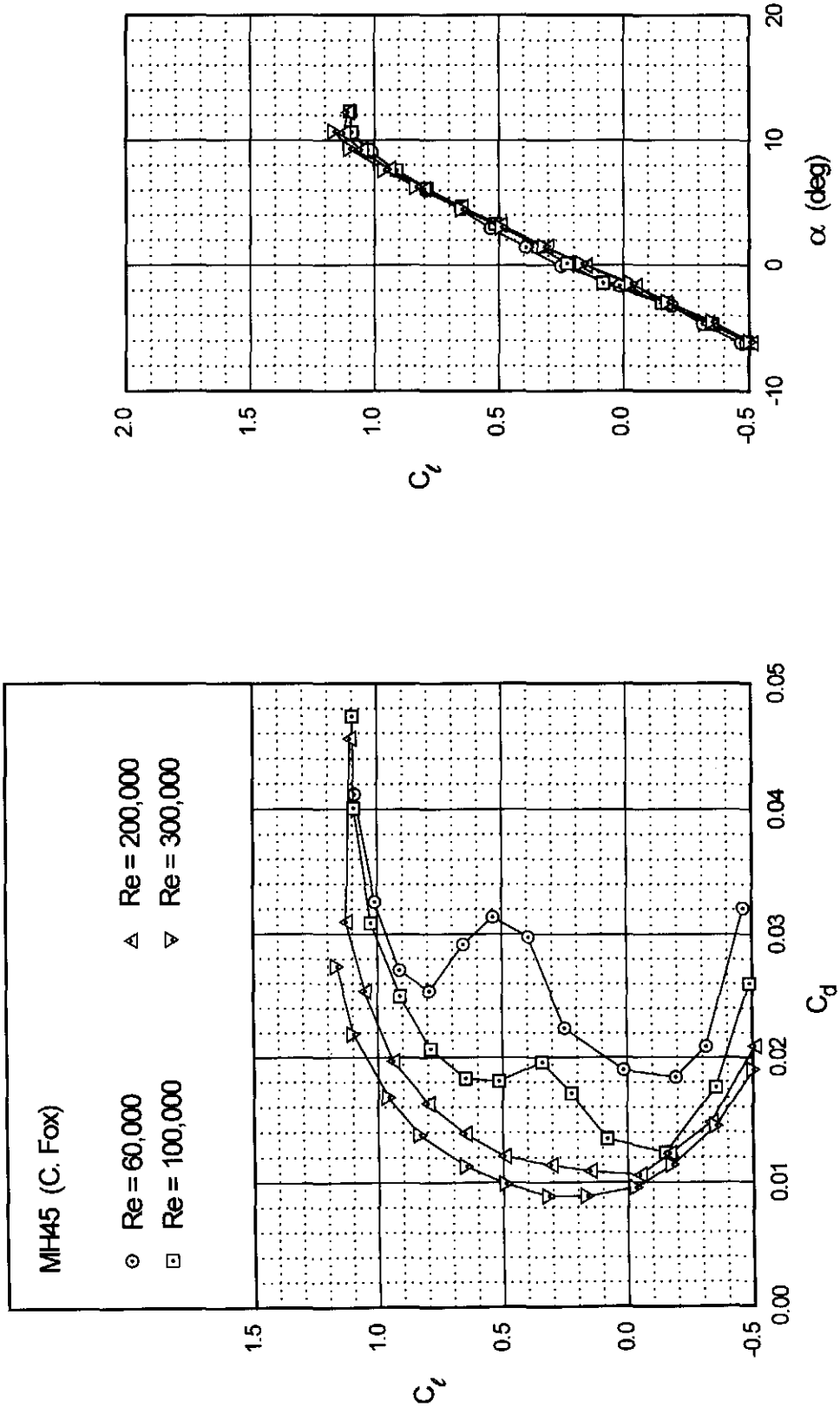

MB253515 (M. Barne)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
20
10
0
-10
α (deg)

MH45

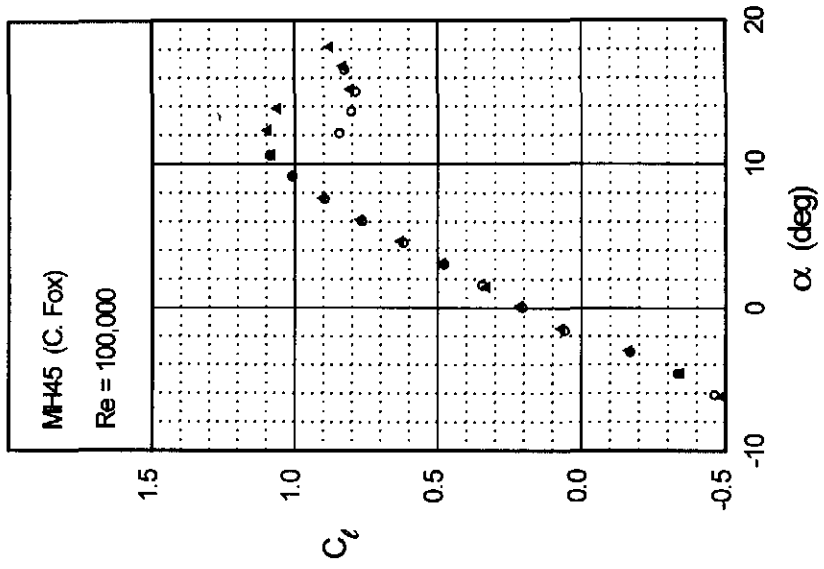

MH45
Avg. Difference = 0.0384 in
0.03
0.00
-0.03
Difference (in)

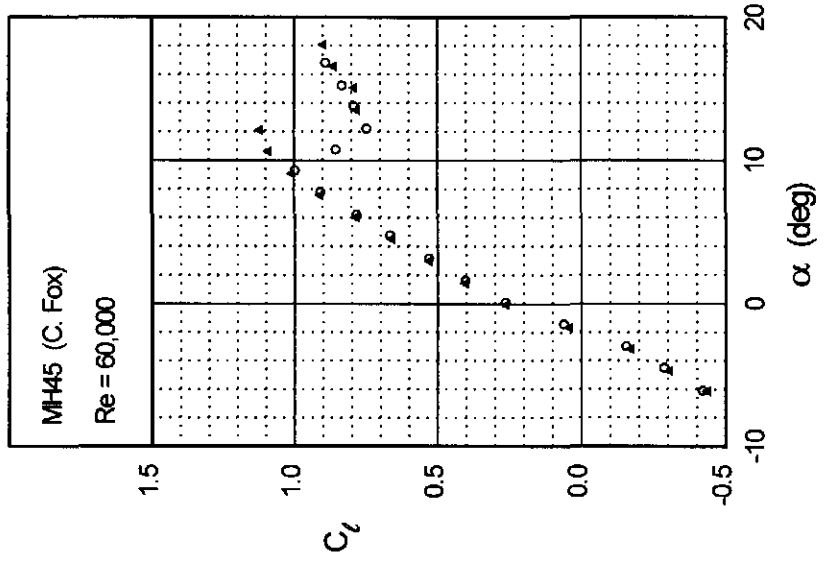

α relative to the zero-lift line
MH45 9.84%
2.5
2
1.5
1
0.5
V
0
0.5
1
x/c

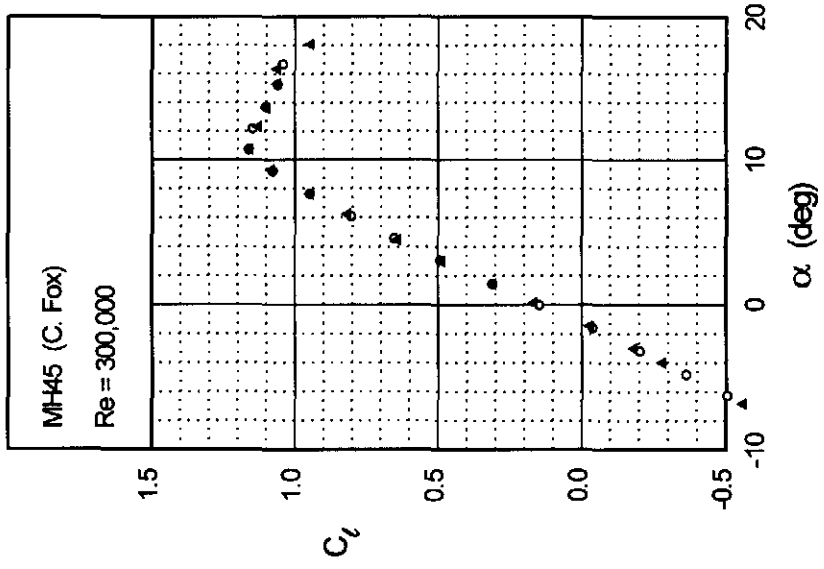
MH45

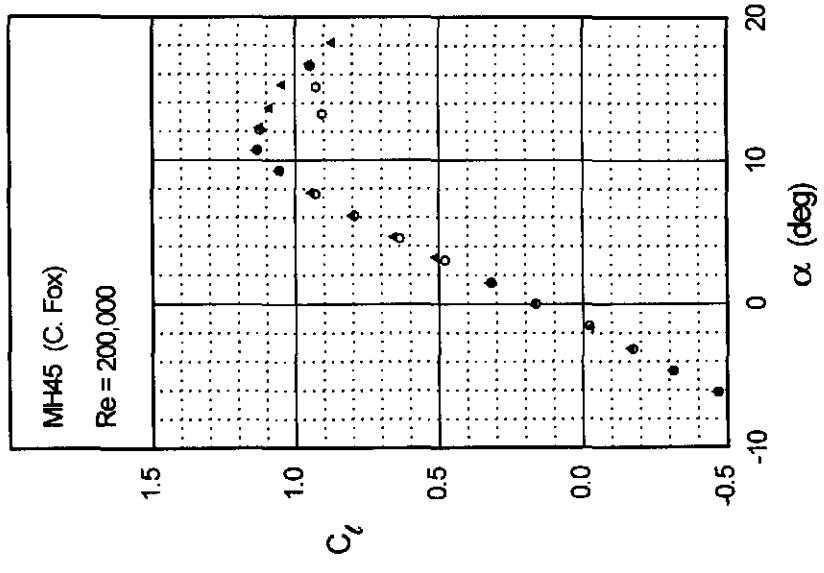

MH45 (C. Fox)
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
$\alpha$ (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
20
10
0
-10
0.05
0.04
0.03
0.02
0.01
0.00

MH45

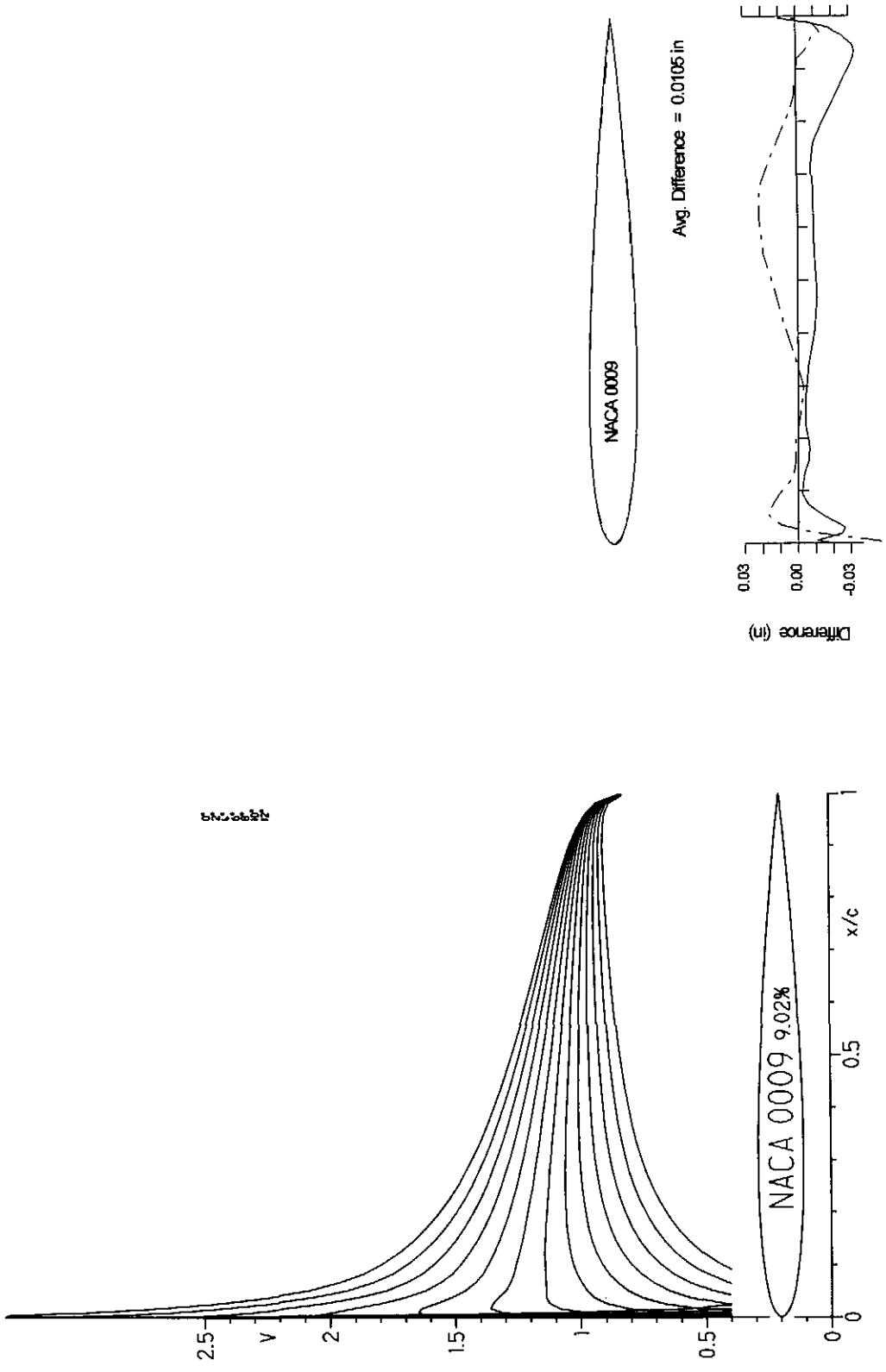

MH45 (C. Fox)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

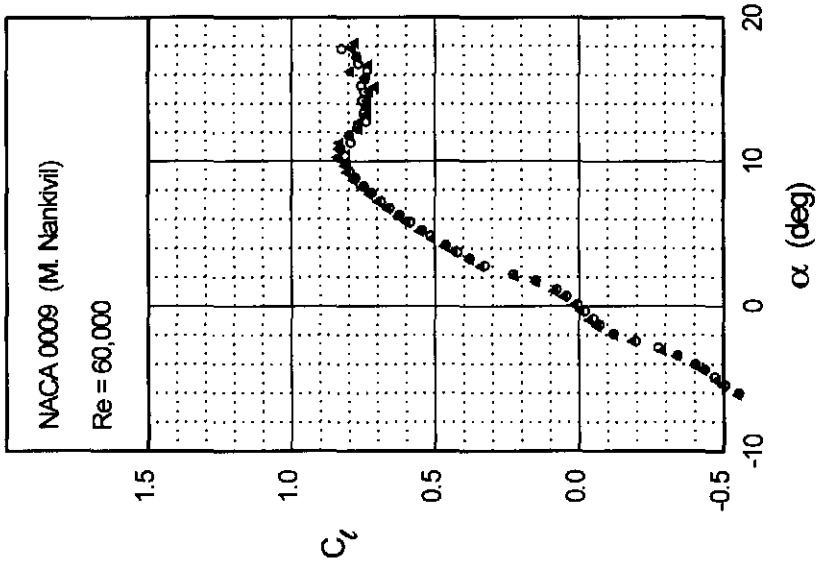

MH45 (C. Fox)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


MH45 (C. Fox)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


MH45 (C. Fox)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

NACA 0009


NACA 0009
Avg. Difference = 0.0105 in
0.03
0.00
-0.03
Difference (in)
2.5
2
1.5
1
0.5
V
NACA 0009 9.02%
0
0.5
1
x/c


NACA 0009 (M. Nankivil)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

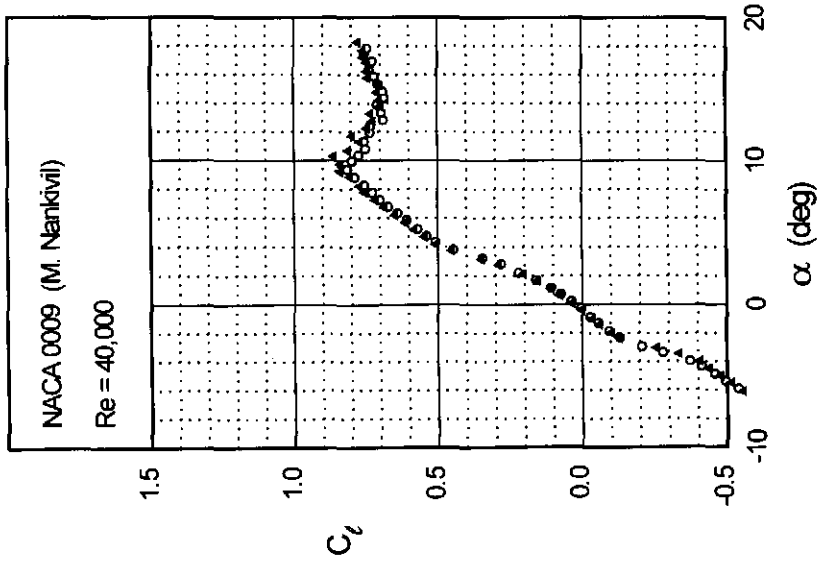
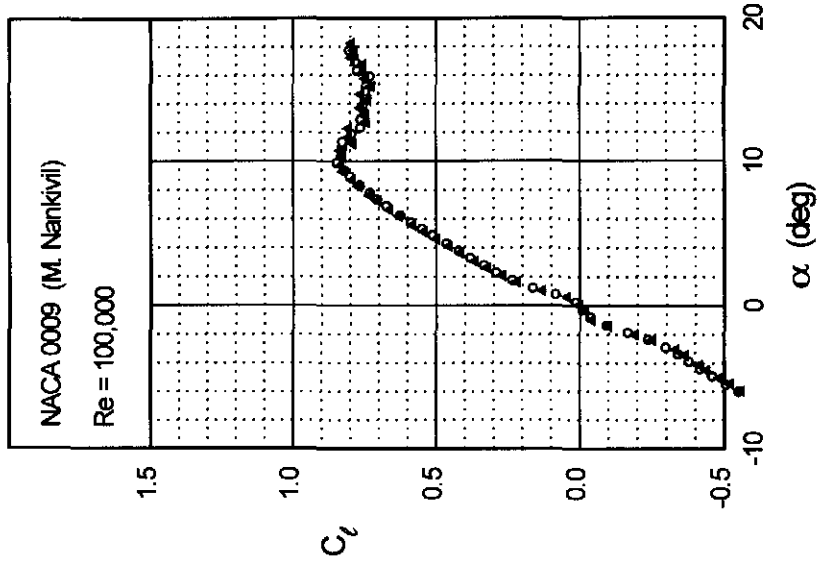
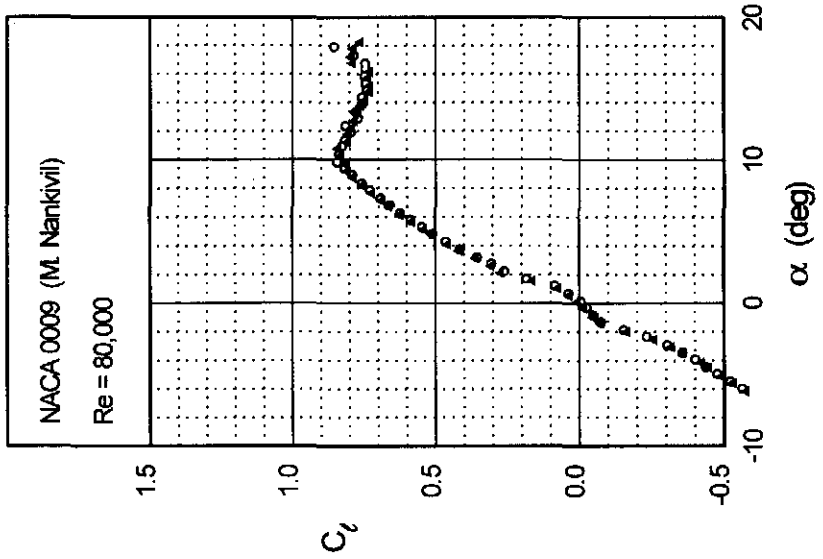

NACA 0009 (M. Nankivil)
Re = 40,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

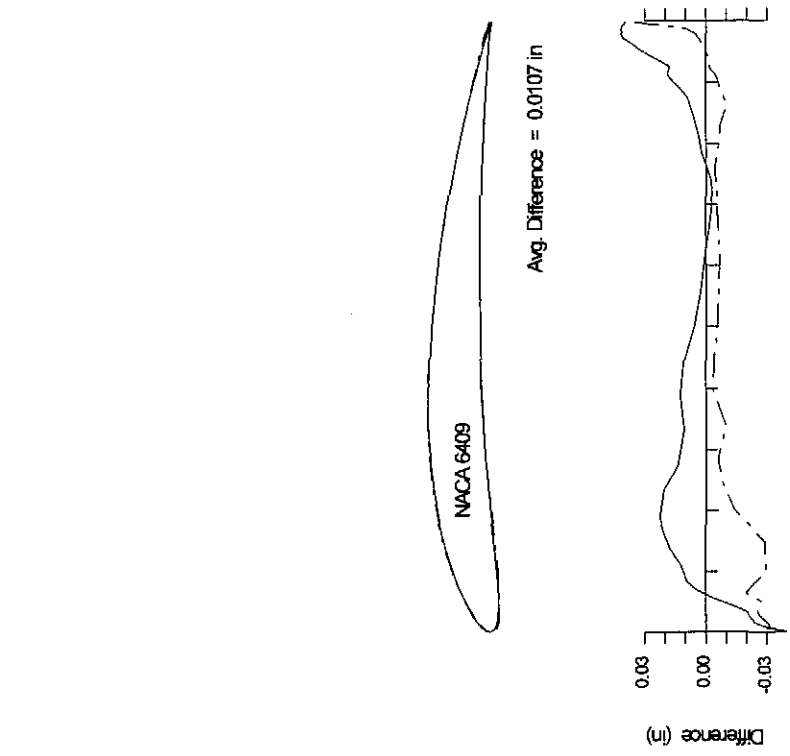
Fig. 4.64 (continued)

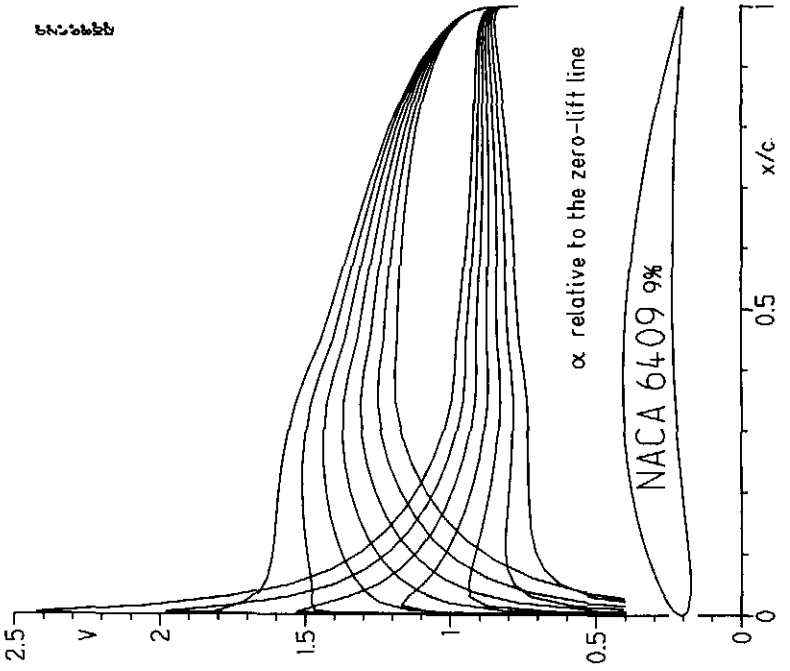
NACA 0009



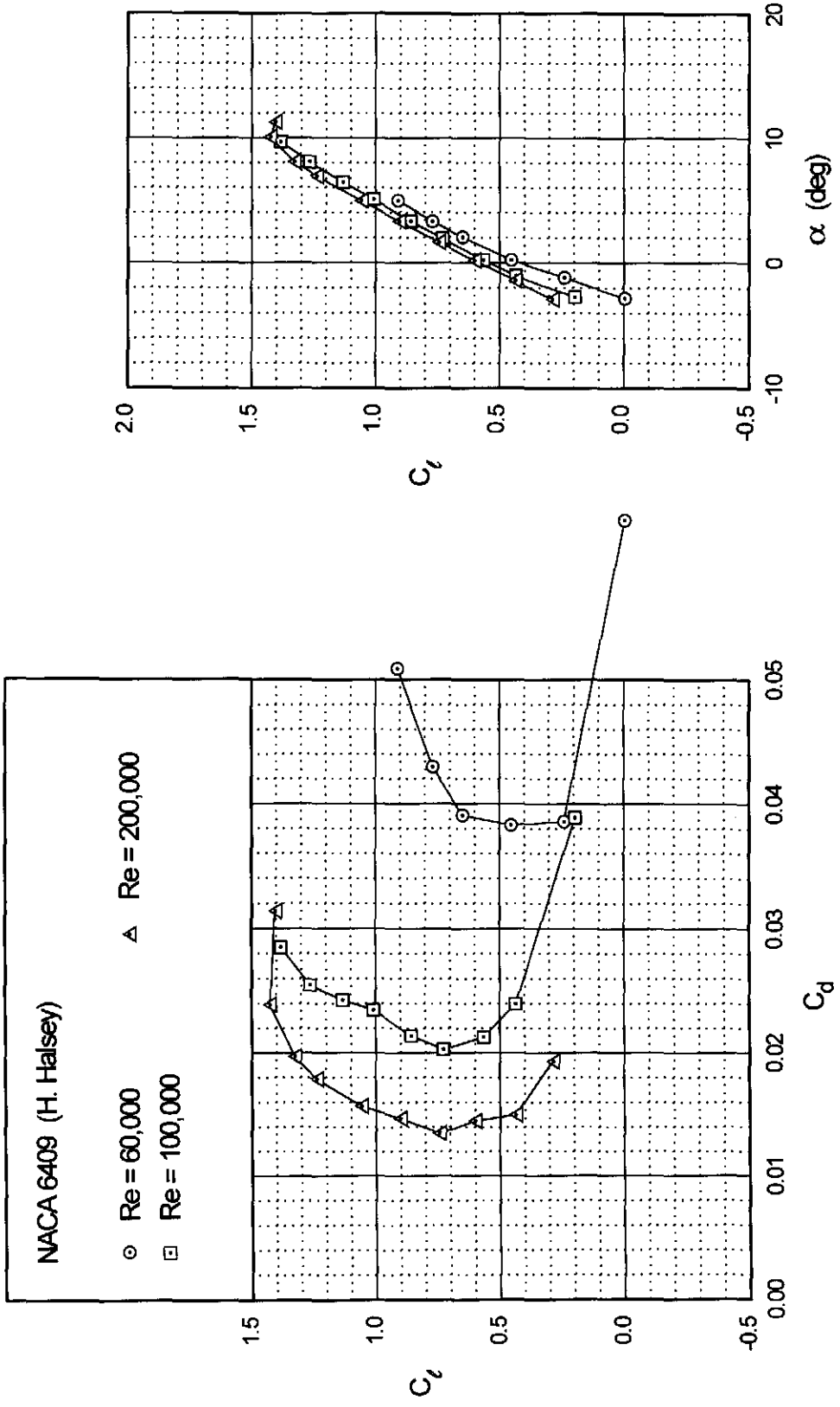



NACA 6409

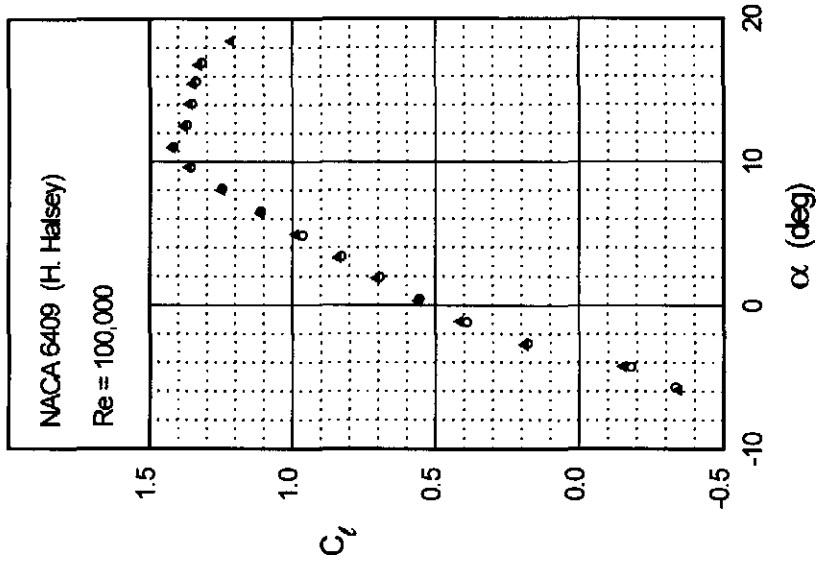

NACA 6409
Avg. Difference = 0.0107 in
0.03
0.00
-0.03
Difference (in)

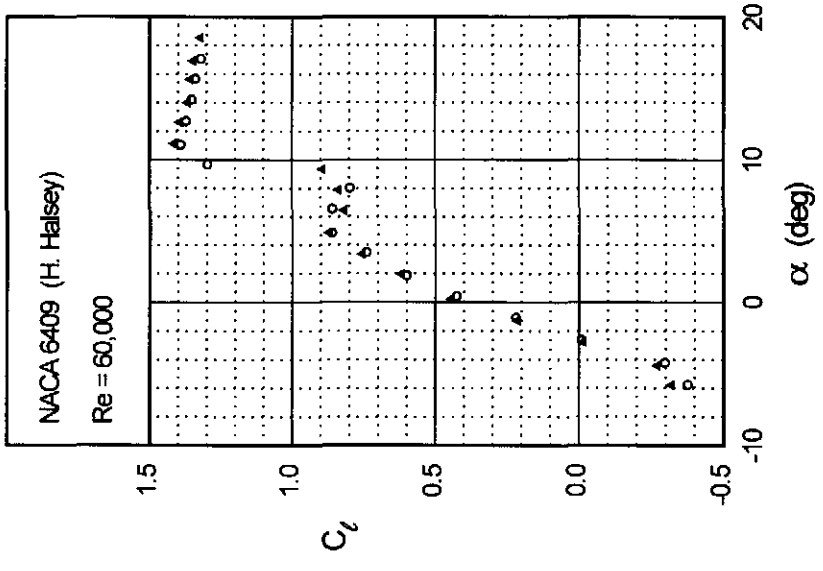

α relative to the zero-lift line
NACA 6409 9%
2.5
2
1.5
1
0.5
0
0.5
1
x/c

NACA 6409

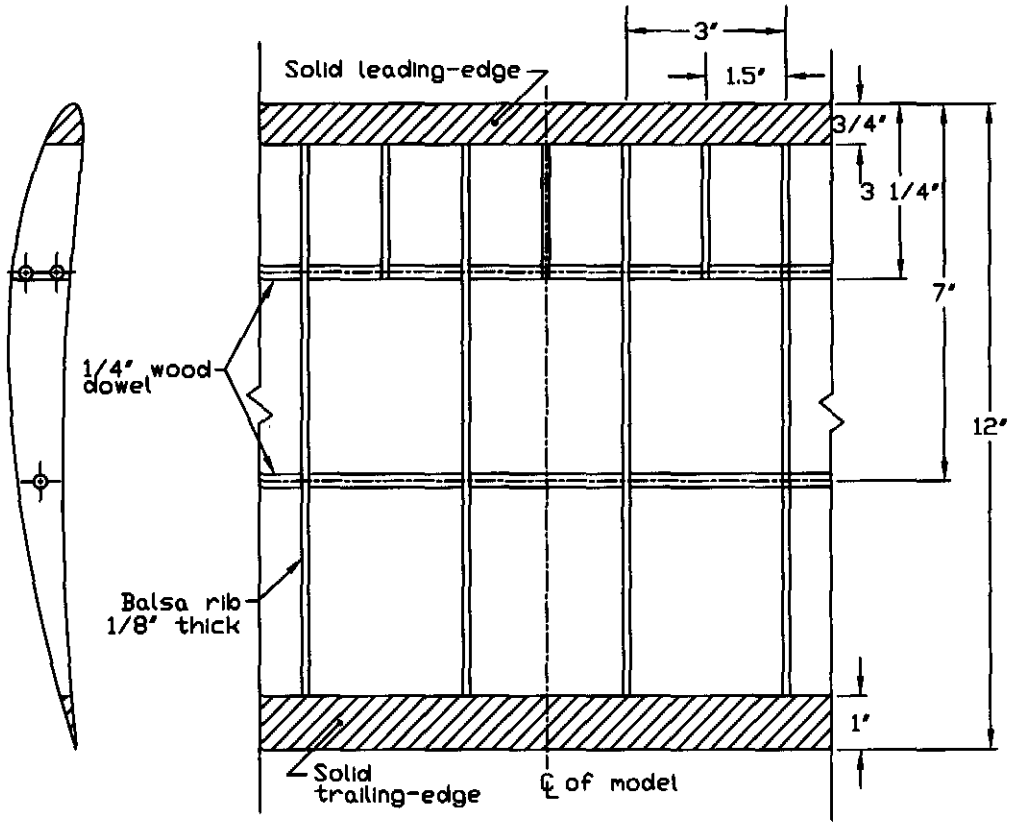

NACA 6409 (H. Halsey)
Re = 60,000
Re = 100,000
Re = 200,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
20
10
0
-10
0.05
0.04
0.03
0.02
0.01
0.00

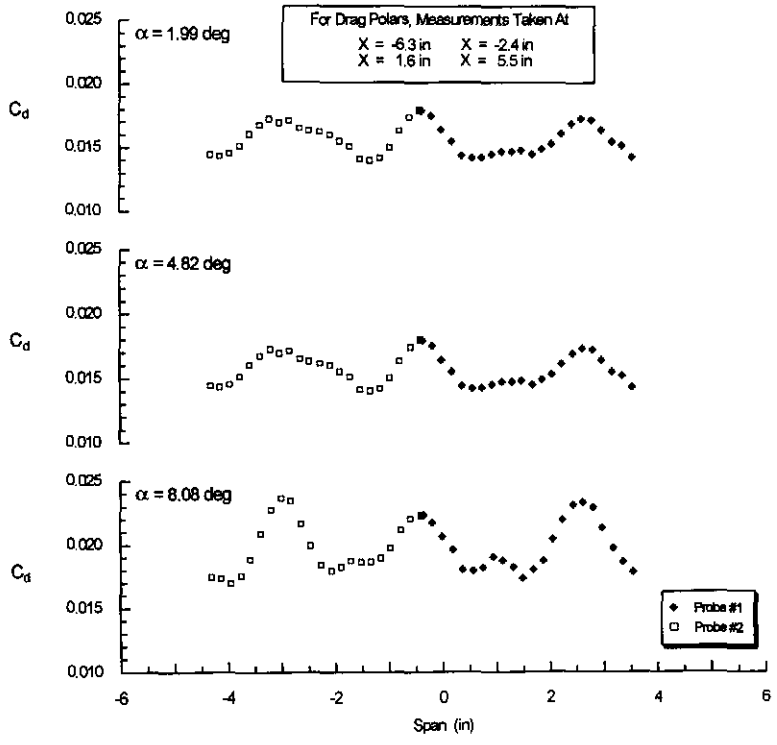
NACA 6409


NACA 6409 (H. Halsey)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

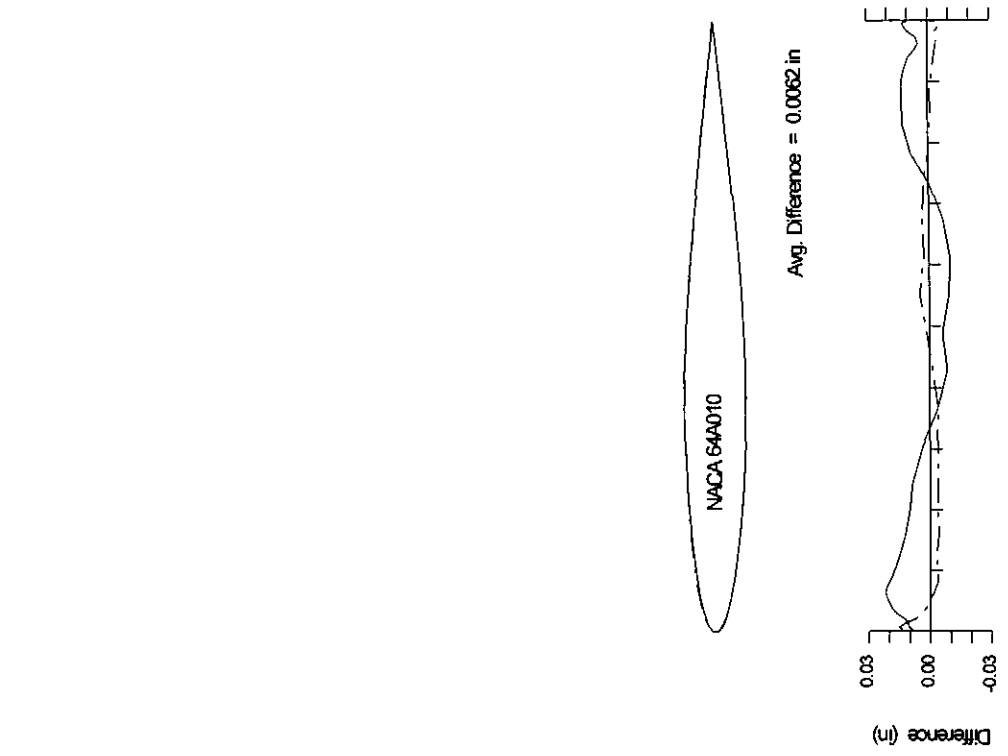

NACA 6409 (H. Halsey)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

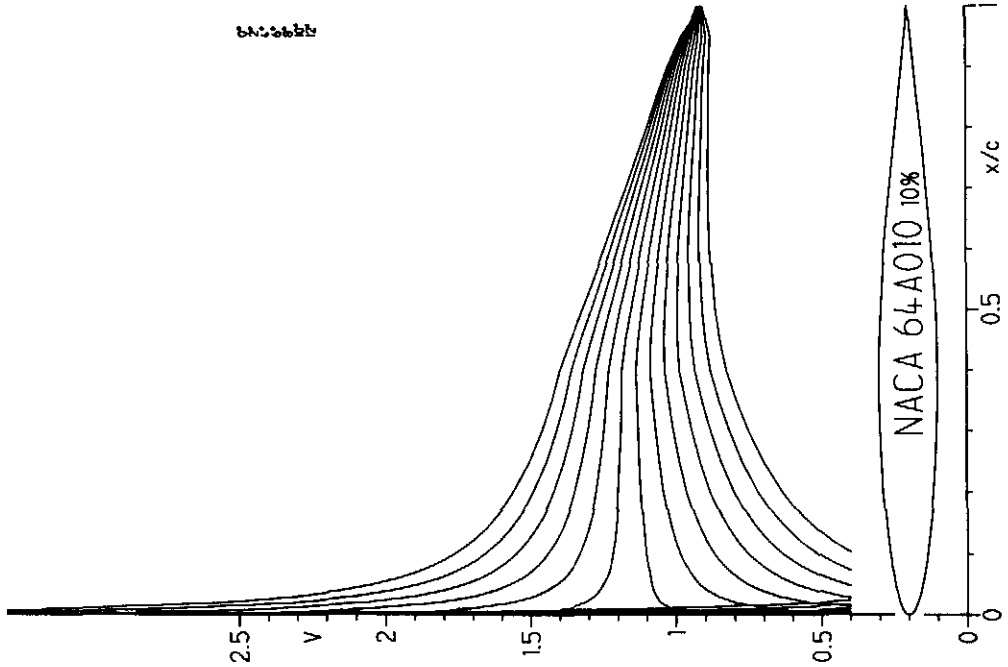
NACA 6409

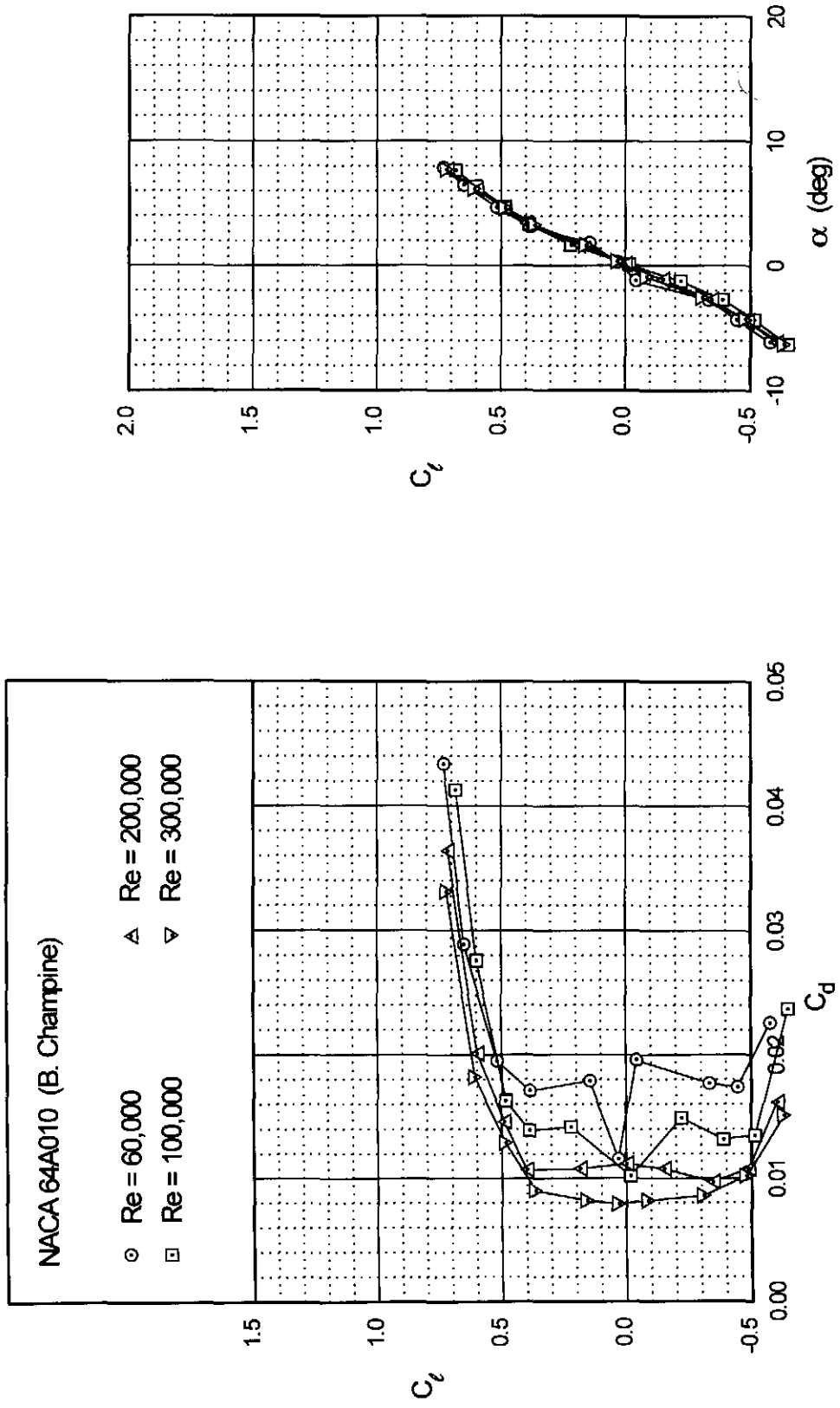

3"
1.5"
Solid leading-edge
3/4"
3 1/4"
7"
12"
1/4" wood dowel
Balsa rib 1/8" thick
1"
Solid trailing-edge
℄ of model


For Drag Polars, Measurements Taken At
X = -6.3 in X = -2.4 in
X = 1.6 in X = 5.5 in
α = 1.99 deg
α = 4.82 deg
α = 8.08 deg
Cd
0.025
0.020
0.015
0.010
Probe #1
Probe #2
-6
-4
-2
0
2
4
6
Span (in)

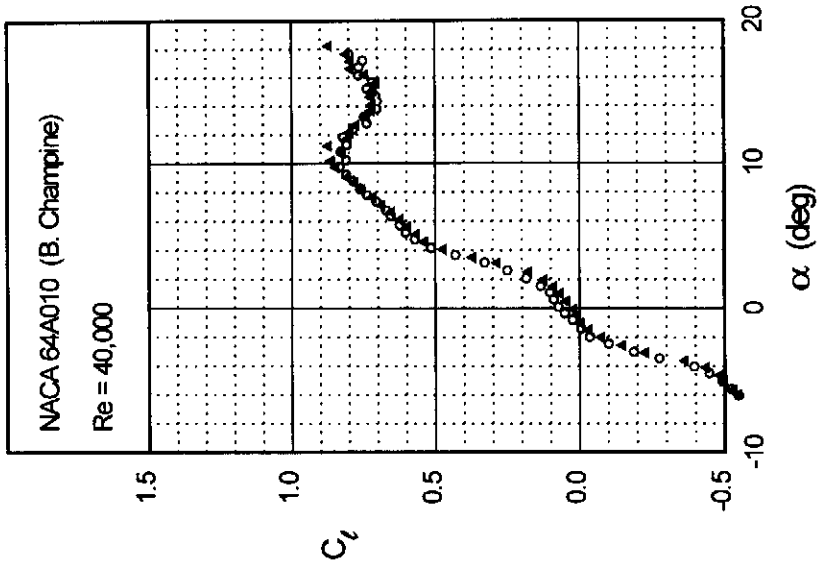
NACA 64A010

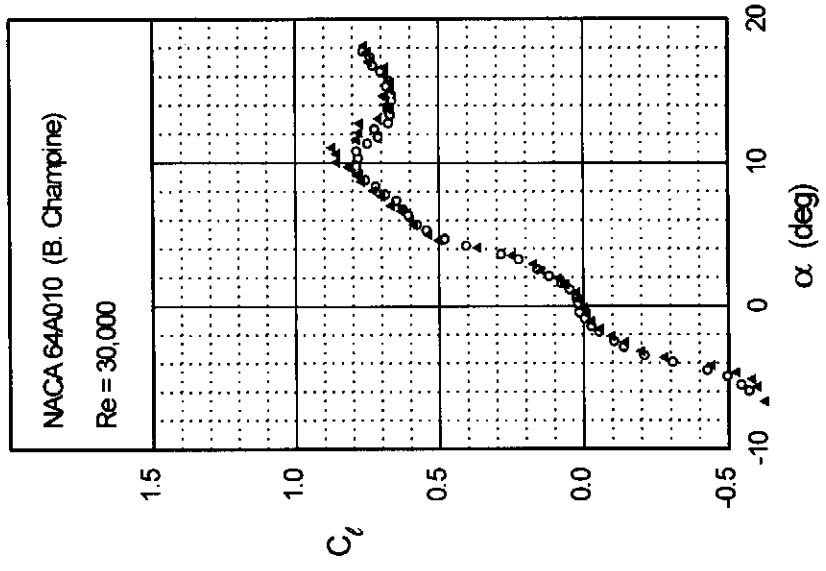

NACA 64A010
Avg. Difference = 0.0062 in
0.03
0.00
-0.03
Difference (in)

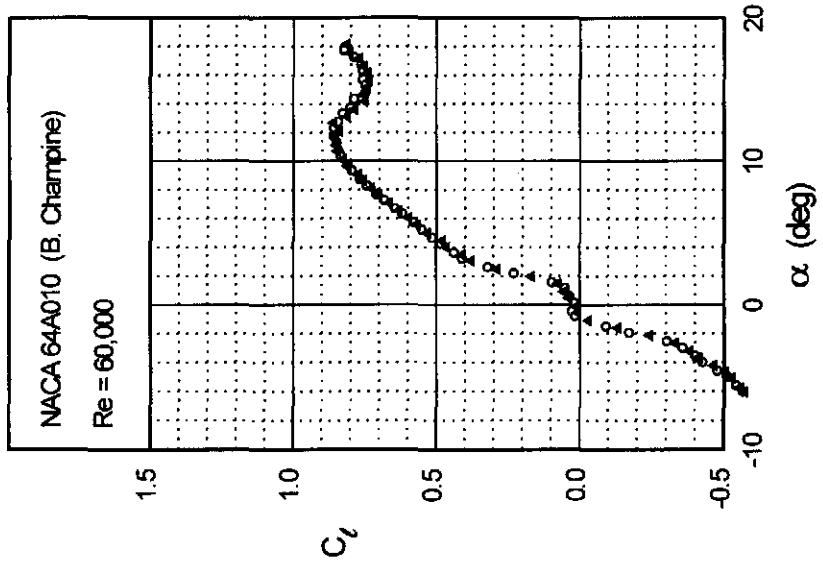

NACA 64A010 10%
x/c
0
0.5
2.5
2
1.5
1
0.5


NACA 64A010
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)
NACA 64A010 (B. Champine)
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
0.05
0.04
0.03
0.02
0.01
0.00
$C_d$

NACA 64A010


NACA 64A010 (B. Champine)
Re = 40,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


NACA 64A010 (B. Champine)
Re = 30,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


NACA 64A010 (B. Champine)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

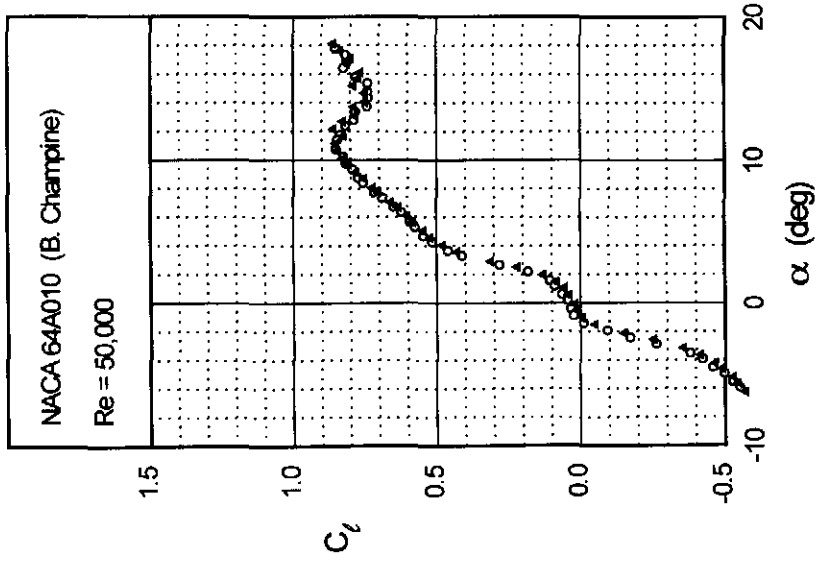
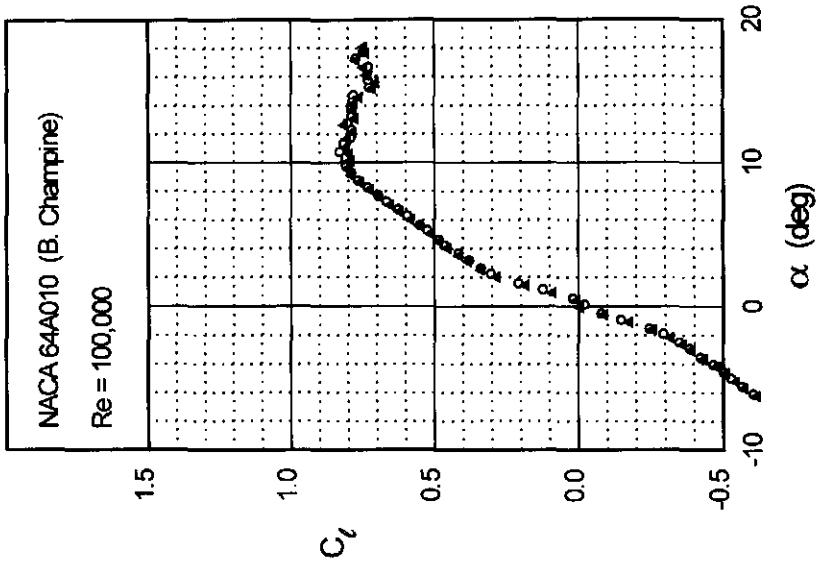
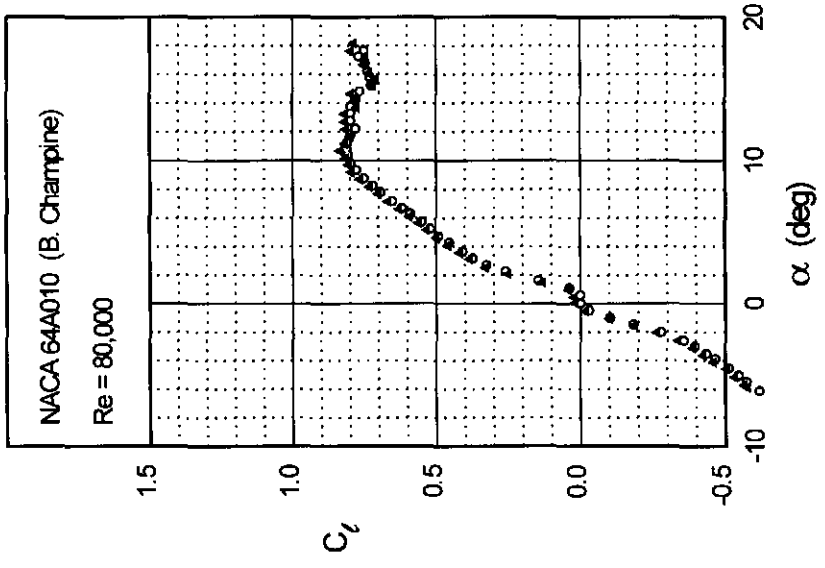
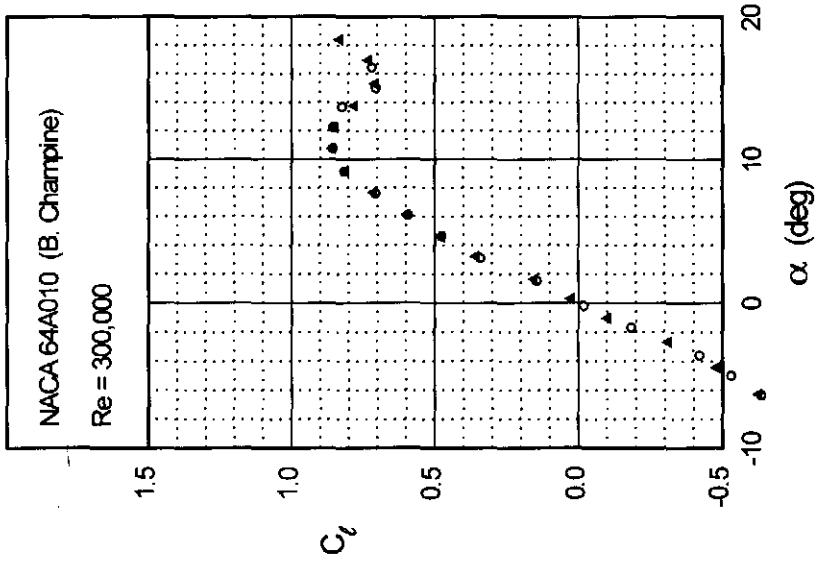

NACA 64A010 (B. Champine)
Re = 50,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

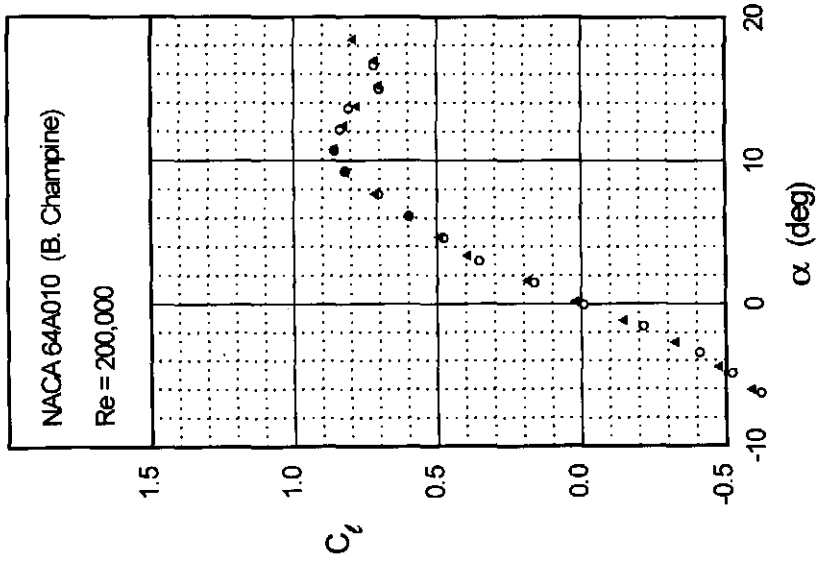
Fig. 4.73 (continued)

NACA 64A010

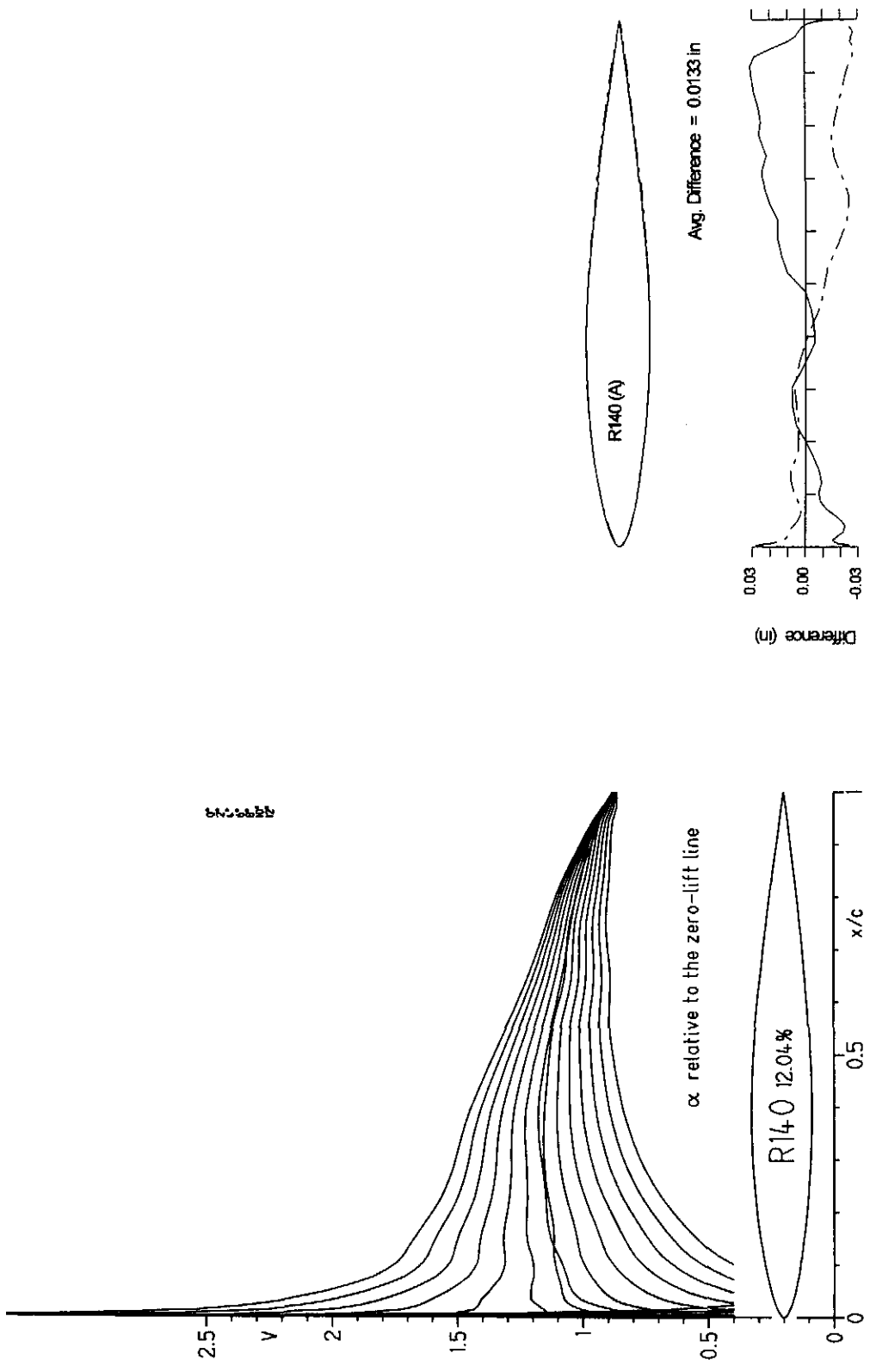


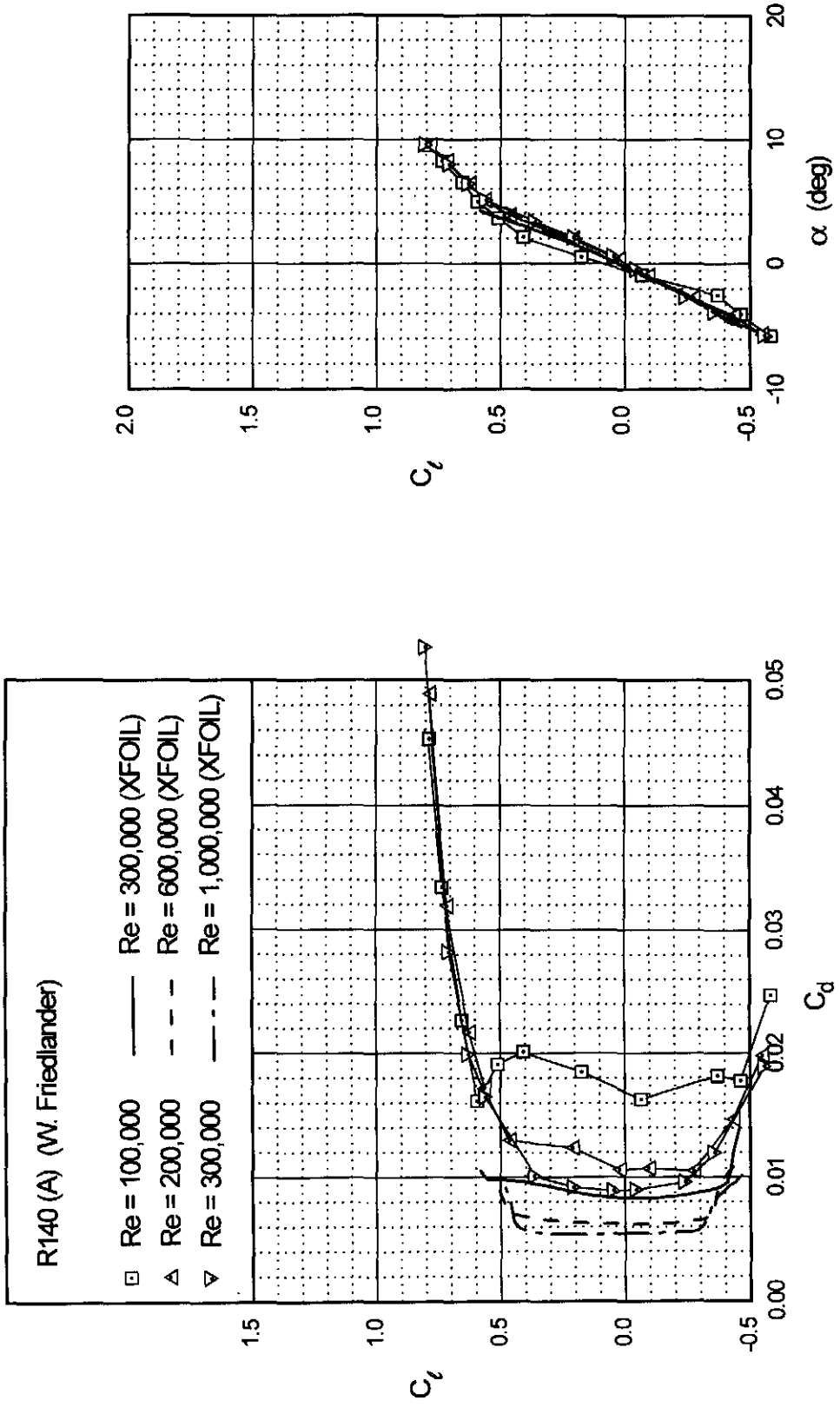

NACA 64A010 (B. Champine)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


NACA 64A010 (B. Champine)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

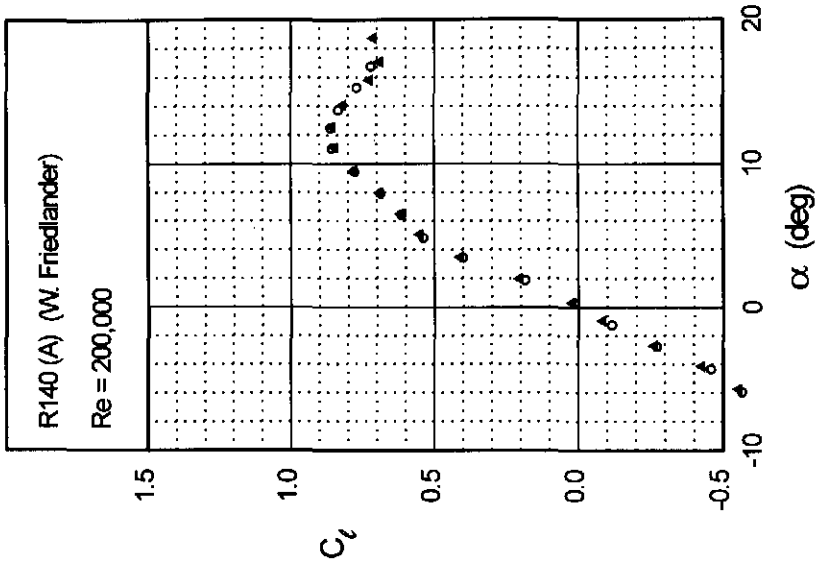
R140 (A)

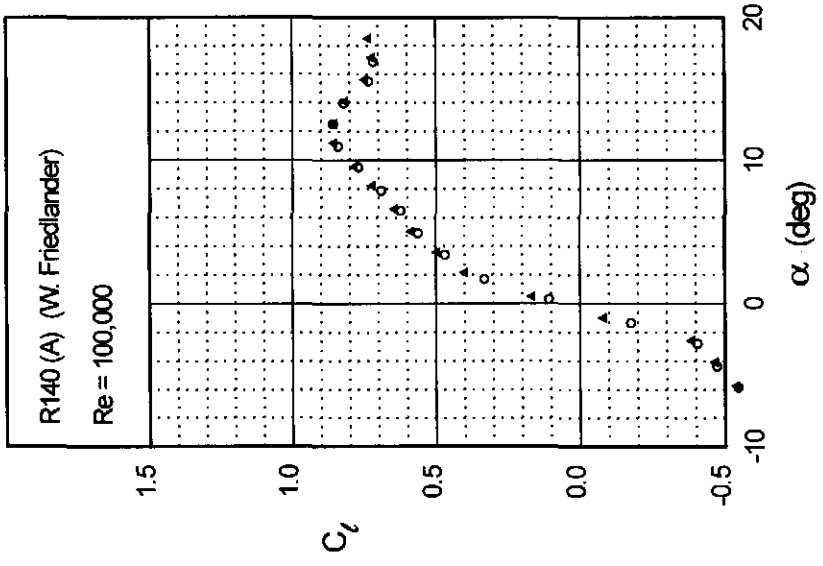

R140 (A)
Avg. Difference = 0.0133 in
0.03
0.00
-0.03
Difference (in)
α relative to the zero-lift line
R140 12.04%
x/c
0
0.5
0
2.5
2
1.5
1
0.5

R140 (A)

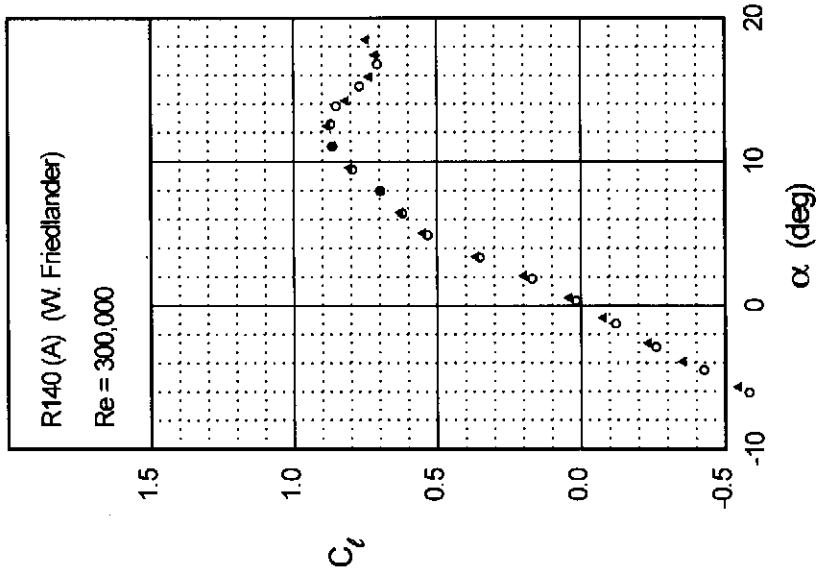

R140 (A) (W. Friedlander)
Re = 100,000
Re = 200,000
Re = 300,000
Re = 300,000 (XFOIL)
Re = 600,000 (XFOIL)
Re = 1,000,000 (XFOIL)
$C_l$
$C_d$
$\alpha$ (deg)

R140 (A)

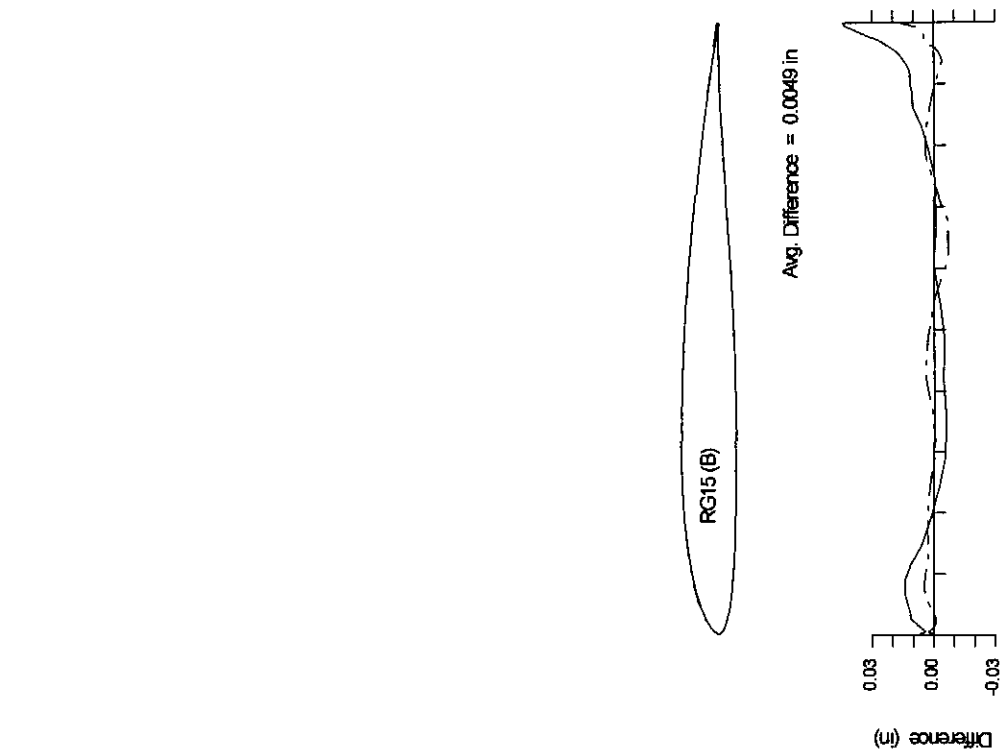

R140 (A) (W. Friedlander)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

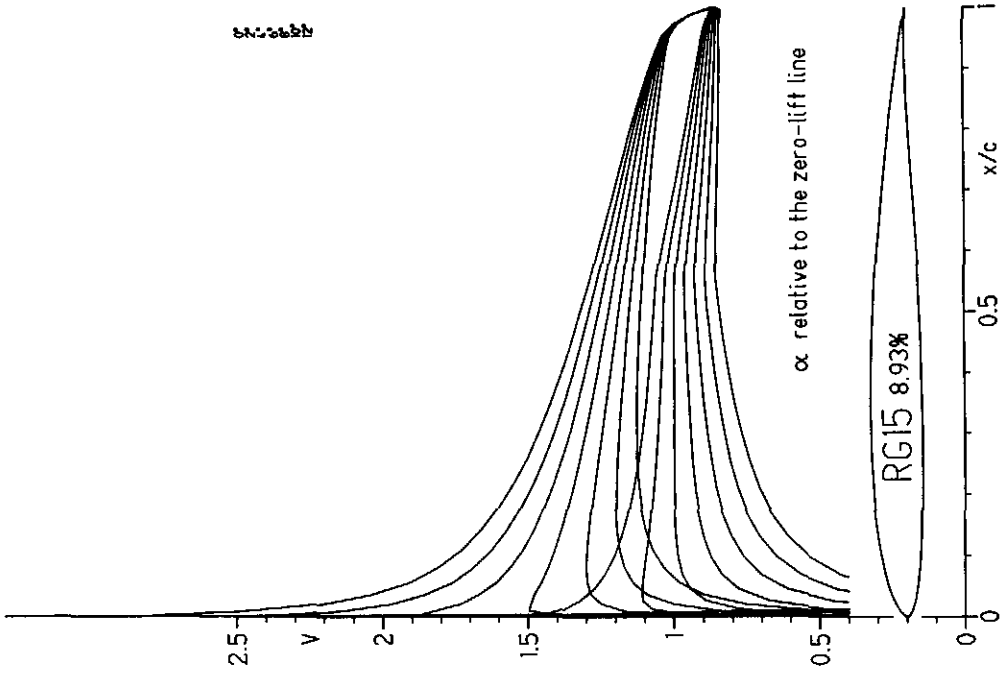

R140 (A) (W. Friedlander)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

R140 (A)

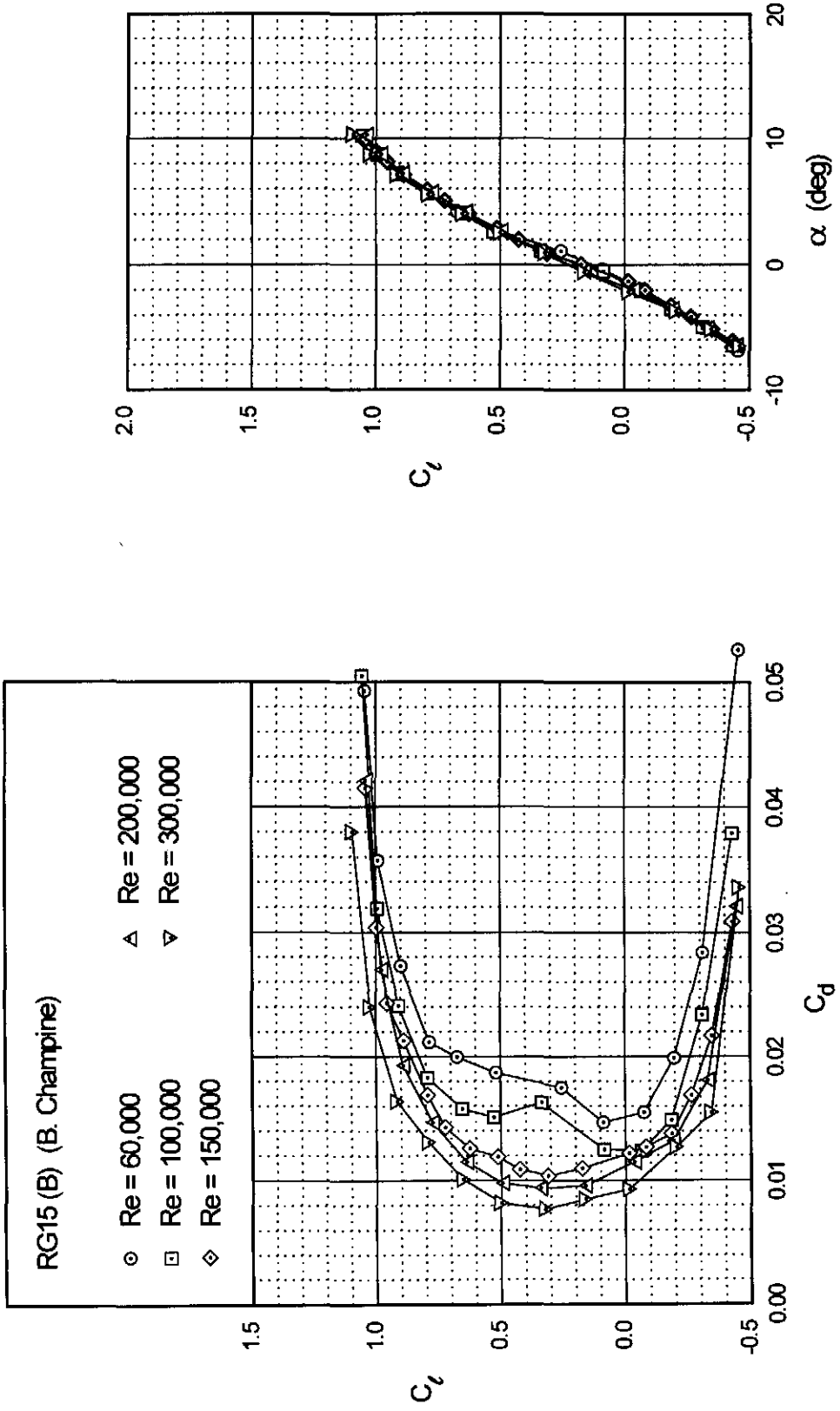


RG15 (B)

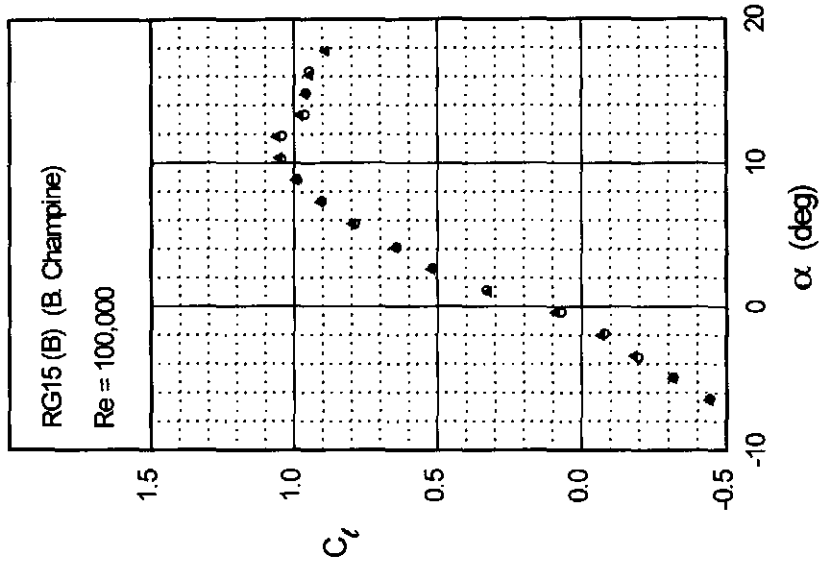

RG15 (B)
Avg. Difference = 0.0049 in
0.03
0.00
-0.03
Difference (in)

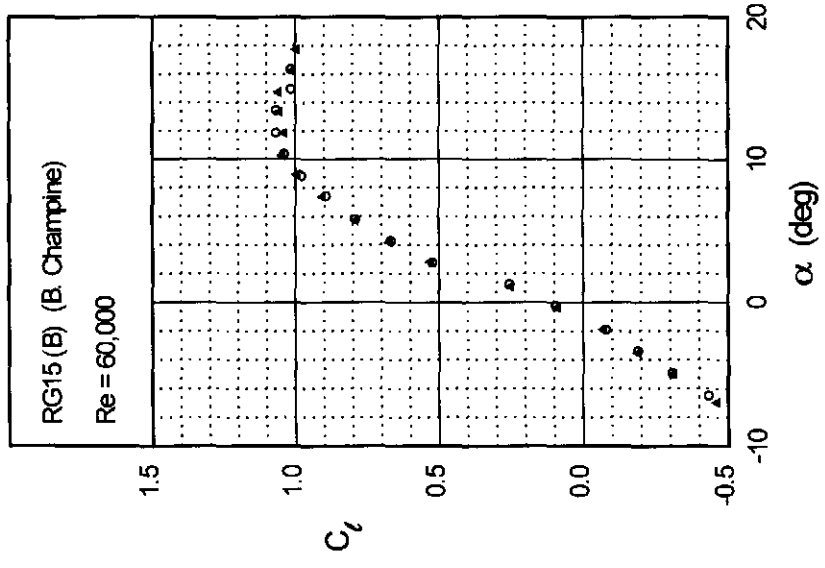

α relative to the zero-lift line
RG15 8.93%
2.5
2
1.5
1
0.5
V
0
0.5
1
x/c

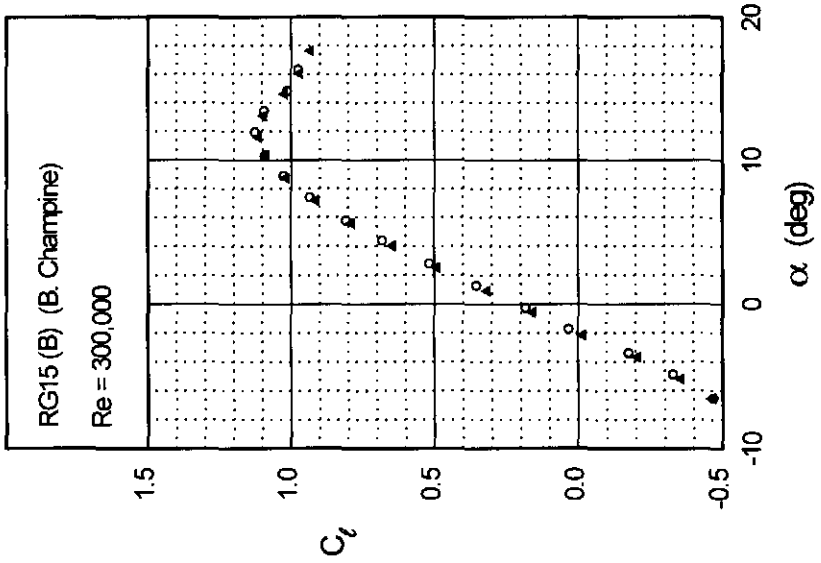
RG15 (B)

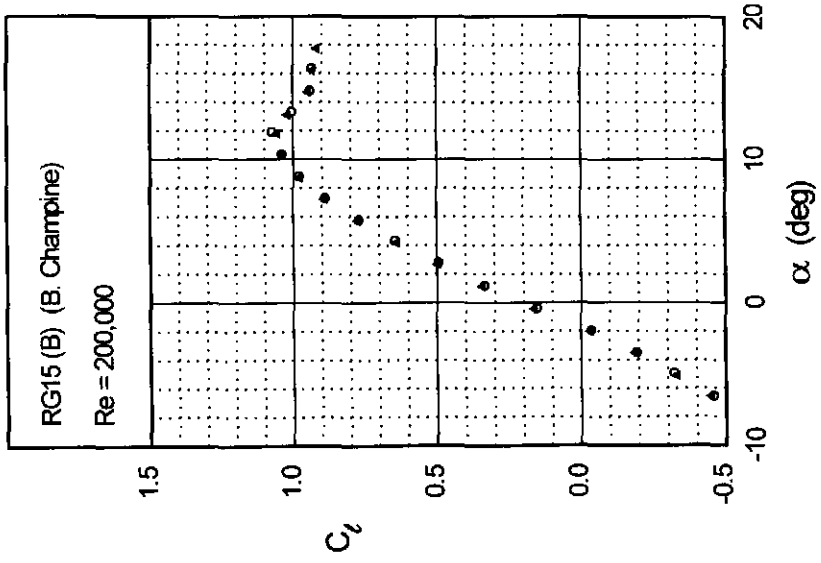

RG15 (B) (B. Champine)
Re = 60,000
Re = 100,000
Re = 150,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
$\alpha$ (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
20
10
0
-10
0.05
0.04
0.03
0.02
0.01
0.00

RG15 (B)

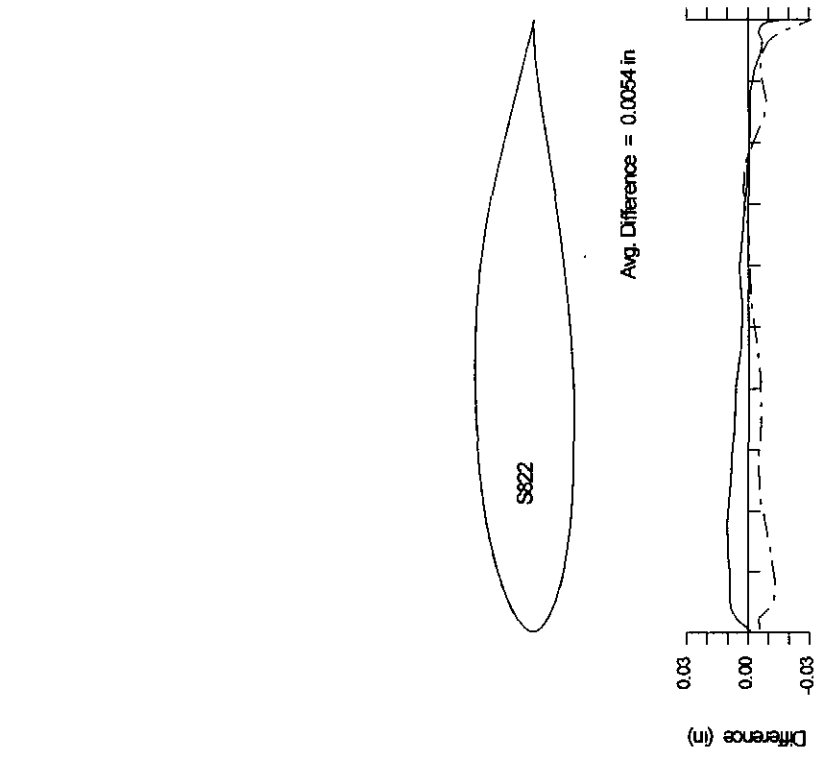

RG15 (B) (B. Champine)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

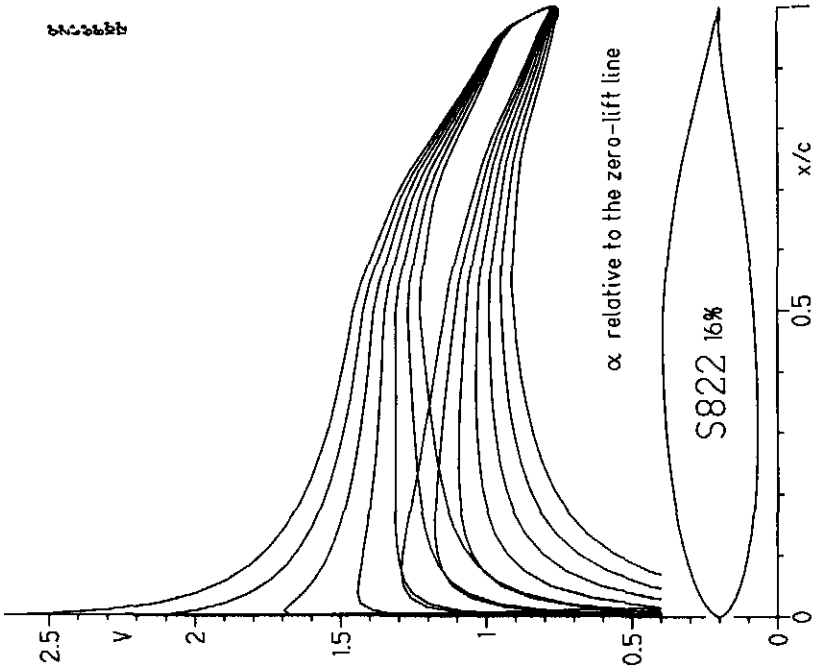

RG15 (B) (B. Champine)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


RG15 (B) (B. Champine)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

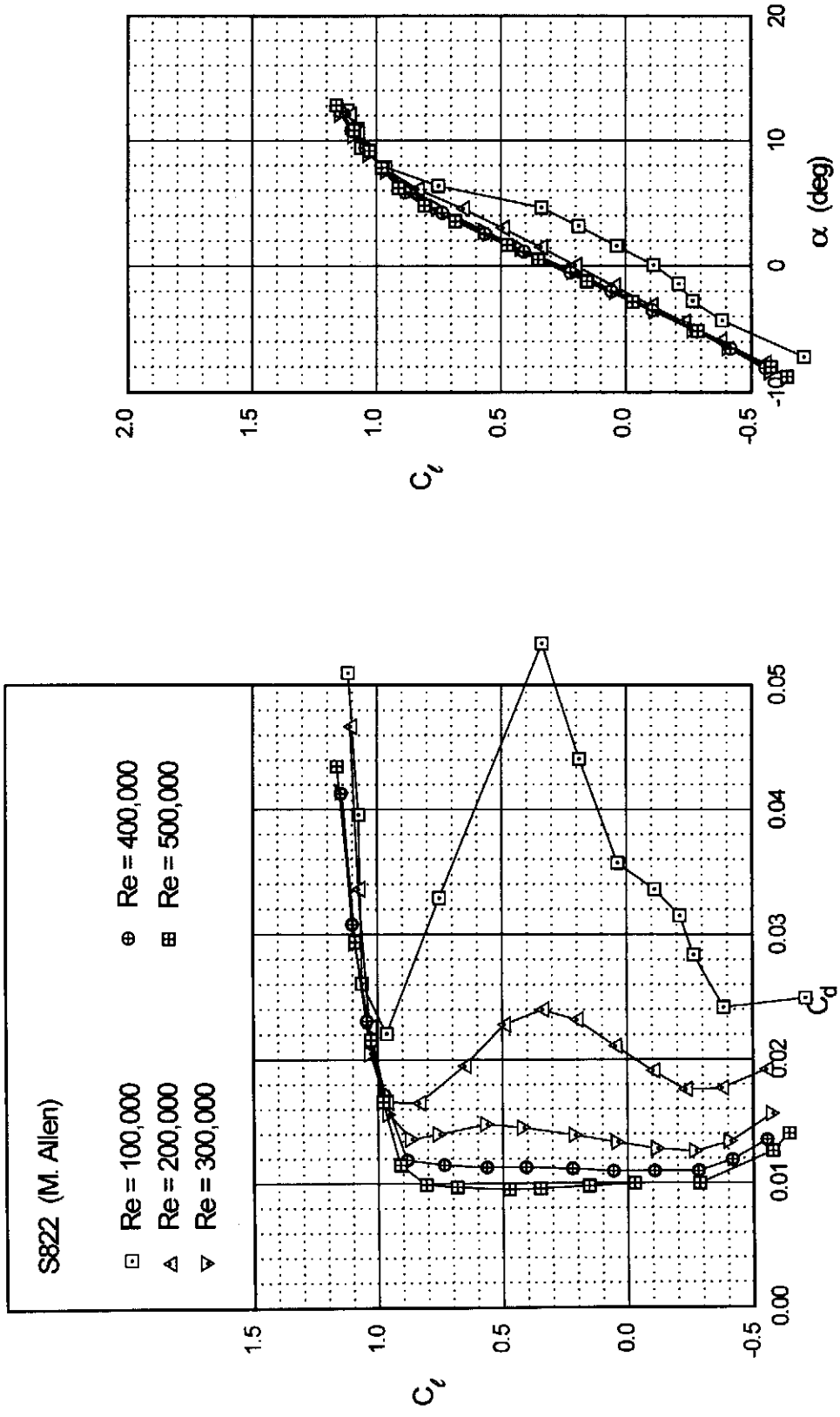

RG15 (B) (B. Champine)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

S822

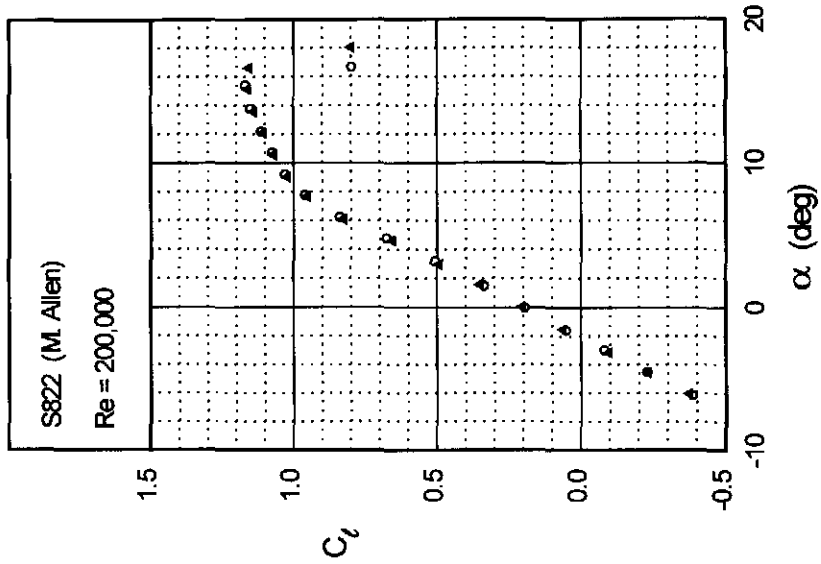

S822
Avg. Difference = 0.0054 in
0.03
0.00
-0.03
Difference (in)

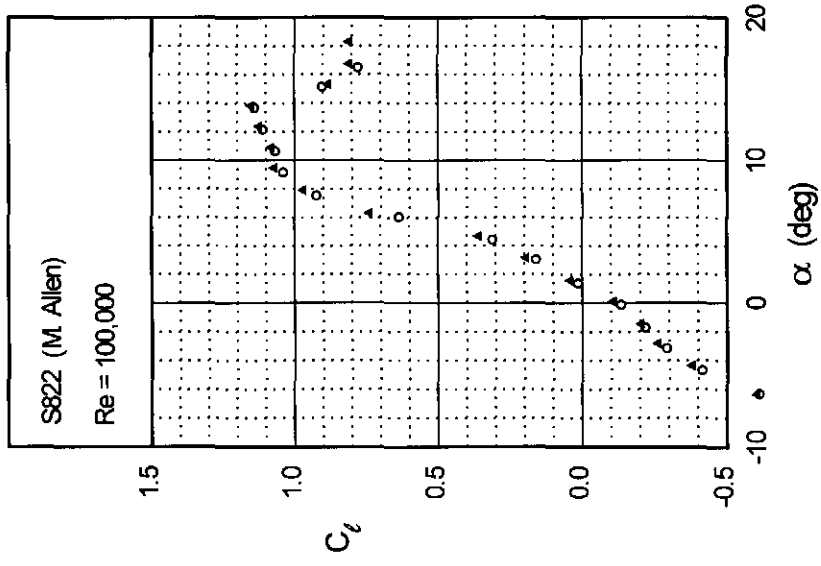

2.5
2
1.5
1
0.5
0
0.5
1
x/c
α relative to the zero-lift line
S822 16%

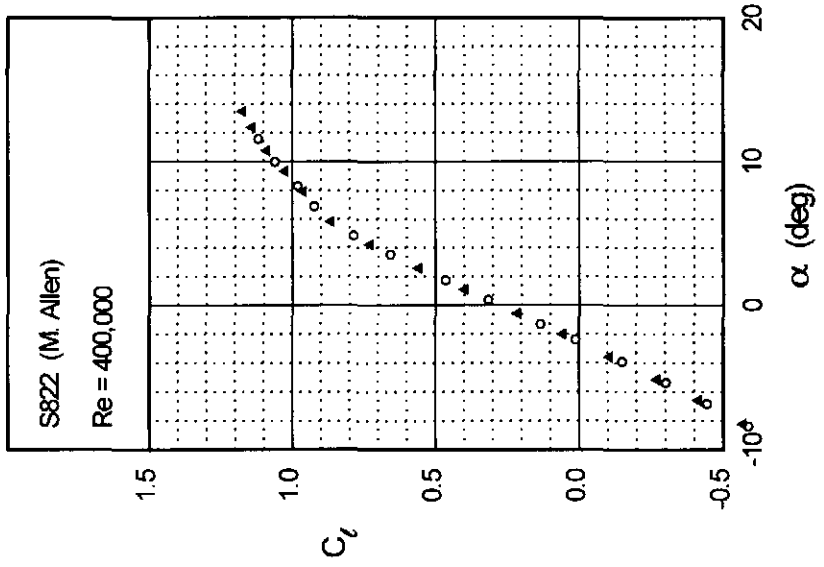
S822

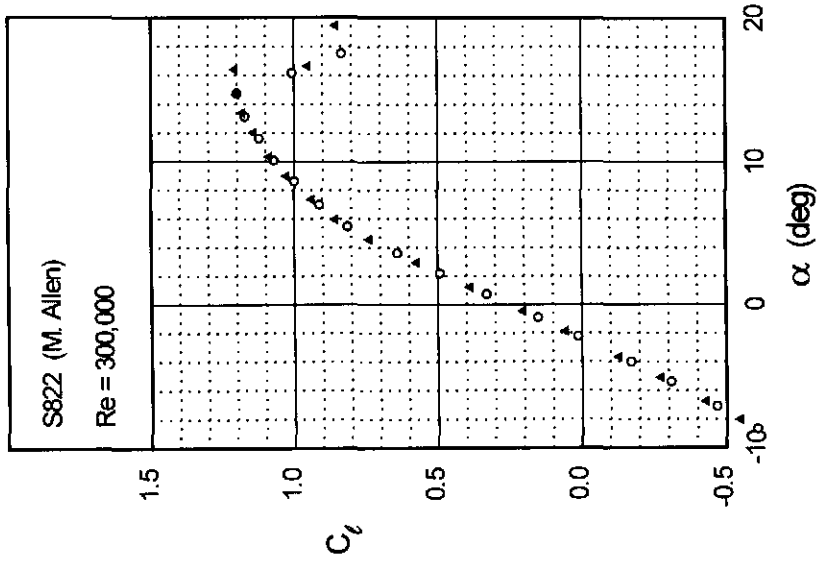

S822 (M. Allen)
Re = 100,000
Re = 200,000
Re = 300,000
Re = 400,000
Re = 500,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
20
10
0
-10
0.05
0.04
0.03
0.02
0.01
0.00

S822

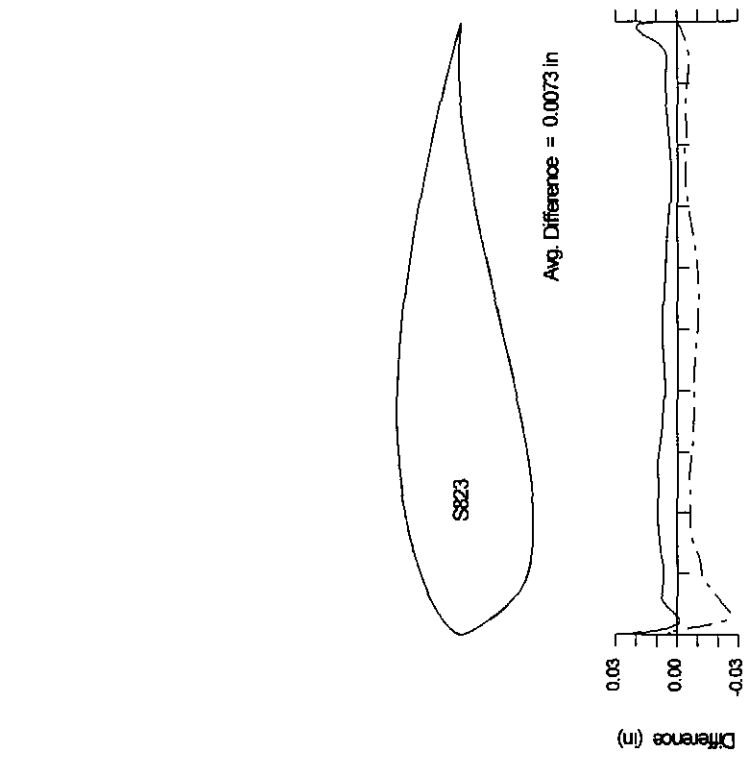

S822 (M. Allen)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

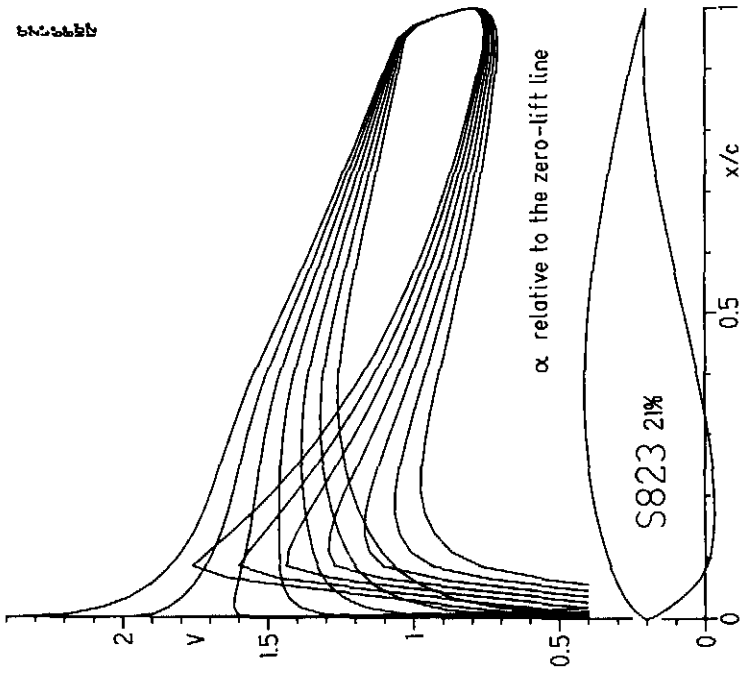

S822 (M. Allen)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


S822 (M. Allen)
Re = 400,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


S822 (M. Allen)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

S823


S823
Avg. Difference = 0.0073 in
0.03
0.00
-0.03
Difference (in)


α relative to the zero-lift line
2
1.5
1
0.5
V
S823 21%
0
0.5
1
x/c

S823

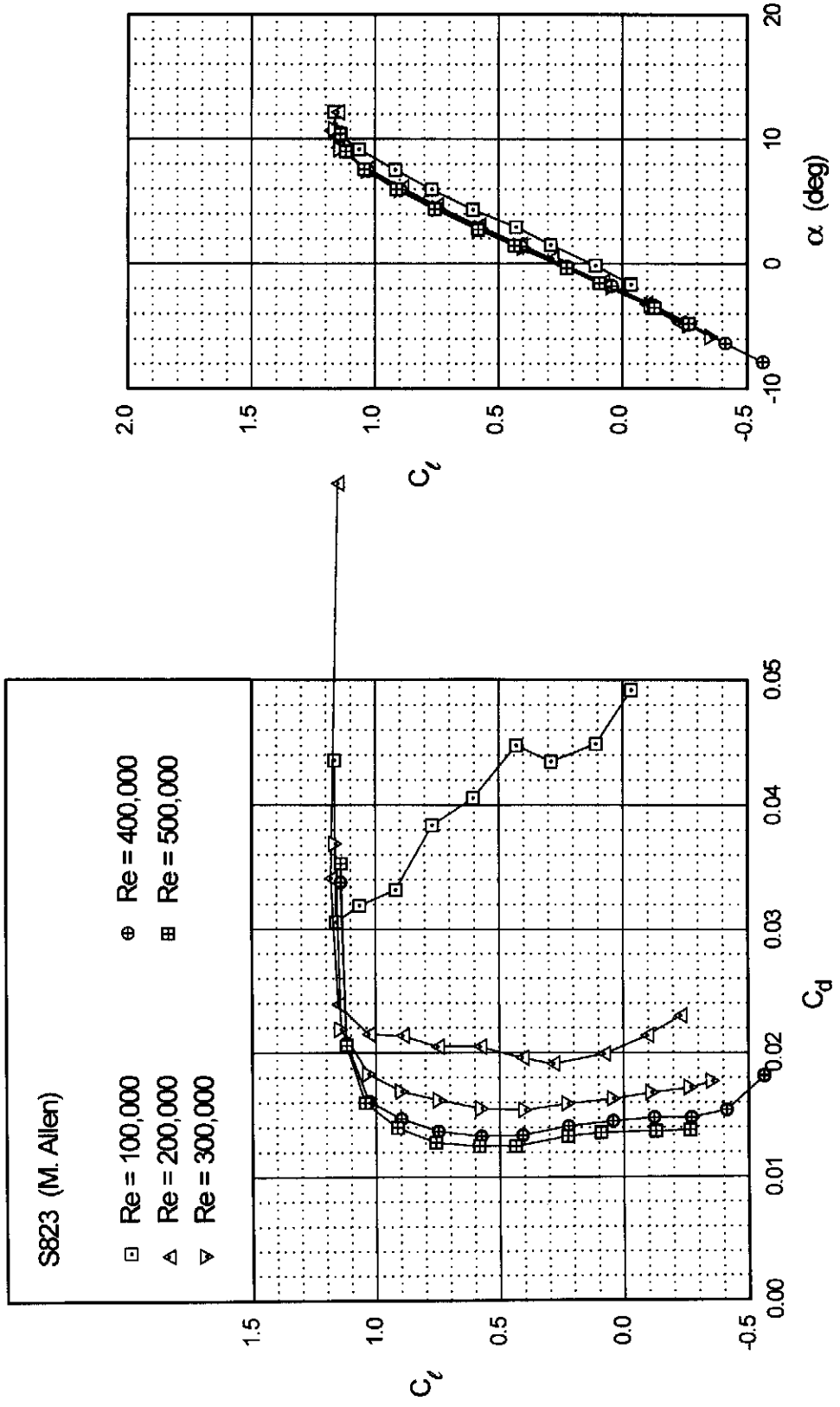
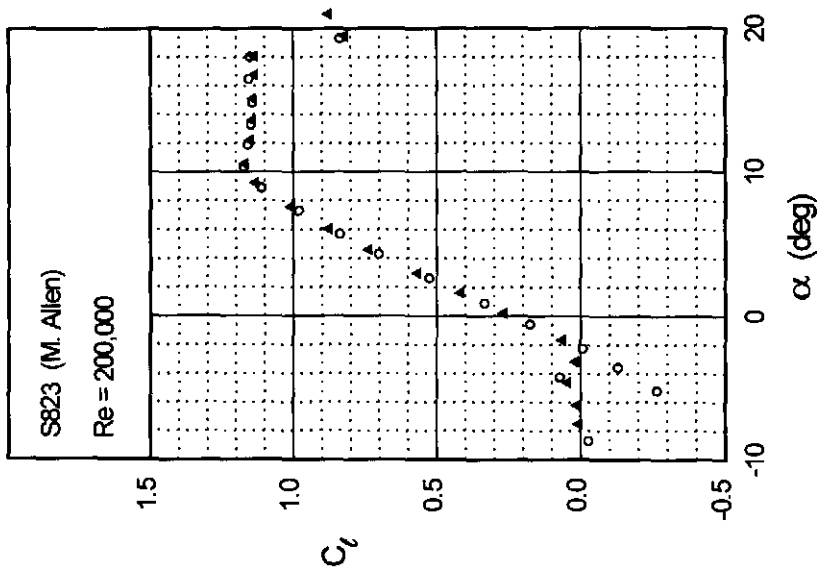
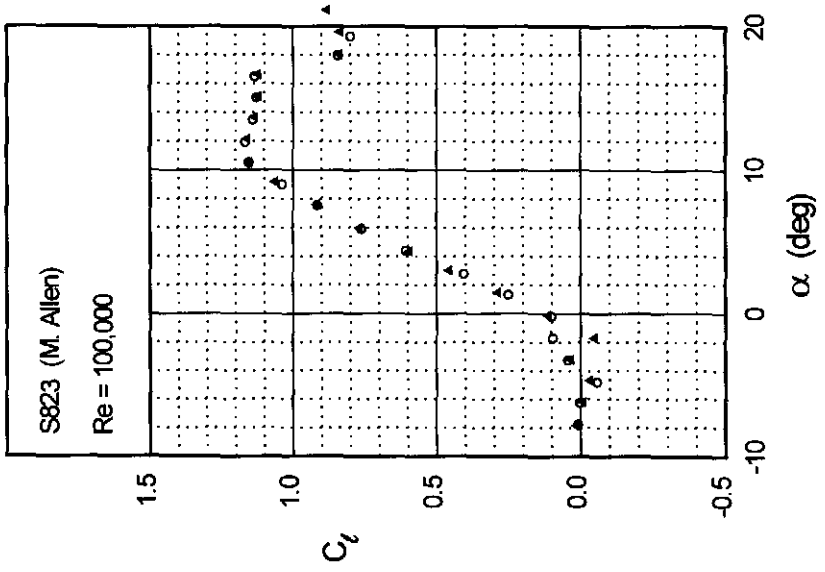
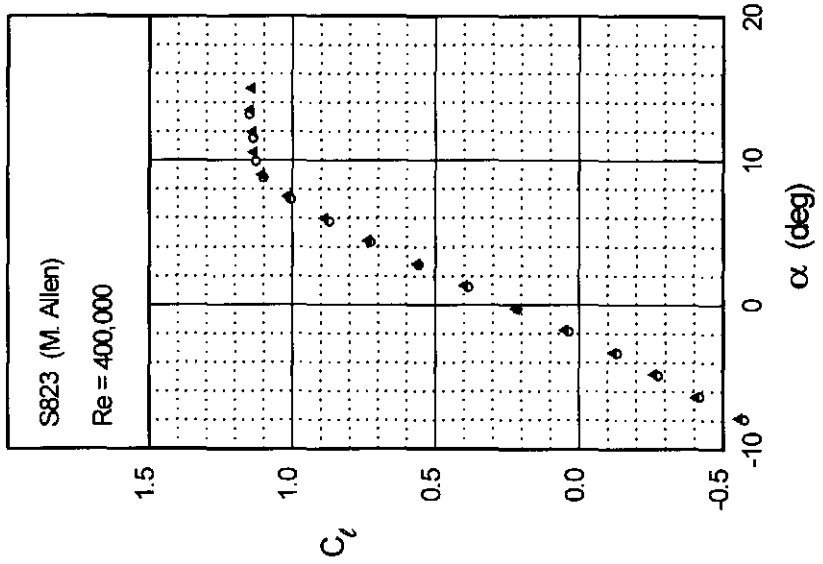

S823 (M. Allen)
Re = 100,000
Re = 200,000
Re = 300,000
Re = 400,000
Re = 500,000
$C_l$
$C_d$
$\alpha$ (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
0.05
0.04
0.03
0.02
0.01
0.00
20
10
0
-10

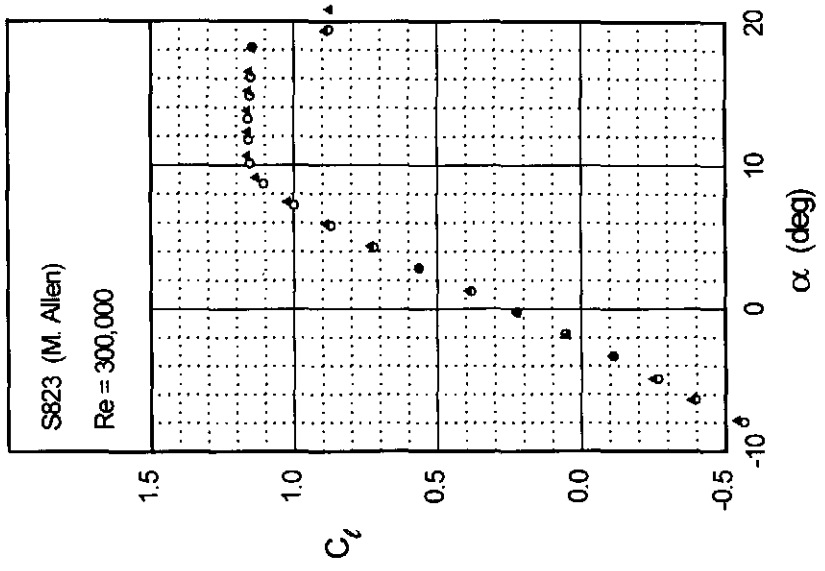
Fig. 4.89

S823

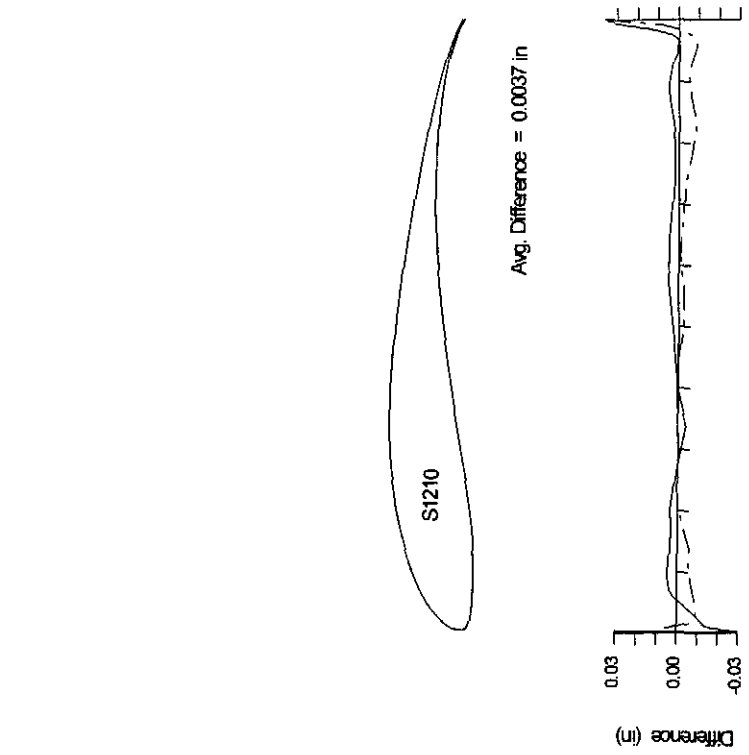

S823 (M. Allen)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

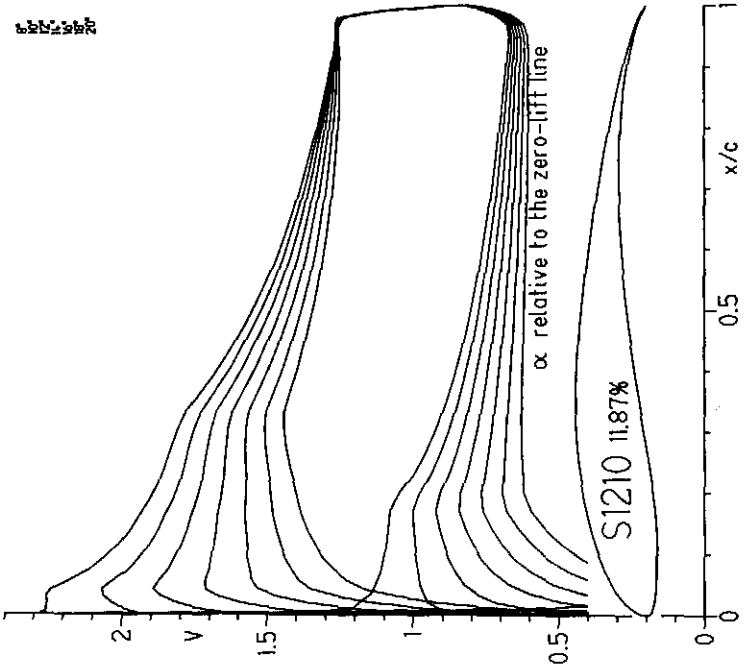

S823 (M. Allen)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


S823 (M. Allen)
Re = 400,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

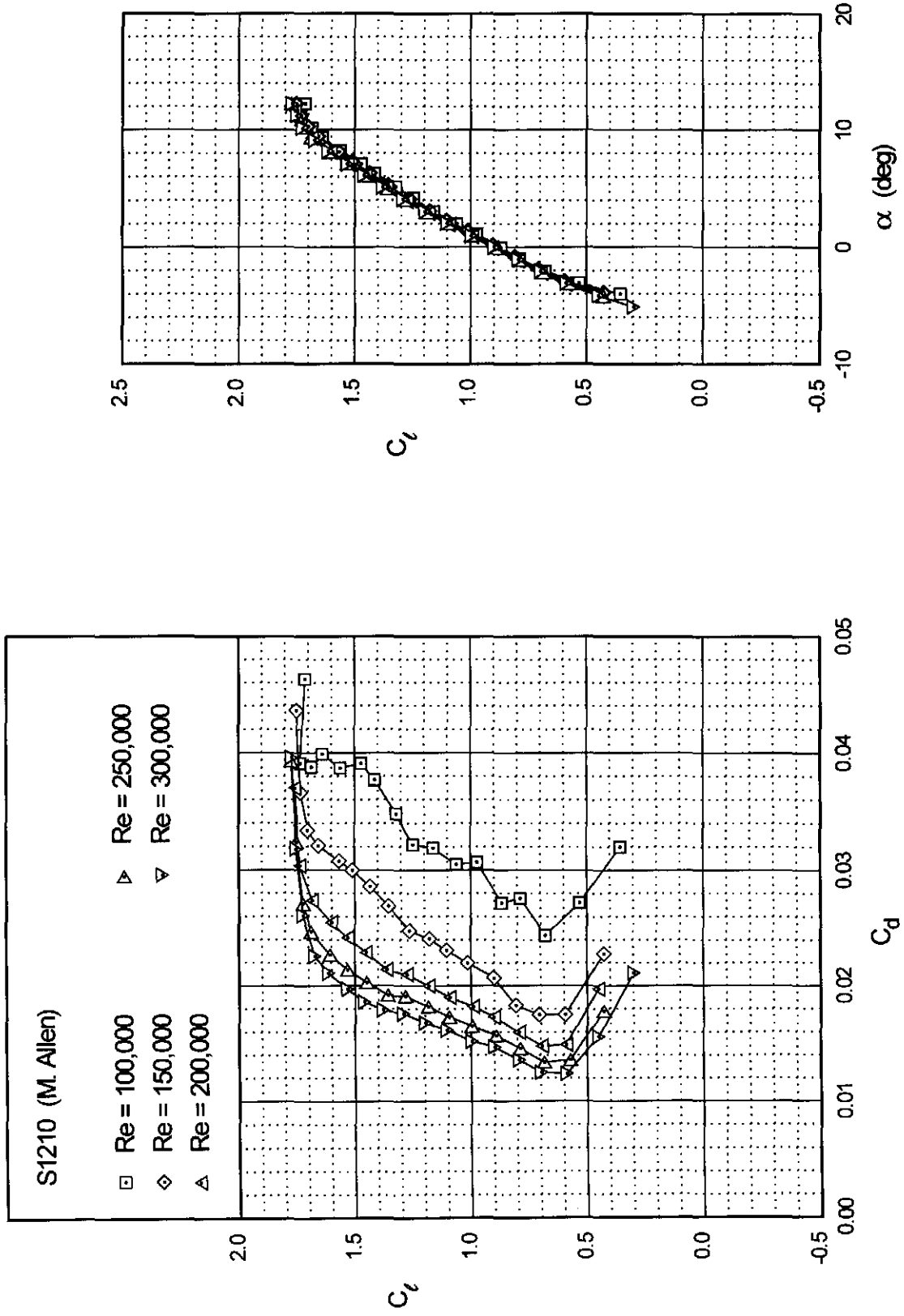

S823 (M. Allen)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

S1210

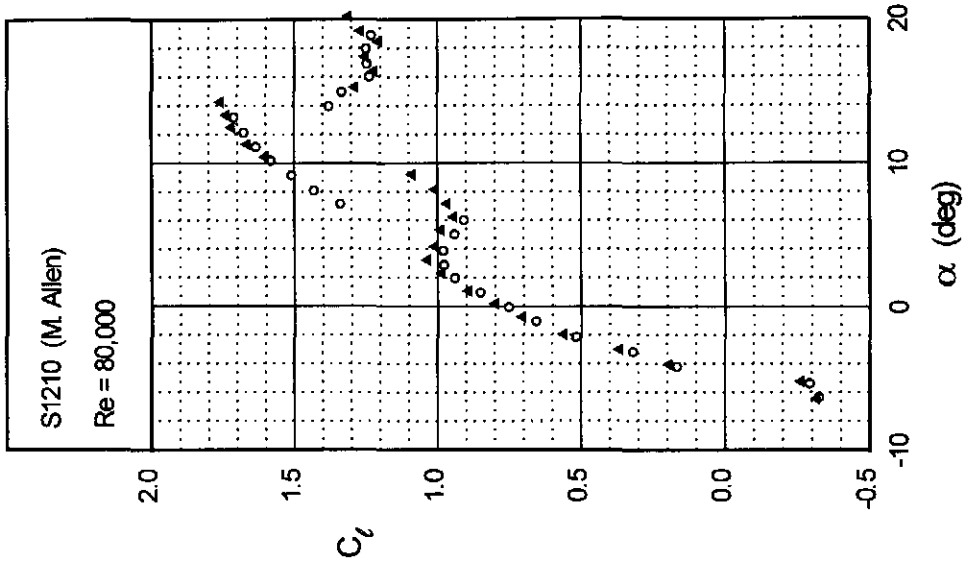

S1210
Avg. Difference = 0.0037 in
0.03
0.00
-0.03
Difference (in)

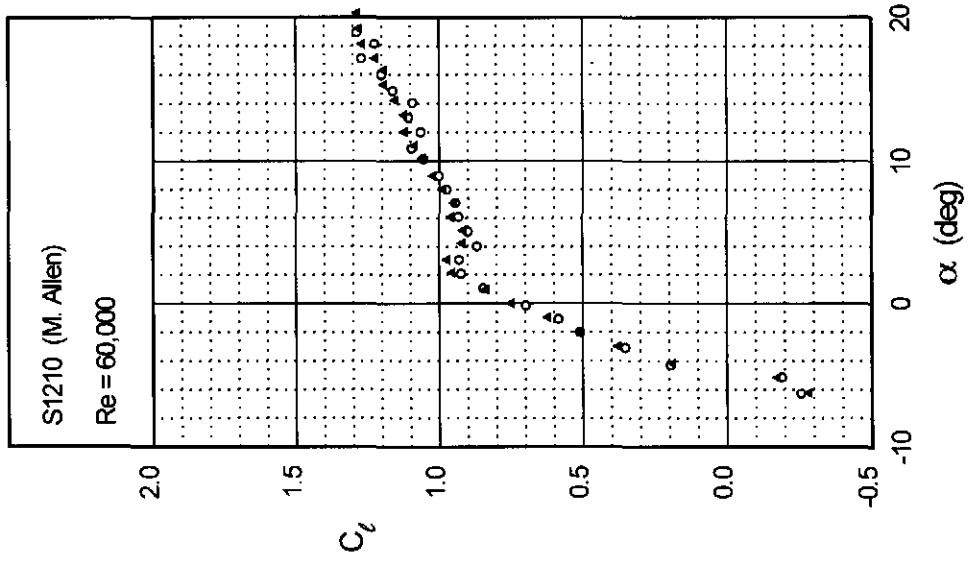

α relative to the zero-lift line
S1210 11.87%
2
1.5
1
0.5
0
0.5
1
x/c

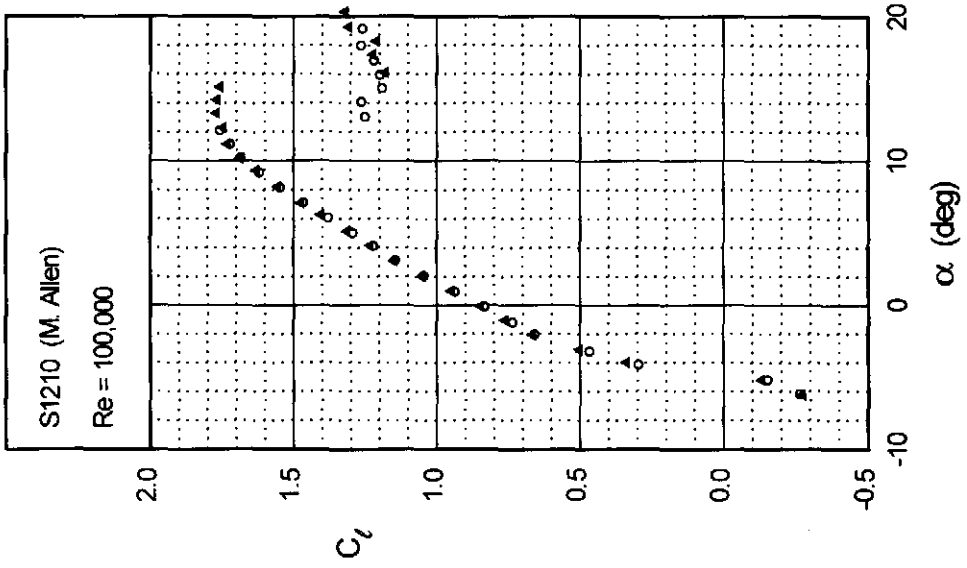
S1210


S1210 (M. Allen)
Re = 100,000
Re = 150,000
Re = 200,000
Re = 250,000
Re = 300,000
$C_l$
$C_d$
$C_l$
α (deg)

S1210


S1210 (M. Allen)
Re = 80,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


S1210 (M. Allen)
Re = 60,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


S1210 (M. Allen)
Re = 100,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

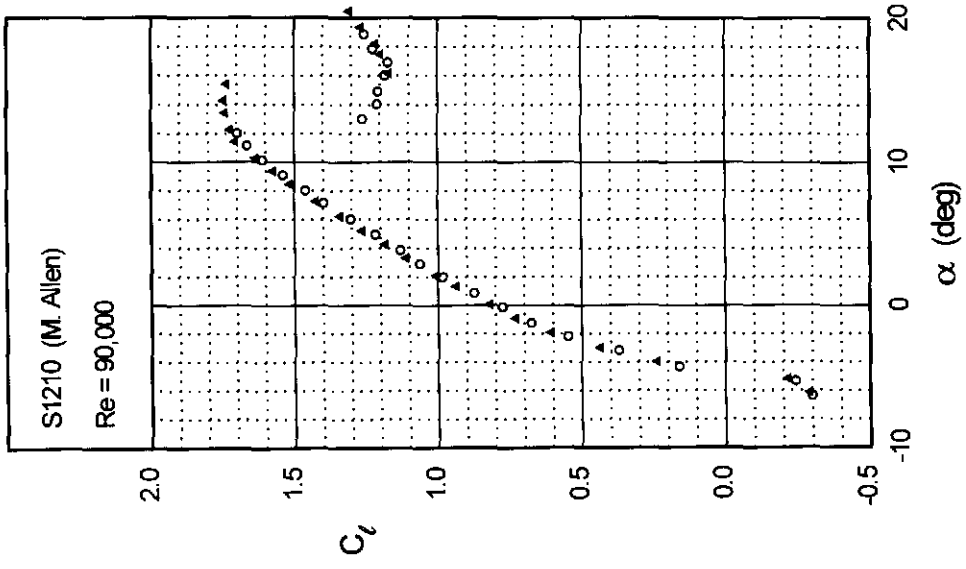
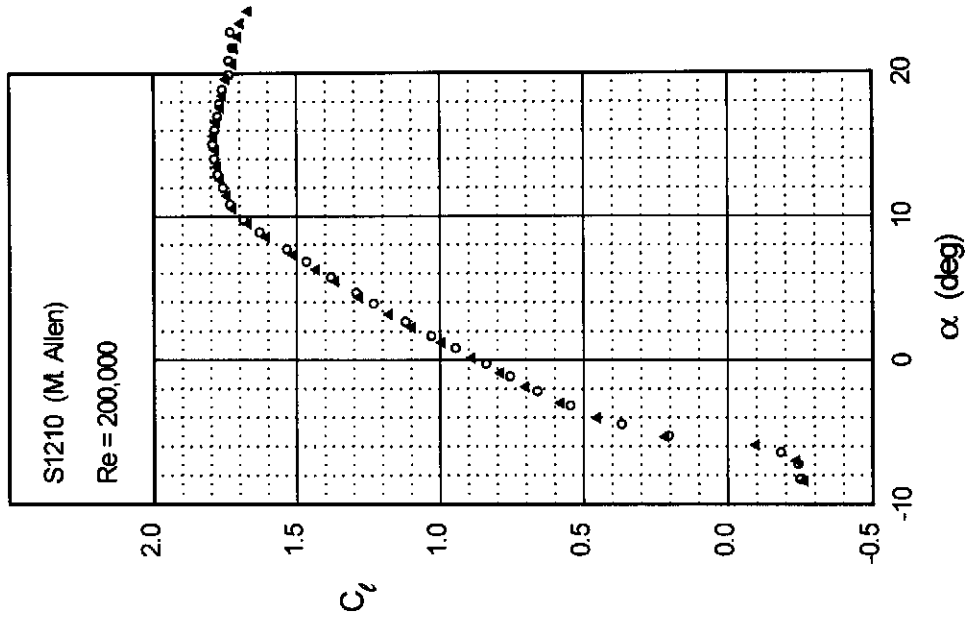
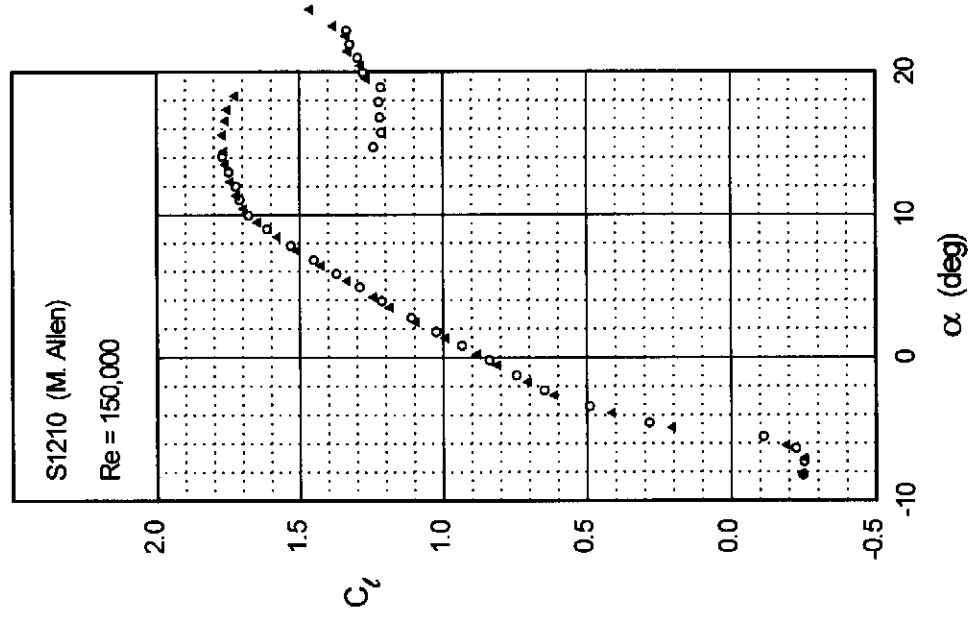
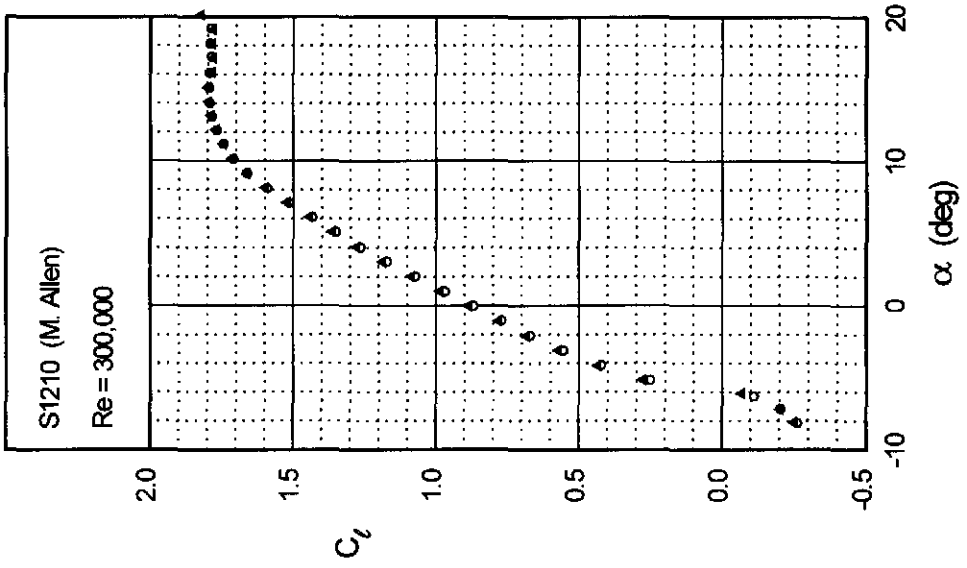

S1210 (M. Allen)
Re = 90,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

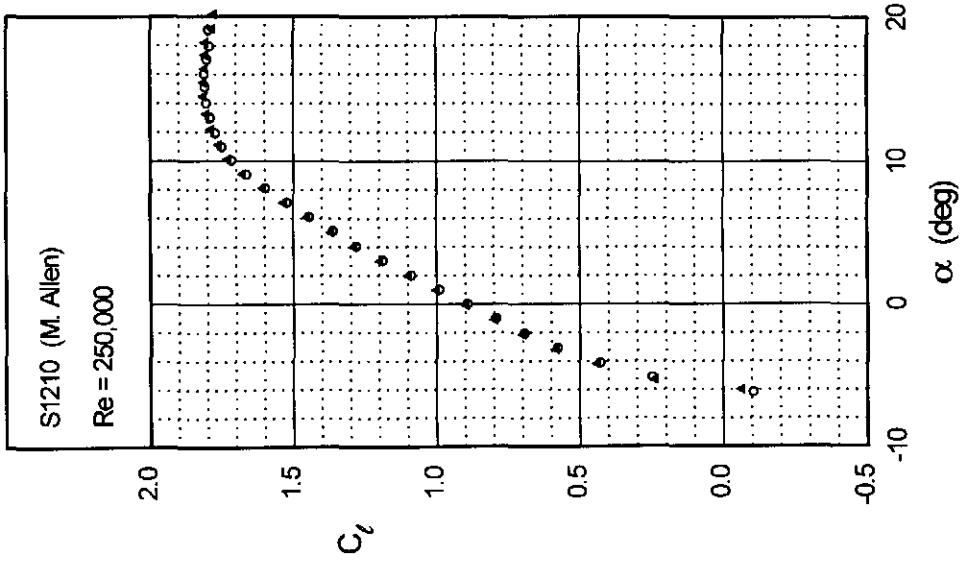
Fig. 4.93 (continued)

S1210

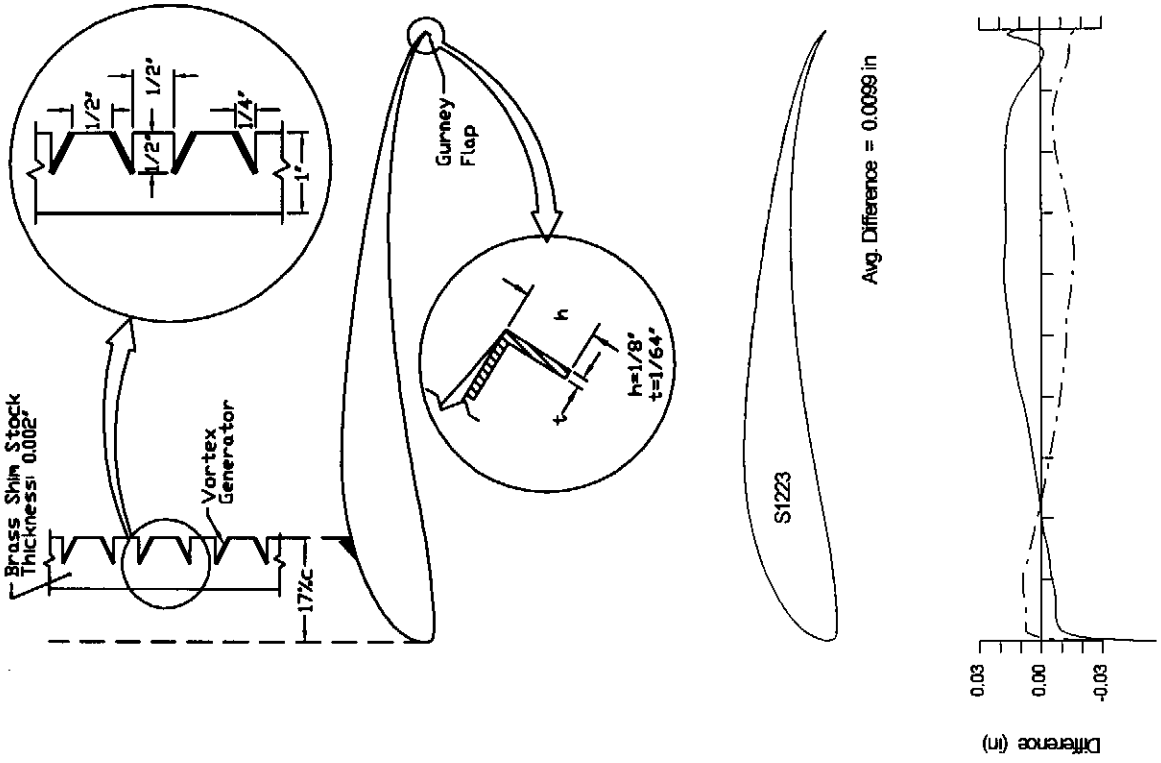


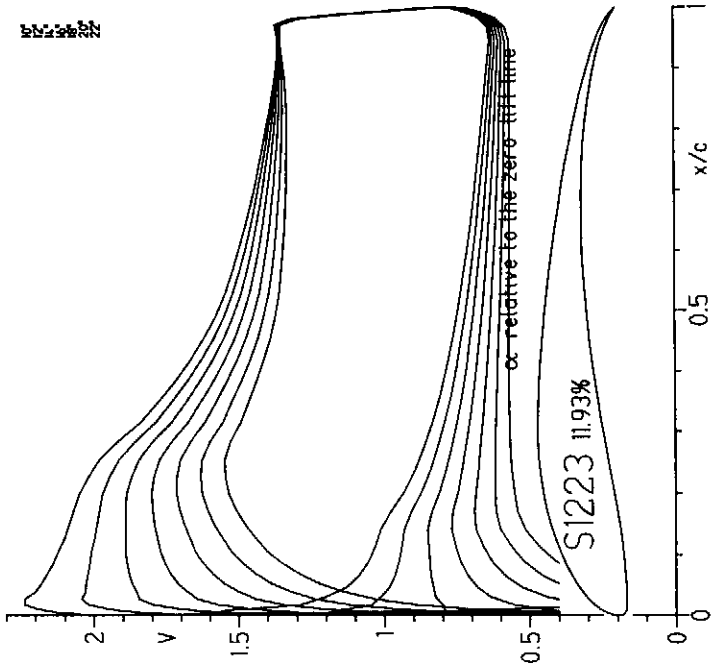




S1210 (M. Allen)
Re = 300,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

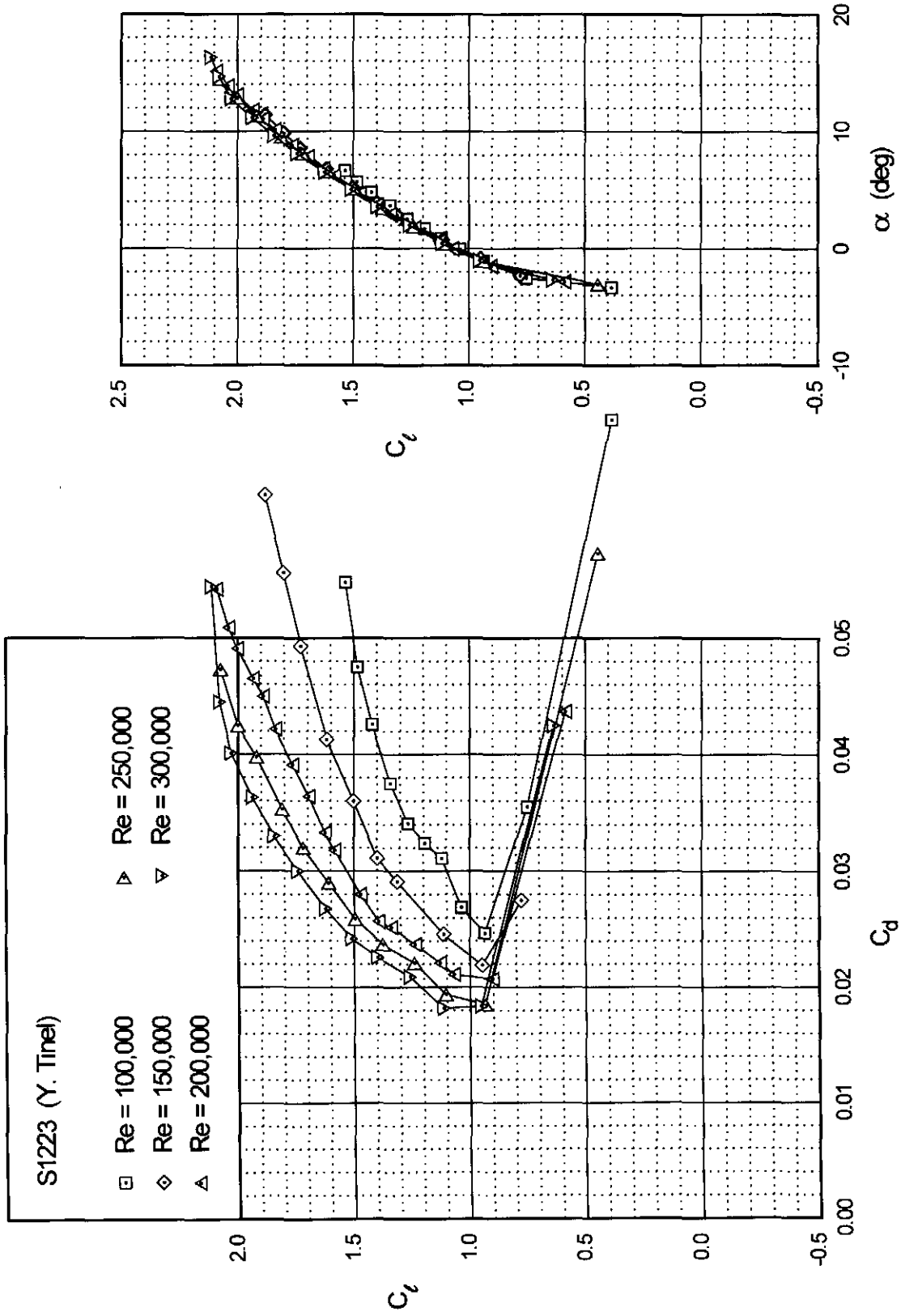

S1210 (M. Allen)
Re = 250,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

S1223

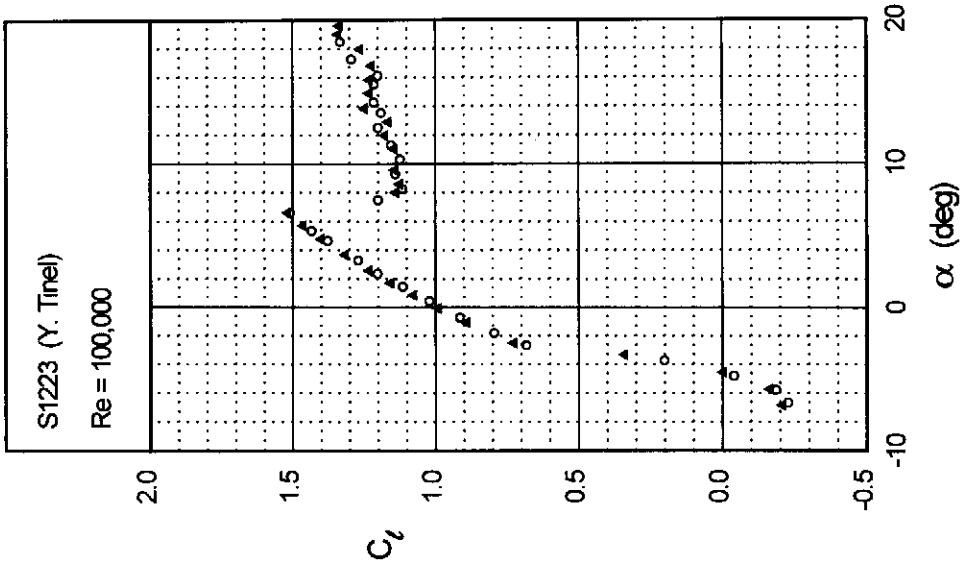

1/2"
1/2"
1/2"
1/4"
1"
Brass Shim Stock
Thickness= 0.002"
Vortex
Generator
17%c
Gurney
Flap
h
t
h=1/8"
t=1/64"
S1223
Avg. Difference = 0.0099 in
0.03
0.00
-0.03
Difference (in)

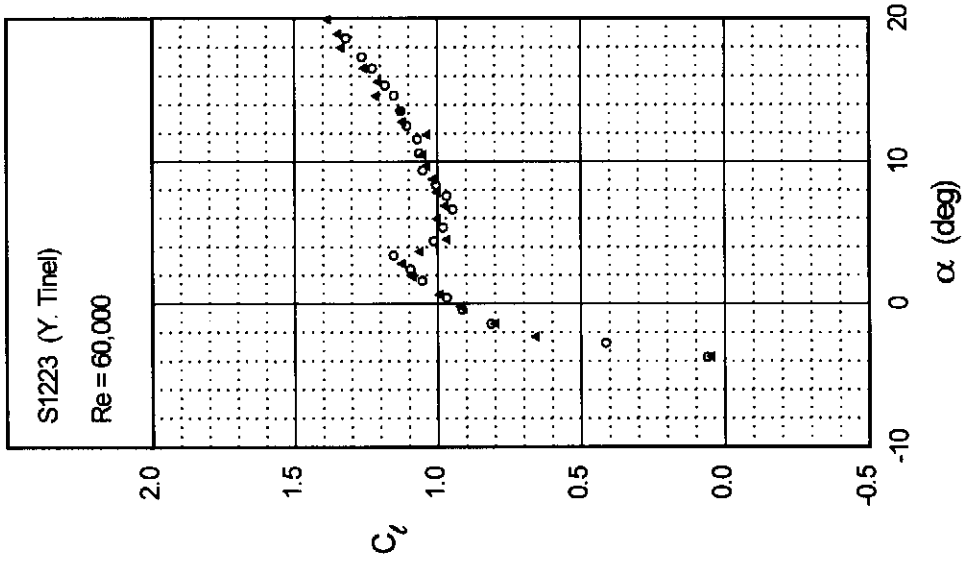

α relative to the zero lift line
S1223 11.93%
2
1.5
1
0.5
0
V
0
0.5
x/c

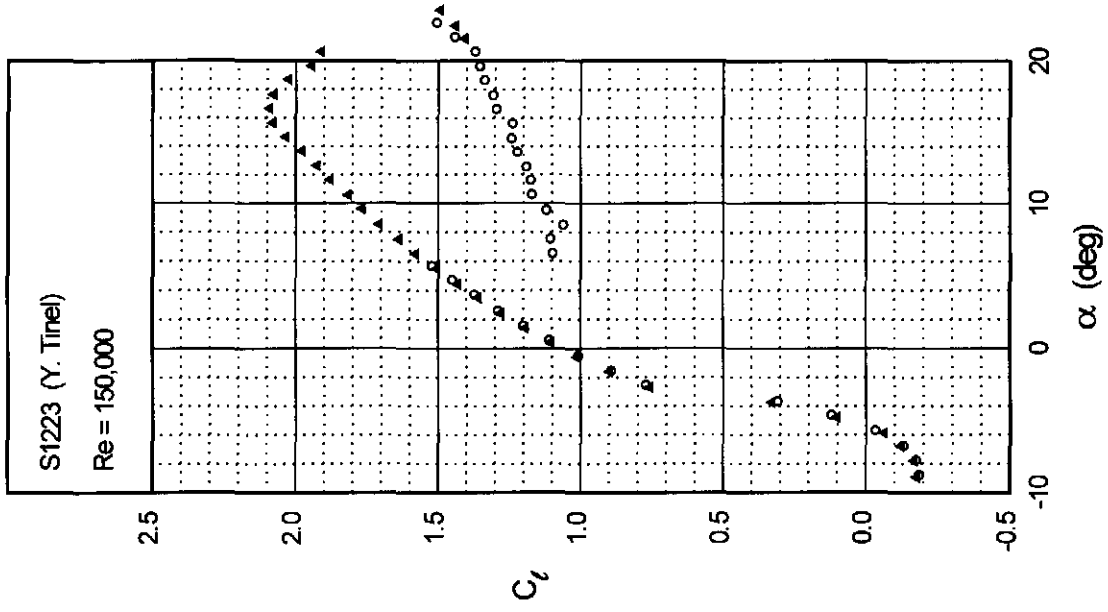
S1223


S1223 (Y. Tinel)
Re = 100,000
Re = 150,000
Re = 200,000
Re = 250,000
Re = 300,000
$C_l$
$C_d$
α (deg)

S1223


S1223 (Y. Tinel)
Re = 100,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


S1223 (Y. Tinel)
Re = 60,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


S1223 (Y. Tinel)
Re = 150,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

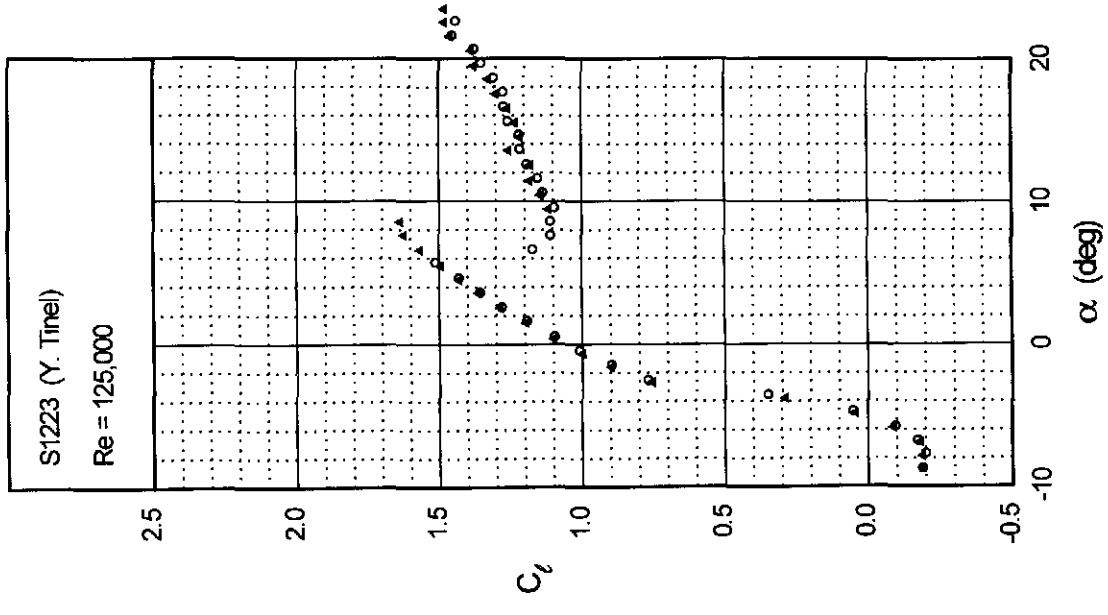
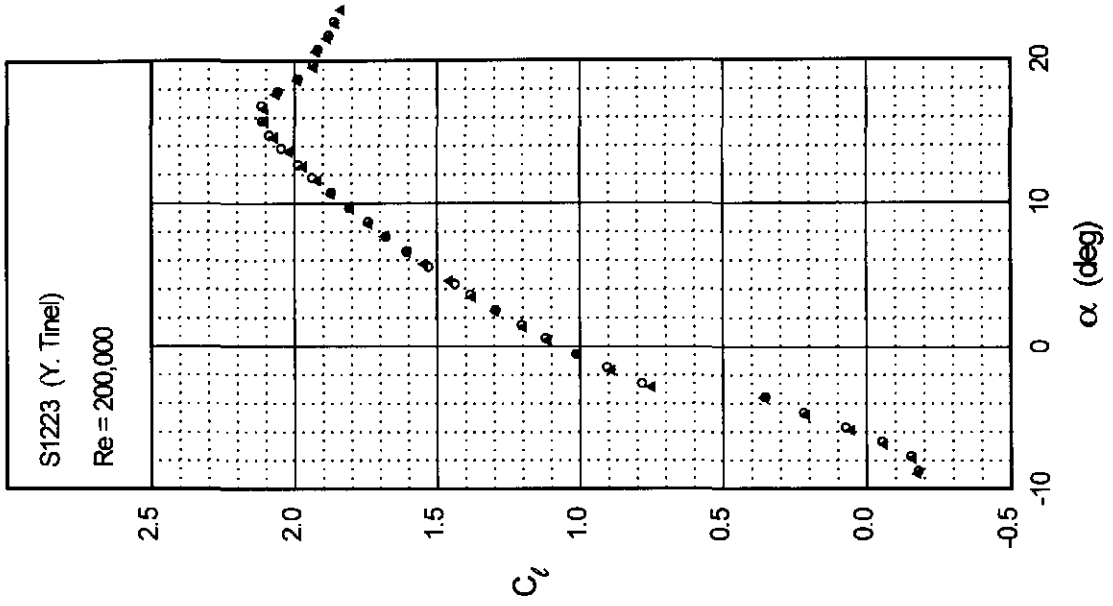
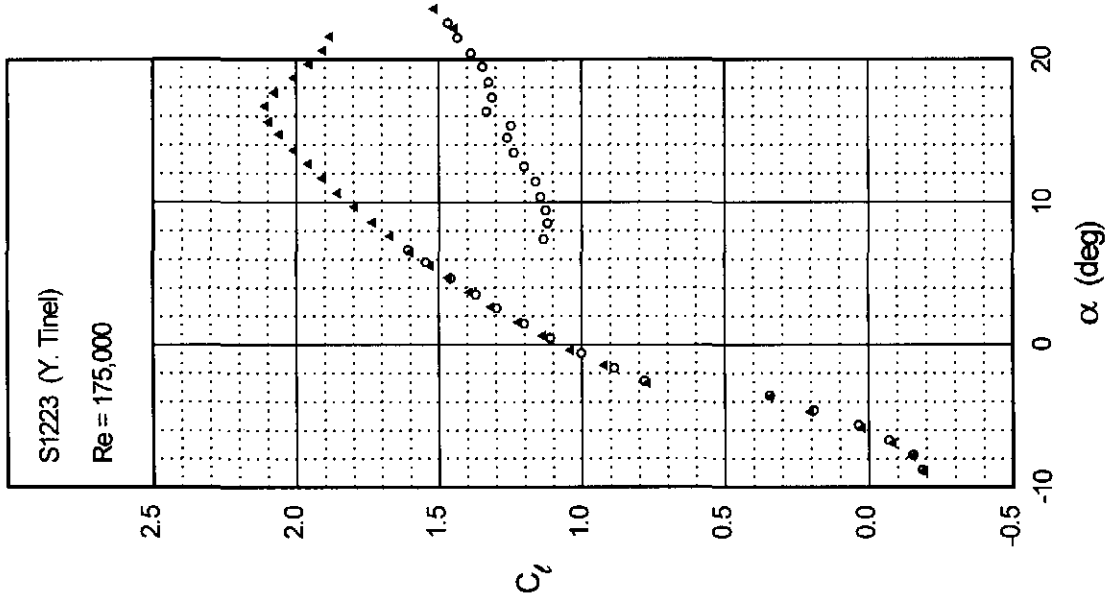
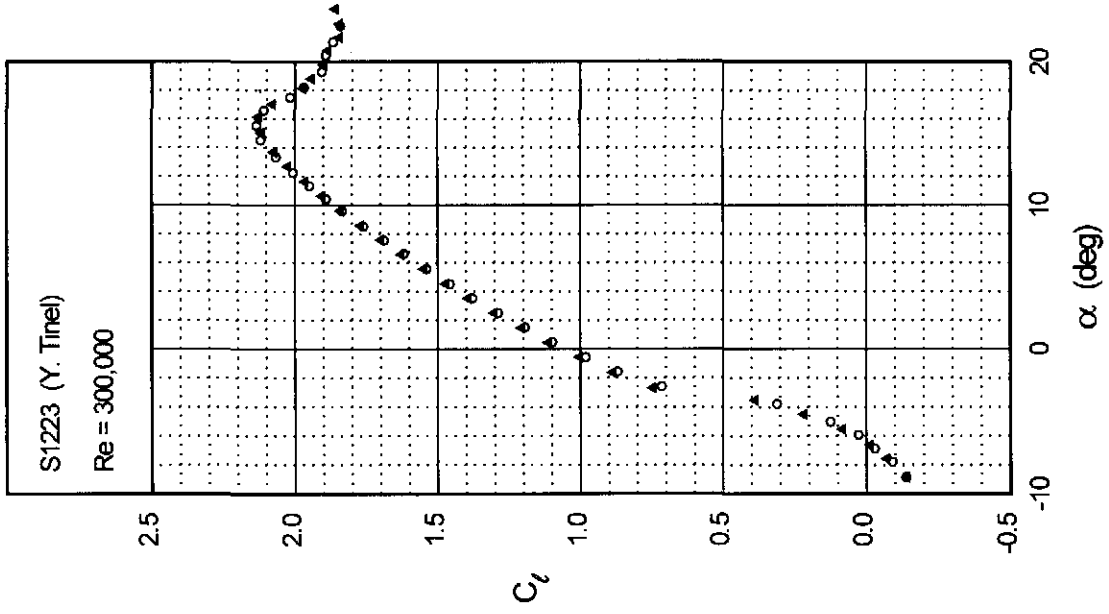

S1223 (Y. Tinel)
Re = 125,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

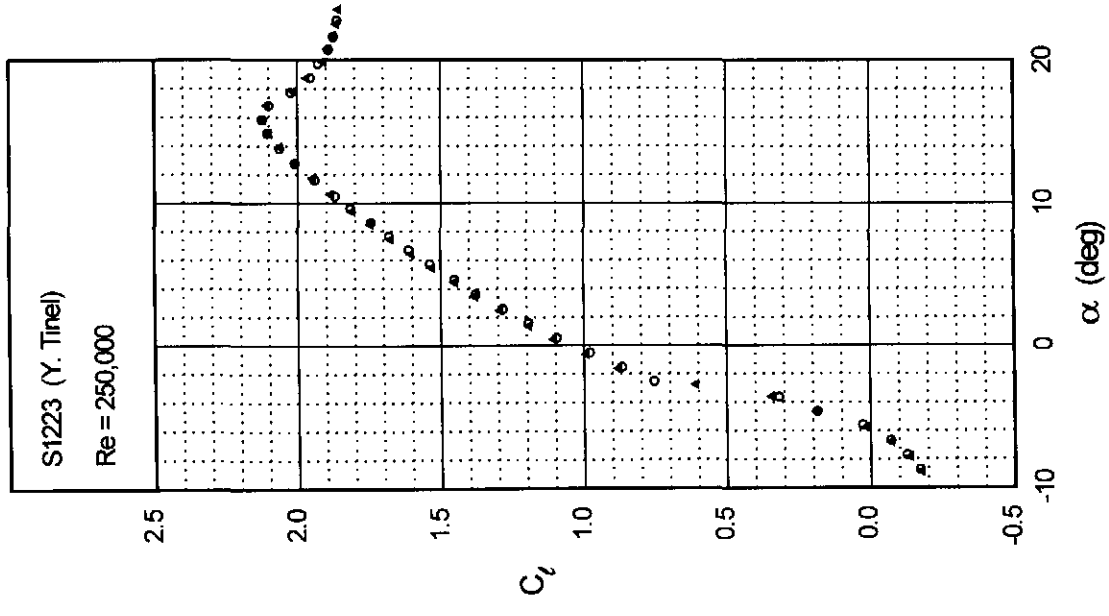
 Fig. 4.97 (continued)

S1223

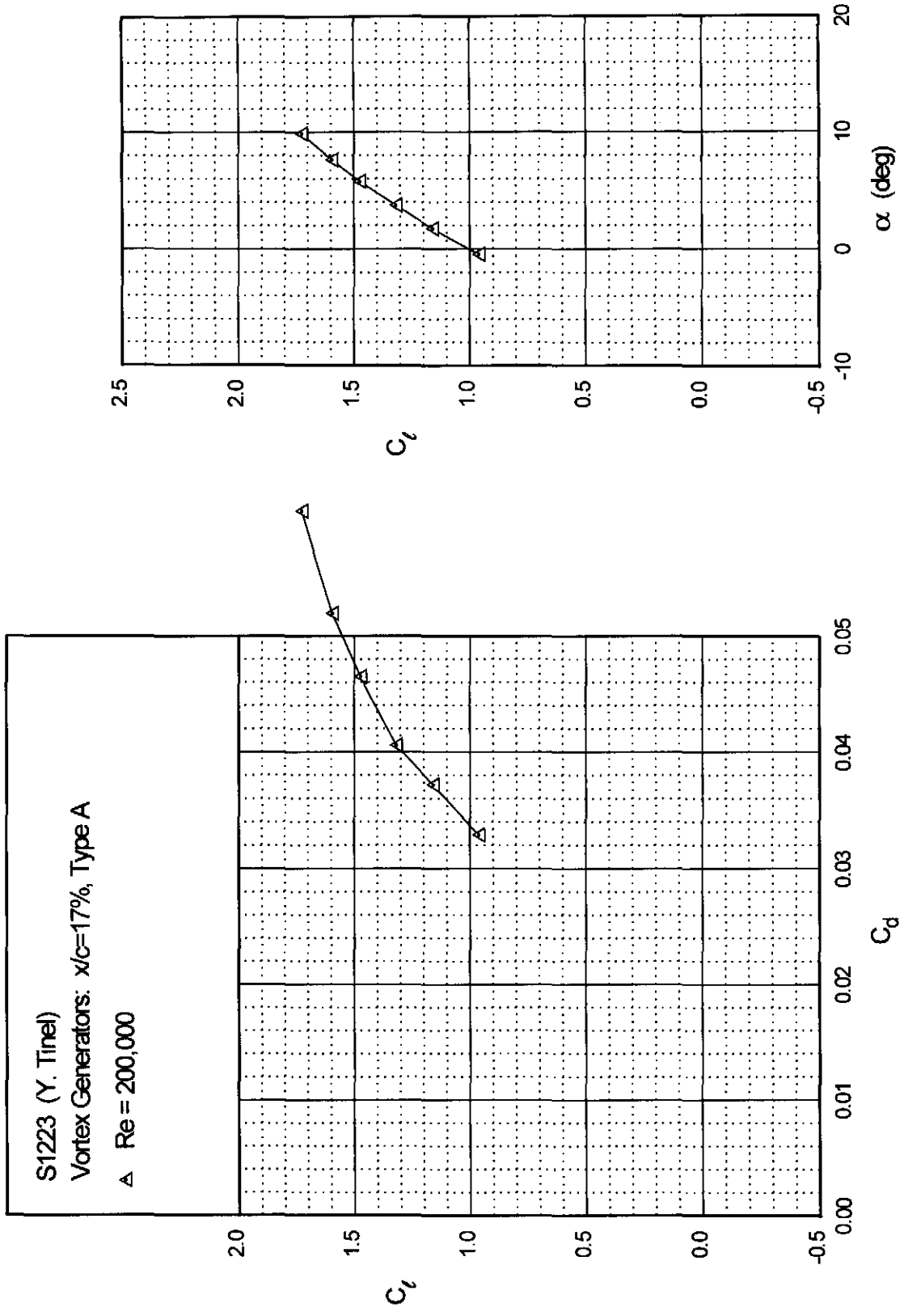


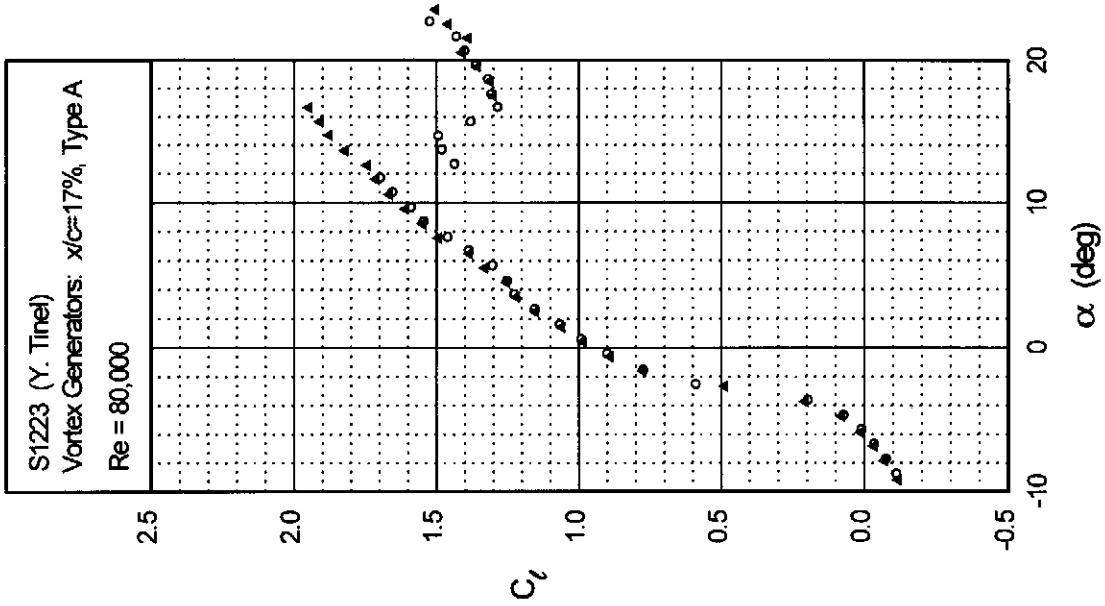

S1223 (Y. Tinel)
Re = 300,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)


S1223 (Y. Tinel)
Re = 250,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)

S1223


S1223 (Y. Tinel)
Vortex Generators: x/c=17%, Type A
Re = 200,000
$C_l$
$C_d$
α (deg)

S1223


S1223 (Y. Tinel)
Vortex Generators: x/c=17%, Type A
Re = 80,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

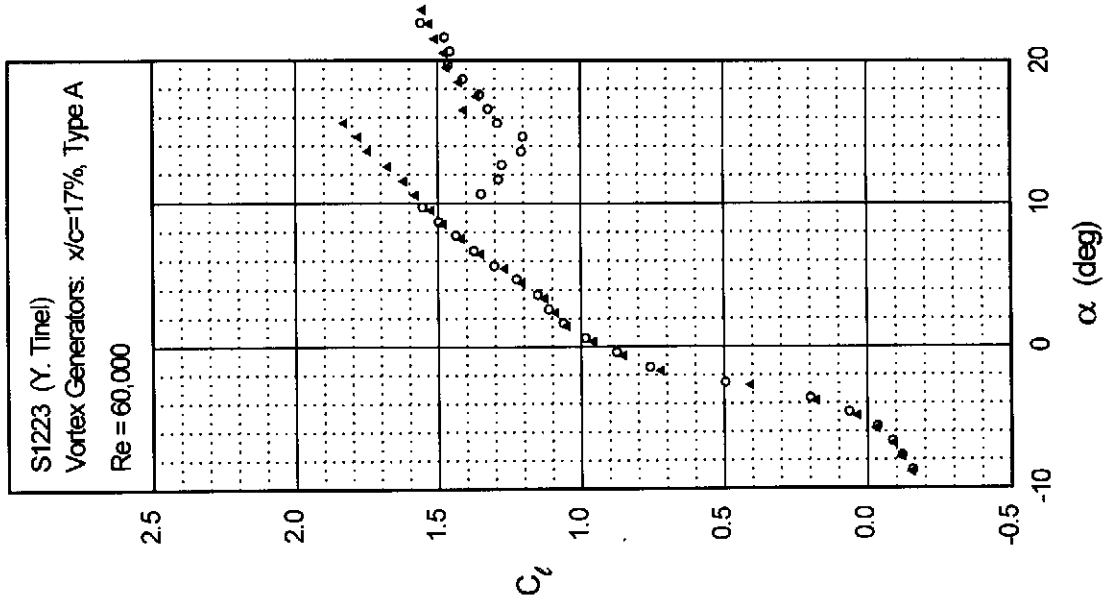
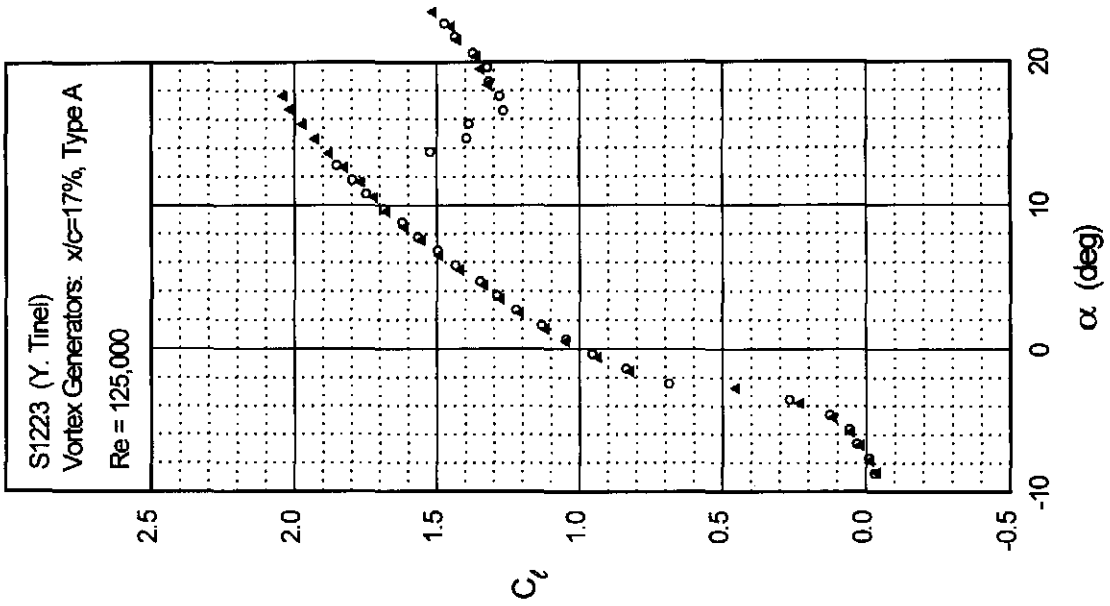
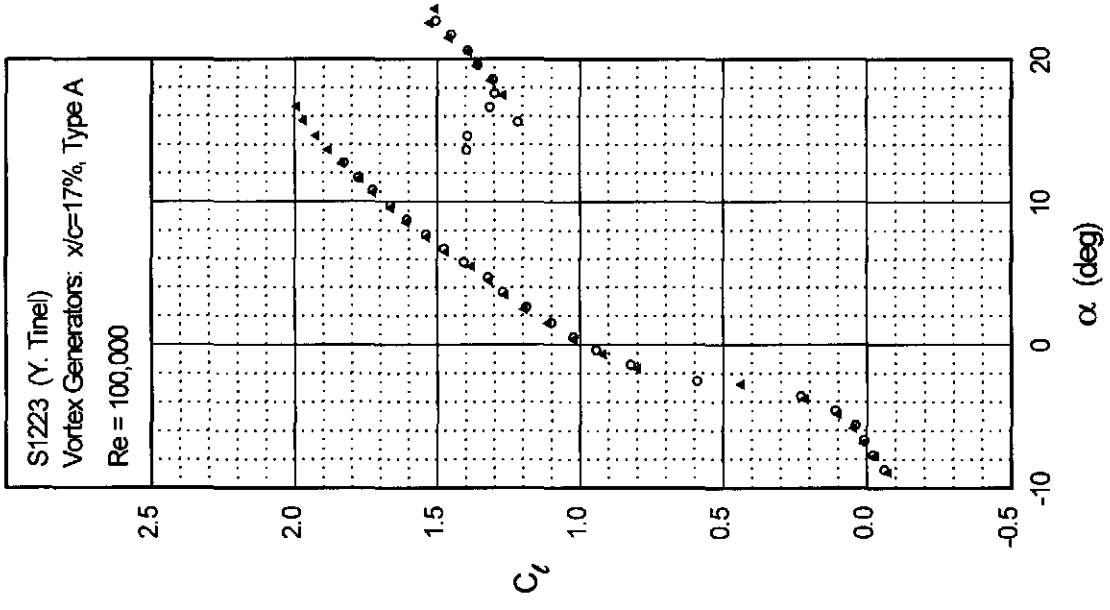
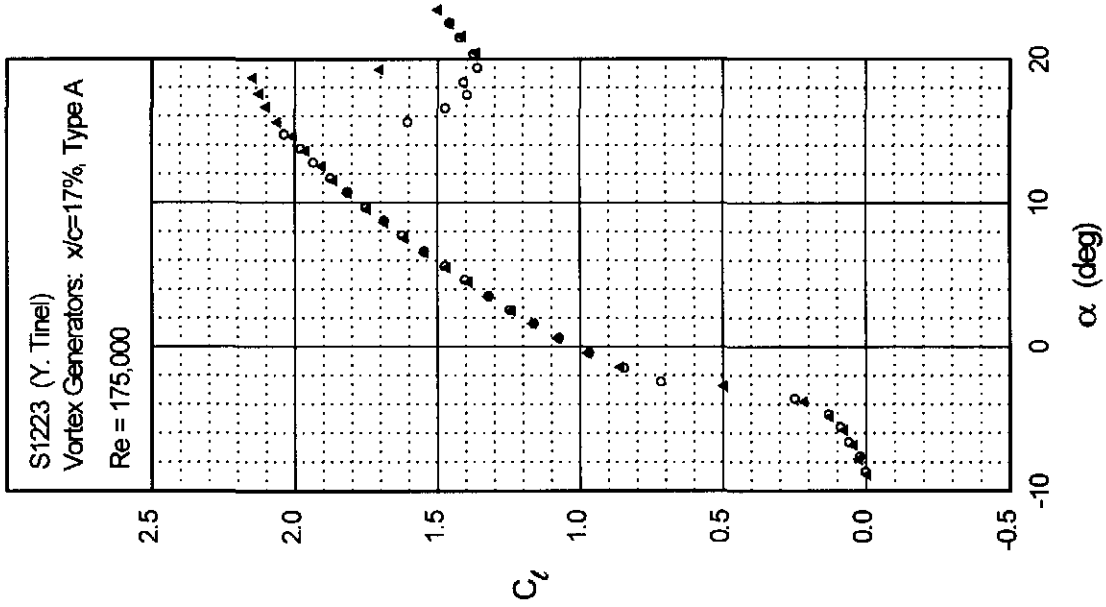

S1223 (Y. Tinel)
Vortex Generators: x/c=17%, Type A
Re = 60,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

Fig. 4.99 (continued)

S1223




S1223 (Y. Tinel)
Vortex Generators: x/c=17%, Type A
Re = 175,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
-10
0
10
20
α (deg)

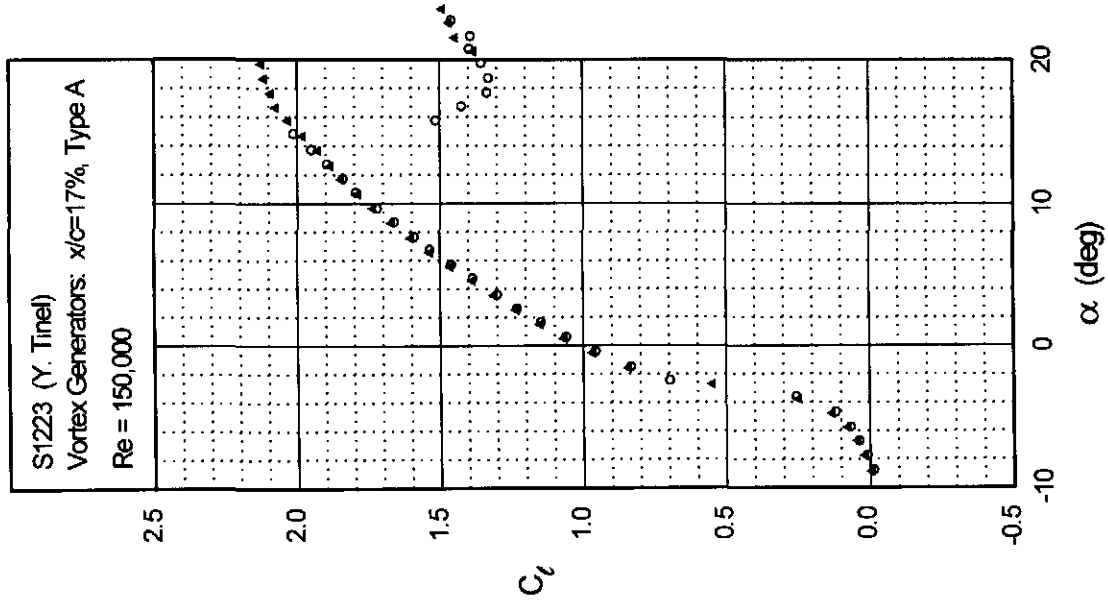
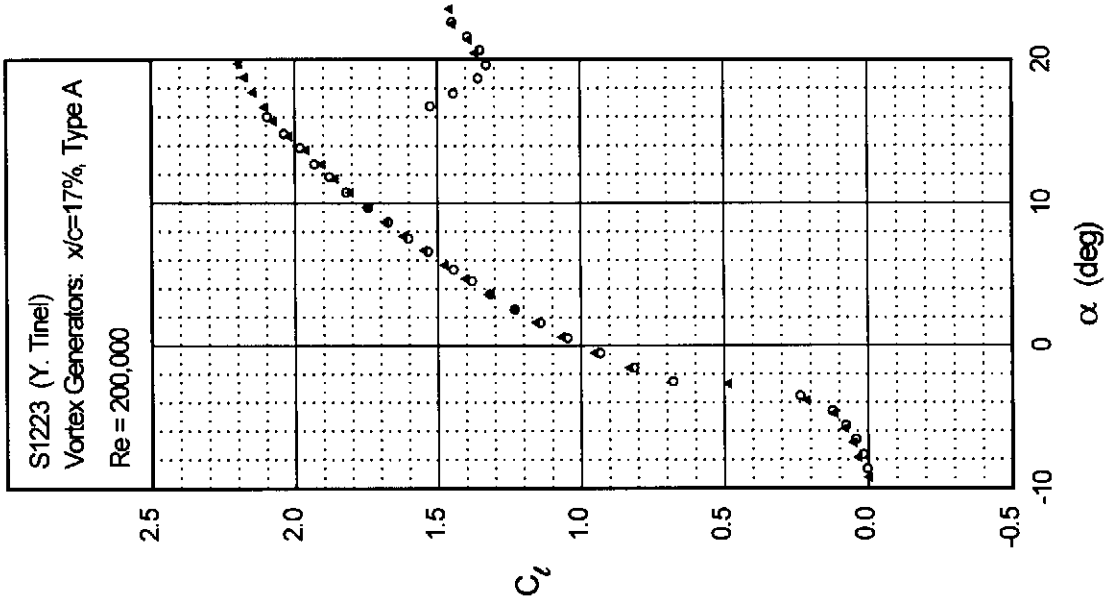
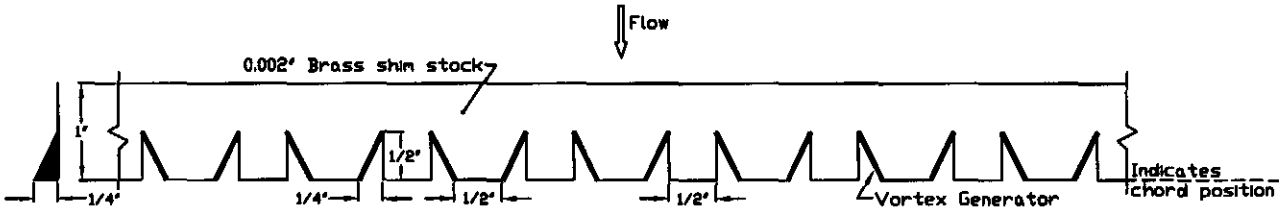

S1223 (Y. Tinel)
Vortex Generators: x/c=17%, Type A
Re = 150,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
-10
0
10
20
α (deg)

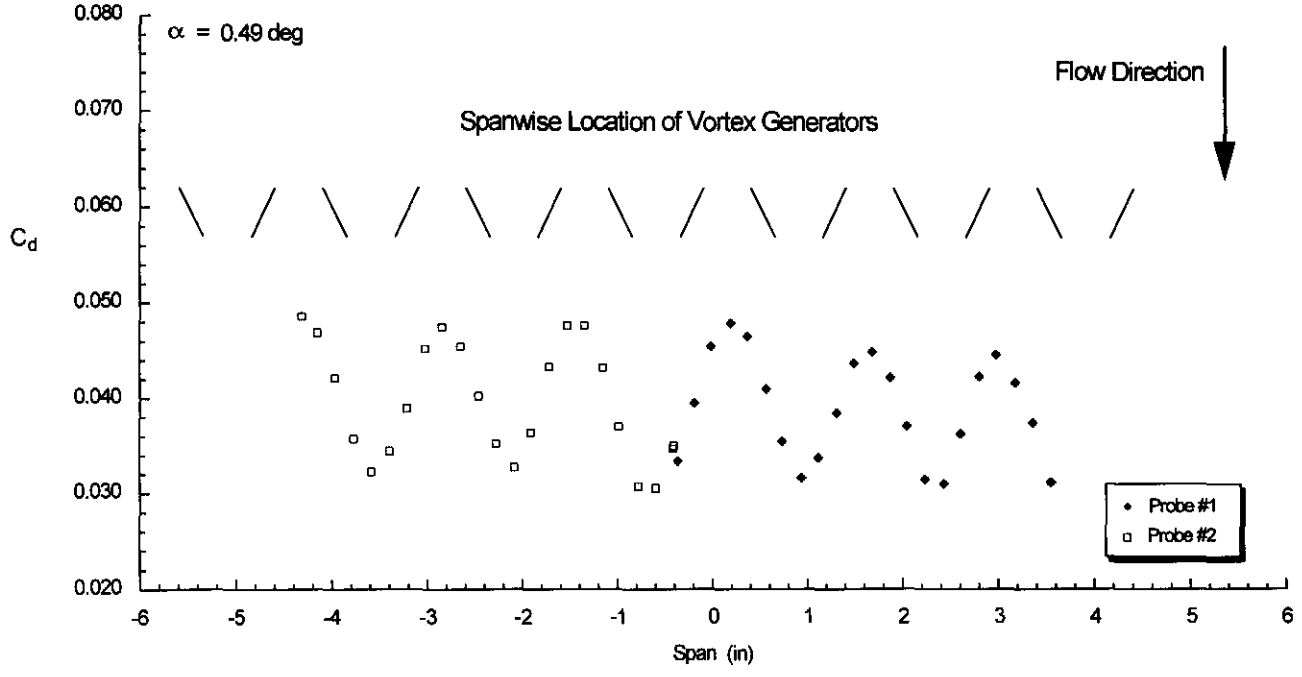
Fig. 4.99 (continued)

S1223

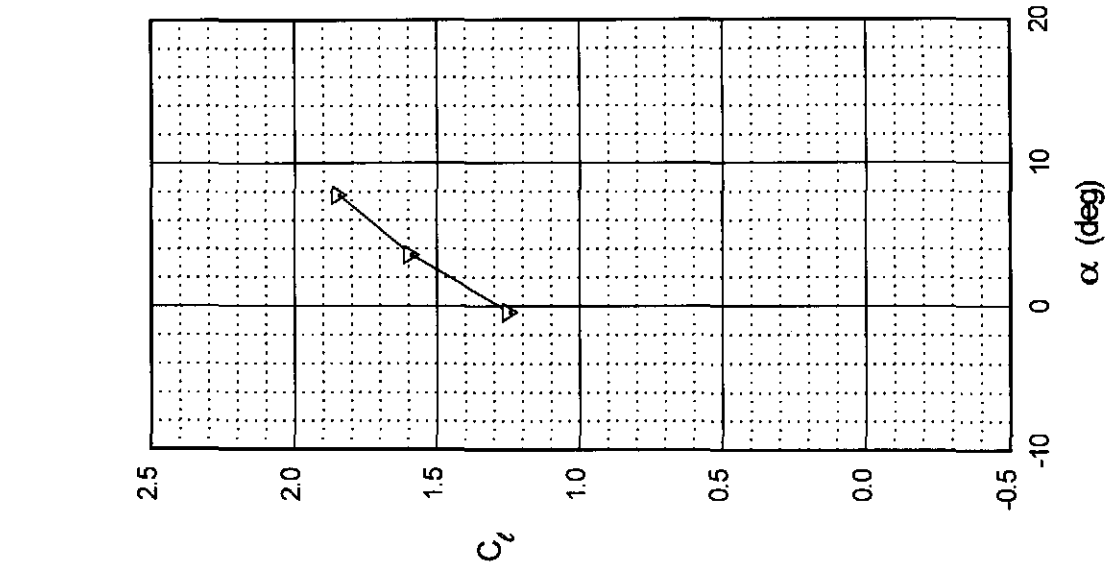


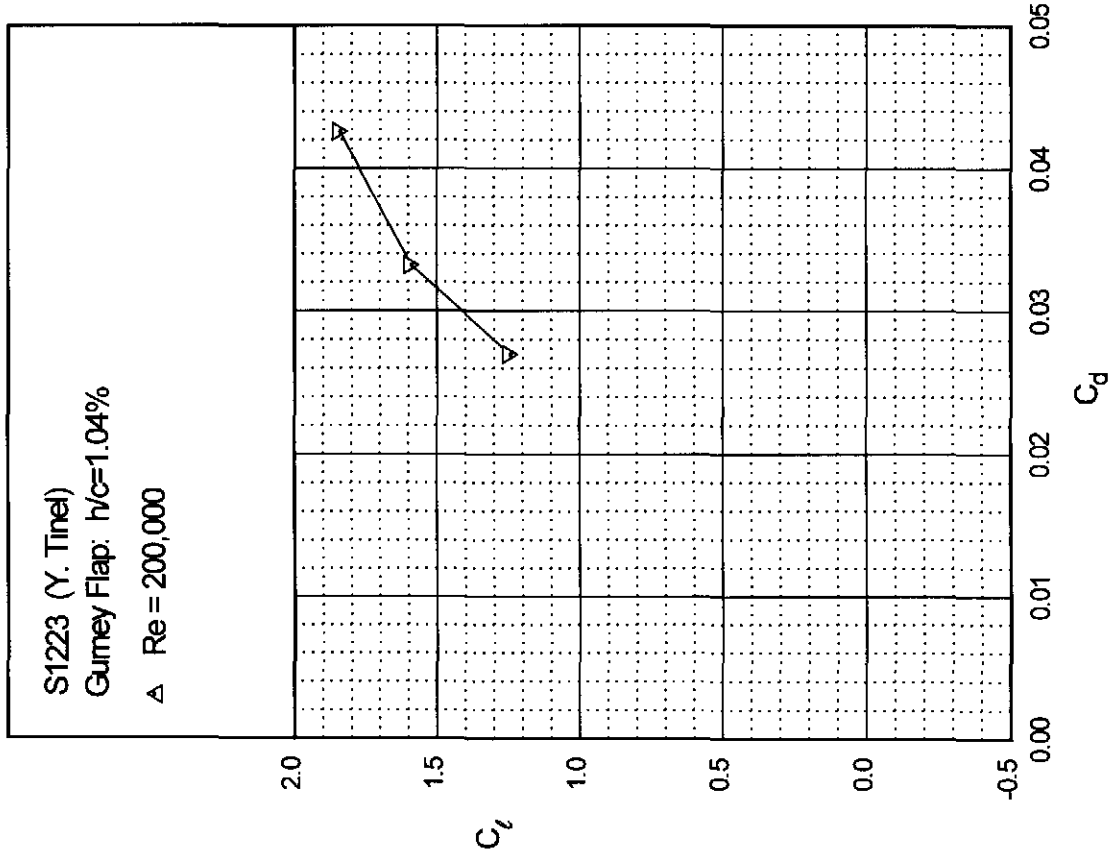
S1223


Flow
0.002" Brass shim stock
1"
1/2"
1/4"
1/4"
1/2"
1/2"
Vortex Generator
Indicates
chord position

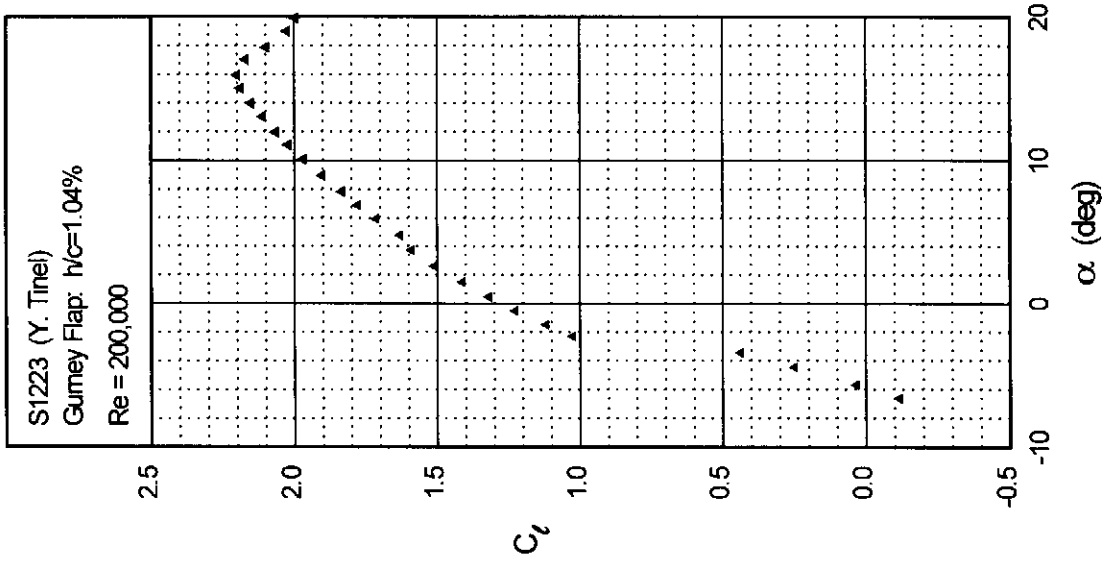

α = 0.49 deg
Flow Direction
Spanwise Location of Vortex Generators
$C_d$
0.080
0.070
0.060
0.050
0.040
0.030
0.020
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
Span (in)
Probe #1
Probe #2

S1223

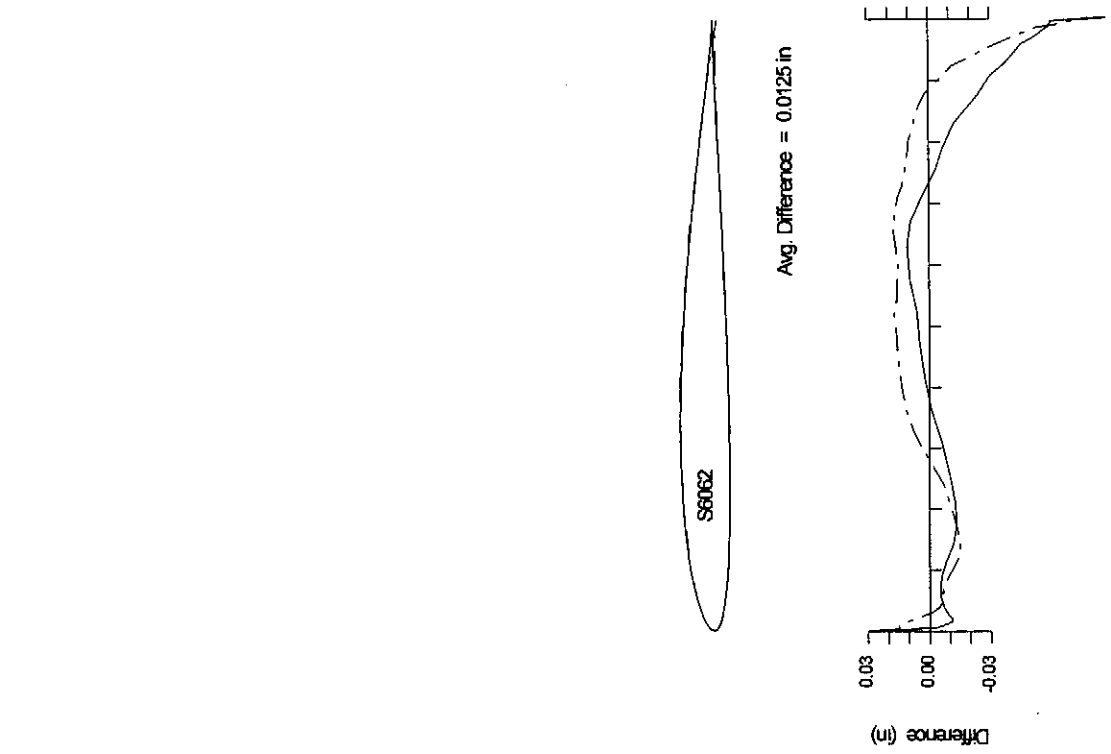

2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)

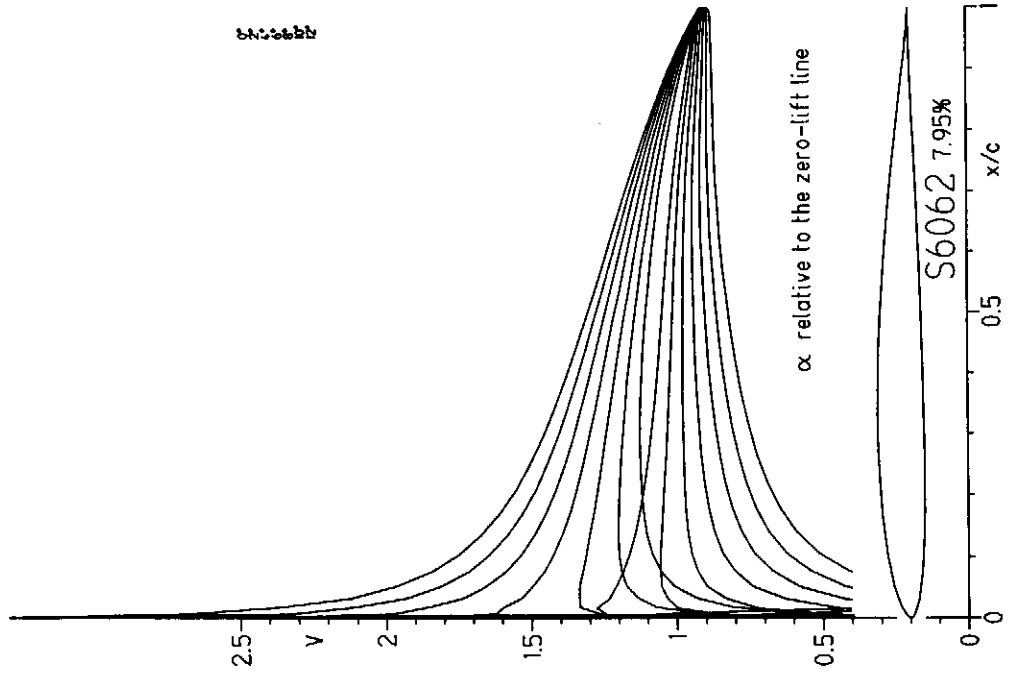

S1223 (Y. Tinel)
Gurney Flap: h/c=1.04%
Re = 200,000
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
0.05
0.04
0.03
0.02
0.01
0.00
$C_d$

S1223

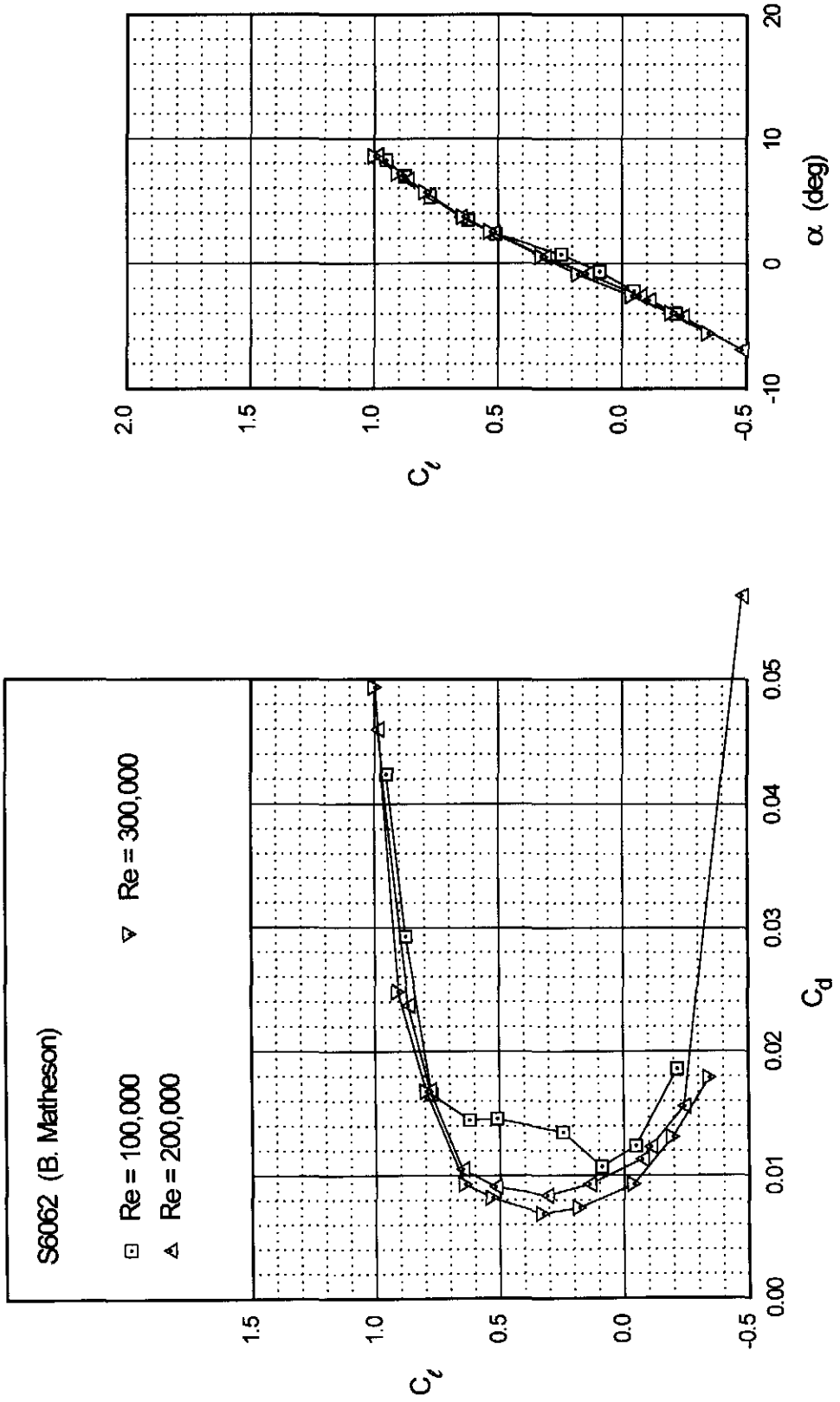

S1223 (Y. Tinel)
Gurney Flap: h/c=1.04%
Re = 200,000
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

S6062

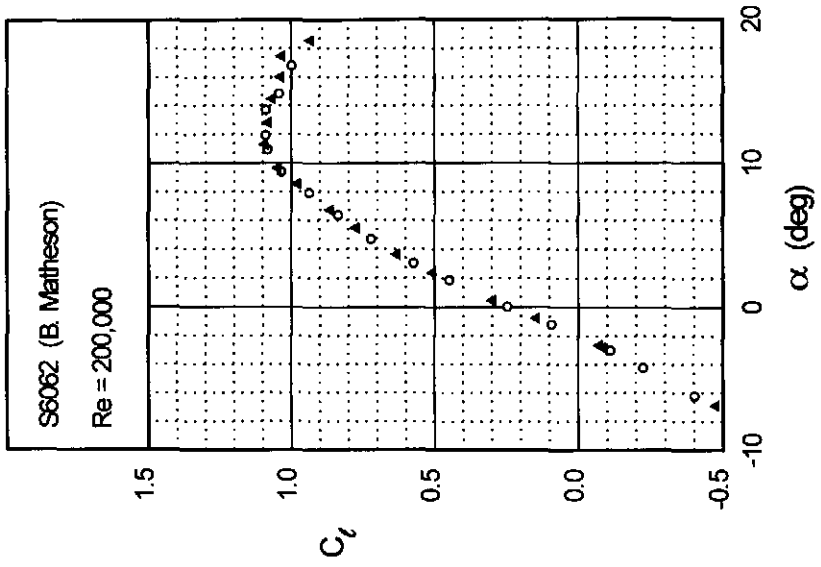

S6062
Avg. Difference = 0.0125 in
0.03
0.00
-0.03
Difference (in)

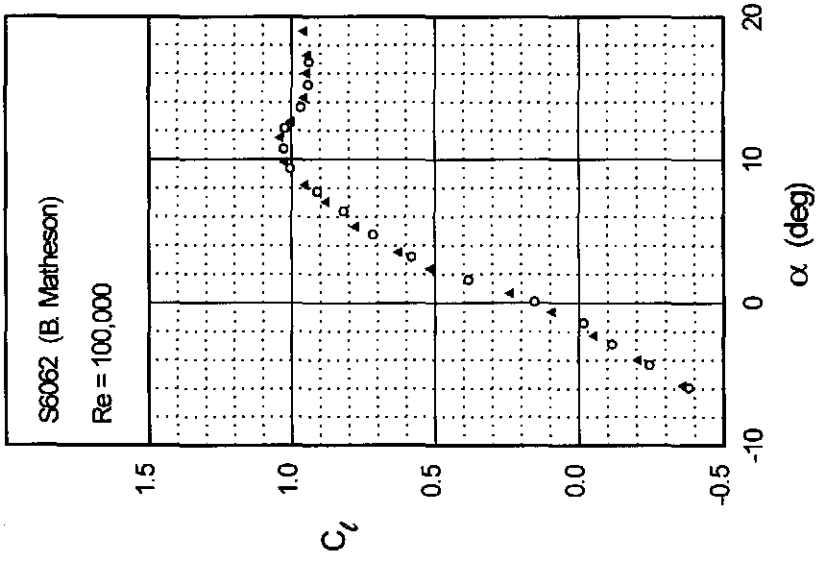

α relative to the zero-lift line
S6062 7.95%
x/c
0
0.5
1
0.5
1
1.5
2
2.5
V

S6062

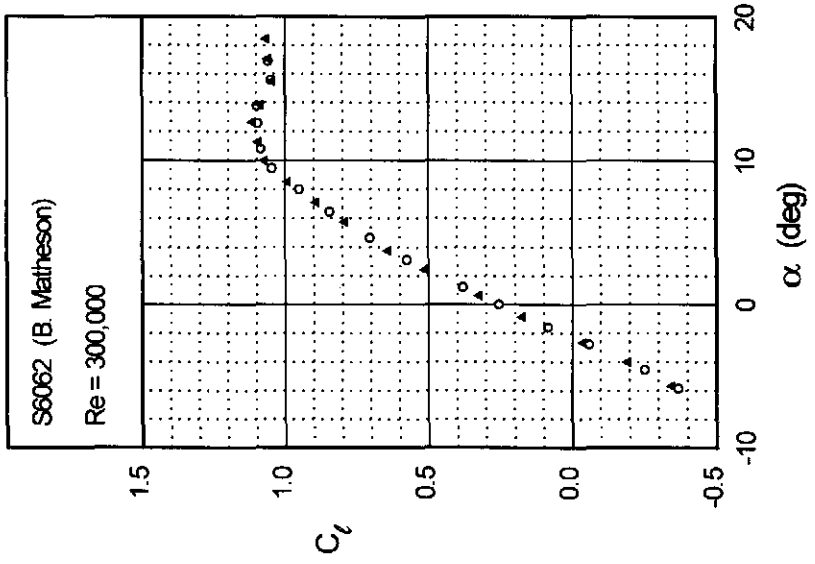

S6062 (B. Matheson)
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
-10
0
10
20
0.00
0.01
0.02
0.03
0.04
0.05

S6062

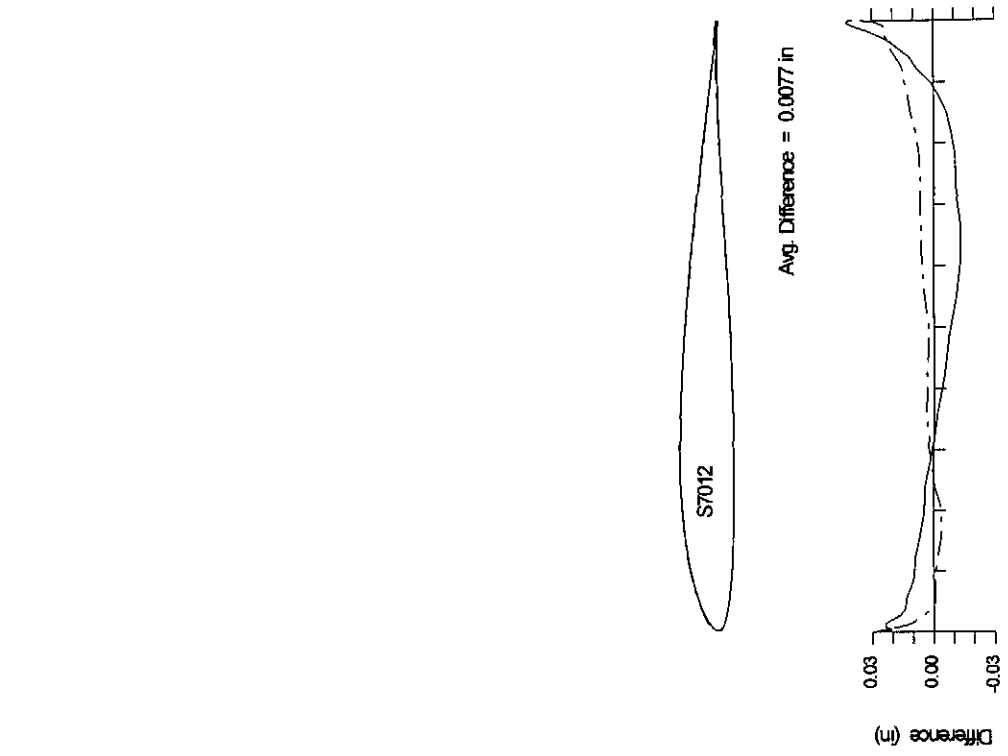

S6062 (B. Matheson)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

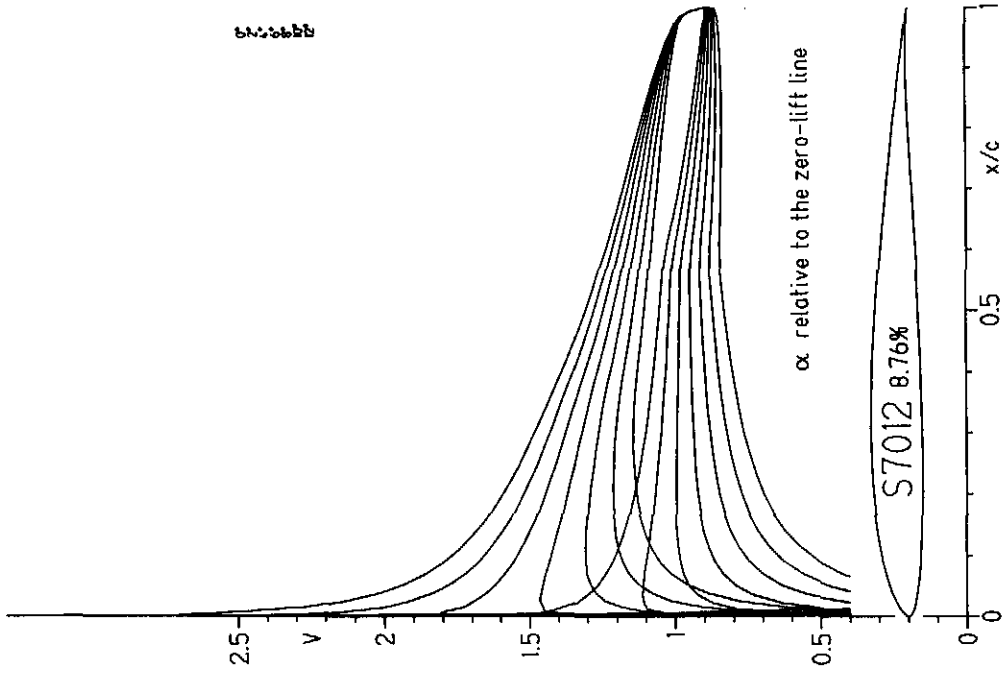

S6062 (B. Matheson)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

S6062

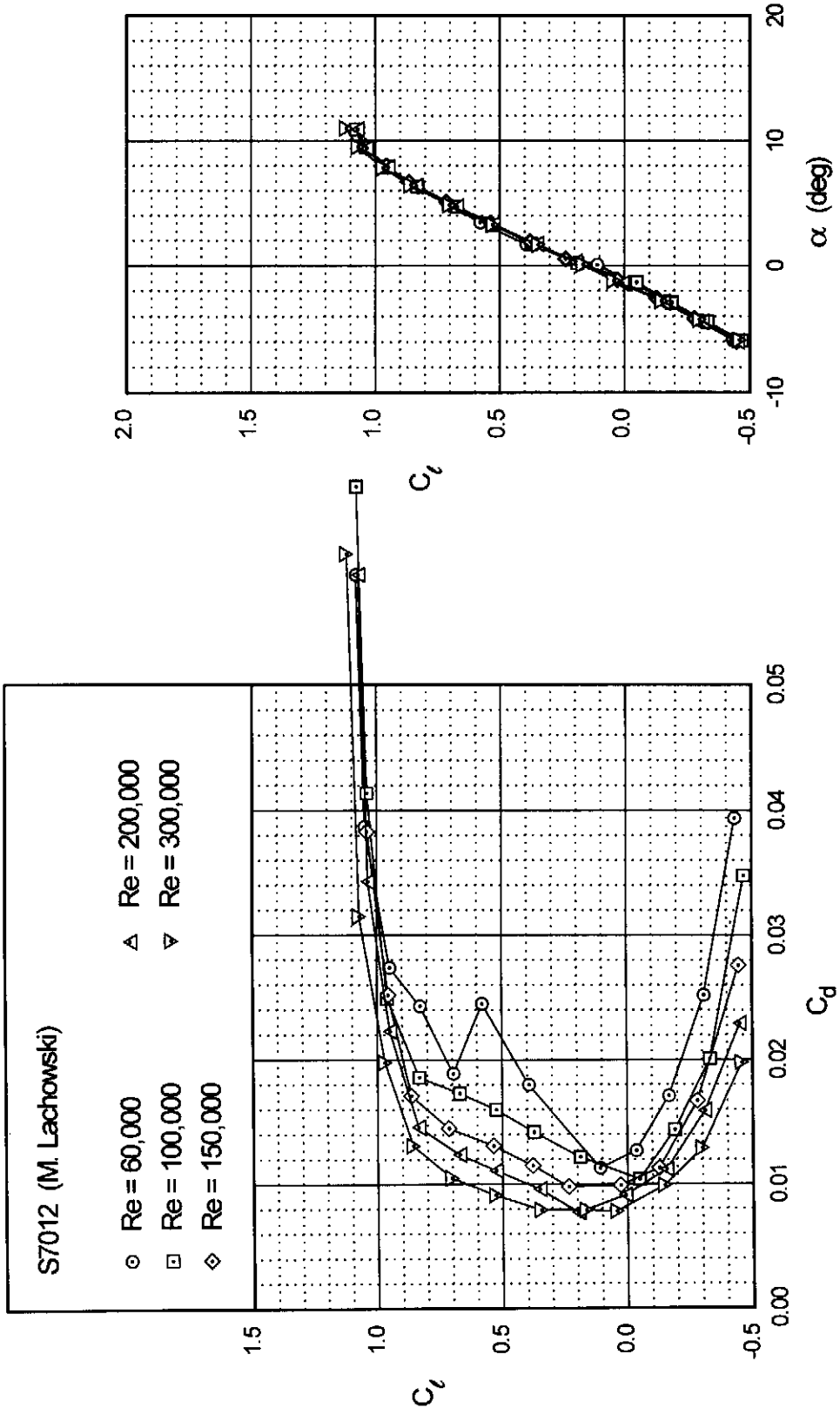


S7012

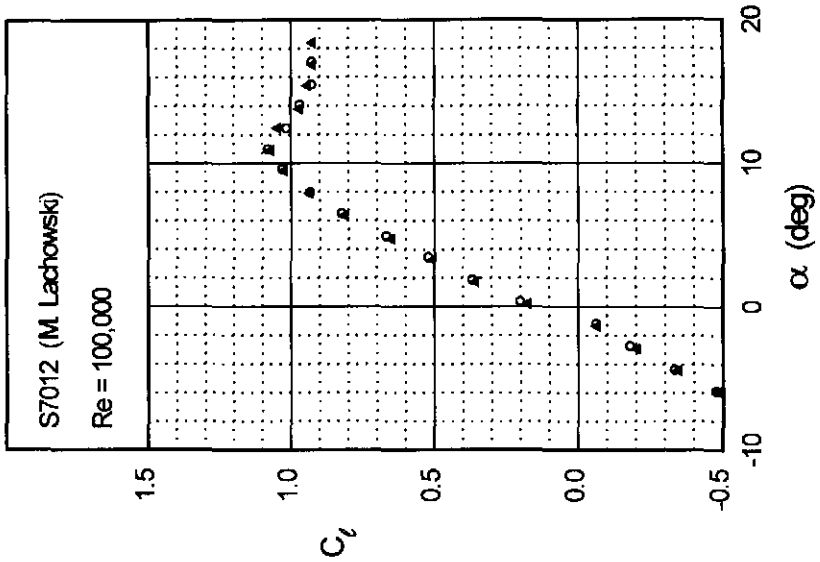

S7012
Avg. Difference = 0.0077 in
0.03
0.00
-0.03
Difference (in)

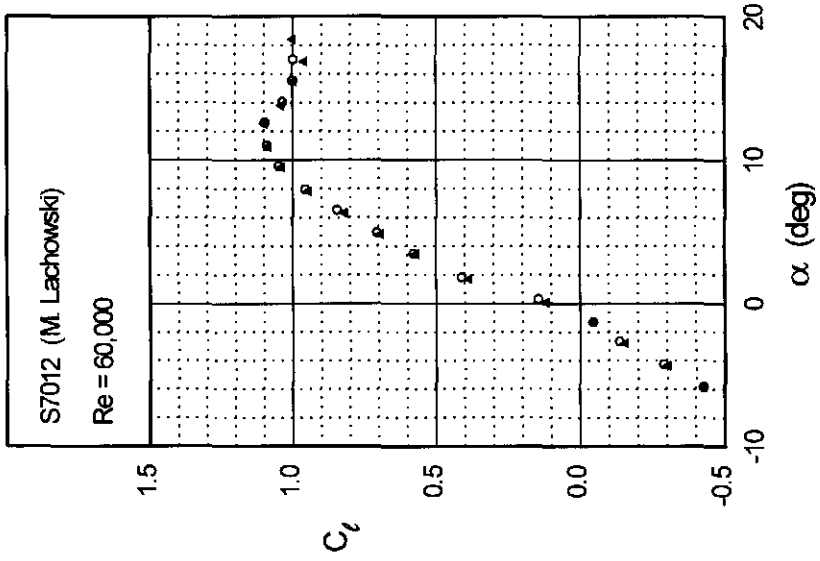

α relative to the zero-lift line
S7012 8.76%
x/c
0
0.5
1
2.5
2
1.5
1
0.5

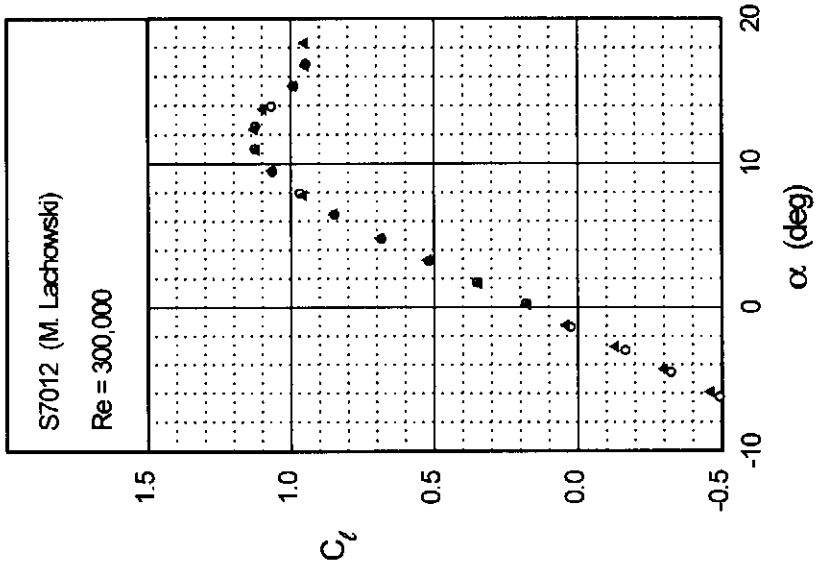
S7012

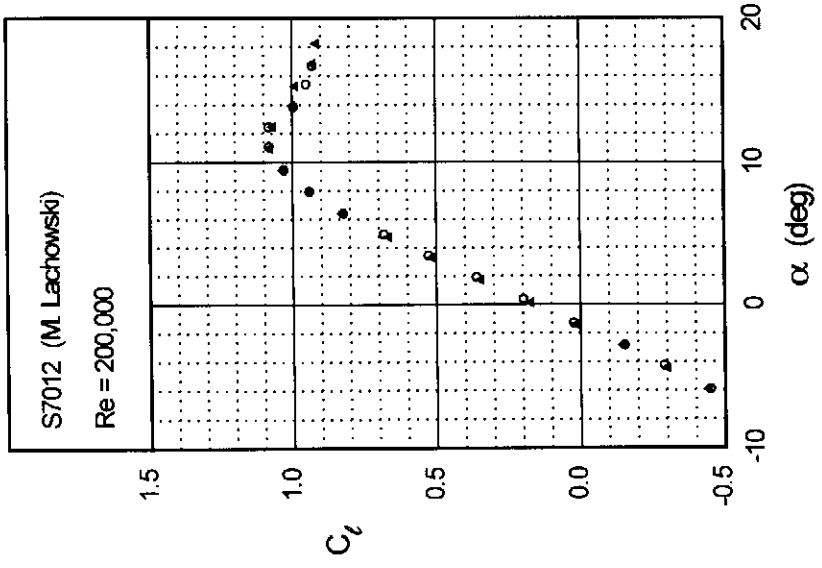

S7012 (M. Lachowski)
Re = 60,000
Re = 100,000
Re = 150,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
20
10
0
-10
0.05
0.04
0.03
0.02
0.01
0.00

S7012

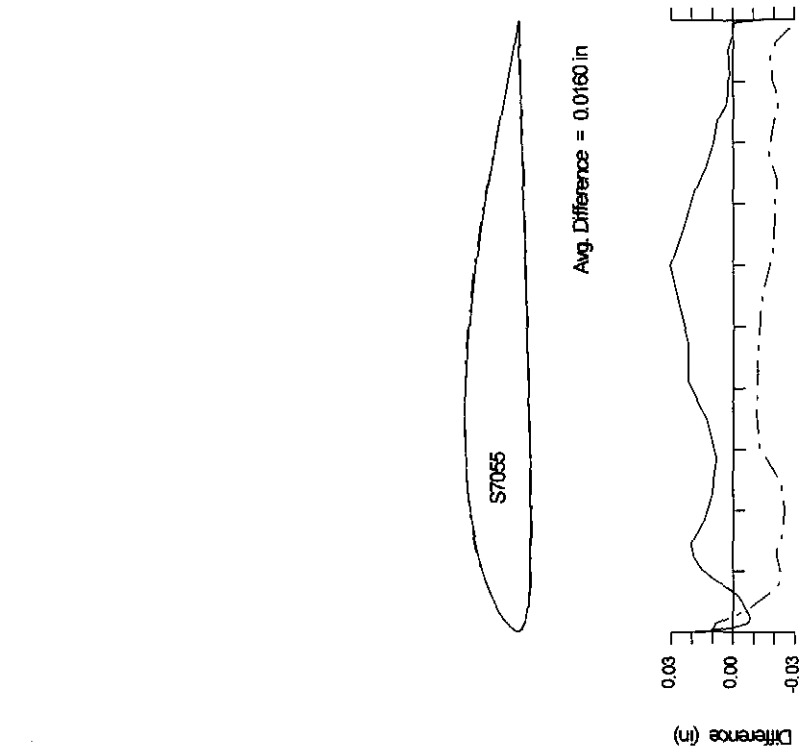

S7012 (M Lachowski)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

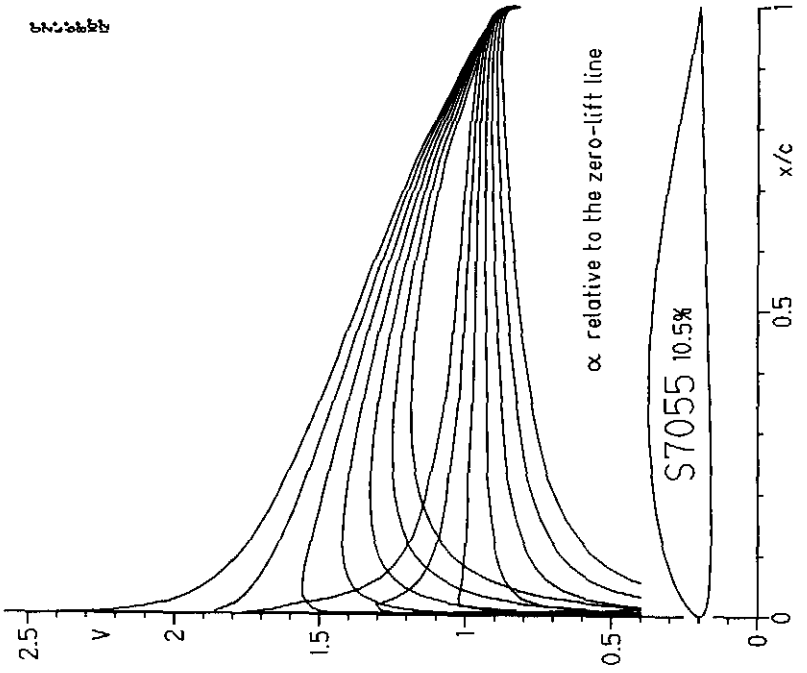

S7012 (M Lachowski)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


S7012 (M. Lachowski)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

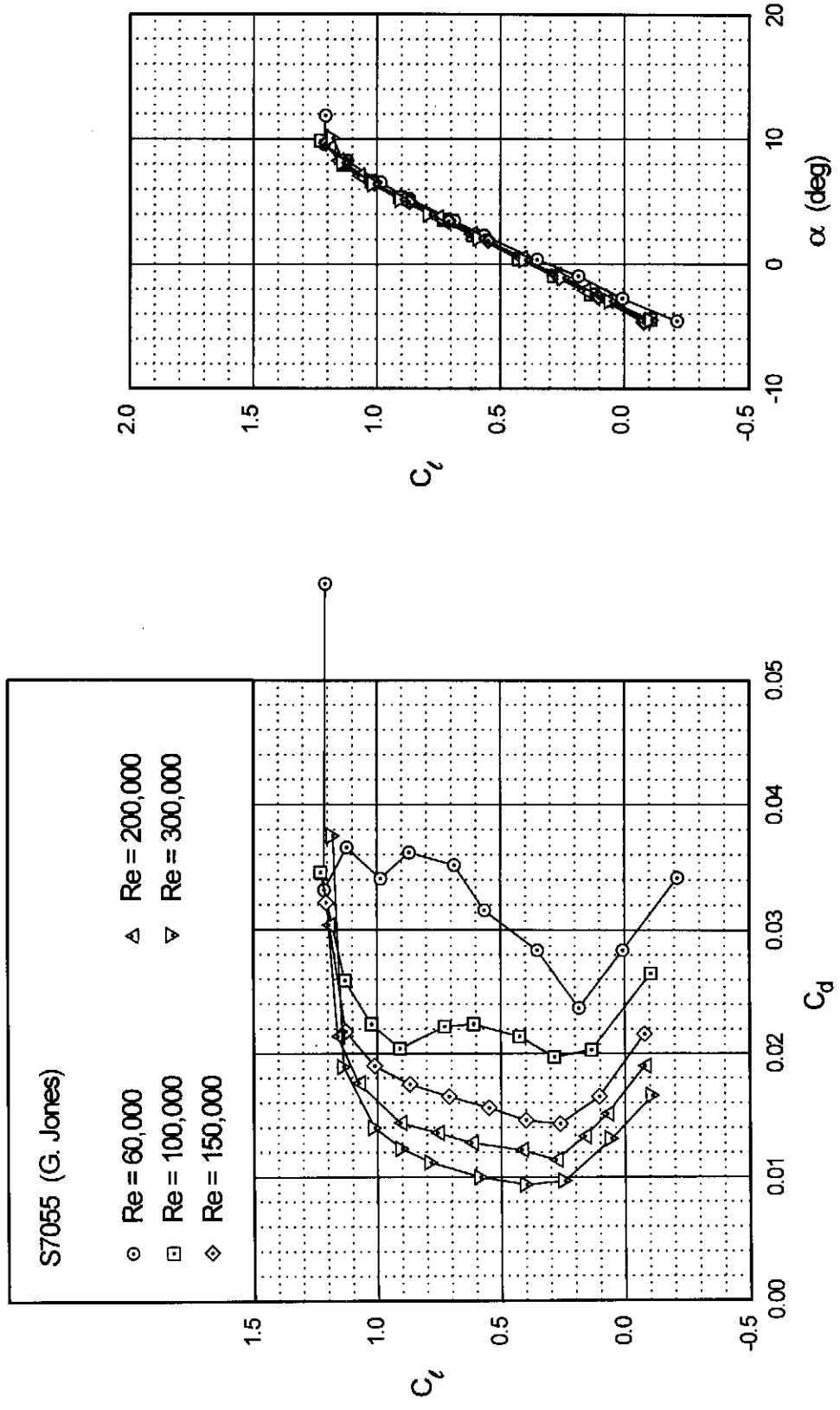

S7012 (M Lachowski)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

S7055

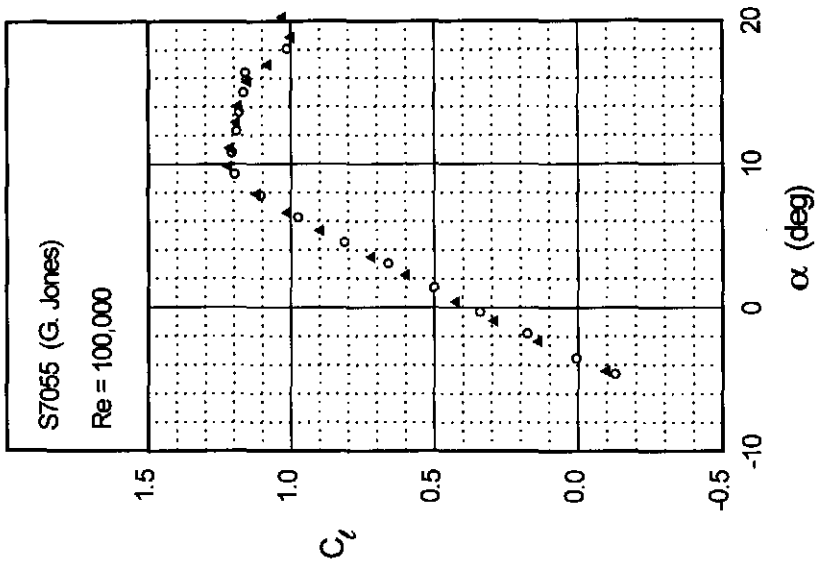

S7055
Avg. Difference = 0.0160 in
0.03
0.00
-0.03
Difference (in)

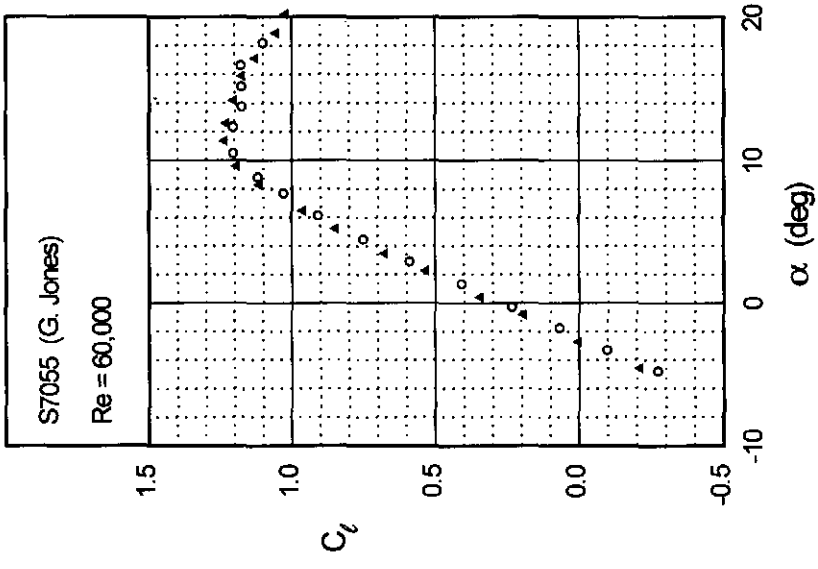

α relative to the zero-lift line
2.5
2
1.5
1
0.5
V
S7055 10.5%
0
0.5
1
x/c

S7055

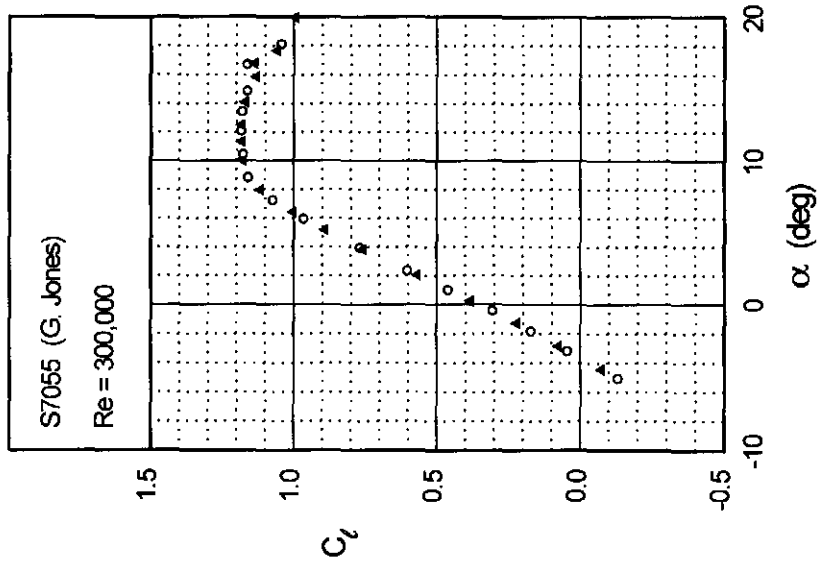

S7055 (G. Jones)
Re = 60,000
Re = 100,000
Re = 150,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
20
10
0
-10
0.05
0.04
0.03
0.02
0.01
0.00

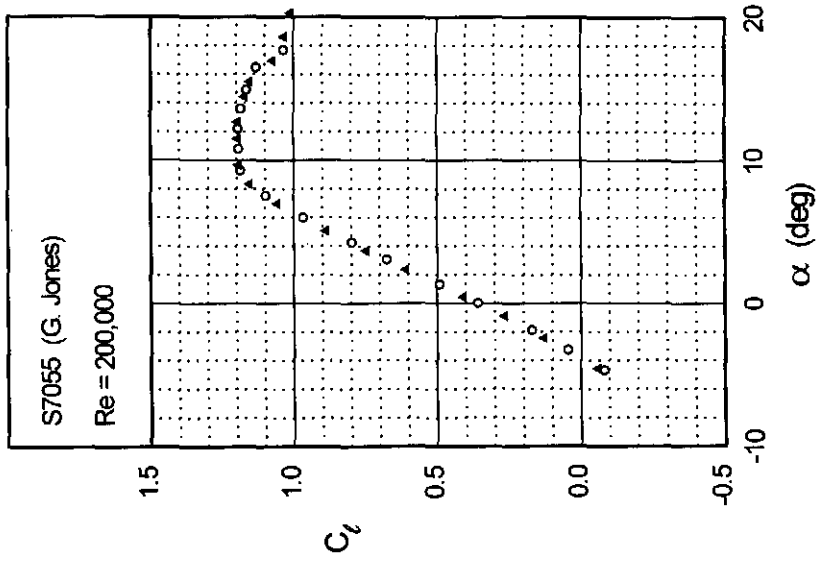
S7055


S7055 (G. Jones)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

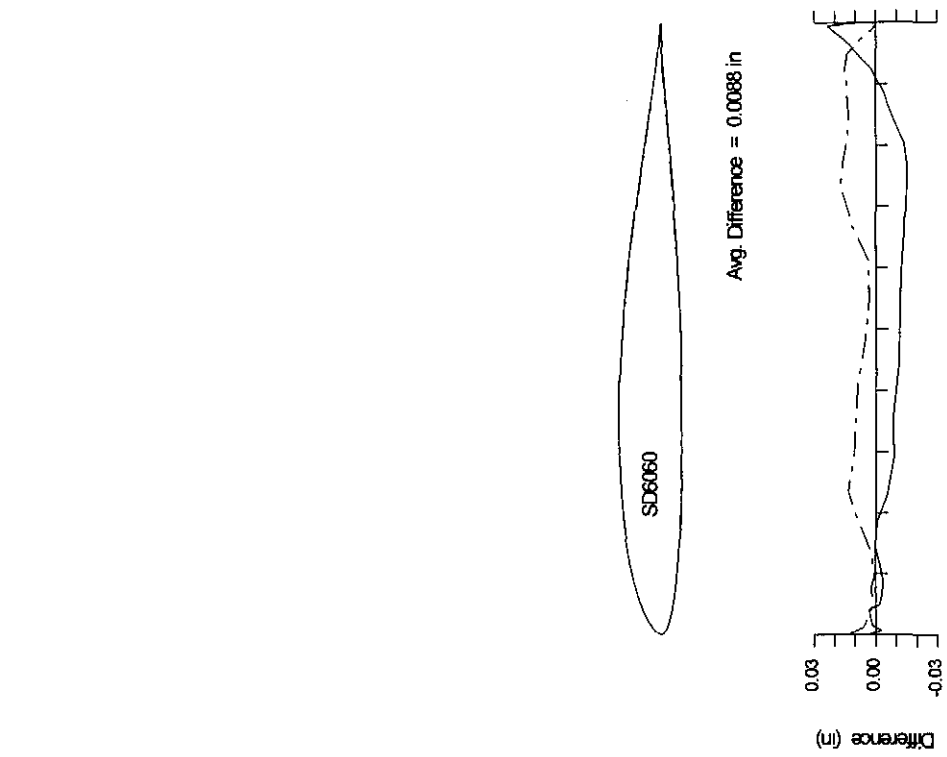

S7055 (G. Jones)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

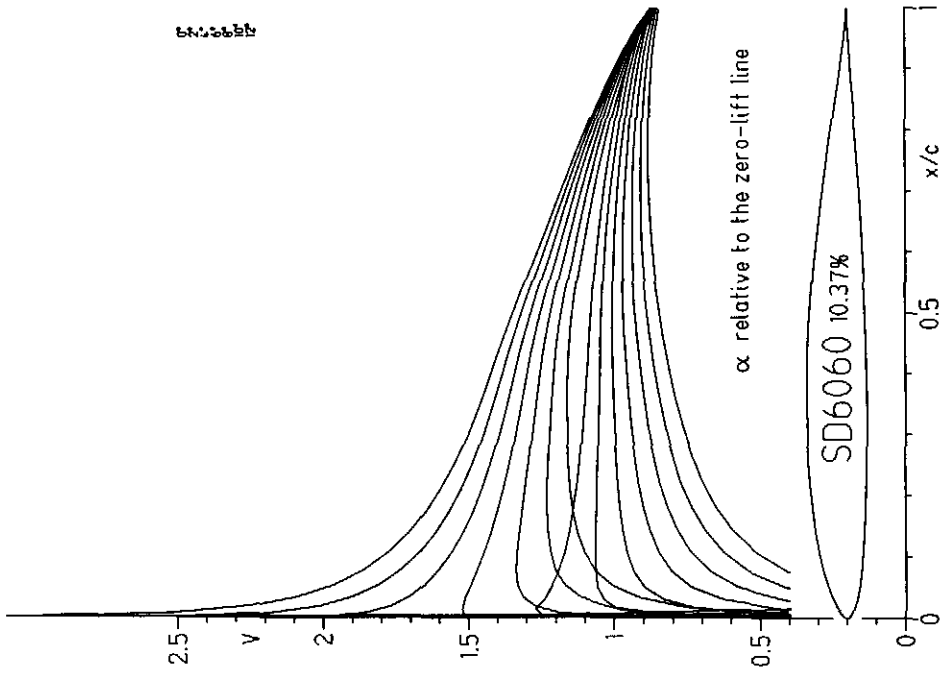
S7055


S7055 (G. Jones)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

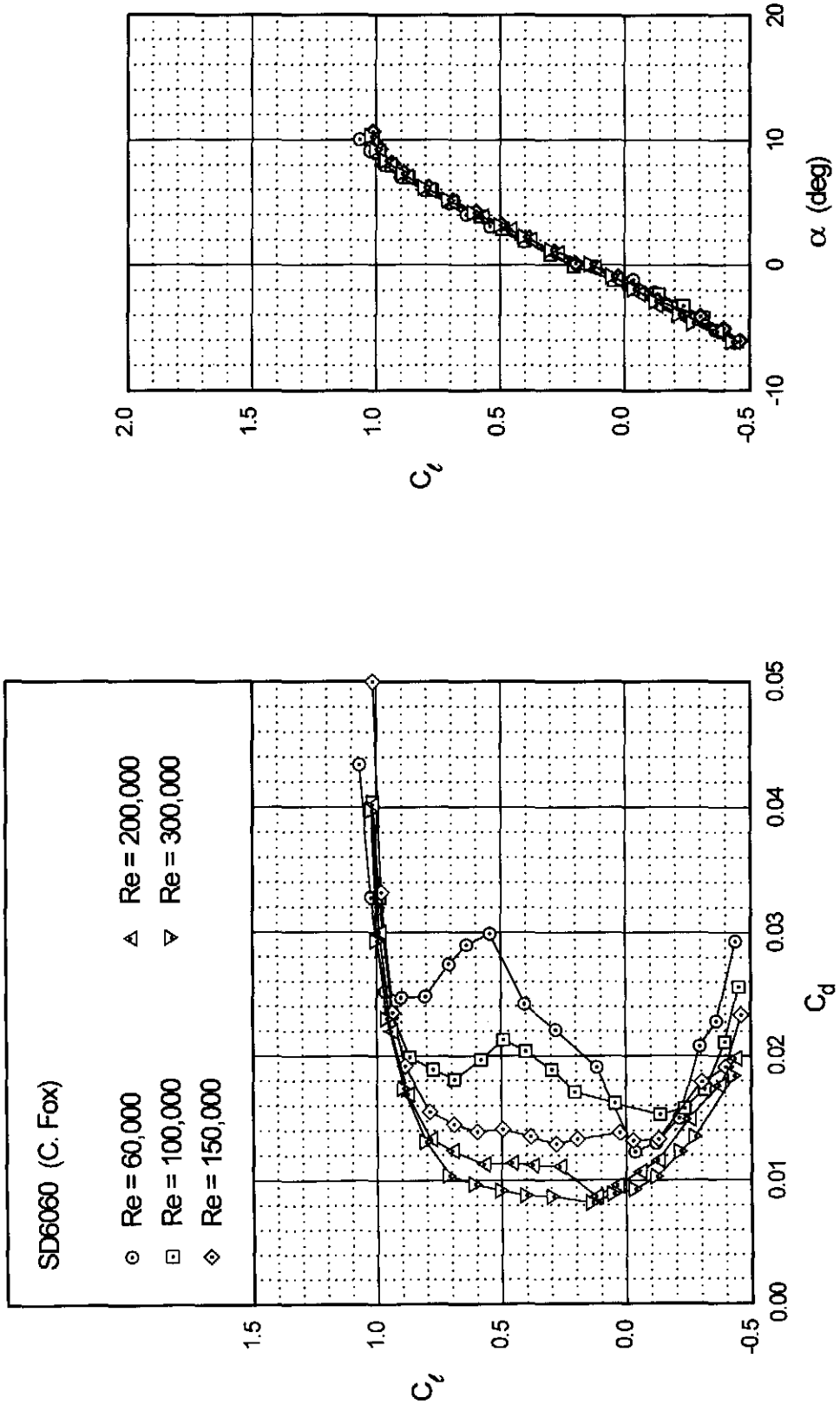

S7055 (G. Jones)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

SD6060

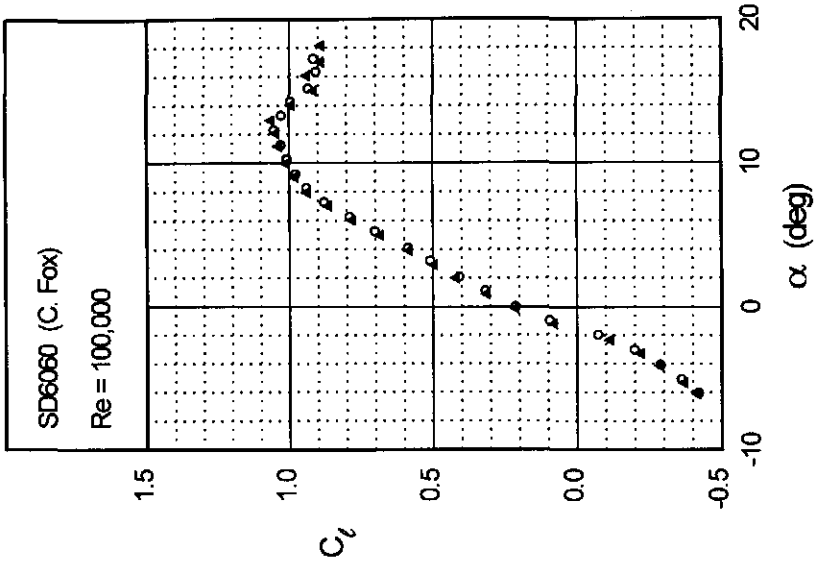

SD6060
Avg. Difference = 0.0088 in
0.03
0.00
-0.03
Difference (in)

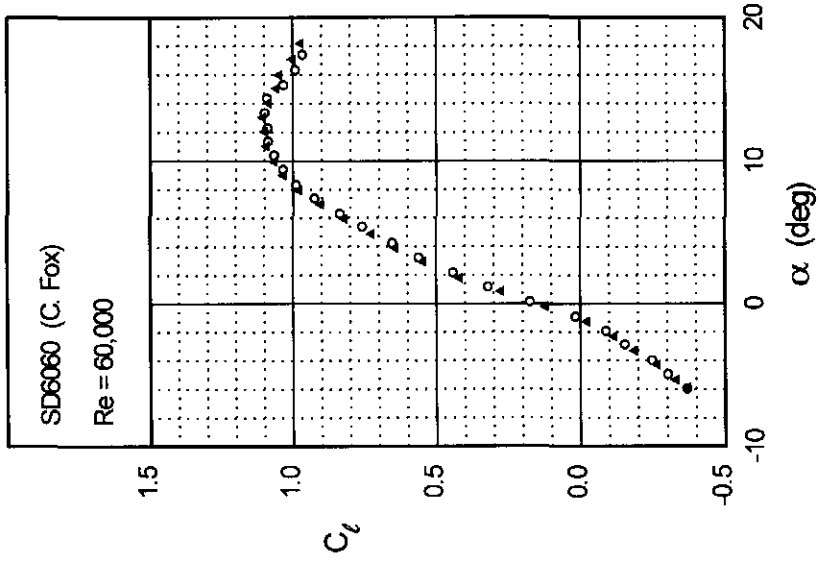

2.5
2
1.5
1
0.5
α relative to the zero-lift line
SD6060 10.37%
0
0.5
1
x/c

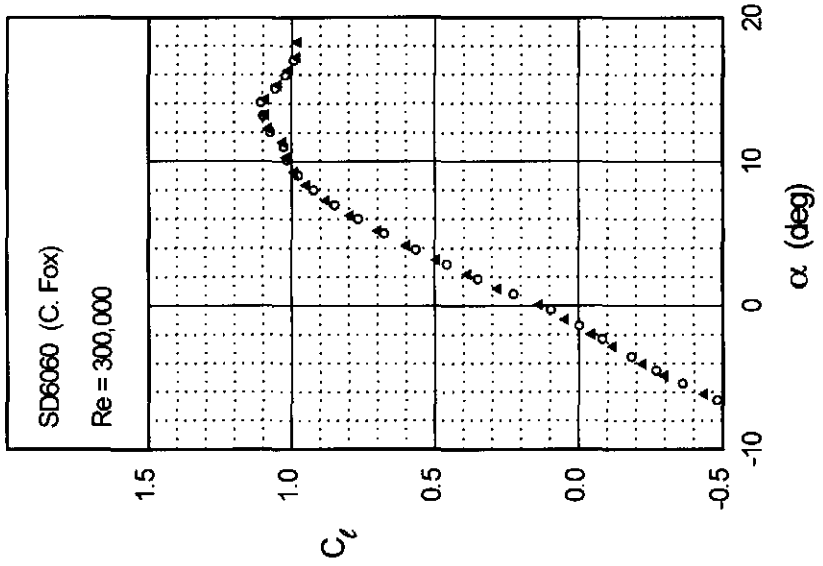
SD6060

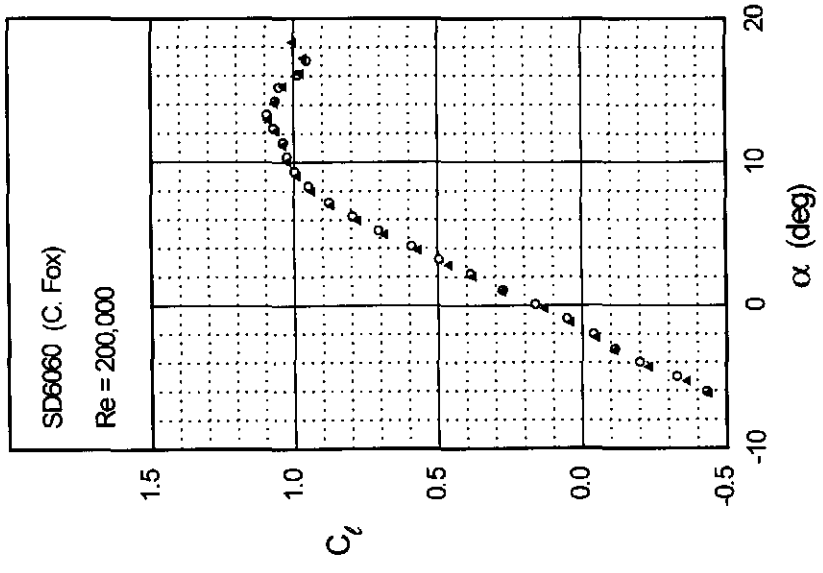

SD6060 (C. Fox)
Re = 60,000
Re = 100,000
Re = 150,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)

SD6060

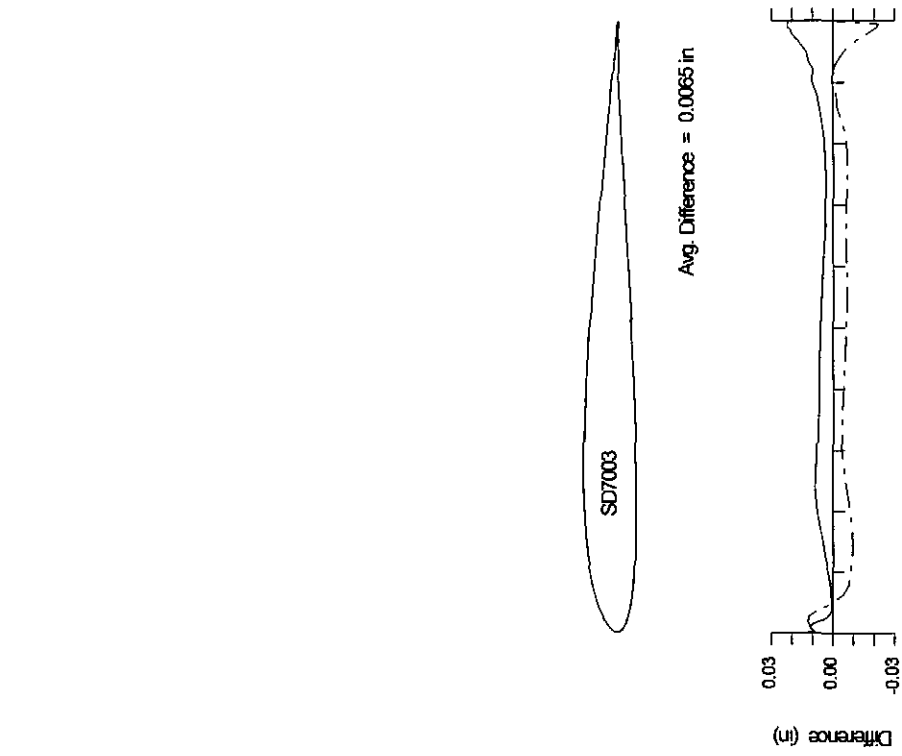

SD6060 (C. Fox)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

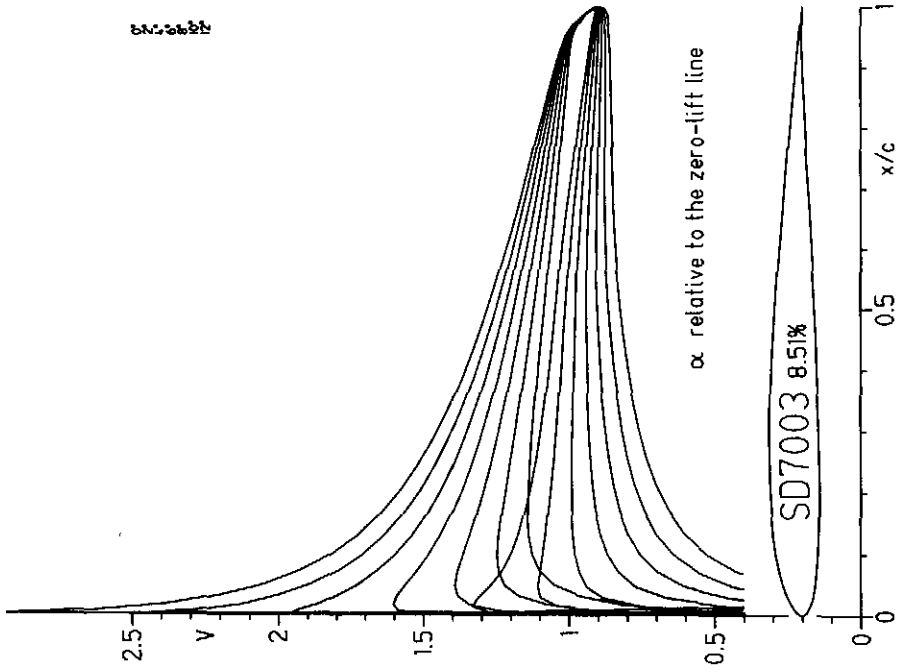

SD6060 (C. Fox)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


SD6060 (C. Fox)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

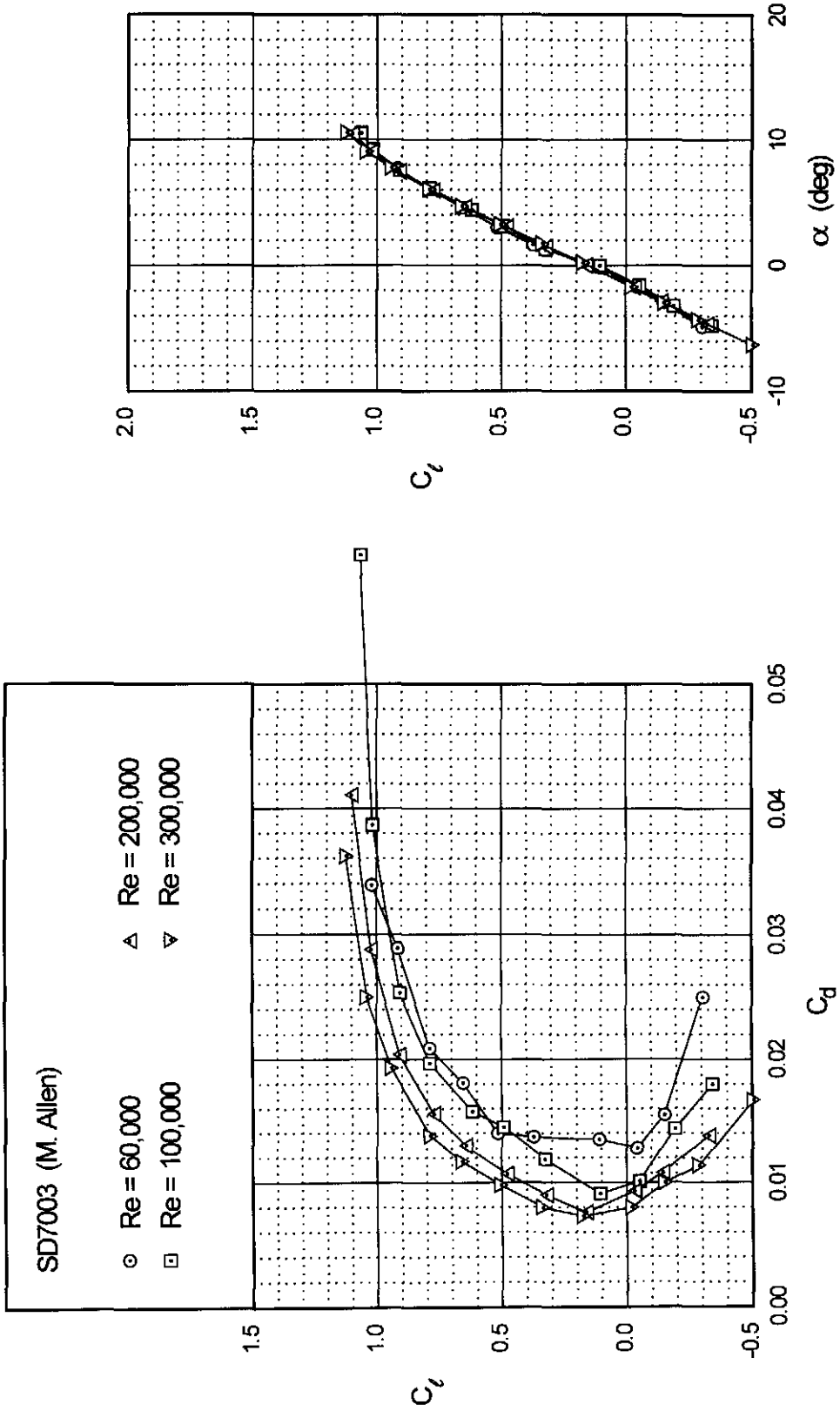

SD6060 (C. Fox)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

SD7003

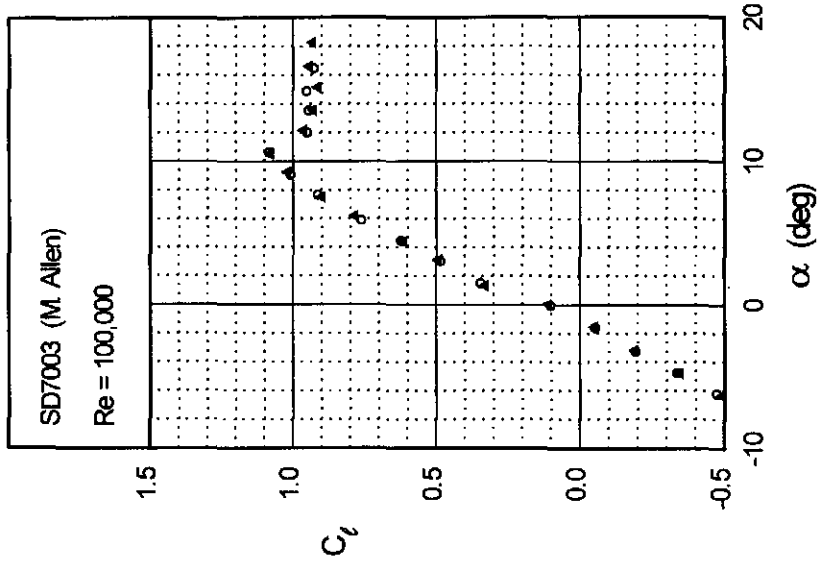

SD7003
Avg. Difference = 0.0065 in
0.03
0.00
-0.03
Difference (in)

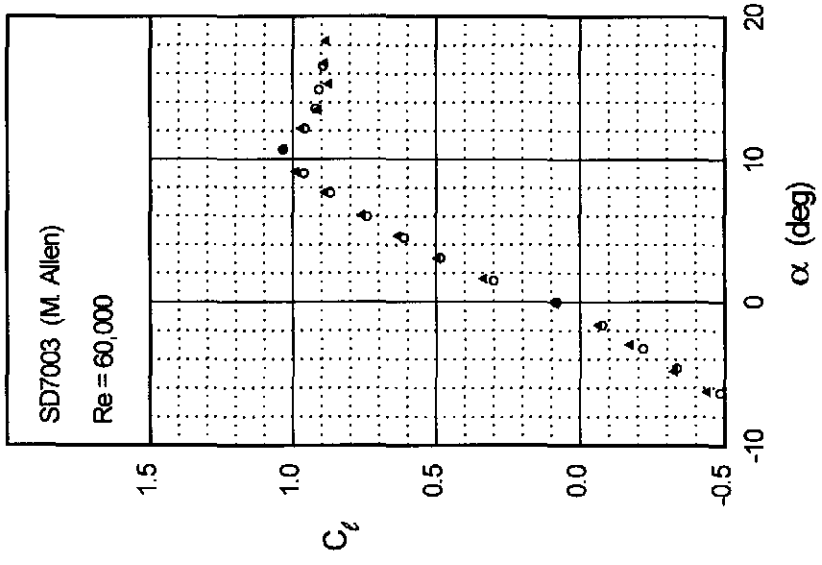

α relative to the zero-lift line
SD7003 8.51%
2.5
2
1.5
1
0.5
0
0.5
1
x/c

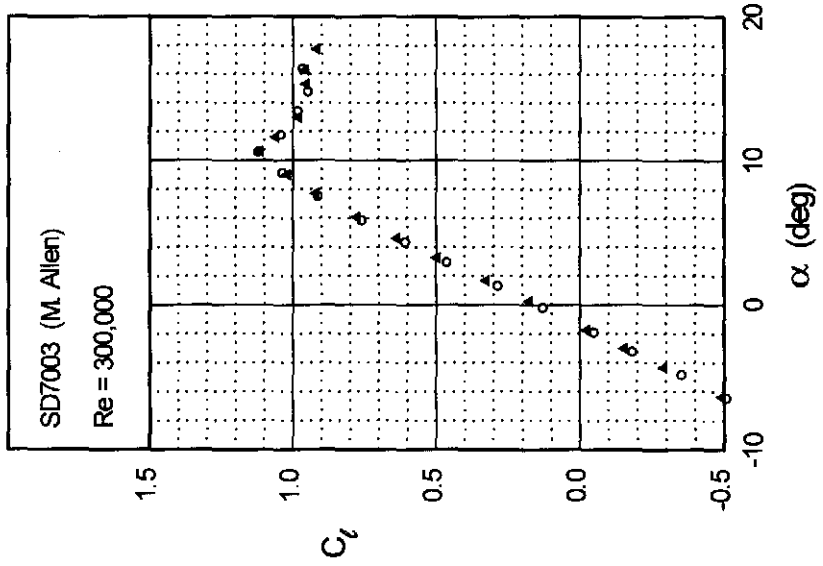
SD7003

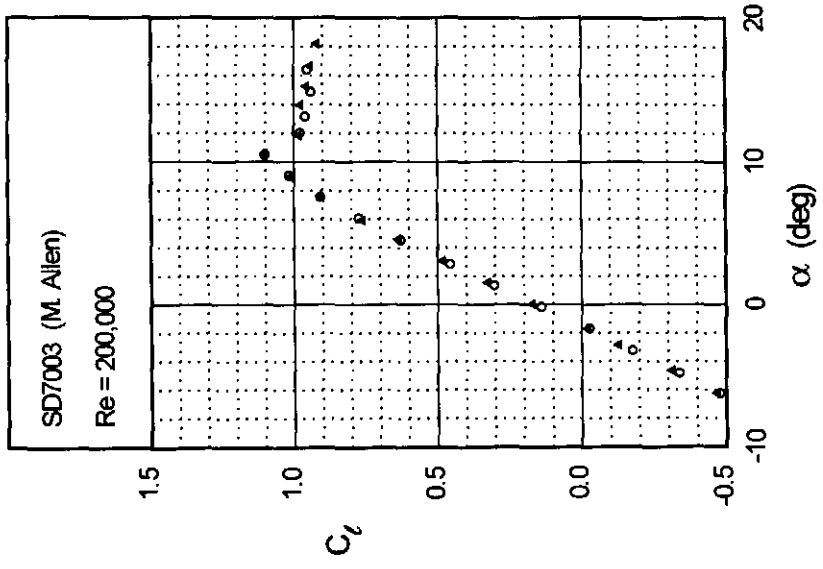

SD7003 (M. Allen)
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
$\alpha$ (deg)

SD7003

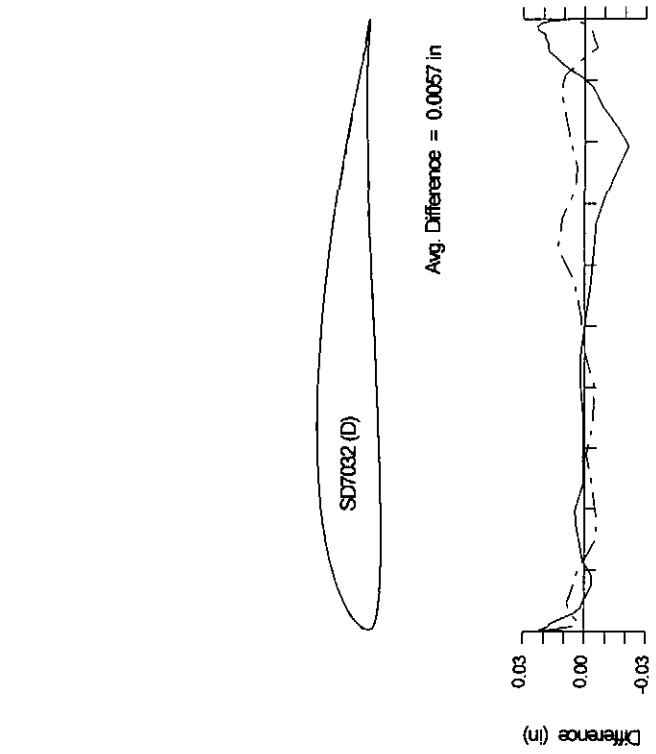

SD7003 (M. Allen)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

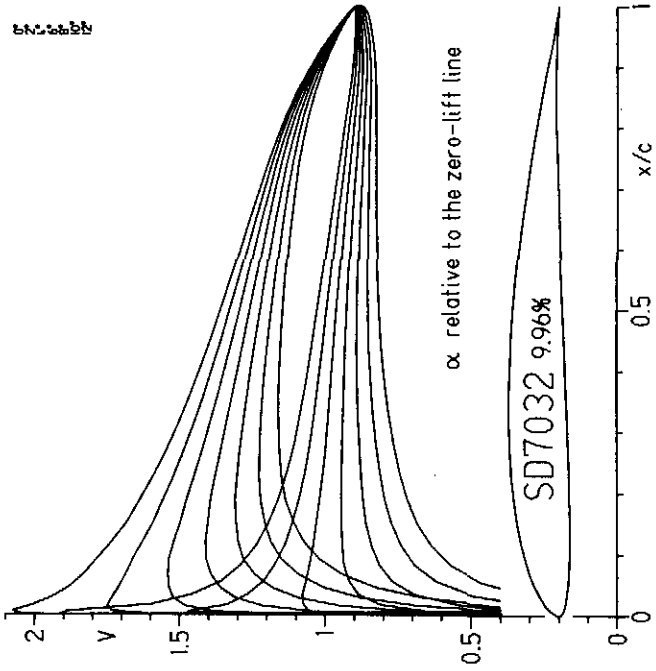

SD7003 (M. Allen)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


SD7003 (M. Allen)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

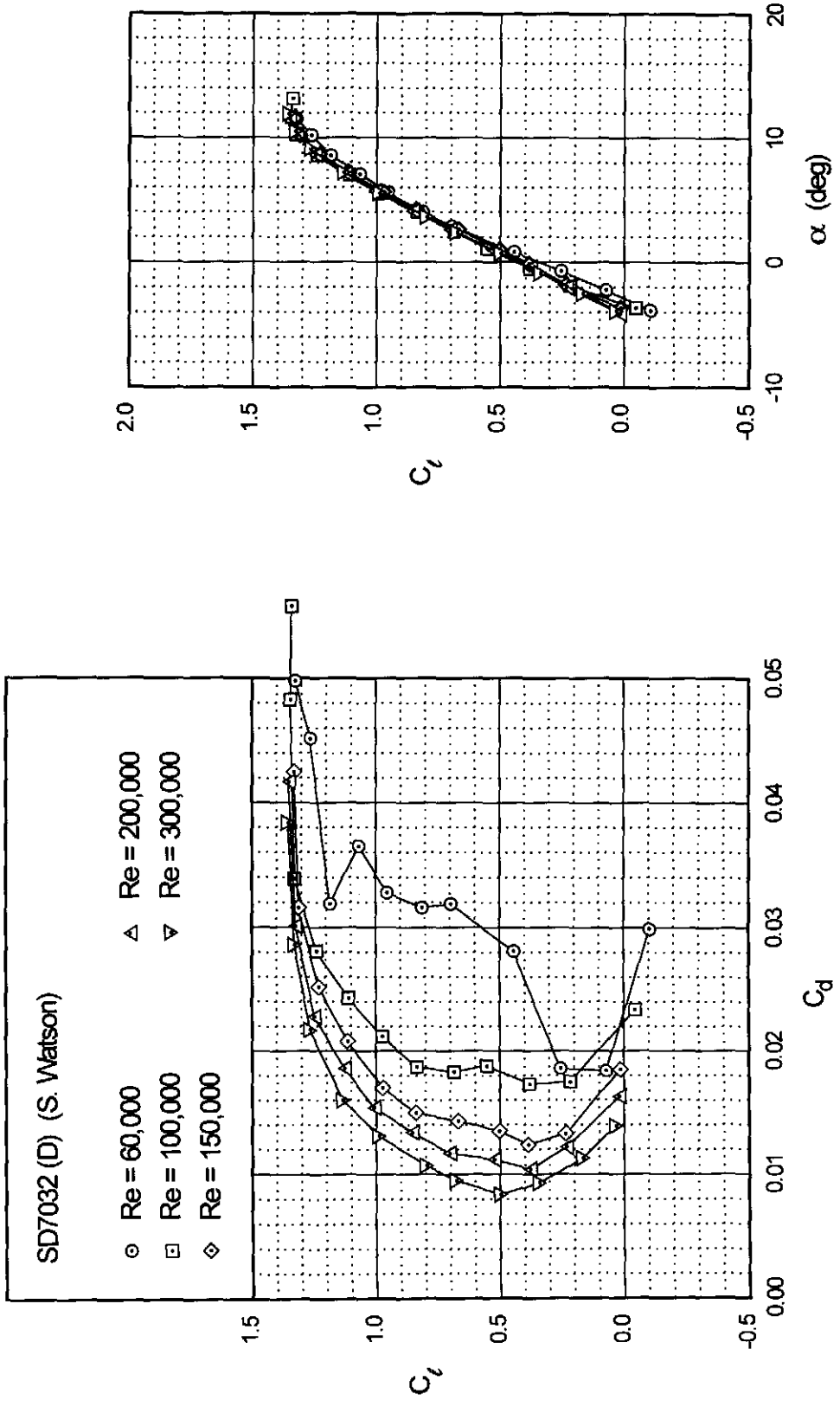

SD7003 (M. Allen)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

SD7032 (D)

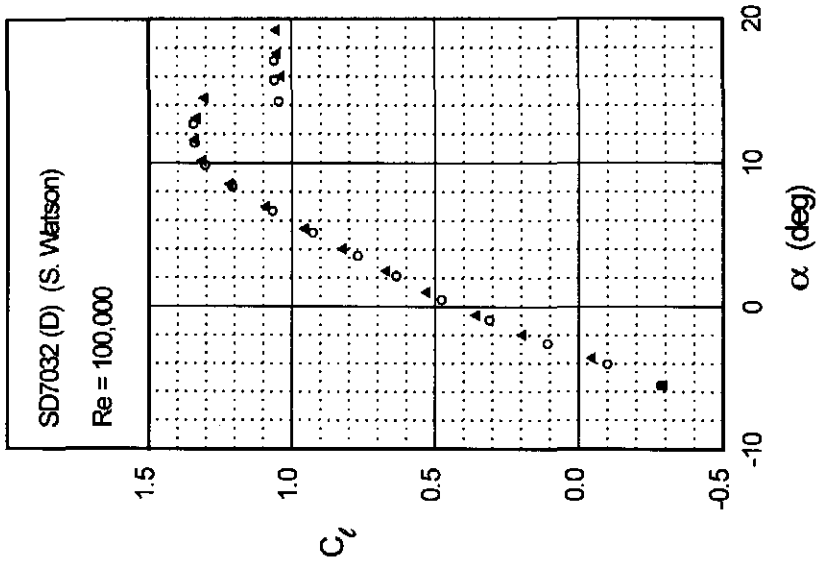

SD7032 (D)
Avg. Difference = 0.0057 in
0.03
0.00
-0.03
Difference (in)

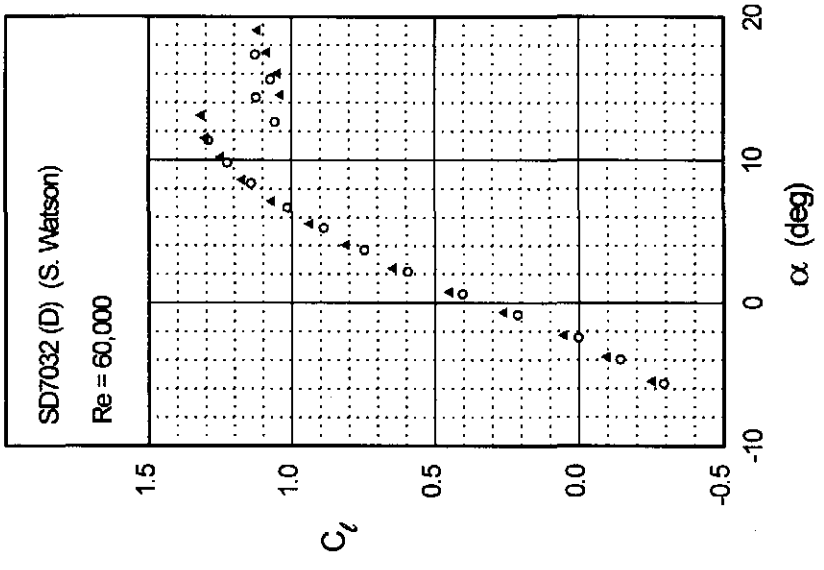

α relative to the zero-lift line
SD7032 9.96%
2
1.5
1
0.5
0
0.5
1
x/c

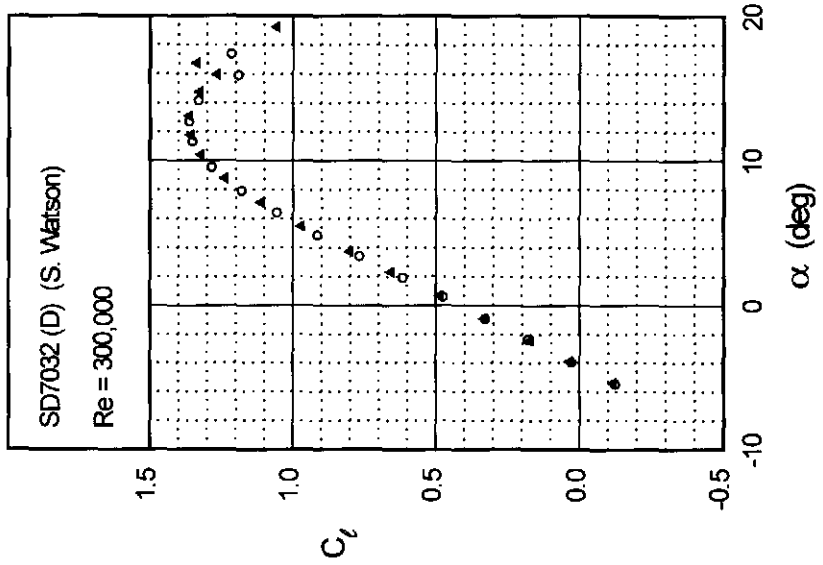
SD7032 (D)

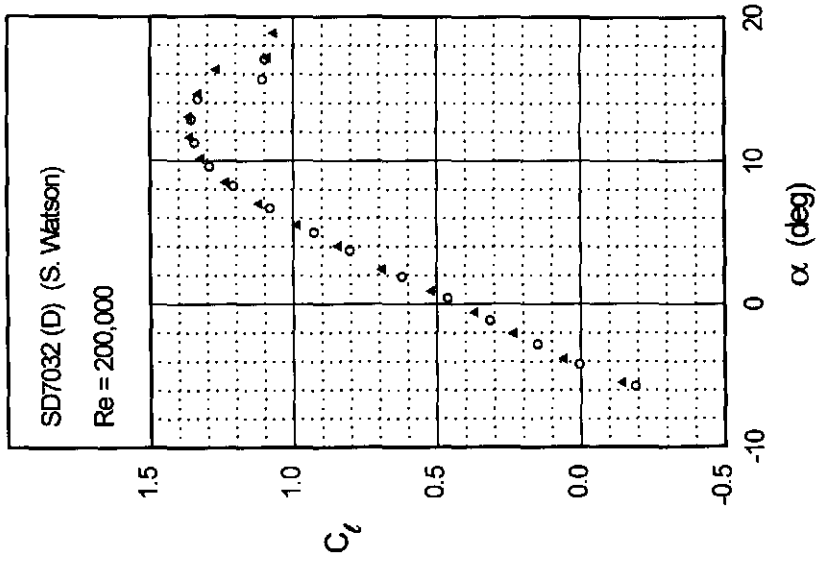

SD7032 (D) (S. Watson)
Re = 60,000
Re = 100,000
Re = 150,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
20
10
0
-10
0.05
0.04
0.03
0.02
0.01
0.00

SD7032 (D)

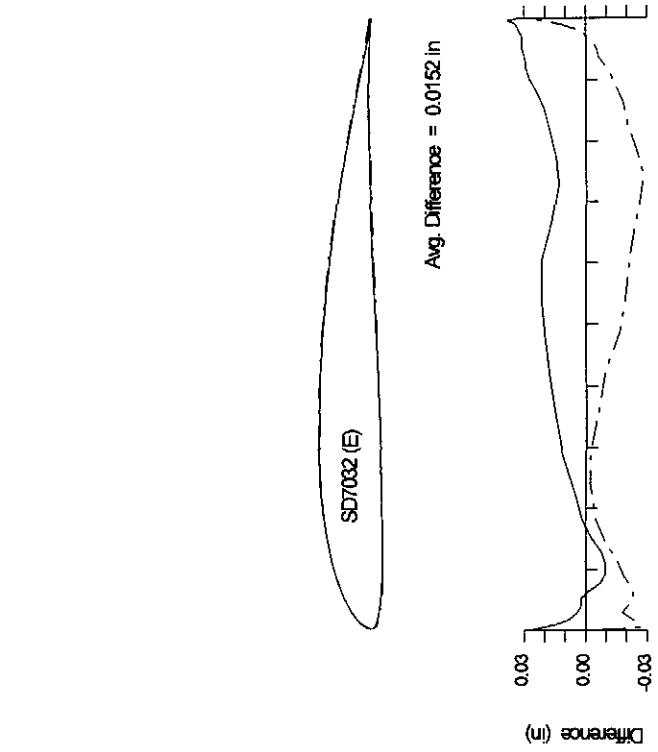

SD7032 (D) (S. Watson)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

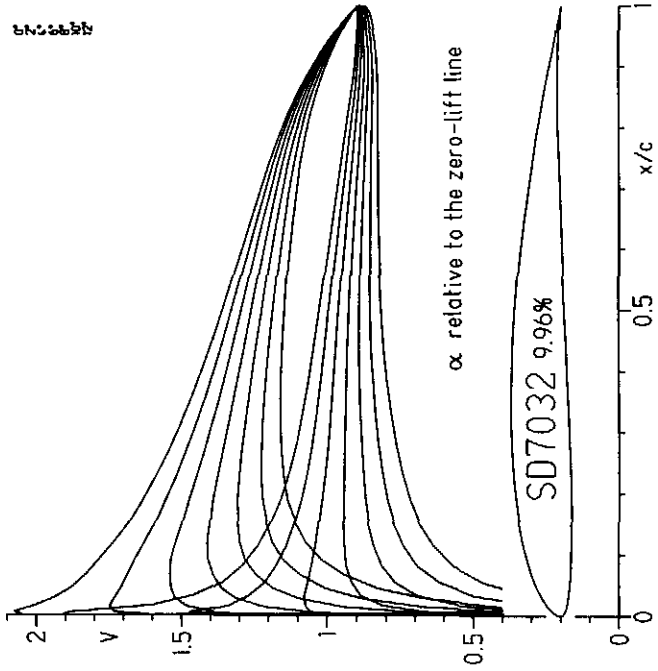

SD7032 (D) (S. Watson)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


SD7032 (D) (S. Watson)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

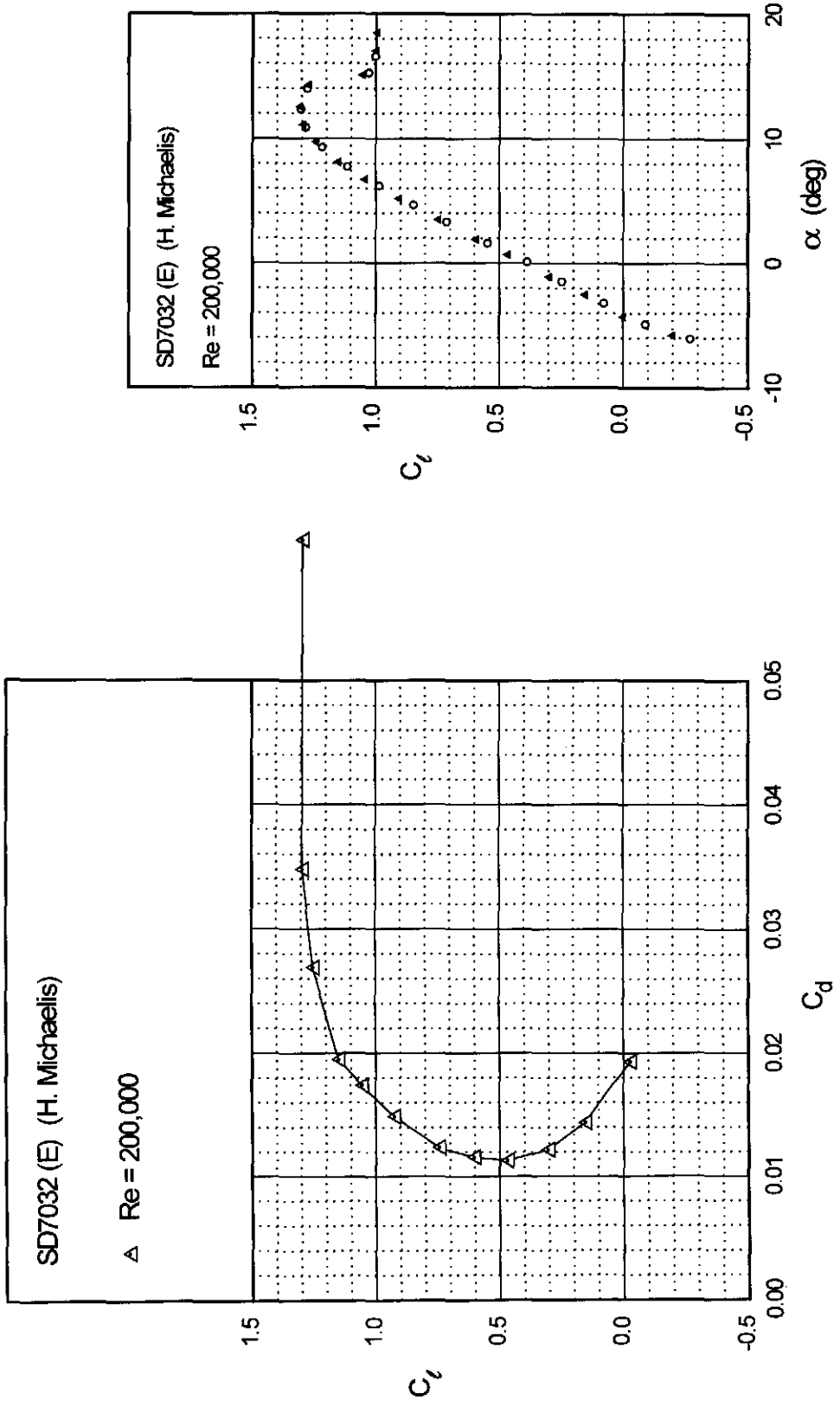

SD7032 (D) (S. Watson)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

SD7032 (E)

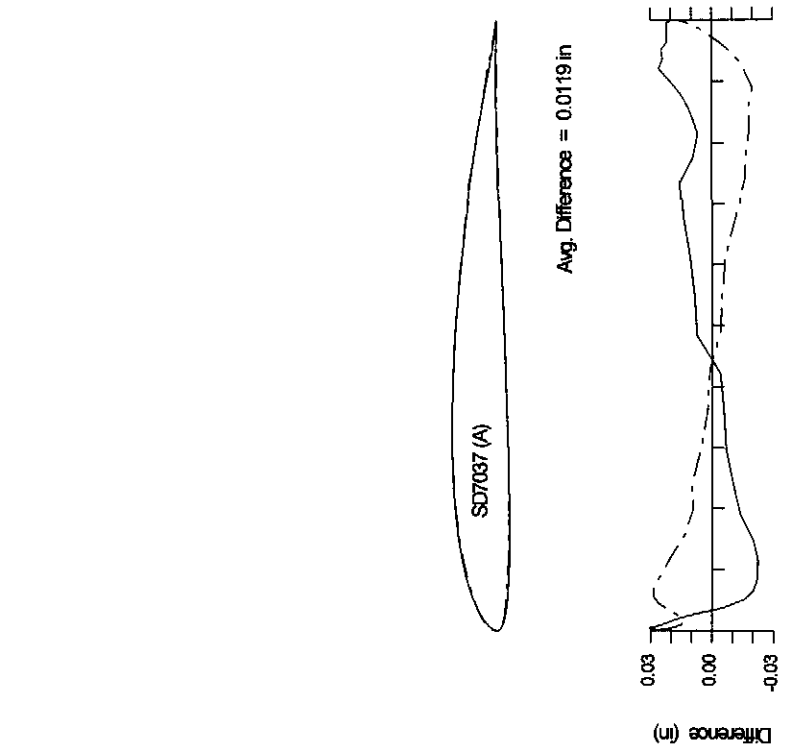

SD7032 (E)
Avg. Difference = 0.0152 in
0.03
0.00
-0.03
Difference (in)

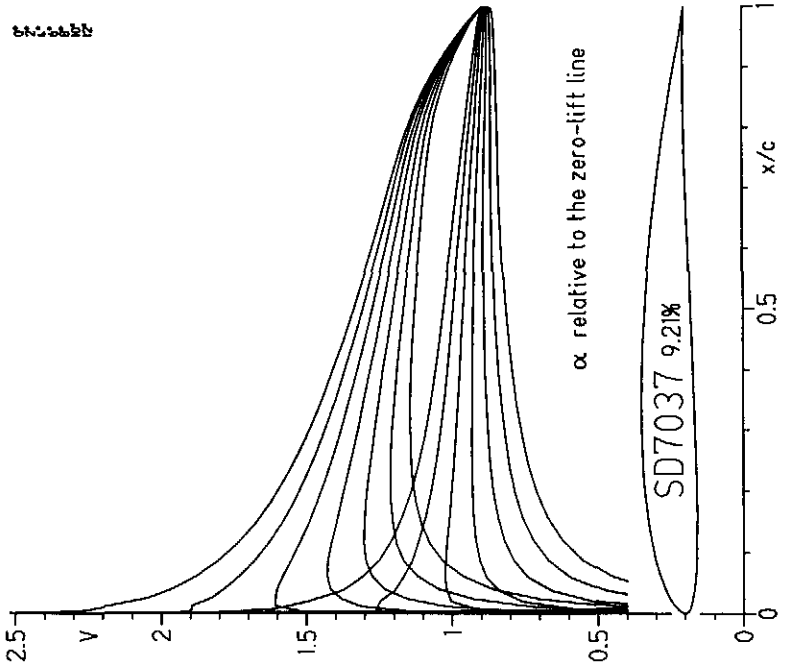

α relative to the zero-lift line
SD7032 9.96%
2
1.5
1
0.5
V
0
0.5
x/c

SD7032 (E)

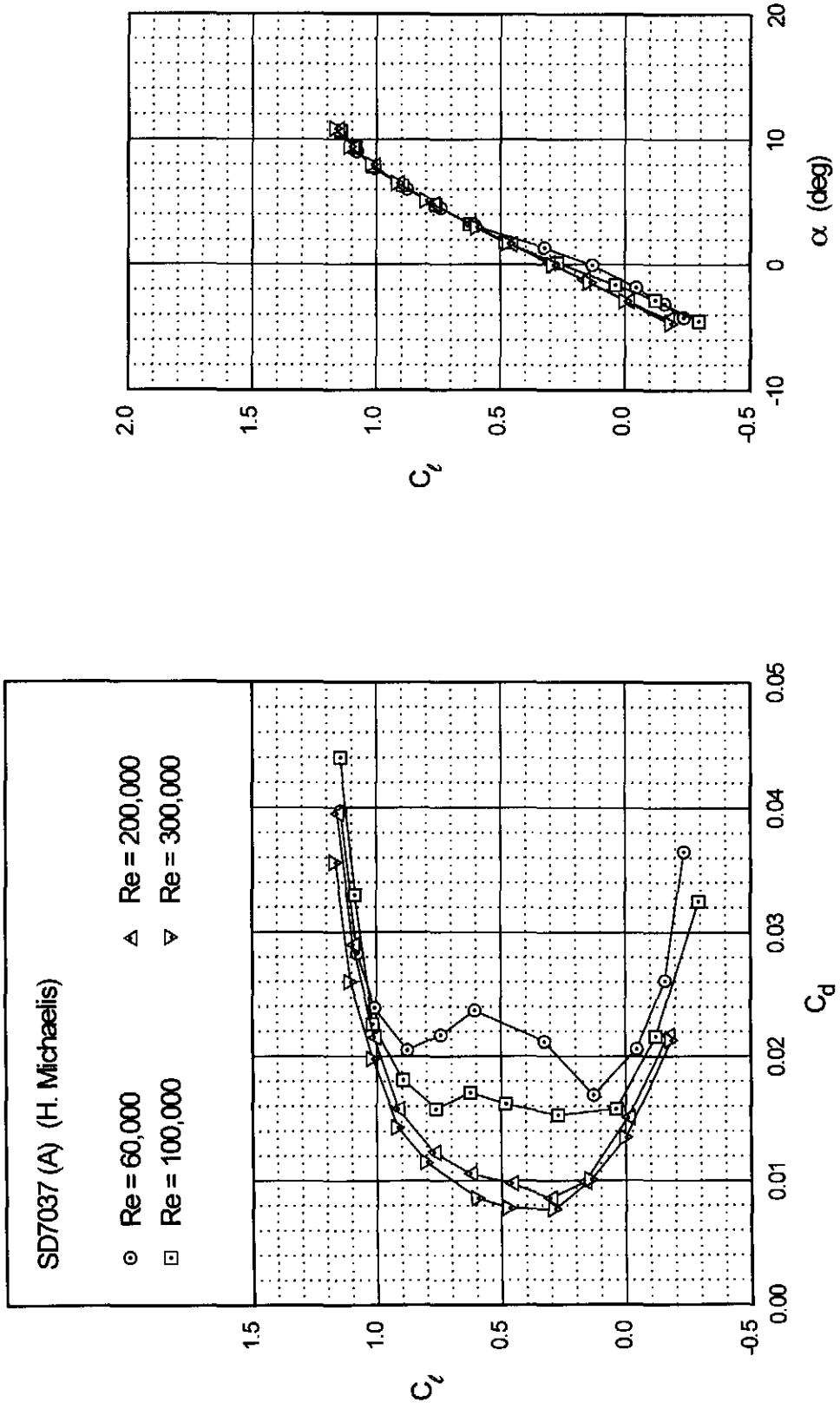

SD7032 (E) (H. Michaelis)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)
SD7032 (E) (H. Michaelis)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
0.05
0.04
0.03
0.02
0.01
0.00
$C_d$

SD7037 (A)

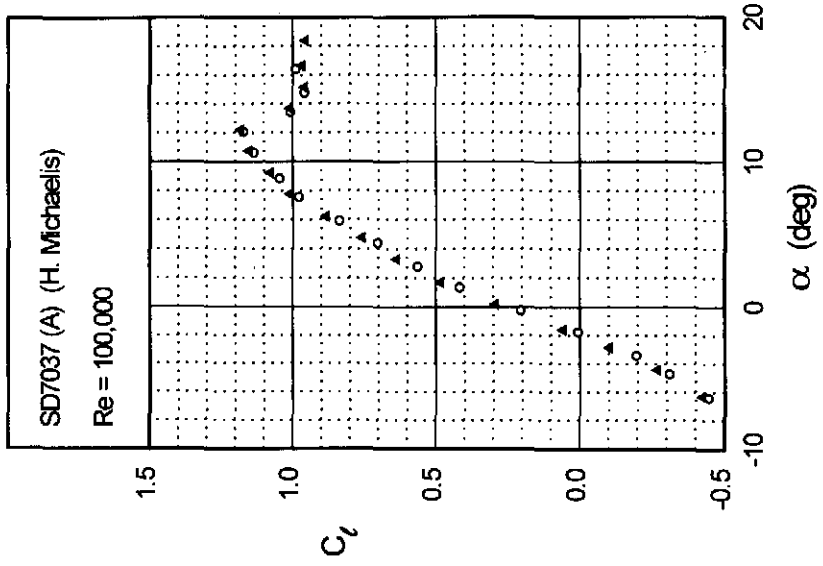

SD7037 (A)
Avg. Difference = 0.0119 in
0.03
0.00
-0.03
Difference (in)

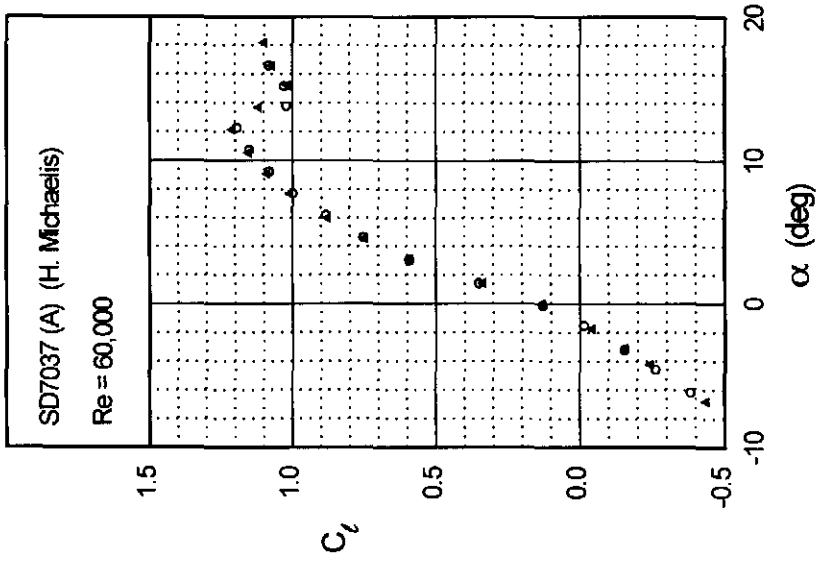

α relative to the zero-lift line
SD7037 9.21%
2.5
2
1.5
1
0.5
V
0
0.5
1
x/c

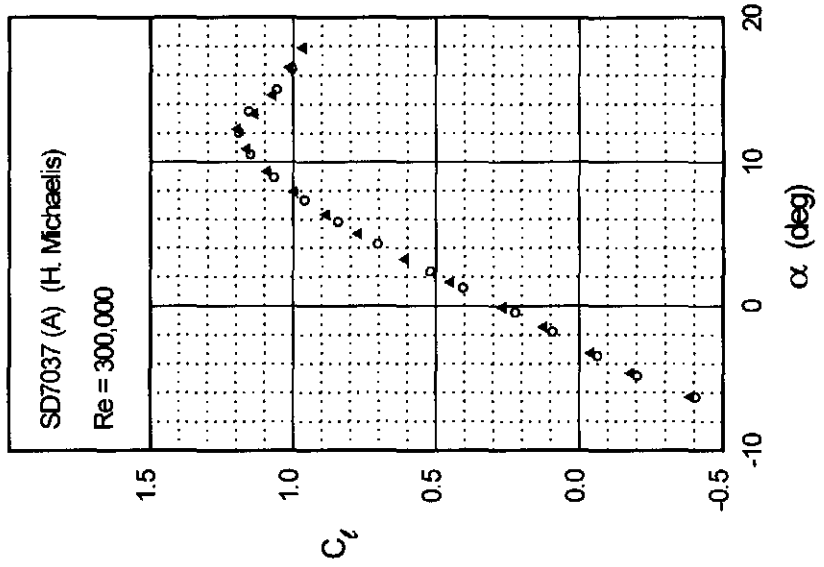
SD7037 (A)

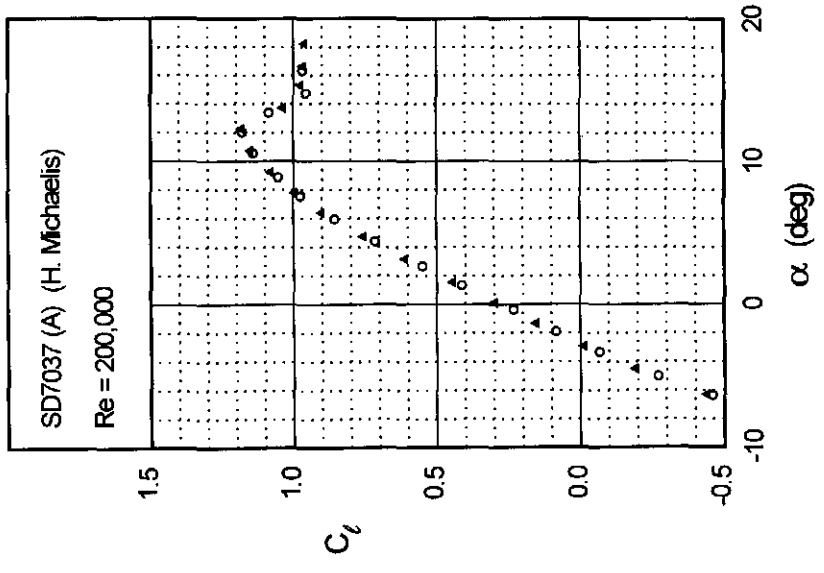

SD7037 (A) (H. Michaelis)
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
$\alpha$ (deg)

SD7037 (A)

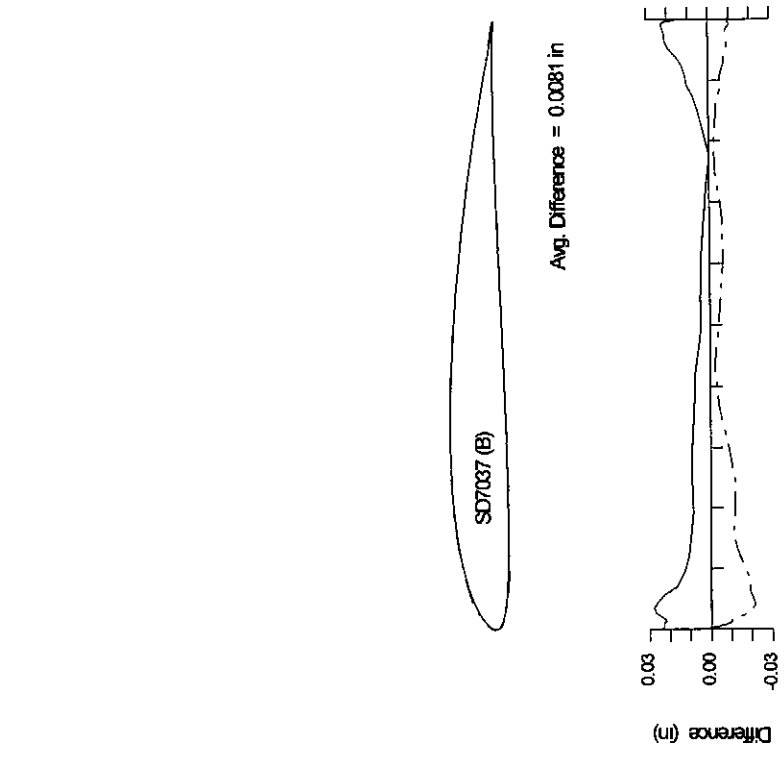

SD7037 (A) (H. Michaelis)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

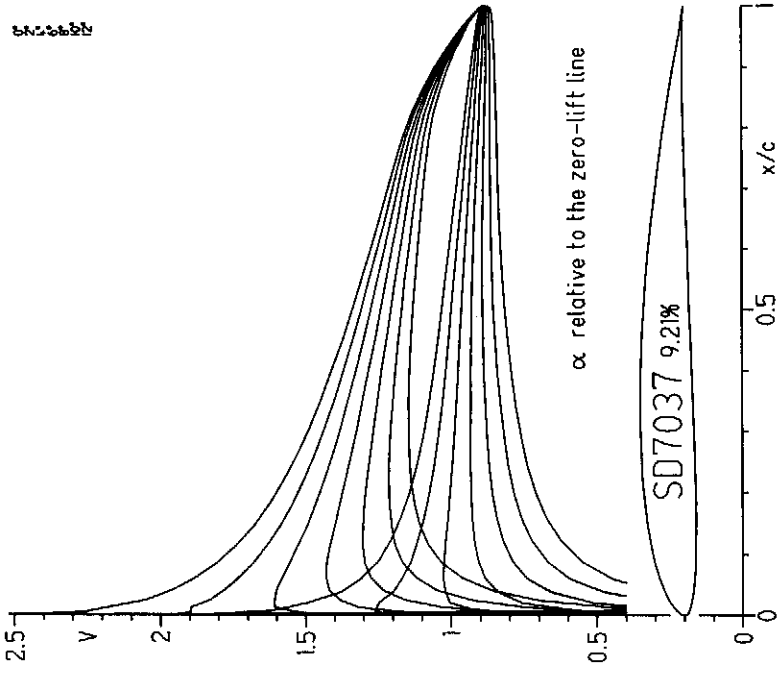

SD7037 (A) (H. Michaelis)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


SD7037 (A) (H. Michaelis)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

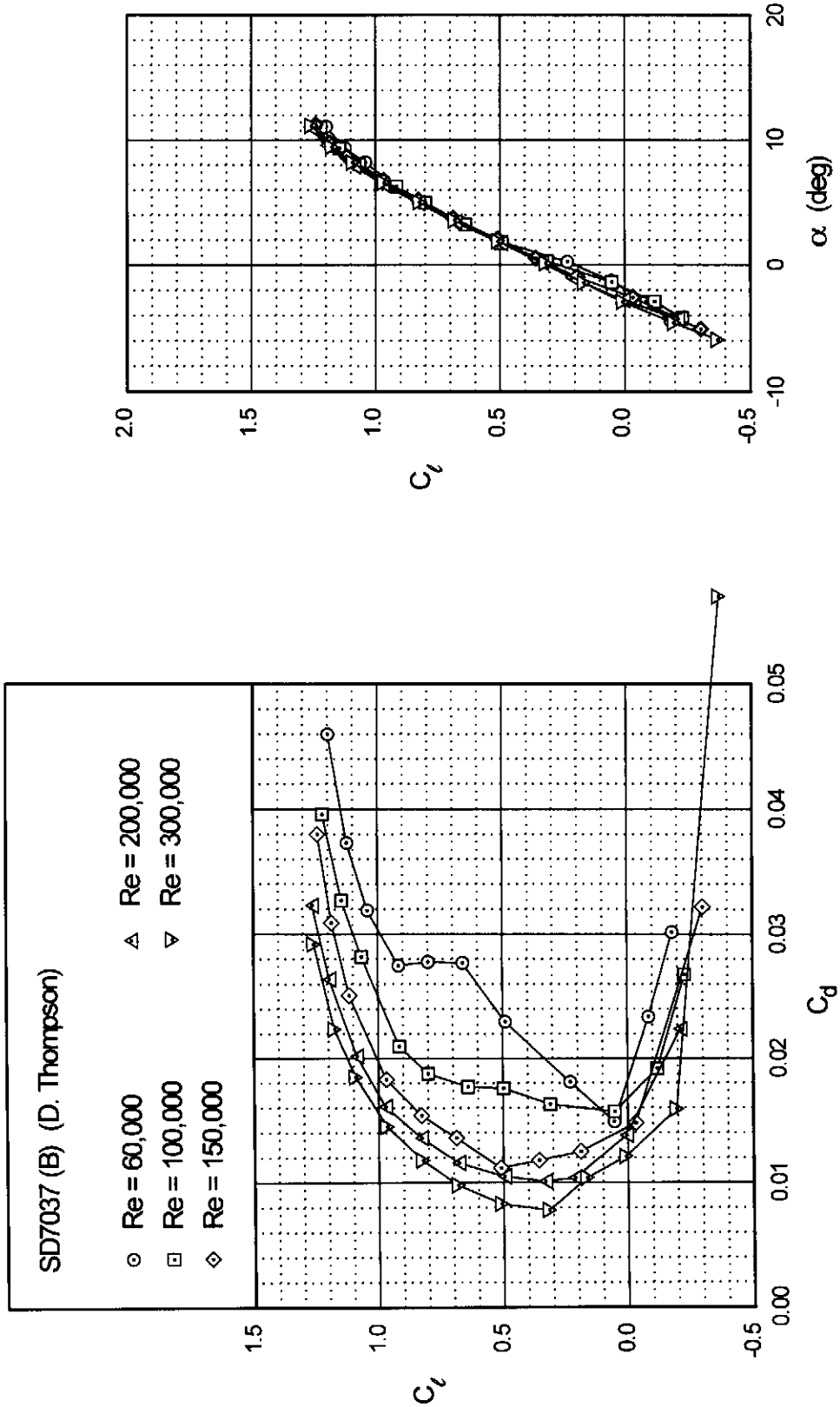

SD7037 (A) (H. Michaelis)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

SD7037 (B)

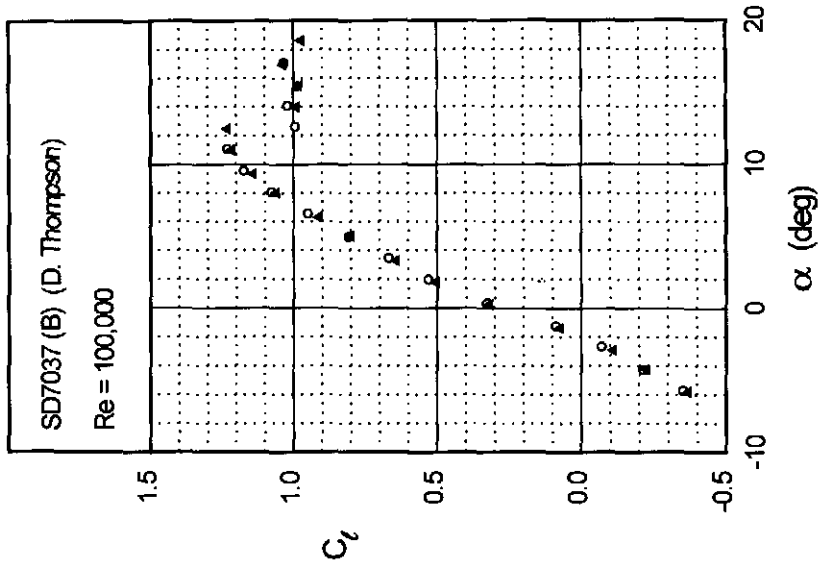

SD7037 (B)
Avg. Difference = 0.0081 in
0.03
0.00
-0.03
Difference (in)

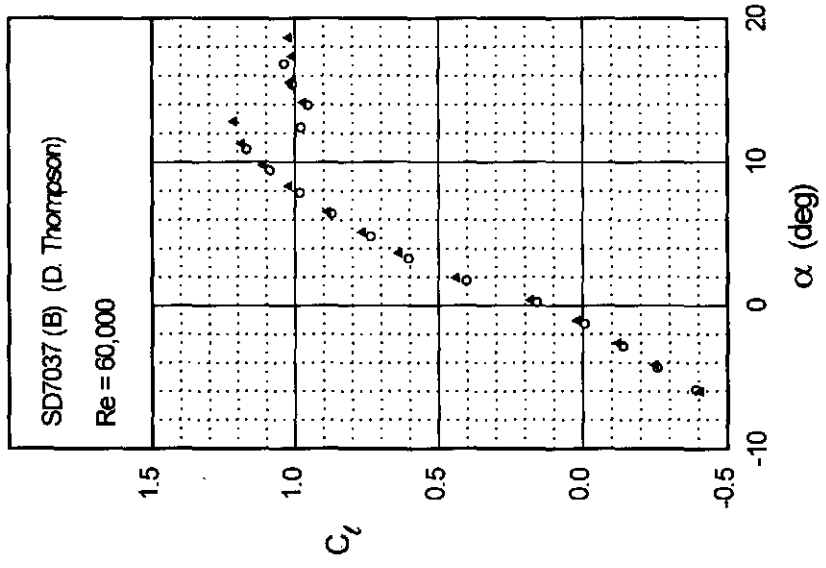

α relative to the zero-lift line
SD7037 9.21%
2.5
2
1.5
1
0.5
0
0.5
x/c

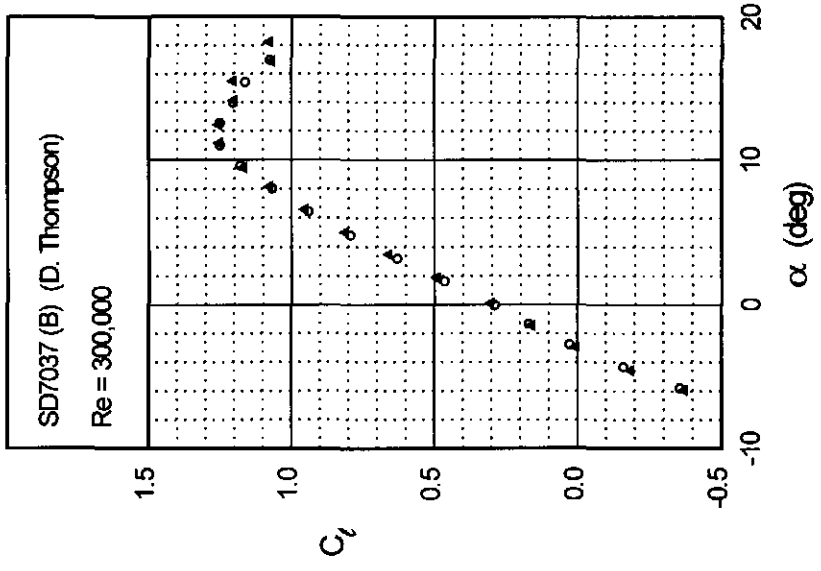
SD7037 (B)

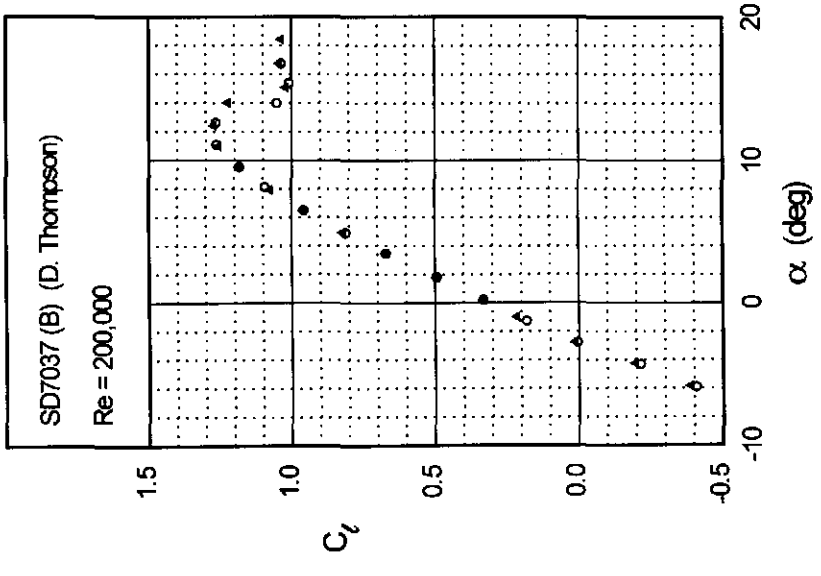

SD7037 (B) (D. Thompson)
Re = 60,000
Re = 100,000
Re = 150,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
20
10
0
-10
0.05
0.04
0.03
0.02
0.01
0.00

SD7037 (B)

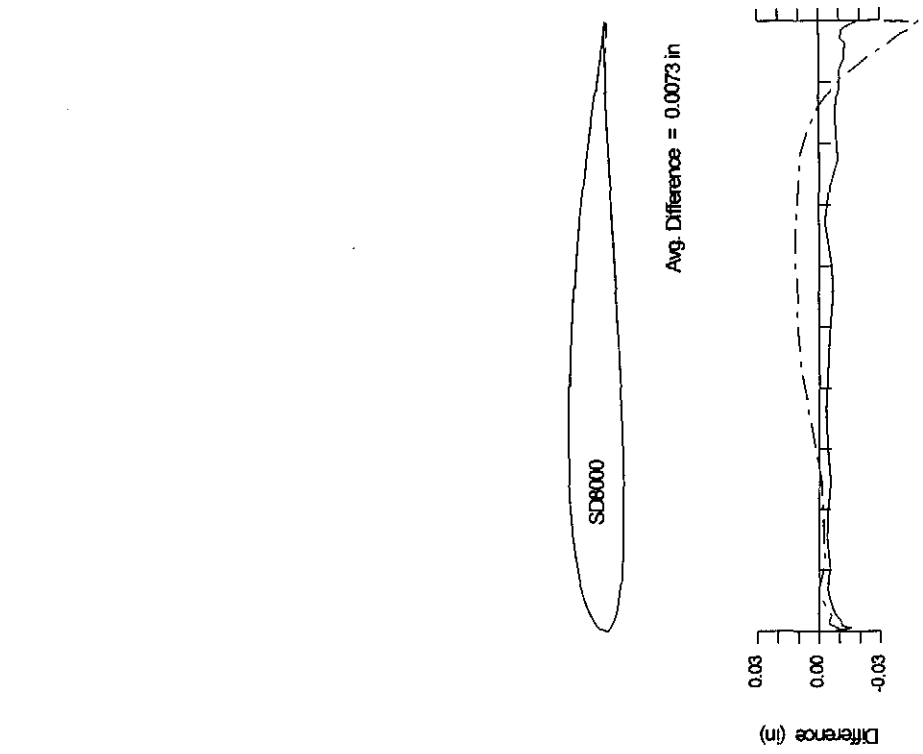

SD7037 (B) (D. Thompson)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

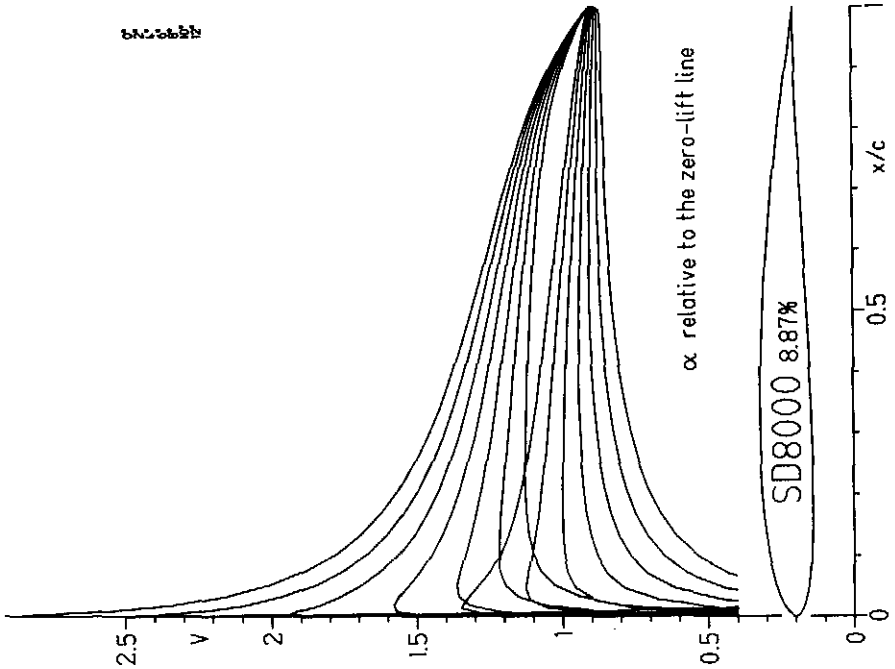

SD7037 (B) (D. Thompson)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


SD7037 (B) (D. Thompson)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

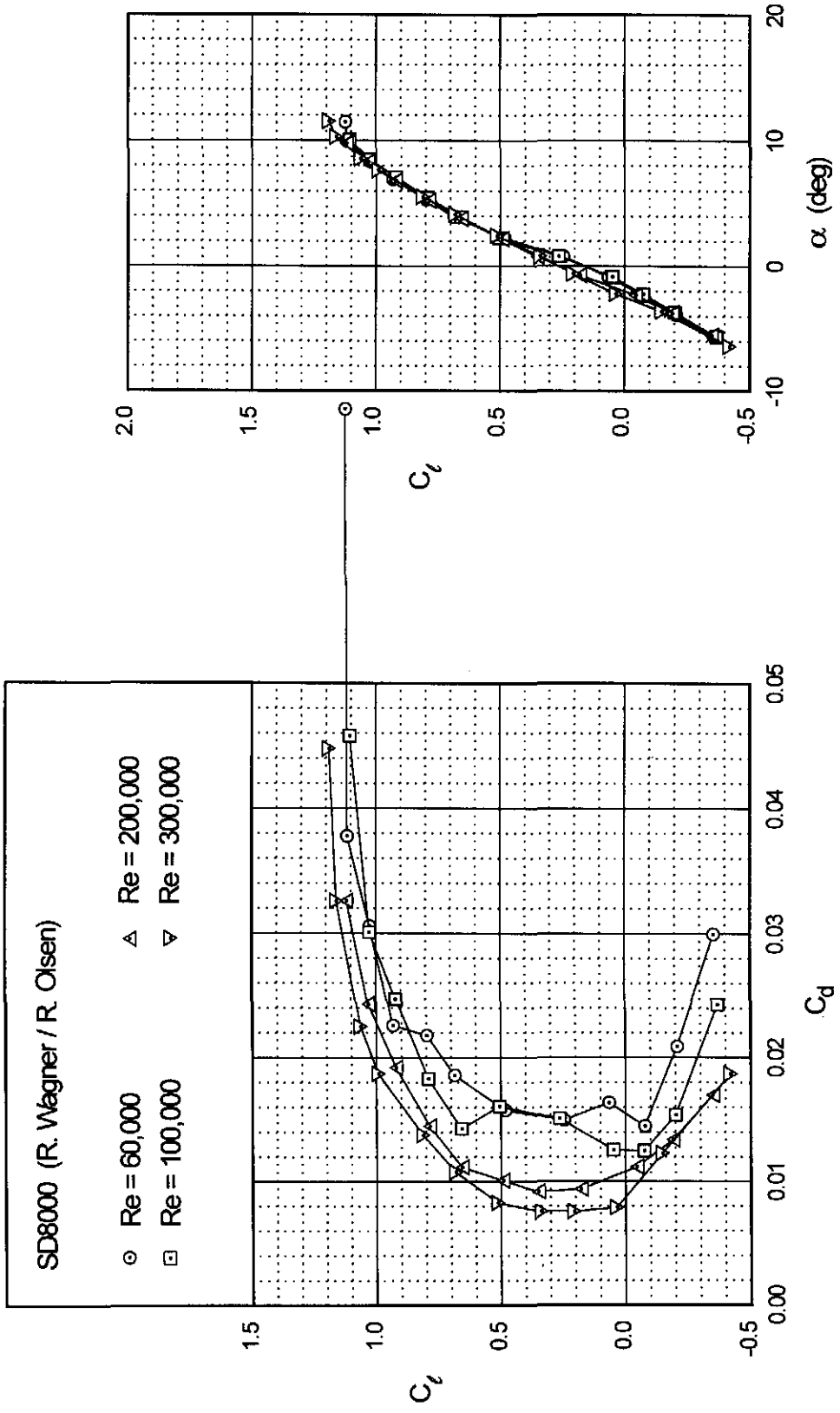

SD7037 (B) (D. Thompson)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

SD8000

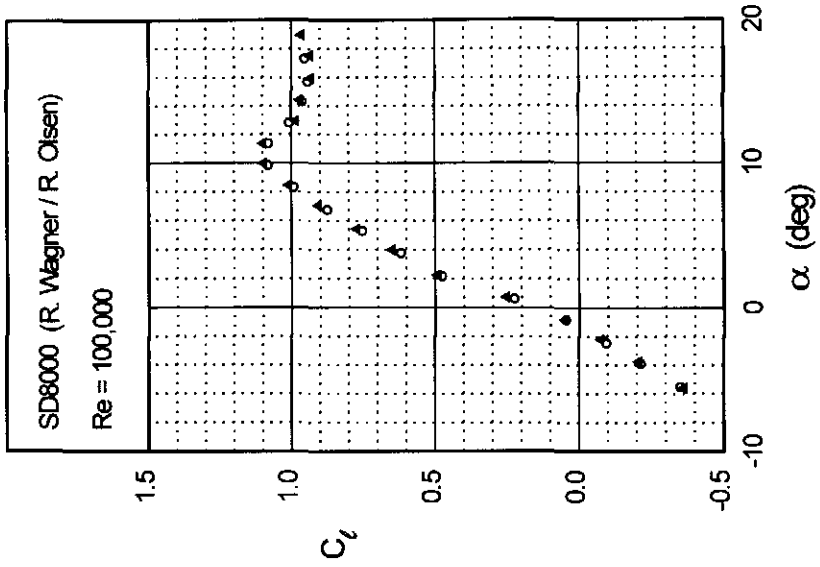

SD8000
Avg. Difference = 0.0073 in
0.03
0.00
-0.03
Difference (in)

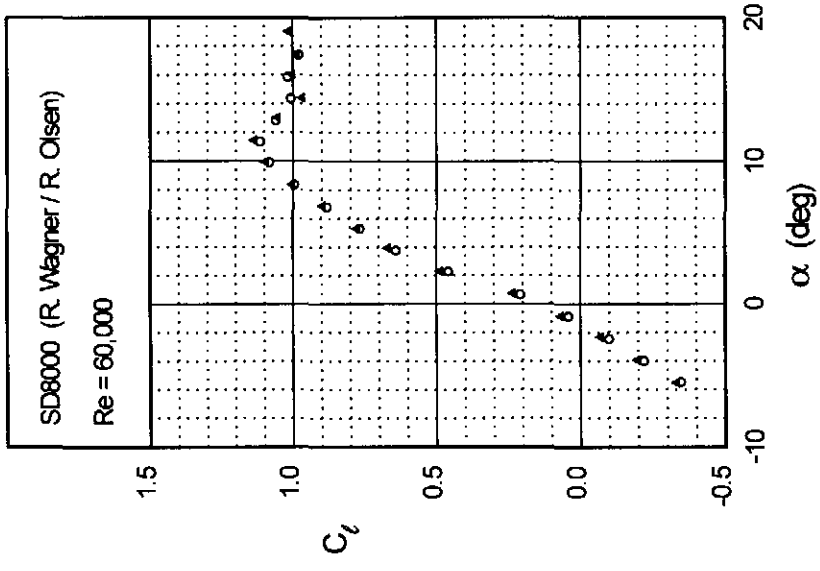

α relative to the zero-lift line
SD8000 8.87%
x/c
0
0.5
0
2.5
2
1.5
1
0.5

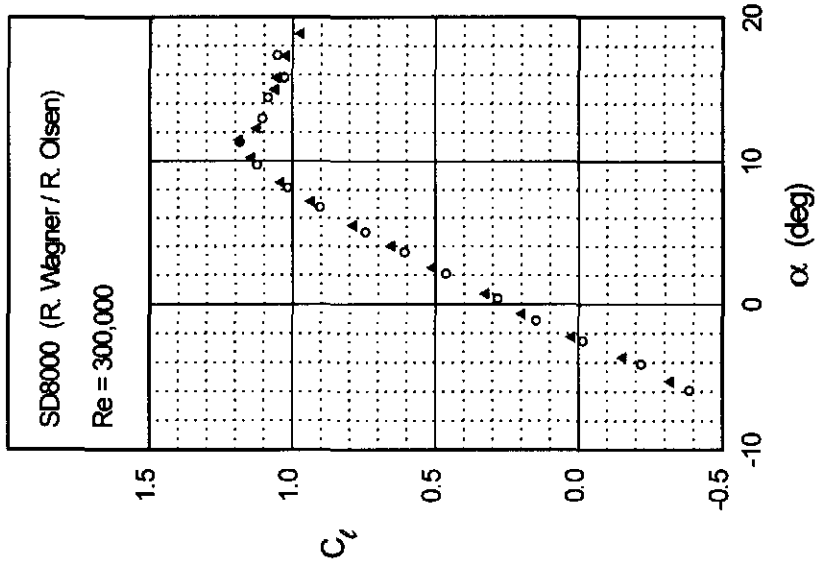
SD8000

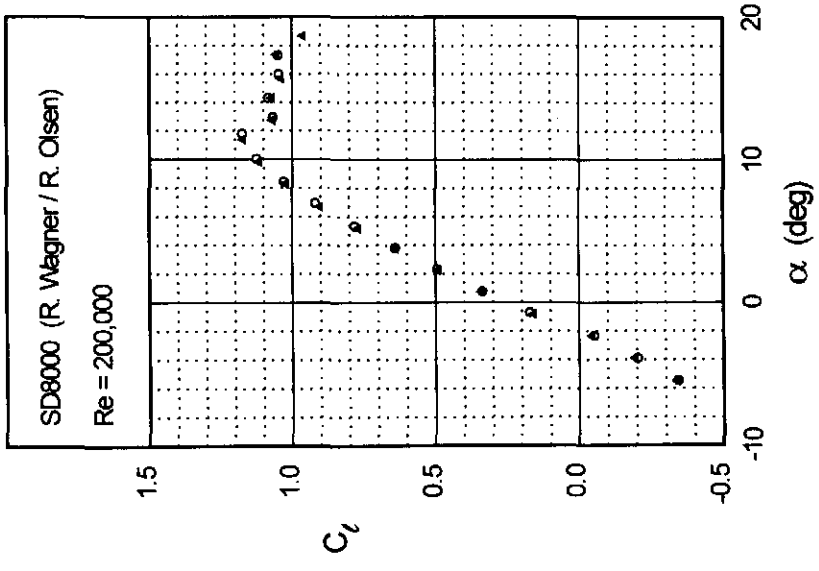

SD8000 (R. Wagner / R. Olsen)
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
$\alpha$ (deg)
1.5
1.0
0.5
0.0
-0.5
0.00
0.01
0.02
0.03
0.04
0.05
2.0
20
10
0
-10

SD8000

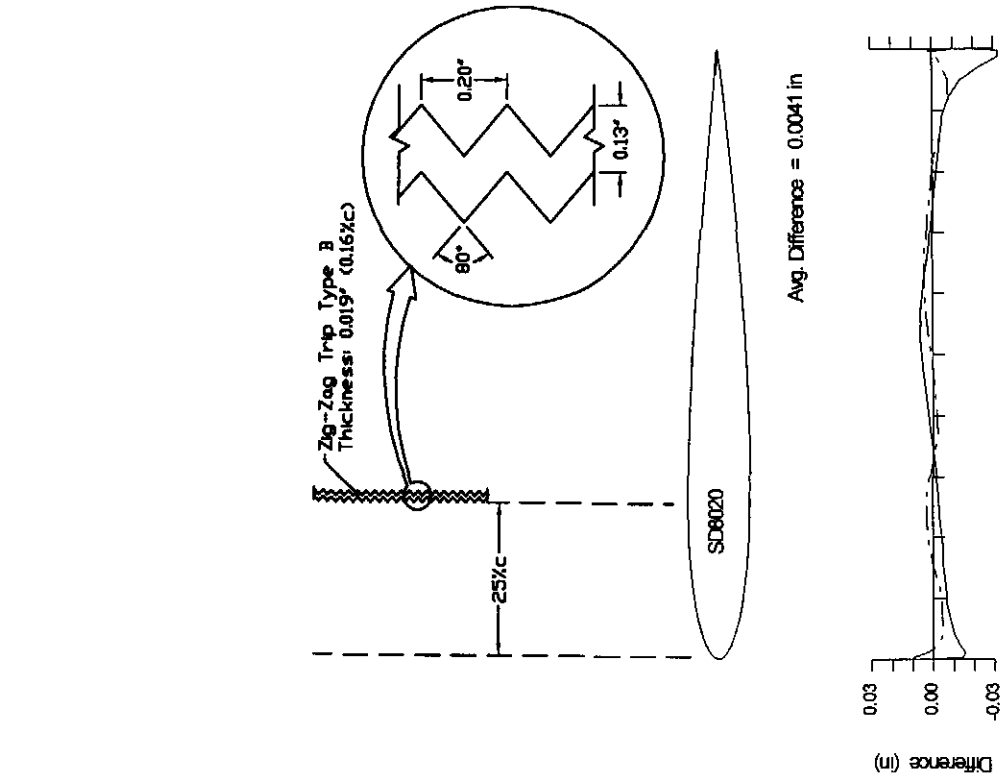

SD8000 (R. Wagner / R. Olsen)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

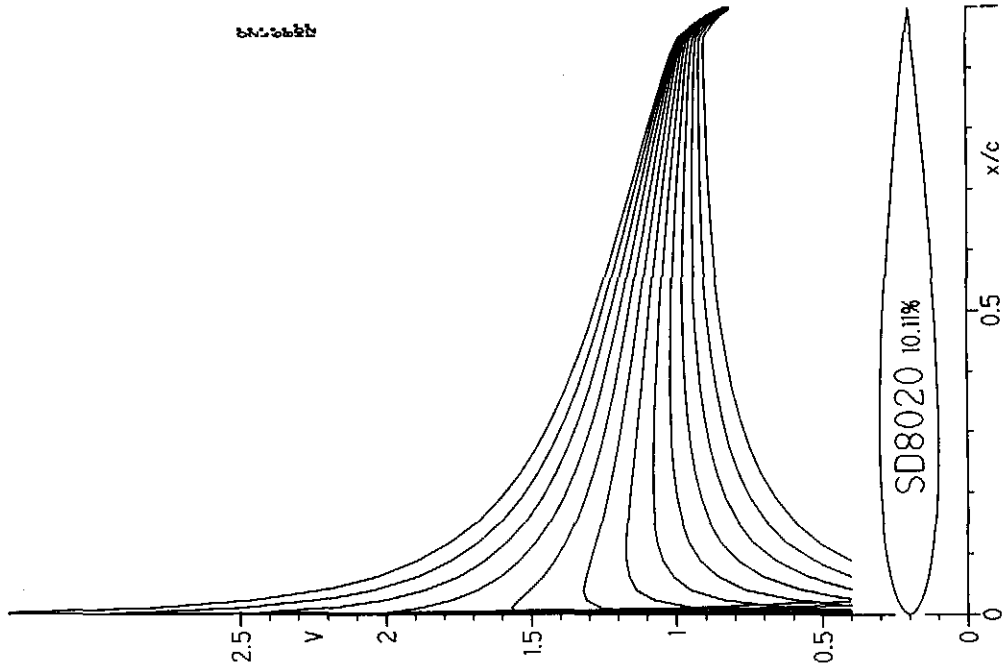

SD8000 (R. Wagner / R. Olsen)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


SD8000 (R. Wagner / R. Olsen)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

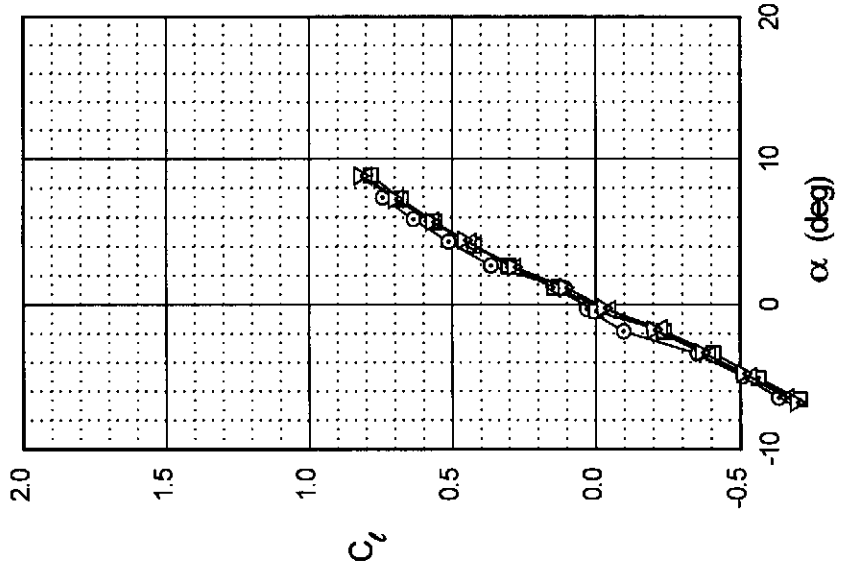

SD8000 (R. Wagner / R. Olsen)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

SD8020


Zig-Zag Trip Type B
Thickness: 0.019" (0.16%c)
0.20"
0.13"
80°
25%c
SD8020
Avg. Difference = 0.0041 in
0.03
0.00
-0.03
Difference (in)


2.5
2
1.5
1
0.5
y
SD8020 10.11%
0
0.5
x/c

SD8020


2.0
1.5
1.0
0.5
0.0
-0.5
$C_l$
20
10
0
-10
α (deg)

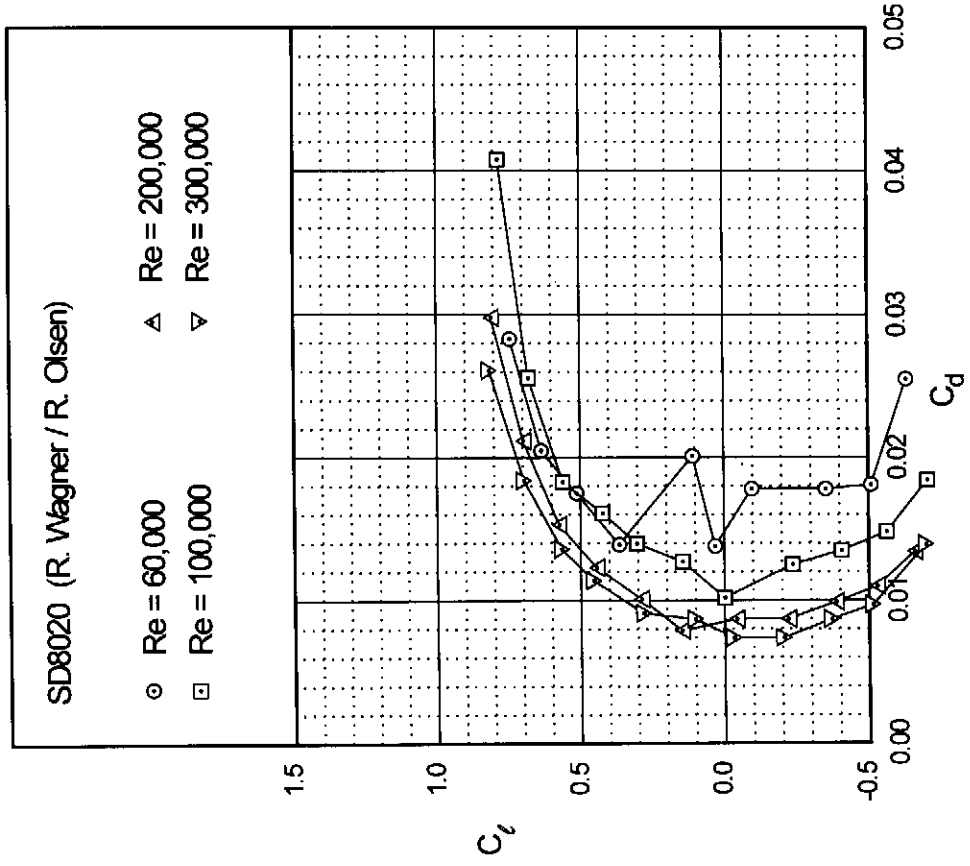
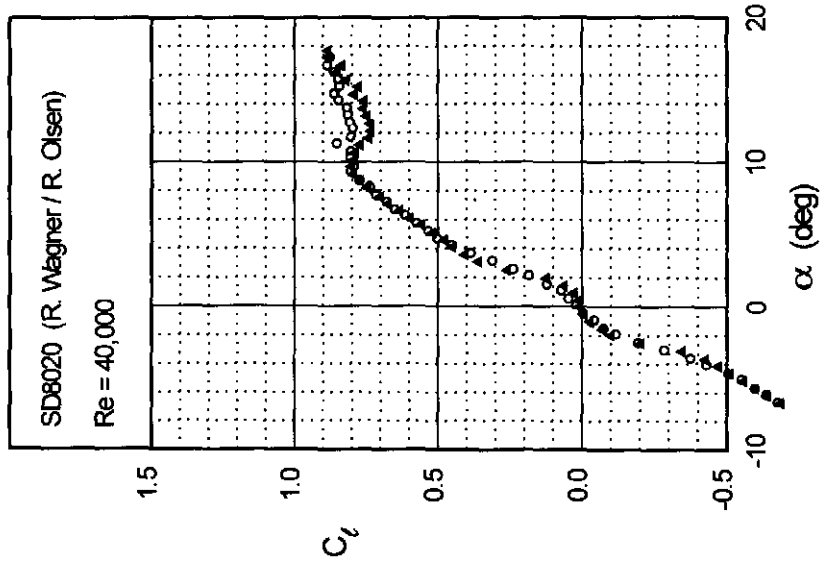
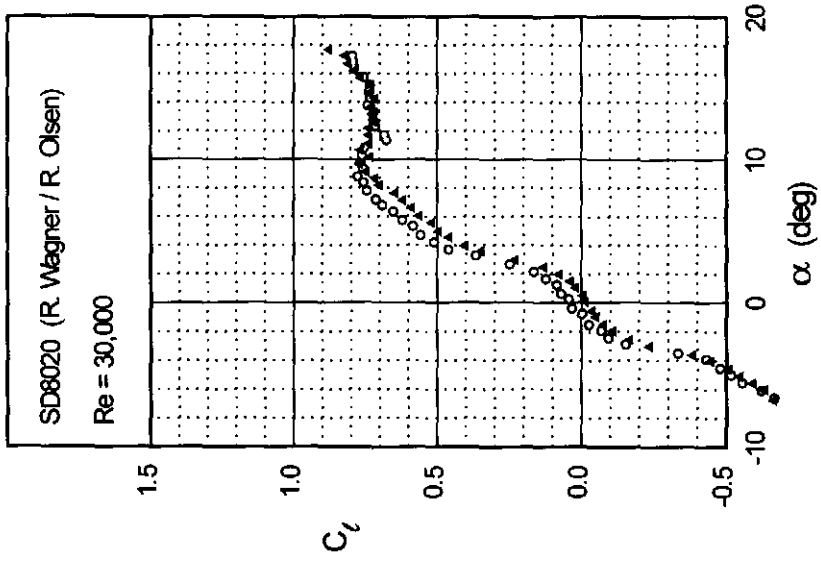
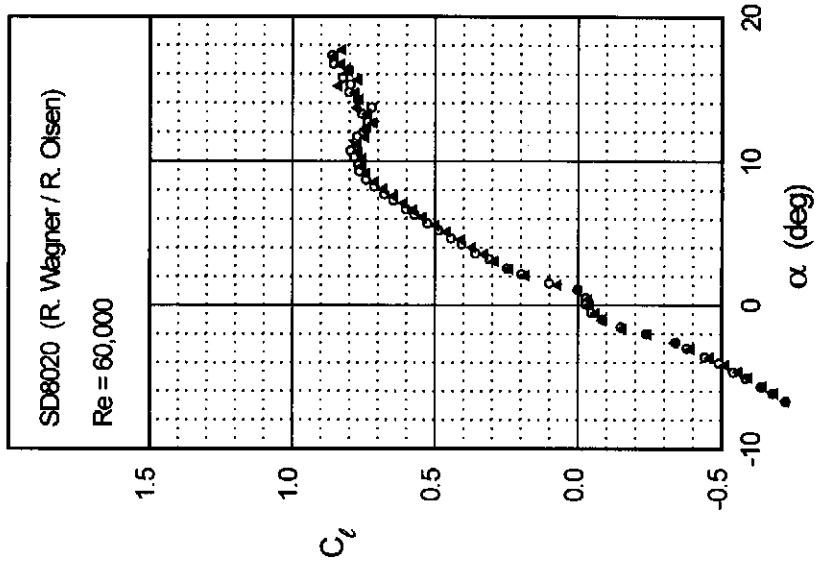

SD8020 (R. Wagner / R. Olsen)
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
0.05
0.04
0.03
0.02
0.01
0.00
$C_d$

Fig. 4.146

SD8020




SD8020 (R. Wagner / R. Olsen)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

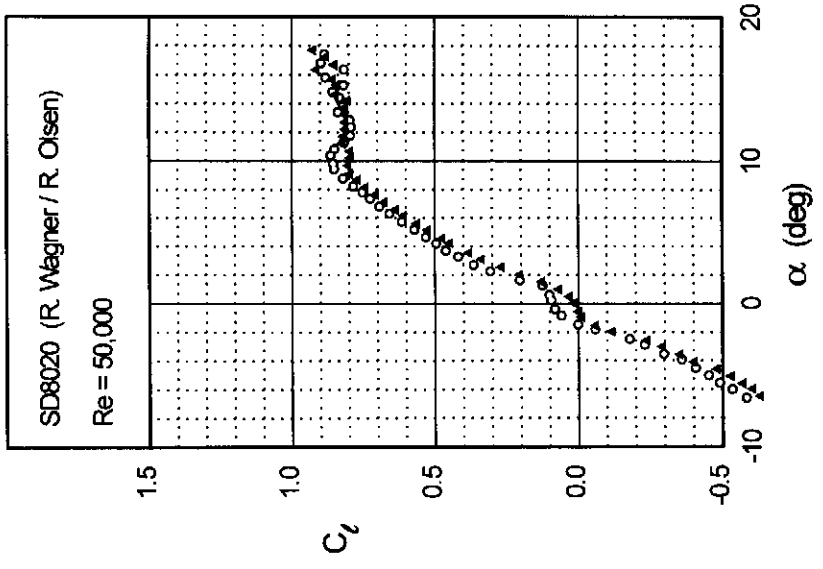
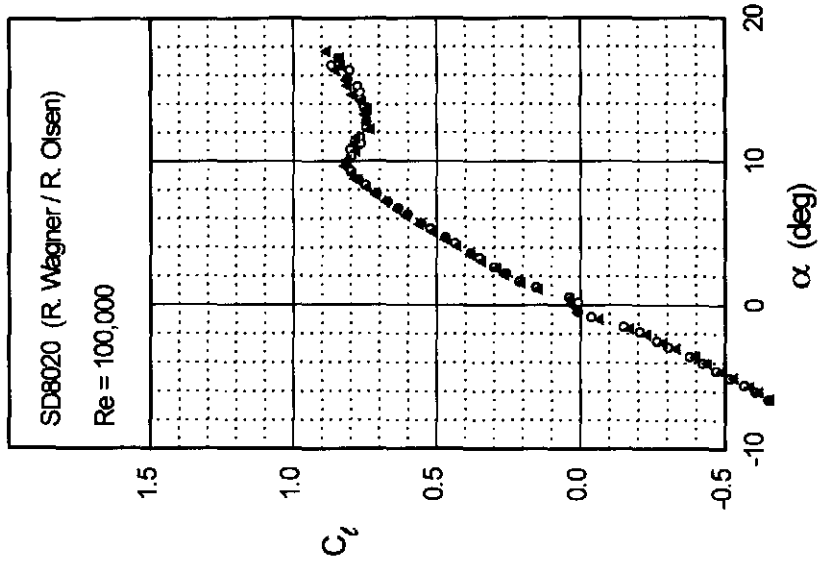
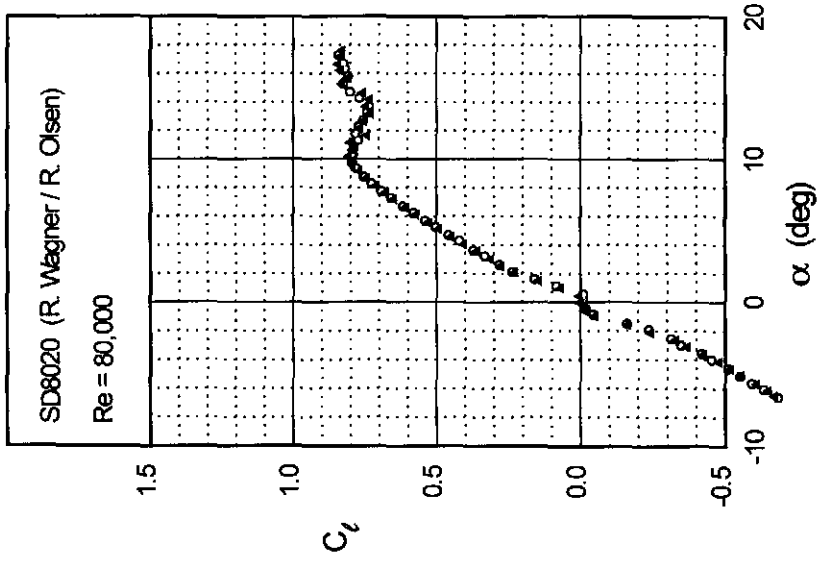
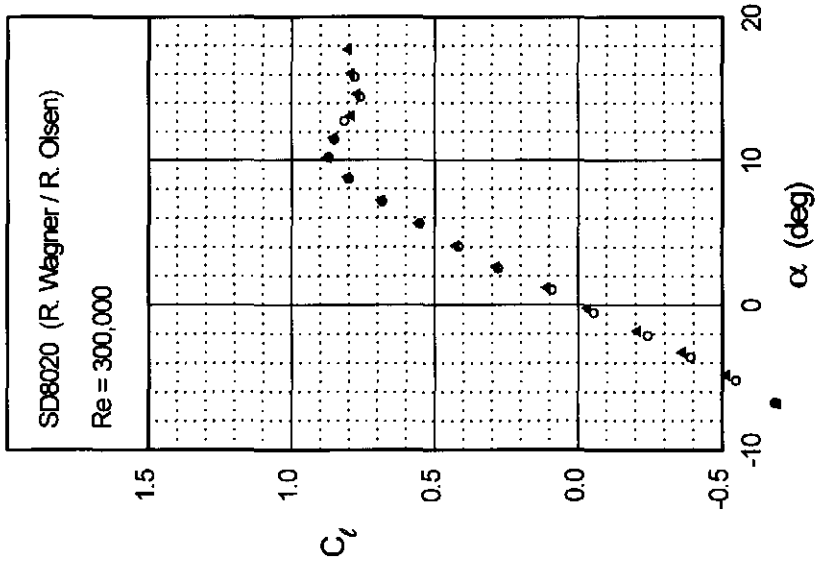

SD8020 (R. Wagner / R. Olsen)
Re = 50,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

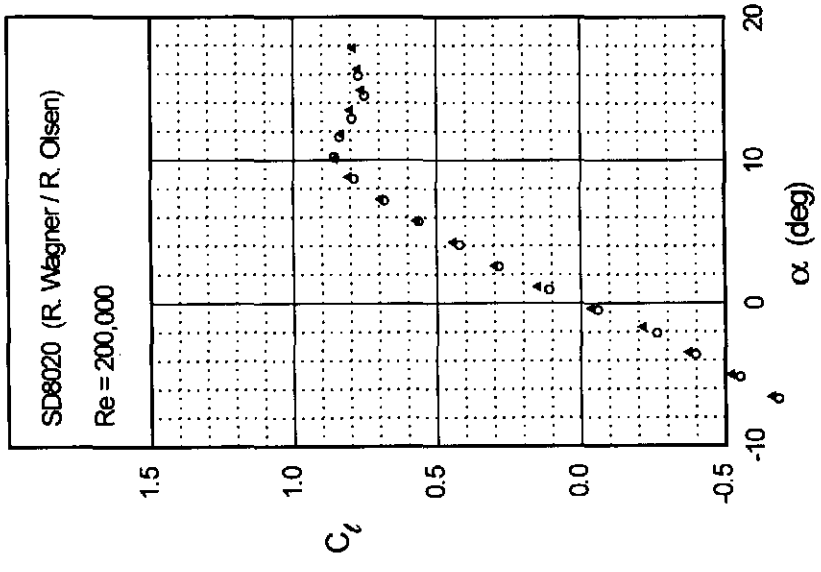
Fig. 4.146 (continued)

SD8020

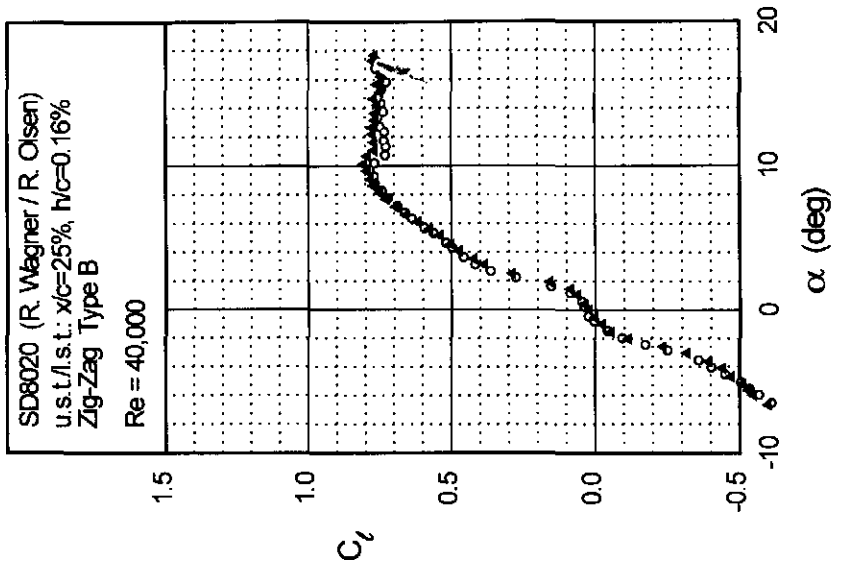


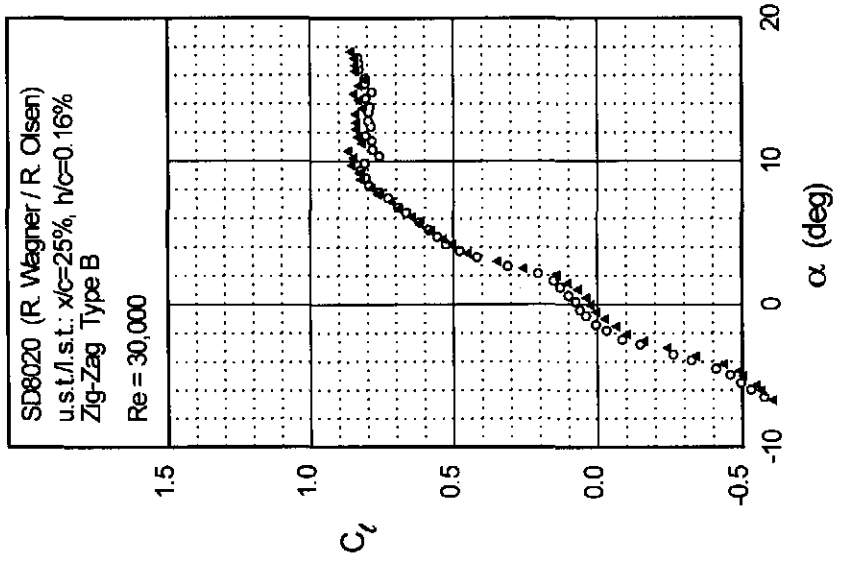



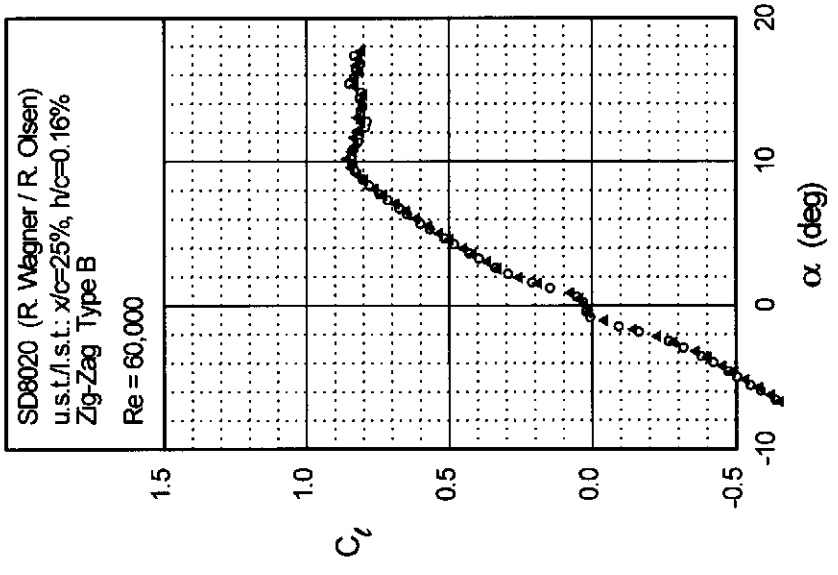

SD8020 (R. Wagner / R. Olsen)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)


SD8020 (R. Wagner / R. Olsen)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

SD8020


SD8020 (R. Wagner / R. Olsen)
u.s.t./l.s.t.: x/c=25%, h/c=0.16%
Zig-Zag Type B
Re = 40,000
1.5
1.0
0.5
0.0
-0.5
-10
0
10
20
α (deg)
$C_l$


SD8020 (R. Wagner / R. Olsen)
u.s.t./l.s.t.: x/c=25%, h/c=0.16%
Zig-Zag Type B
Re = 30,000
1.5
1.0
0.5
0.0
-0.5
-10
0
10
20
α (deg)
$C_l$


SD8020 (R. Wagner / R. Olsen)
u.s.t./l.s.t.: x/c=25%, h/c=0.16%
Zig-Zag Type B
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

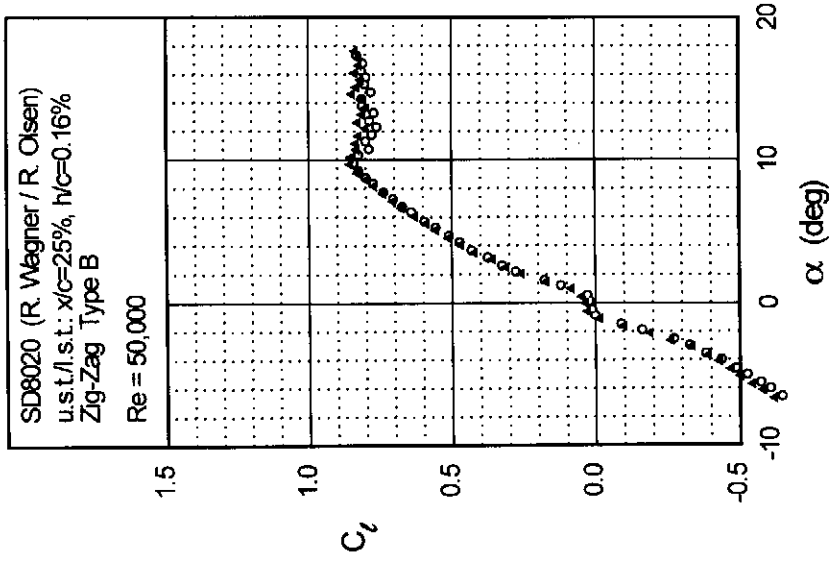
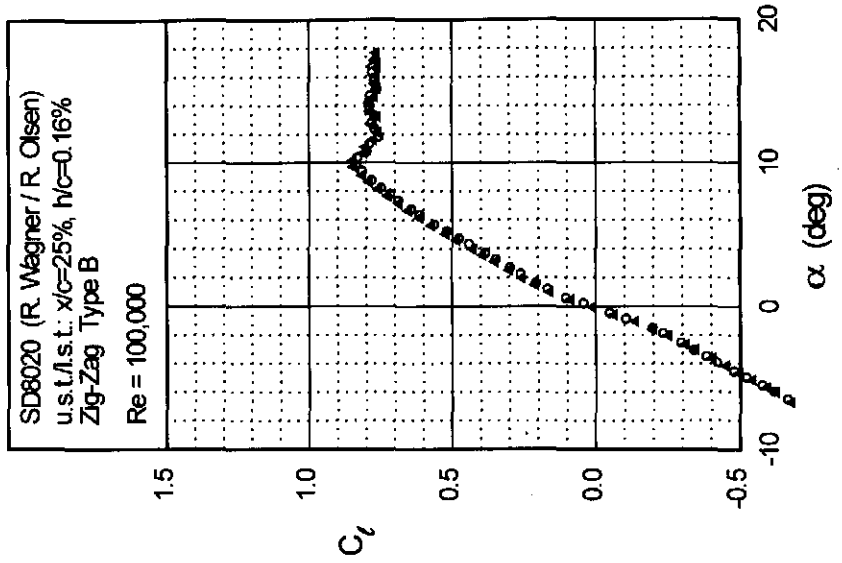
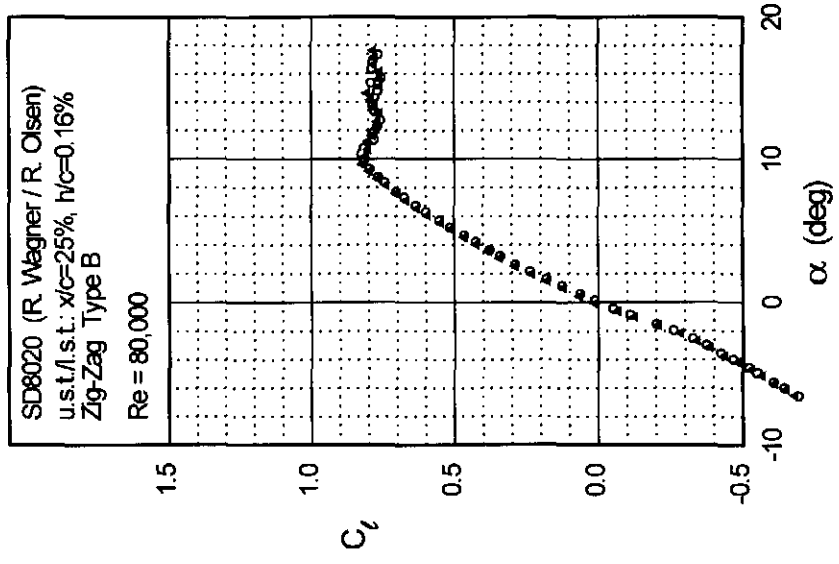

SD8020 (R. Wagner / R. Olsen)
u.s.t./l.s.t.: x/c=25%, h/c=0.16%
Zig-Zag Type B
Re = 50,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

Fig. 4.147 (continued)

SD8020



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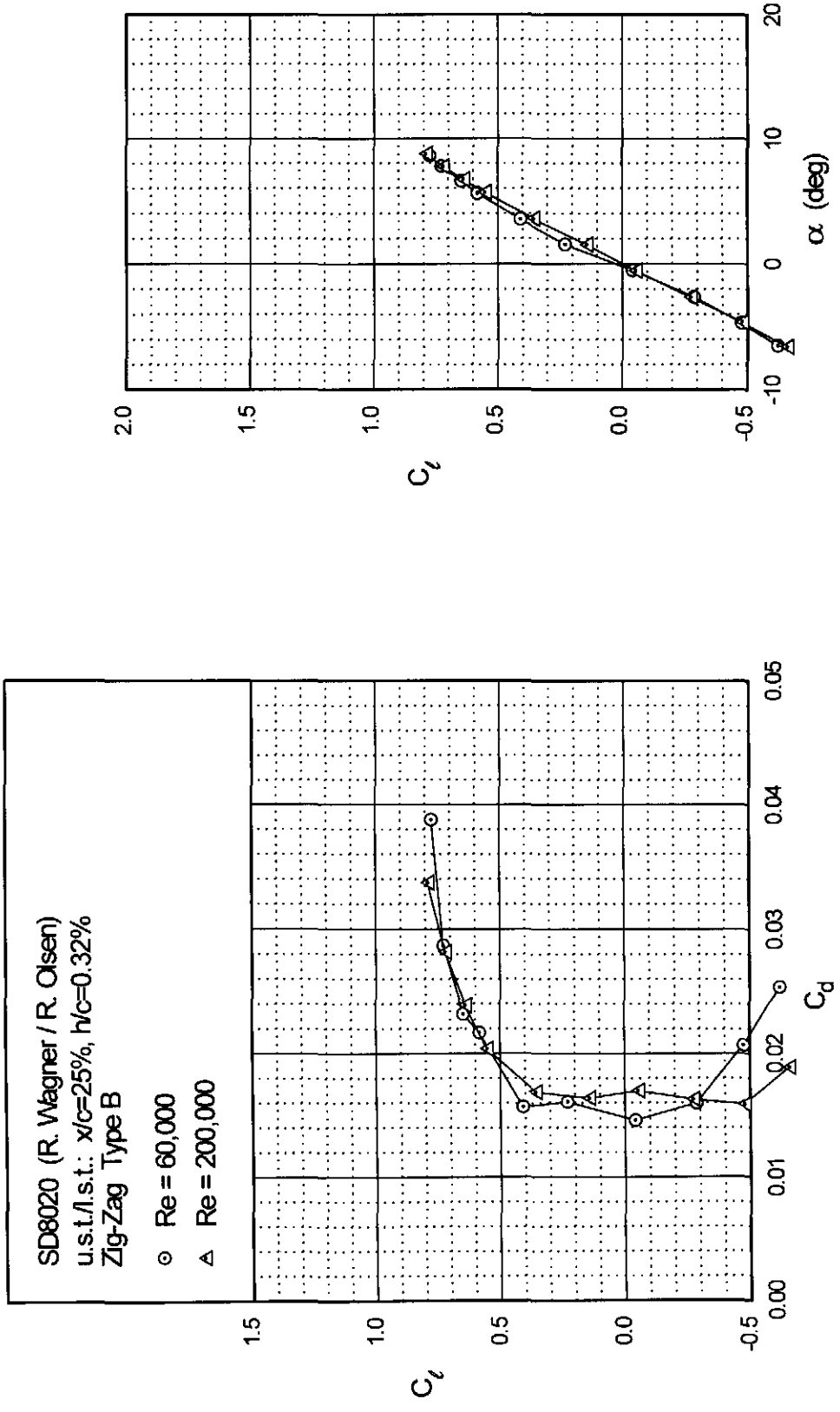
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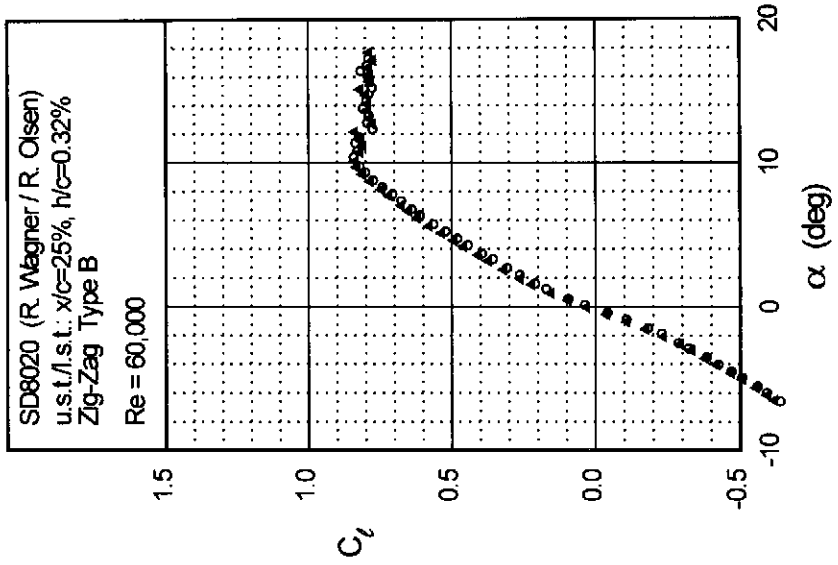
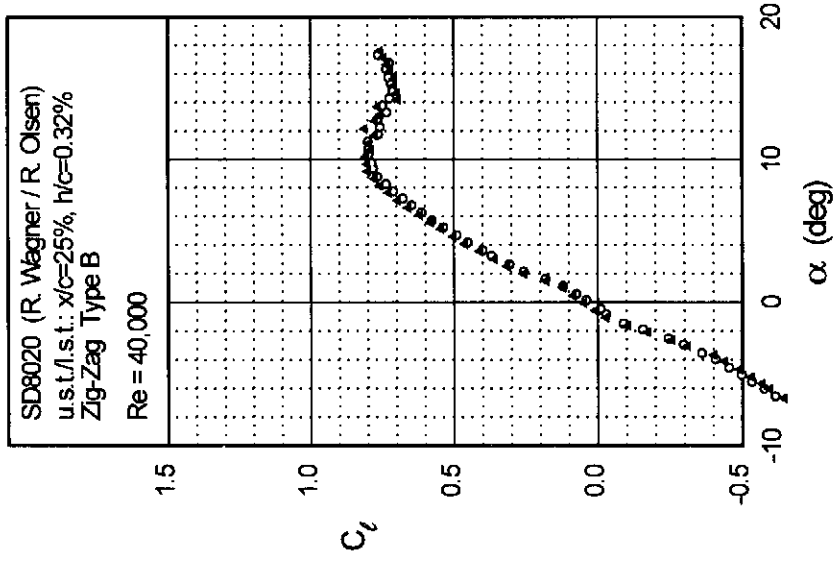
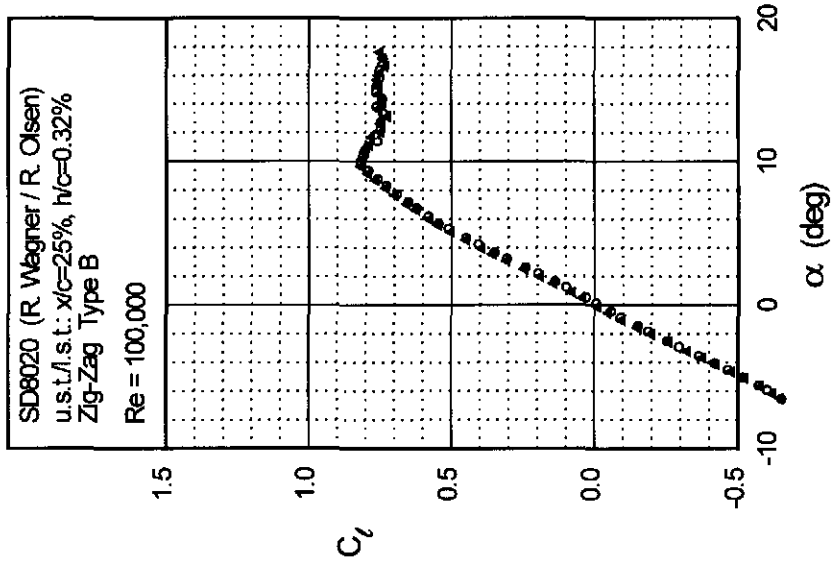
u.s.t./l.s.t.: x/c=25%, h/c=0.32%
Zig-Zag Type B
Re = 60,000
Re = 200,000
$C_l$
$C_d$
α (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
0.05
0.04
0.03
0.02
0.01
0.00
20
10
0
-10

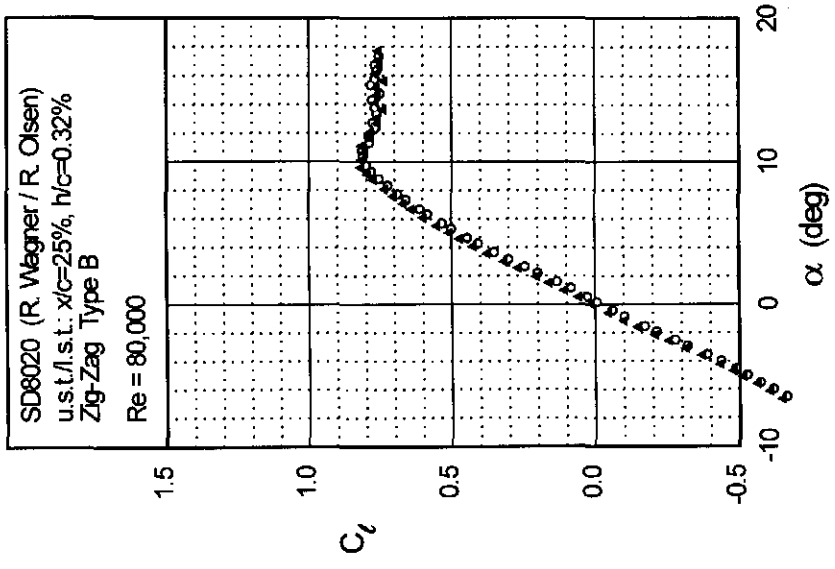
Fig. 4.148 (continued)

SD8020

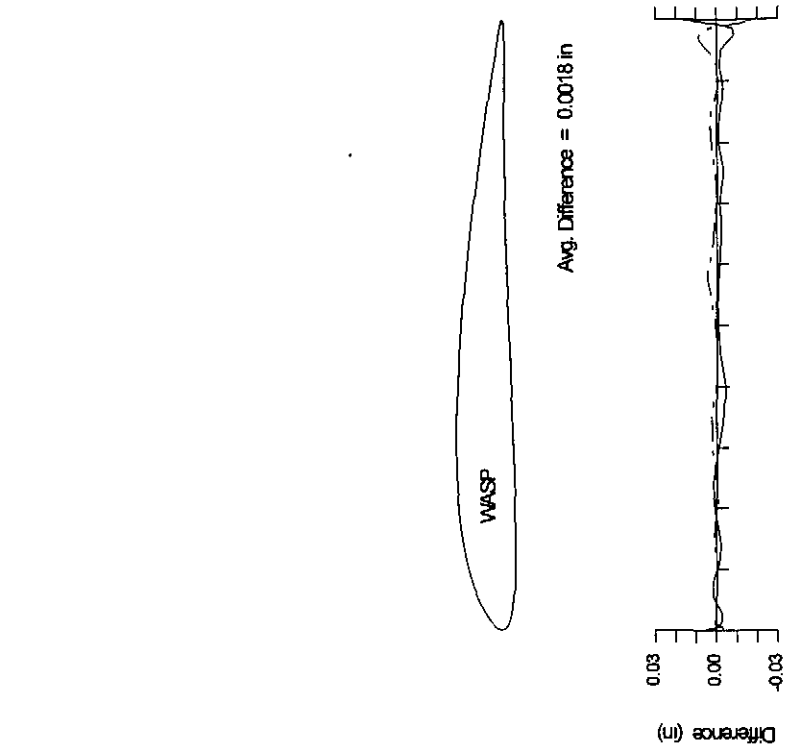


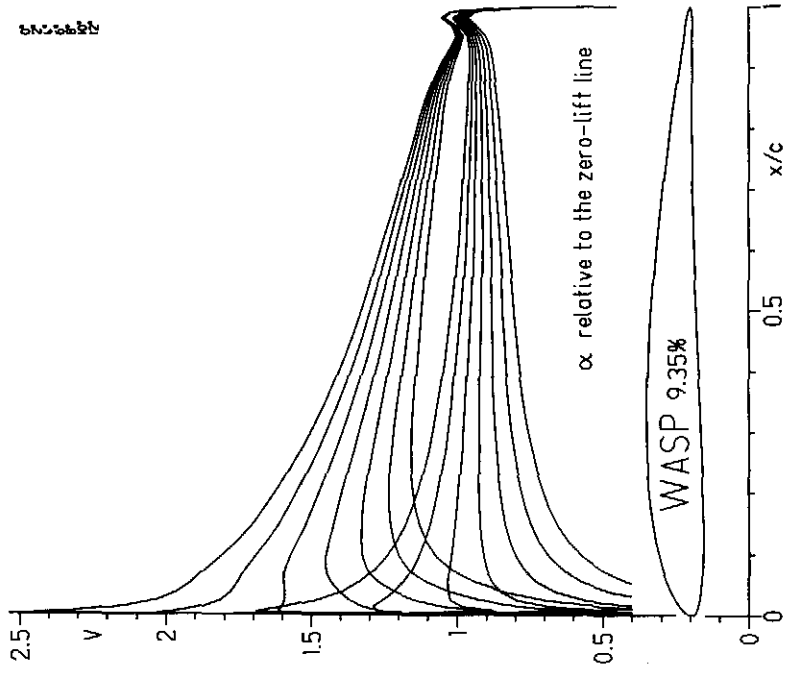




SD8020 (R. Wagner / R. Olsen)
u.s.t./l.s.t.: x/c=25%, h/c=0.32%
Zig-Zag Type B
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

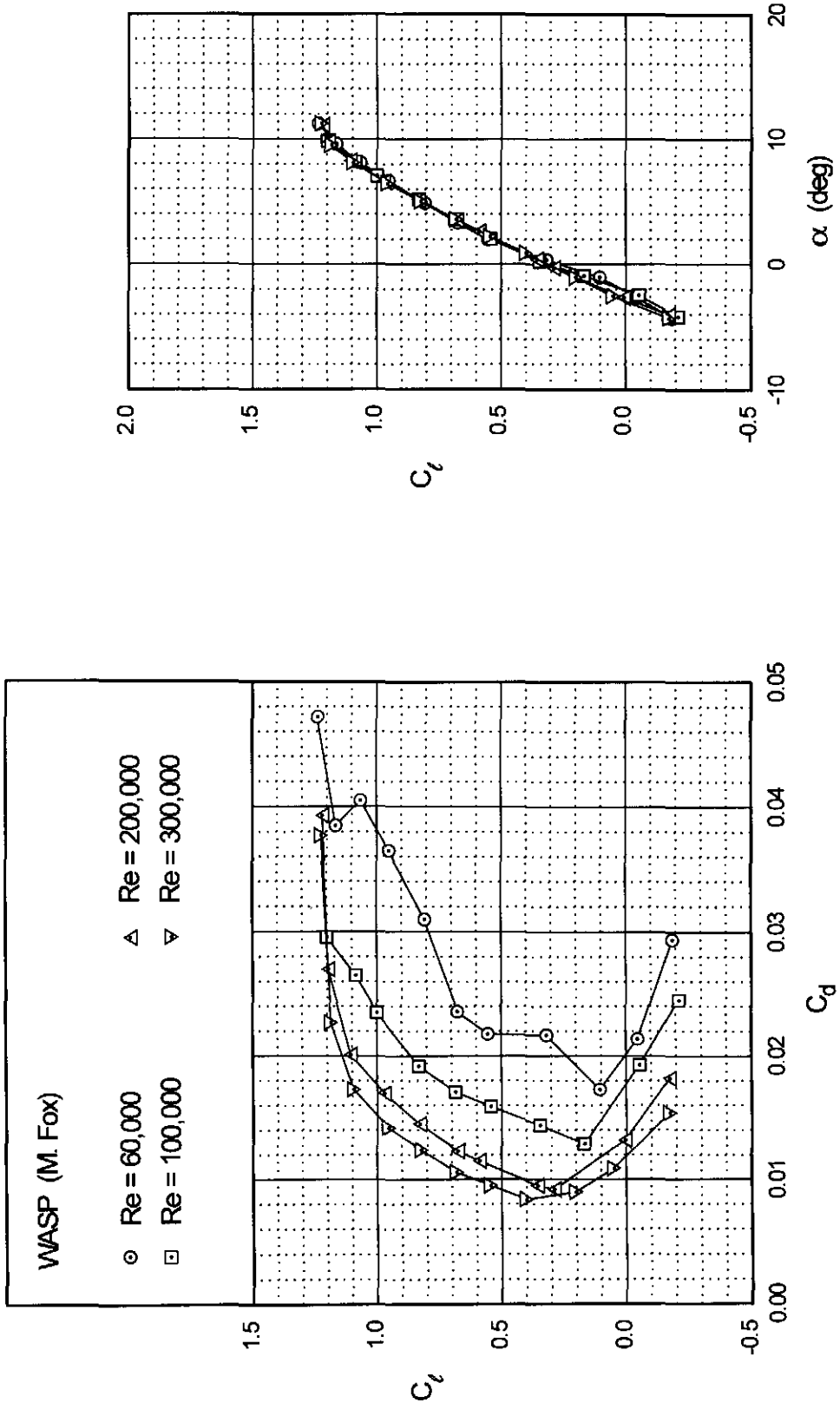

SD8020 (R. Wagner / R. Olsen)
u.s.t./l.s.t.: x/c=25%, h/c=0.32%
Zig-Zag Type B
Re = 80,000
1.5
1.0
0.5
0.0
-0.5
$C_l$
-10
0
10
20
α (deg)

WASP

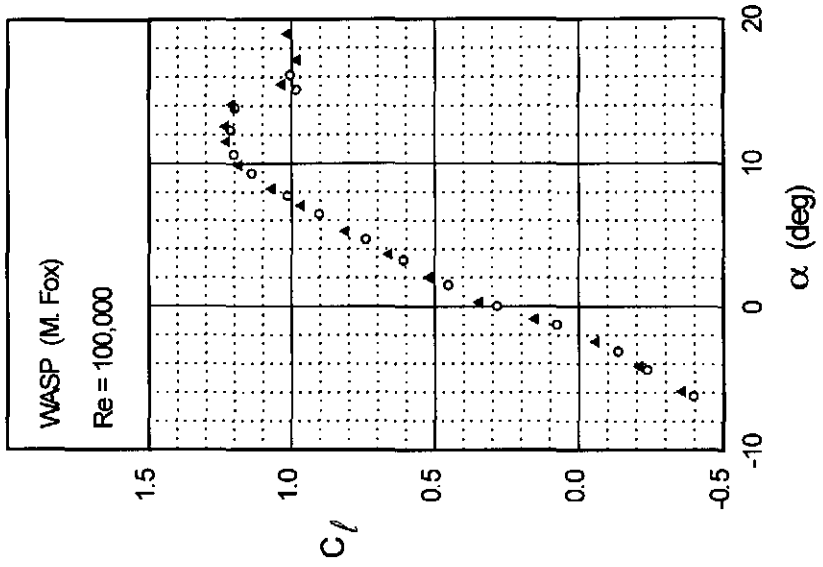

WASP
Avg. Difference = 0.0018 in
0.03
0.00
-0.03
Difference (in)

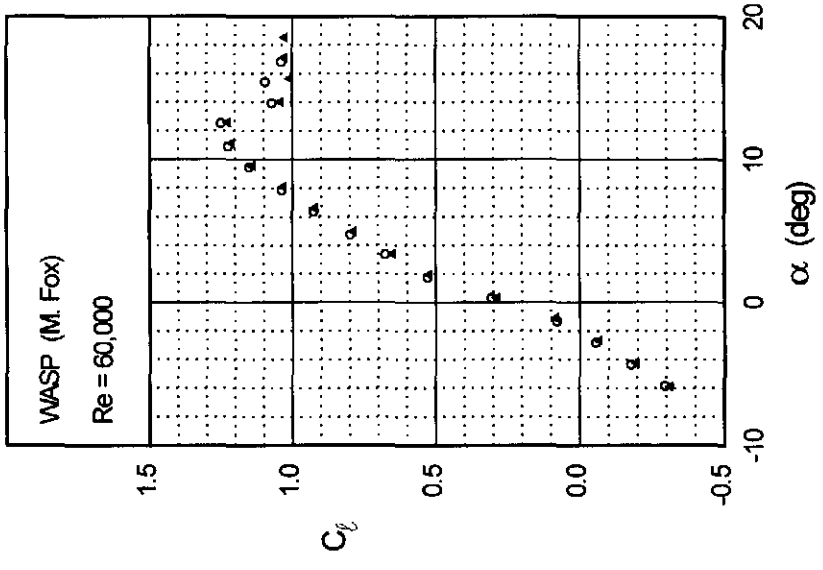

α relative to the zero-lift line
WASP 9.35%
2.5
2
1.5
1
0.5
V
0
0.5
1
x/c

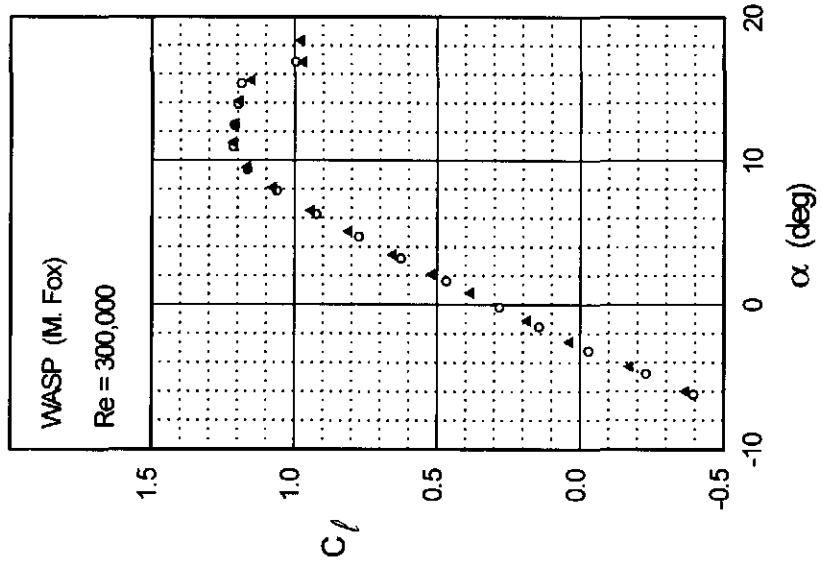
WASP

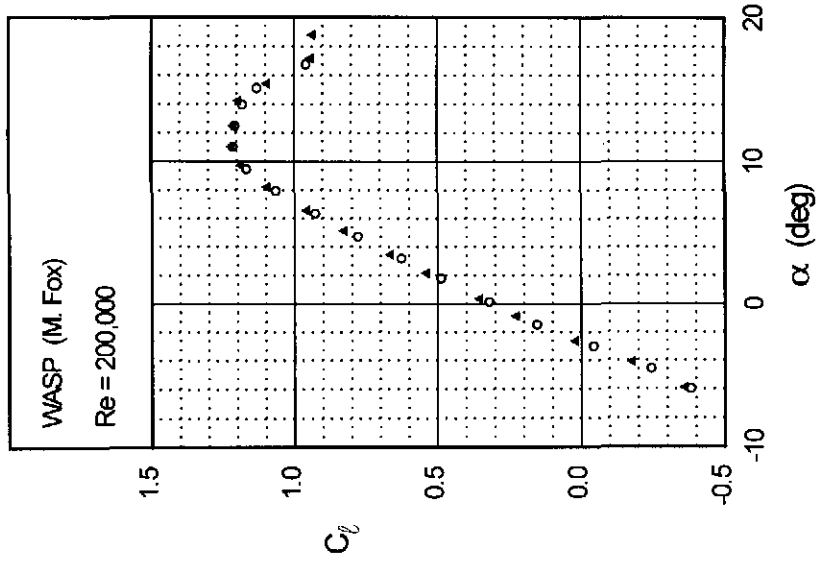

WASP (M. Fox)
Re = 60,000
Re = 100,000
Re = 200,000
Re = 300,000
$C_l$
$C_d$
$\alpha$ (deg)
2.0
1.5
1.0
0.5
0.0
-0.5
0.05
0.04
0.03
0.02
0.01
0.00
20
10
0
-10

WASP


WASP (M. Fox)
Re = 100,000
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
-10
0
10
20
α (deg)


WASP (M. Fox)
Re = 60,000
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
-10
0
10
20
α (deg)


WASP (M. Fox)
Re = 300,000
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
-10
0
10
20
α (deg)


WASP (M. Fox)
Re = 200,000
1.5
1.0
0.5
0.0
-0.5
$C_\ell$
-10
0
10
20
α (deg)

# Extended Notes to the Text

**n1.** The "bunt," as applied to F1C free-flight models, is a term used to describe a flight maneuver from the straight-up power position to a horizontal glide. The stabilizer is momentarily deflected after the engine stops to dive the model 90 deg from vertical straight-up to horizontal and in so doing optimize the model's kinetic energy into the highest possible altitude for glide. The familiar corkscrew roll-out from power-to-glide does not work well on long winged models. High aspect ratio wings resist rolling about the longitudinal axis. The bunt allows the wing to roll about the lateral axis which long wings do with grace.

*- Gilbert Morris*

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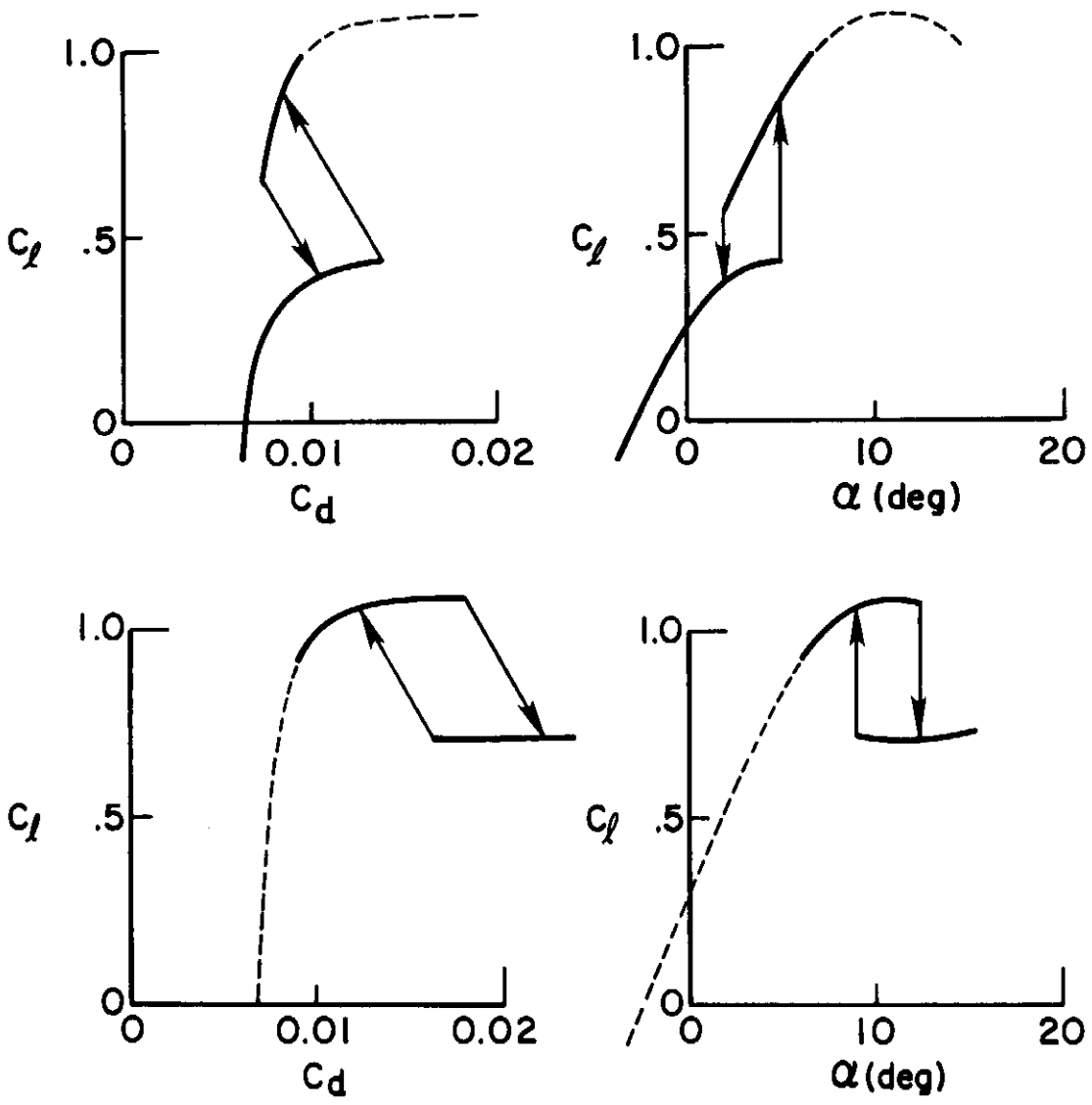
**n2.** Some airfoils at low Reynolds numbers behave differently depending on whether the angle of attack is increasing or decreasing. Such airfoils are said to have hysteresis, which appears in the lift, drag and moment characteristics. In the current work, hysteresis is seen in the lift data but not the drag data since the drag was only measured for increasing angles of attack.

As depicted in the figures on the following page, two common types of airfoil hysteresis are found at low Reynolds numbers. The first type is initiated by a long laminar separation bubble present on the airfoil in the mid-lift range. As the angle of attack increases, the bubble grows larger. As this happens the drag rises dramatically to form a high-drag knee, and the lift falls-off to form a plateau—a process that is similar to trailing-edge stall. Further increasing the angle of attack "unstalls" the airfoil and causes the long bubble to collapse into a short bubble near the airfoil leading edge, resulting in markedly lower drag. Through decreasing angles of attack, a sharp decrease in lift occurs due to the return of the long bubble at an angle of attack lower than that at which the increase occurred. For some airfoils the collapse and return of the long bubble happens at the same angle of attack. This type of hysteresis can be called "long-bubble hysteresis," although other names have been applied.[32,33]

A second type of hysteresis is caused by a short laminar separation bubble. In this case, before stall near $C_{l_{max}}$ a short bubble exists on the airfoil leading edge. As the angle of attack increases, the airfoil stalls either by the bursting of a bubble (a leading edge stall). Through decreasing angle of attack from stall, the short bubble reattaches, identified by a sharp increase in the lift, at an angle of attack lower than that of stall for increasing angle of attack. This type of hysteresis can be called "short-bubble hysteresis."




Long-bubble and short-bubble hysteresis.

As discussed, the type of hysteresis depends on the behavior of either a long-bubble present near the airfoil mid-chord or a short-bubble near the leading edge. (A description of how these two types of hysteresis are related to the airfoil velocity distribution can be found in Ref. 32.) Since the two types of hysteresis tend to be associated with different parts of the airfoil, it is possible for a single airfoil to exhibit both types of hysteresis, such as that seen on the FX 63-137 at *Re* of 90k. Finally, it should be noted that some airfoils cannot be classified by the two types of hysteresis discussed (see the FX 74-CL5-140 MOD and CH 10-48-13 characteristics).

**n3.** The *reduced* Reynolds number for an aircraft can be obtained by starting with the definition of the airfoil chord Reynolds number given by

$$Re = \frac{\rho V c}{\mu}$$

For an aircraft in steady level flight, the aircraft speed is expressed as

$$V = \sqrt{\frac{2W/S}{\rho C_L}}$$

These two equations can be combined to yield

$$Re\sqrt{C_L} = \frac{c}{\mu}\sqrt{2\rho W/S}$$

For an aircraft at any given time in flight, the right-hand side of this equation is a constant. Consequently, the left-hand side is also a constant—an increase in the $Re$ occurs through a decrease in $C_L$. It is this constant that is termed the reduced Reynolds number, that is,

$$\mathcal{R} = Re\sqrt{C_L}$$

Although this parameter has been given various names, the terminology used here is that due to Drela.[34] The reduced Reynolds number $\mathcal{R}$ is most useful when comparing airfoil data since $\mathcal{R}$ is constant for a given aircraft; whereas, the $Re$ is not constant. Thus, when the airfoil data is plotted for various values of $\mathcal{R}$, airfoils can be more easily compared for aircraft applications.

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**n4.** The S1223 as well as the other new Selig airfoils were designed through the use of several low-speed airfoil design and analysis codes, in particular, the PROFOIL code,[35–38] the Eppler code,[10,11] and either the ISES[12,13] or XFOIL code.[14] The general design methodology is as follows. First, PROFOIL is used for rapid interactive design. A new airfoil that appears to meet the performance objectives is then screened through the use of two analysis codes, beginning with the Eppler code, and ending with either the ISES or XFOIL code. If at any state the candidate airfoil fails to meet the design goals, the experience is used to redesign the airfoil to more closely match the desired performance. This iterative process continues until a successful airfoil is designed.

The PROFOIL code, like the Eppler code, embodies an inverse airfoil design method and an integral boundary-layer method for rapid analysis at the design points. PROFOIL, however, differs from the Eppler code in that laminar and turbulent boundary-layer developments can be prescribed. For example, the laminar boundary layer can be directly specified to approach

transition in a favorable way for low Reynolds numbers. Such an ability, for instance, allows for control over the design of the bubble ramp. Beyond transition, the turbulent boundary-layer development can be specified to avoid turbulent separation by a desired margin. This capability is especially useful when designing for maximum lift. The method also allows for control over geometric characteristics like local geometry, maximum thickness, thickness distribution, etc.

The Eppler code is used for first stage screening of candidate airfoils. In the analysis mode, the inviscid velocity distributions are determined by a panel method. Performance is then done through the use of an integral boundary-layer method. In the drag calculation, the drag due to a laminar separation bubble is not determined. If the bubble is predicted to be longer than $0.03c$, however, a warning is issued to indicate that the bubble drag is probably large, and consequently the predicted drag is probably in error. Although the magnitude of the bubble drag is not determined, the method is invaluable when the user has had experience comparing its predictions with experiments.

The ISES code solves the two-dimensional Euler equations coupled with an integral boundary-layer formulation through a global Newton iteration method. Over the Reynolds number range considered here, the agreement between predicted and experimentally measured results is often good, although some discrepancies do exist. Since the ISES code is computationally intensive, it is only used in the later stages of design. It should be mentioned that the XFOIL code is more computationally efficient than the ISES code; however, XFOIL does not converge as readily as ISES for cases where there is significant separation, e.g., that found during the initiation and development of airfoil stall and that due to the presence of a large laminar separation bubble. Thus, ISES is preferred for its overall robustness, albeit at the cost of considerably more computation time. Neither code is capable of predicting airfoil stall characteristics or hysteresis.

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# Appendix A

# Airfoil Coordinates

This appendix lists the airfoil coordinates. For any given airfoil, the true airfoil coordinates, if provided, are listed first. If the original coordinates were not 'mathematically' smooth or when there were too few points defining the airfoil (especially in the vicinity of the leading and trailing edges), the airfoil coordinates were smoothed with the program AFSMO[18] developed at NASA Langley. Following the true coordinates and (if generated) smoothed coordinates, the actual wind-tunnel model coordinates are given. For the CH 10-48-13, FX 74-CL5-140 MOD, GEMINI, GM15, K3311 and WASP airfoils the smoothed coordinates were determined by smoothing the actual coordinates. As to be expected in these cases, the average difference between the smoothed airfoil and actual airfoil seen in the profile plots in Chapter 4 is quite small ($\sim$0.003 in) and is due to the model surface waviness and measurement error. Finally, coordinates for the NREL S822 and S823 airfoils designed by D.M. Somers (Airfoils, Inc.) can be acquired from NREL under a licensing agreement.

**A18**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00614 |
| 0.95000 | 0.01817 |
| 0.90000 | 0.02858 |
| 0.80000 | 0.04624 |
| 0.70000 | 0.06056 |
| 0.60000 | 0.07197 |
| 0.55000 | 0.07612 |
| 0.50000 | 0.07975 |
| 0.45000 | 0.08293 |
| 0.40000 | 0.08376 |
| 0.35000 | 0.08466 |
| 0.30000 | 0.08383 |
| 0.25000 | 0.08065 |
| 0.20000 | 0.07601 |
| 0.15000 | 0.07026 |
| 0.10000 | 0.06234 |
| 0.07500 | 0.05660 |
| 0.05000 | 0.04923 |
| 0.02500 | 0.03947 |
| 0.01250 | 0.03239 |
| 0.00000 | 0.01865 |
| 0.01250 | 0.00781 |
| 0.02500 | 0.00357 |
| 0.05000 | 0.00075 |
| 0.07500 | 0.00000 |
| 0.10000 | 0.00006 |
| 0.15000 | 0.00200 |
| 0.20000 | 0.00475 |
| 0.25000 | 0.00806 |
| 0.30000 | 0.01038 |
| 0.35000 | 0.01353 |
| 0.40000 | 0.01657 |
| 0.45000 | 0.01780 |
| 0.50000 | 0.01884 |
| 0.55000 | 0.01980 |
| 0.60000 | 0.01998 |
| 0.70000 | 0.01924 |
| 0.80000 | 0.01452 |
| 0.90000 | 0.00813 |
| 0.95000 | 0.00434 |
| 1.00000 | 0.00000 |

**A18**
smoothed

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00307 |
| 0.99754 | 0.00365 |
| 0.99070 | 0.00530 |
| 0.98037 | 0.00771 |
| 0.96698 | 0.01070 |
| 0.95044 | 0.01421 |
| 0.93064 | 0.01819 |
| 0.90775 | 0.02253 |
| 0.88202 | 0.02712 |
| 0.85370 | 0.03185 |
| 0.82309 | 0.03661 |
| 0.79048 | 0.04132 |
| 0.75616 | 0.04591 |
| 0.72043 | 0.05029 |
| 0.68359 | 0.05440 |
| 0.64594 | 0.05819 |
| 0.60778 | 0.06160 |
| 0.56937 | 0.06458 |
| 0.53099 | 0.06710 |
| 0.49265 | 0.06911 |
| 0.45435 | 0.07058 |
| 0.41638 | 0.07143 |
| 0.37887 | 0.07157 |
| 0.34204 | 0.07094 |
| 0.30609 | 0.06951 |
| 0.27120 | 0.06733 |
| 0.23760 | 0.06451 |
| 0.20549 | 0.06114 |
| 0.17504 | 0.05734 |
| 0.14648 | 0.05315 |
| 0.11999 | 0.04860 |
| 0.09576 | 0.04368 |
| 0.07395 | 0.03839 |
| 0.05468 | 0.03277 |
| 0.03811 | 0.02694 |
| 0.02433 | 0.02103 |
| 0.01338 | 0.01513 |
| 0.00548 | 0.00932 |
| 0.00098 | 0.00376 |
| 0.00000 | 0.00000 |
| 0.00098 | -0.00348 |
| 0.00548 | -0.00770 |
| 0.01338 | -0.01118 |
| 0.02433 | -0.01388 |
| 0.03811 | -0.01581 |
| 0.05468 | -0.01699 |
| 0.07395 | -0.01740 |
| 0.09576 | -0.01708 |
| 0.11999 | -0.01611 |
| 0.14648 | -0.01461 |
| 0.17504 | -0.01269 |
| 0.20549 | -0.01047 |
| 0.23760 | -0.00805 |
| 0.27120 | -0.00550 |
| 0.30609 | -0.00290 |
| 0.34204 | -0.00033 |
| 0.37887 | 0.00209 |
| 0.41638 | 0.00429 |
| 0.45435 | 0.00617 |
| 0.49265 | 0.00773 |
| 0.53099 | 0.00895 |
| 0.56937 | 0.00984 |
| 0.60778 | 0.01042 |
| 0.64594 | 0.01067 |
| 0.68359 | 0.01060 |
| 0.72043 | 0.01022 |
| 0.75616 | 0.00954 |
| 0.79048 | 0.00858 |
| 0.82309 | 0.00738 |
| 0.85370 | 0.00600 |
| 0.88202 | 0.00450 |
| 0.90775 | 0.00297 |
| 0.93064 | 0.00149 |
| 0.95044 | 0.00015 |
| 0.96698 | -0.00098 |
| 0.98037 | -0.00187 |
| 0.99070 | -0.00252 |
| 0.99754 | -0.00292 |
| 1.00000 | -0.00306 |

**A18**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00033 |
| 0.99690 | 0.00099 |
| 0.99191 | 0.00224 |
| 0.98482 | 0.00374 |
| 0.97861 | 0.00511 |
| 0.96785 | 0.00735 |
| 0.95536 | 0.00972 |
| 0.94364 | 0.01198 |
| 0.93398 | 0.01379 |
| 0.92071 | 0.01632 |
| 0.90411 | 0.01925 |
| 0.89181 | 0.02141 |
| 0.86400 | 0.02621 |
| 0.83715 | 0.03060 |
| 0.80818 | 0.03498 |
| 0.76407 | 0.04104 |
| 0.71992 | 0.04669 |
| 0.66487 | 0.05312 |
| 0.60663 | 0.05896 |
| 0.54910 | 0.06333 |
| 0.49645 | 0.06654 |
| 0.43814 | 0.06926 |
| 0.38347 | 0.06938 |
| 0.33236 | 0.06958 |
| 0.29351 | 0.06837 |
| 0.24769 | 0.06500 |
| 0.20920 | 0.06121 |
| 0.17697 | 0.05768 |
| 0.14758 | 0.05409 |
| 0.11892 | 0.04994 |
| 0.10641 | 0.04776 |
| 0.09459 | 0.04542 |
| 0.08092 | 0.04235 |
| 0.07075 | 0.03975 |
| 0.06073 | 0.03692 |
| 0.04549 | 0.03203 |
| 0.03643 | 0.02853 |
| 0.02720 | 0.02440 |
| 0.02028 | 0.02095 |
| 0.01302 | 0.01674 |
| 0.00710 | 0.01159 |
| 0.00109 | 0.00346 |
| 0.00000 | -0.00001 |
| 0.00489 | -0.00732 |
| 0.01059 | -0.01050 |
| 0.01487 | -0.01187 |
| 0.02173 | -0.01345 |
| 0.02945 | -0.01488 |
| 0.04403 | -0.01646 |
| 0.05870 | -0.01696 |
| 0.07258 | -0.01694 |
| 0.08798 | -0.01669 |
| 0.10106 | -0.01628 |
| 0.11648 | -0.01556 |
| 0.14251 | -0.01381 |
| 0.16858 | -0.01185 |
| 0.19992 | -0.00957 |
| 0.24110 | -0.00652 |
| 0.28536 | -0.00401 |
| 0.34013 | -0.00031 |
| 0.40095 | 0.00398 |
| 0.45970 | 0.00579 |
| 0.51571 | 0.00740 |
| 0.57735 | 0.00844 |
| 0.63480 | 0.00884 |
| 0.67858 | 0.00911 |
| 0.71898 | 0.00854 |
| 0.76508 | 0.00691 |
| 0.80917 | 0.00532 |
| 0.83733 | 0.00423 |
| 0.87102 | 0.00289 |
| 0.90385 | 0.00148 |
| 0.92078 | 0.00075 |
| 0.93589 | 0.00012 |
| 0.95129 | -0.00055 |
| 0.96349 | -0.00080 |
| 0.97274 | -0.00121 |
| 0.98152 | -0.00116 |
| 0.98959 | -0.00119 |
| 0.99507 | -0.00100 |
| 1.00000 | 0.00033 |

**BE50**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00260 |
| 0.95000 | 0.01270 |
| 0.90000 | 0.02276 |
| 0.80000 | 0.03956 |
| 0.70000 | 0.05314 |
| 0.60000 | 0.06489 |
| 0.55000 | 0.06991 |
| 0.50000 | 0.07407 |
| 0.45000 | 0.07783 |
| 0.40000 | 0.07992 |
| 0.35000 | 0.08090 |
| 0.30000 | 0.08126 |
| 0.25000 | 0.08087 |
| 0.20000 | 0.07837 |
| 0.15000 | 0.07308 |
| 0.10000 | 0.06403 |
| 0.07500 | 0.05727 |
| 0.05000 | 0.04838 |
| 0.02500 | 0.03639 |
| 0.01500 | 0.03011 |
| 0.01000 | 0.02600 |
| 0.00000 | 0.01271 |
| 0.01000 | 0.00400 |
| 0.01500 | 0.00274 |
| 0.02500 | 0.00156 |
| 0.05000 | 0.00003 |
| 0.07500 | 0.00000 |
| 0.10000 | 0.00053 |
| 0.15000 | 0.00294 |
| 0.20000 | 0.00571 |
| 0.25000 | 0.00812 |
| 0.30000 | 0.01048 |
| 0.35000 | 0.01310 |
| 0.40000 | 0.01617 |
| 0.45000 | 0.01847 |
| 0.50000 | 0.02021 |
| 0.55000 | 0.02136 |
| 0.60000 | 0.02129 |
| 0.70000 | 0.01936 |
| 0.80000 | 0.01492 |
| 0.90000 | 0.00856 |

| | |
|---|---|
| 0.95000 | 0.00471 |
| 1.00000 | 0.00000 |

**BE50**
smoothed

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00129 |
| 0.99754 | 0.00178 |
| 0.99070 | 0.00314 |
| 0.98037 | 0.00517 |
| 0.96698 | 0.00777 |
| 0.95044 | 0.01091 |
| 0.93064 | 0.01457 |
| 0.90775 | 0.01865 |
| 0.88202 | 0.02305 |
| 0.85370 | 0.02766 |
| 0.82309 | 0.03238 |
| 0.79048 | 0.03710 |
| 0.75616 | 0.04176 |
| 0.72043 | 0.04627 |
| 0.68359 | 0.05058 |
| 0.64594 | 0.05463 |
| 0.60778 | 0.05835 |
| 0.56937 | 0.06171 |
| 0.53099 | 0.06466 |
| 0.49265 | 0.06714 |
| 0.45435 | 0.06911 |
| 0.41638 | 0.07054 |
| 0.37887 | 0.07144 |
| 0.34204 | 0.07186 |
| 0.30609 | 0.07180 |
| 0.27120 | 0.07119 |
| 0.23760 | 0.06993 |
| 0.20549 | 0.06792 |
| 0.17504 | 0.06505 |
| 0.14648 | 0.06128 |
| 0.11999 | 0.05662 |
| 0.09576 | 0.05113 |
| 0.07395 | 0.04491 |
| 0.05468 | 0.03812 |
| 0.03811 | 0.03098 |
| 0.02433 | 0.02374 |
| 0.01338 | 0.01662 |
| 0.00548 | 0.00989 |
| 0.00098 | 0.00382 |
| 0.00000 | -0.00003 |
| 0.00098 | -0.00332 |
| 0.00548 | -0.00695 |
| 0.01338 | -0.00956 |
| 0.02433 | -0.01127 |
| 0.03811 | -0.01224 |
| 0.05468 | -0.01256 |
| 0.07395 | -0.01229 |
| 0.09576 | -0.01152 |
| 0.11999 | -0.01033 |
| 0.14648 | -0.00882 |
| 0.17504 | -0.00709 |
| 0.20549 | -0.00522 |
| 0.23760 | -0.00323 |
| 0.27120 | -0.00115 |
| 0.30609 | 0.00102 |
| 0.34204 | 0.00330 |
| 0.37887 | 0.00563 |
| 0.41638 | 0.00792 |
| 0.45435 | 0.01002 |
| 0.49265 | 0.01177 |
| 0.53099 | 0.01310 |
| 0.56937 | 0.01397 |
| 0.60778 | 0.01440 |
| 0.64594 | 0.01440 |
| 0.68359 | 0.01402 |
| 0.72043 | 0.01331 |
| 0.75616 | 0.01233 |
| 0.79048 | 0.01114 |
| 0.82309 | 0.00980 |
| 0.85370 | 0.00836 |
| 0.88202 | 0.00688 |
| 0.90775 | 0.00540 |
| 0.93064 | 0.00398 |
| 0.95044 | 0.00265 |
| 0.96698 | 0.00146 |
| 0.98037 | 0.00041 |
| 0.99070 | -0.00046 |
| 0.99754 | -0.00107 |
| 1.00000 | -0.00130 |

**BE50**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00003 |
| 0.99583 | 0.00090 |
| 0.99130 | 0.00176 |
| 0.98326 | 0.00291 |
| 0.97591 | 0.00383 |
| 0.96797 | 0.00490 |
| 0.95533 | 0.00646 |
| 0.94261 | 0.00832 |
| 0.92506 | 0.01089 |
| 0.91026 | 0.01315 |
| 0.89515 | 0.01540 |
| 0.86287 | 0.01998 |
| 0.82777 | 0.02486 |
| 0.80038 | 0.02841 |
| 0.75832 | 0.03366 |
| 0.71784 | 0.03836 |
| 0.67117 | 0.04378 |
| 0.62764 | 0.04847 |
| 0.56632 | 0.05440 |
| 0.51206 | 0.05864 |
| 0.45727 | 0.06238 |
| 0.40031 | 0.06455 |
| 0.33420 | 0.06543 |
| 0.28537 | 0.06554 |
| 0.23887 | 0.06509 |
| 0.19310 | 0.06264 |
| 0.16732 | 0.06029 |
| 0.14237 | 0.05740 |
| 0.11376 | 0.05323 |
| 0.09915 | 0.05037 |
| 0.08729 | 0.04758 |
| 0.07255 | 0.04346 |
| 0.06203 | 0.04005 |
| 0.04793 | 0.03488 |
| 0.03917 | 0.03136 |
| 0.02973 | 0.02707 |
| 0.01795 | 0.01986 |
| 0.01129 | 0.01465 |
| 0.00588 | 0.00975 |
| 0.00029 | 0.00215 |
| 0.00057 | -0.00307 |
| 0.00440 | -0.00796 |
| 0.00934 | -0.00977 |
| 0.01555 | -0.01123 |
| 0.02299 | -0.01267 |
| 0.03451 | -0.01425 |
| 0.04815 | -0.01526 |
| 0.06087 | -0.01566 |
| 0.07498 | -0.01579 |
| 0.08891 | -0.01563 |
| 0.10403 | -0.01514 |
| 0.11790 | -0.01446 |
| 0.15101 | -0.01252 |
| 0.18500 | -0.01058 |
| 0.21545 | -0.00896 |
| 0.25632 | -0.00682 |
| 0.29934 | -0.00459 |
| 0.34231 | -0.00201 |
| 0.38434 | 0.00084 |
| 0.43953 | 0.00402 |
| 0.49864 | 0.00658 |
| 0.55247 | 0.00811 |
| 0.60994 | 0.00850 |
| 0.67034 | 0.00809 |
| 0.72948 | 0.00695 |
| 0.77737 | 0.00545 |
| 0.82030 | 0.00394 |
| 0.84965 | 0.00292 |
| 0.87774 | 0.00172 |
| 0.90758 | 0.00081 |
| 0.92014 | 0.00047 |
| 0.93617 | 0.00002 |
| 0.95086 | -0.00034 |
| 0.96493 | -0.00092 |
| 0.97271 | -0.00111 |
| 0.98126 | -0.00114 |
| 0.98898 | -0.00119 |
| 0.99652 | -0.00090 |
| 1.00000 | -0.00003 |

**CH 10-48-13**
smoothed

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00005 |
| 0.99754 | 0.00169 |
| 0.99070 | 0.00579 |
| 0.98037 | 0.01111 |
| 0.96698 | 0.01721 |
| 0.95044 | 0.02452 |
| 0.93064 | 0.03317 |
| 0.90775 | 0.04292 |
| 0.88202 | 0.05367 |
| 0.85370 | 0.06522 |
| 0.82309 | 0.07725 |
| 0.79048 | 0.08942 |
| 0.75616 | 0.10143 |
| 0.72043 | 0.11298 |
| 0.68359 | 0.12384 |
| 0.64594 | 0.13374 |
| 0.60778 | 0.14243 |
| 0.56937 | 0.14970 |
| 0.53099 | 0.15538 |
| 0.49265 | 0.15942 |
| 0.45435 | 0.16176 |
| 0.41638 | 0.16240 |
| 0.37887 | 0.16133 |
| 0.34204 | 0.15862 |
| 0.30609 | 0.15434 |
| 0.27120 | 0.14859 |
| 0.23760 | 0.14148 |
| 0.20549 | 0.13310 |
| 0.17504 | 0.12355 |
| 0.14648 | 0.11291 |
| 0.11999 | 0.10132 |
| 0.09576 | 0.08896 |
| 0.07395 | 0.07611 |
| 0.05468 | 0.06312 |
| 0.03811 | 0.05032 |
| 0.02433 | 0.03793 |
| 0.01338 | 0.02615 |
| 0.00548 | 0.01531 |
| 0.00098 | 0.00586 |
| 0.00000 | 0.00014 |
| 0.00098 | -0.00450 |
| 0.00548 | -0.00914 |
| 0.01338 | -0.01179 |
| 0.02433 | -0.01269 |
| 0.03811 | -0.01209 |
| 0.05468 | -0.01028 |
| 0.07395 | -0.00759 |
| 0.09576 | -0.00435 |
| 0.11999 | -0.00076 |
| 0.14648 | 0.00320 |
| 0.17504 | 0.00748 |
| 0.20549 | 0.01201 |
| 0.23760 | 0.01667 |
| 0.27120 | 0.02136 |
| 0.30609 | 0.02597 |
| 0.34204 | 0.03040 |
| 0.37887 | 0.03457 |
| 0.41638 | 0.03839 |
| 0.45435 | 0.04178 |
| 0.49265 | 0.04466 |
| 0.53099 | 0.04693 |
| 0.56937 | 0.04851 |
| 0.60778 | 0.04933 |
| 0.64594 | 0.04932 |
| 0.68359 | 0.04845 |
| 0.72043 | 0.04672 |
| 0.75616 | 0.04423 |
| 0.79048 | 0.04108 |
| 0.82309 | 0.03739 |
| 0.85370 | 0.03322 |
| 0.88202 | 0.02867 |
| 0.90775 | 0.02386 |
| 0.93064 | 0.01896 |
| 0.95044 | 0.01410 |
| 0.96698 | 0.00936 |
| 0.98037 | 0.00516 |
| 0.99070 | 0.00212 |
| 0.99754 | 0.00044 |
| 1.00000 | -0.00006 |

**CH 10-48-13**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00095 |

| | |
|---|---|
| 0.99773 | 0.00103 |
| 0.99274 | 0.00376 |
| 0.98612 | 0.00720 |
| 0.97773 | 0.01108 |
| 0.96741 | 0.01590 |
| 0.95938 | 0.01968 |
| 0.94945 | 0.02417 |
| 0.94049 | 0.02810 |
| 0.93053 | 0.03234 |
| 0.91837 | 0.03745 |
| 0.90484 | 0.04316 |
| 0.88927 | 0.04968 |
| 0.86246 | 0.06072 |
| 0.82116 | 0.07729 |
| 0.78669 | 0.09023 |
| 0.75894 | 0.09990 |
| 0.71822 | 0.11315 |
| 0.67728 | 0.12511 |
| 0.63478 | 0.13591 |
| 0.59270 | 0.14512 |
| 0.53610 | 0.15463 |
| 0.48363 | 0.16010 |
| 0.42576 | 0.16241 |
| 0.36667 | 0.16034 |
| 0.31014 | 0.15444 |
| 0.25403 | 0.14510 |
| 0.21164 | 0.13517 |
| 0.17178 | 0.12297 |
| 0.14292 | 0.11171 |
| 0.11299 | 0.09782 |
| 0.08917 | 0.08514 |
| 0.07757 | 0.07841 |
| 0.06804 | 0.07248 |
| 0.05601 | 0.06428 |
| 0.04474 | 0.05577 |
| 0.03043 | 0.04364 |
| 0.02142 | 0.03505 |
| 0.01041 | 0.02255 |
| 0.00564 | 0.01550 |
| 0.00071 | 0.00437 |
| 0.00012 | -0.00139 |
| 0.00159 | -0.00510 |
| 0.00676 | -0.00971 |
| 0.01569 | -0.01228 |
| 0.02641 | -0.01266 |
| 0.03736 | -0.01212 |
| 0.04974 | -0.01093 |
| 0.06196 | -0.00933 |
| 0.07896 | -0.00678 |
| 0.09346 | -0.00465 |
| 0.10898 | -0.00239 |
| 0.11417 | -0.00165 |
| 0.14760 | 0.00324 |
| 0.17333 | 0.00696 |
| 0.20376 | 0.01158 |
| 0.24943 | 0.01827 |
| 0.28349 | 0.02298 |
| 0.34683 | 0.03087 |
| 0.39967 | 0.03646 |
| 0.45729 | 0.04165 |
| 0.51585 | 0.04599 |
| 0.57726 | 0.04824 |
| 0.63124 | 0.04907 |
| 0.67481 | 0.04828 |
| 0.71300 | 0.04657 |
| 0.75665 | 0.04350 |
| 0.79719 | 0.03978 |
| 0.82374 | 0.03675 |
| 0.85452 | 0.03249 |
| 0.87977 | 0.02835 |
| 0.90587 | 0.02328 |
| 0.91595 | 0.02132 |
| 0.92632 | 0.01912 |
| 0.94087 | 0.01579 |
| 0.95096 | 0.01325 |
| 0.96104 | 0.01044 |
| 0.96873 | 0.00815 |
| 0.97791 | 0.00530 |
| 0.98464 | 0.00318 |
| 0.99005 | 0.00140 |
| 0.99706 | -0.00102 |
| 1.00000 | -0.00095 |

**E374**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99640 | 0.00045 |
| 0.98610 | 0.00204 |
| 0.97000 | 0.00485 |
| 0.94864 | 0.00846 |
| 0.92214 | 0.01264 |
| 0.89078 | 0.01747 |
| 0.85508 | 0.02297 |
| 0.81560 | 0.02905 |
| 0.77293 | 0.03560 |
| 0.72769 | 0.04246 |
| 0.68053 | 0.04944 |
| 0.63210 | 0.05629 |
| 0.58309 | 0.06269 |
| 0.53398 | 0.06821 |
| 0.48511 | 0.07252 |
| 0.43682 | 0.07544 |
| 0.38939 | 0.07685 |
| 0.34312 | 0.07670 |
| 0.29824 | 0.07507 |
| 0.25510 | 0.07217 |
| 0.21415 | 0.06817 |
| 0.17583 | 0.06319 |
| 0.14053 | 0.05734 |
| 0.10860 | 0.05073 |
| 0.08036 | 0.04351 |
| 0.05605 | 0.03581 |
| 0.03589 | 0.02781 |
| 0.02004 | 0.01973 |
| 0.00862 | 0.01186 |
| 0.00178 | 0.00459 |
| 0.00014 | -0.00121 |
| 0.00437 | -0.00622 |
| 0.01427 | -0.01130 |
| 0.02935 | -0.01600 |
| 0.04949 | -0.02015 |
| 0.07454 | -0.02369 |
| 0.10428 | -0.02660 |
| 0.13845 | -0.02890 |
| 0.17669 | -0.03060 |
| 0.21861 | -0.03175 |
| 0.26374 | -0.03238 |
| 0.31158 | -0.03255 |
| 0.36159 | -0.03228 |
| 0.41320 | -0.03163 |
| 0.46580 | -0.03064 |
| 0.51877 | -0.02931 |
| 0.57150 | -0.02767 |
| 0.62336 | -0.02569 |
| 0.67382 | -0.02333 |
| 0.72243 | -0.02059 |
| 0.76873 | -0.01760 |
| 0.81228 | -0.01450 |
| 0.85254 | -0.01153 |
| 0.88892 | -0.00882 |
| 0.92085 | -0.00643 |
| 0.94783 | -0.00432 |
| 0.96958 | -0.00241 |
| 0.98594 | -0.00091 |
| 0.99637 | -0.00016 |
| 1.00000 | 0.00000 |

**E374**
actual model B

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00002 |
| 0.99931 | 0.00133 |
| 0.99547 | 0.00193 |
| 0.99075 | 0.00259 |
| 0.98553 | 0.00323 |
| 0.97942 | 0.00403 |
| 0.97449 | 0.00478 |
| 0.96606 | 0.00620 |
| 0.95897 | 0.00737 |
| 0.95051 | 0.00873 |
| 0.94089 | 0.01035 |
| 0.92731 | 0.01261 |
| 0.91006 | 0.01542 |
| 0.88922 | 0.01879 |
| 0.87081 | 0.02175 |
| 0.84125 | 0.02638 |
| 0.80842 | 0.03160 |
| 0.76422 | 0.03834 |
| 0.72768 | 0.04383 |
| 0.66531 | 0.05294 |
| 0.60199 | 0.06157 |
| 0.54234 | 0.06862 |
| 0.41405 | 0.07751 |
| 0.34811 | 0.07769 |
| 0.28951 | 0.07547 |
| 0.22319 | 0.07015 |
| 0.17954 | 0.06464 |
| 0.14136 | 0.05815 |
| 0.11425 | 0.05246 |
| 0.09448 | 0.04762 |
| 0.08072 | 0.04382 |
| 0.06739 | 0.03970 |
| 0.05486 | 0.03534 |
| 0.04468 | 0.03137 |
| 0.03449 | 0.02693 |
| 0.02480 | 0.02219 |
| 0.01653 | 0.01759 |
| 0.00821 | 0.01213 |
| 0.00459 | 0.00912 |
| 0.00059 | 0.00354 |
| 0.00003 | 0.00062 |
| 0.00177 | -0.00446 |
| 0.00544 | -0.00769 |
| 0.00958 | -0.01000 |
| 0.01319 | -0.01157 |
| 0.02096 | -0.01420 |
| 0.03009 | -0.01668 |
| 0.03948 | -0.01882 |
| 0.05464 | -0.02171 |
| 0.06817 | -0.02379 |
| 0.08950 | -0.02626 |
| 0.10662 | -0.02784 |
| 0.13833 | -0.02995 |
| 0.16421 | -0.03111 |
| 0.19316 | -0.03200 |
| 0.23635 | -0.03279 |
| 0.29760 | -0.03315 |
| 0.35915 | -0.03278 |
| 0.42077 | -0.03187 |
| 0.48279 | -0.03053 |
| 0.54271 | -0.02895 |
| 0.60527 | -0.02673 |
| 0.66857 | -0.02379 |
| 0.73107 | -0.02022 |
| 0.77240 | -0.01746 |
| 0.81508 | -0.01434 |
| 0.85142 | -0.01141 |
| 0.87900 | -0.00911 |
| 0.89676 | -0.00765 |
| 0.91943 | -0.00589 |
| 0.93686 | -0.00452 |
| 0.95206 | -0.00329 |
| 0.96402 | -0.00250 |
| 0.97295 | -0.00191 |
| 0.98200 | -0.00151 |
| 0.99124 | -0.00145 |
| 0.99865 | -0.00133 |
| 1.00000 | -0.00002 |

**E387**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99677 | 0.00043 |
| 0.98729 | 0.00180 |
| 0.97198 | 0.00423 |
| 0.95128 | 0.00763 |
| 0.92554 | 0.01184 |
| 0.89510 | 0.01679 |
| 0.86035 | 0.02242 |
| 0.82183 | 0.02866 |
| 0.78007 | 0.03540 |
| 0.73567 | 0.04249 |
| 0.68922 | 0.04975 |
| 0.64136 | 0.05696 |
| 0.59272 | 0.06390 |
| 0.54394 | 0.07020 |
| 0.49549 | 0.07546 |
| 0.44767 | 0.07936 |
| 0.40077 | 0.08173 |
| 0.35505 | 0.08247 |
| 0.31078 | 0.08156 |
| 0.26813 | 0.07908 |
| 0.22742 | 0.07529 |
| 0.18906 | 0.07037 |
| 0.15345 | 0.06448 |
| 0.12094 | 0.05775 |
| 0.09185 | 0.05033 |

| | |
|---|---|
| 0.06643 | 0.04238 |
| 0.04493 | 0.03408 |
| 0.02748 | 0.02562 |
| 0.01423 | 0.01726 |
| 0.00519 | 0.00931 |
| 0.00044 | 0.00234 |
| 0.00091 | -0.00286 |
| 0.00717 | -0.00682 |
| 0.01890 | -0.01017 |
| 0.03596 | -0.01265 |
| 0.05827 | -0.01425 |
| 0.08569 | -0.01500 |
| 0.11800 | -0.01502 |
| 0.15490 | -0.01441 |
| 0.19599 | -0.01329 |
| 0.24083 | -0.01177 |
| 0.28892 | -0.00998 |
| 0.33968 | -0.00804 |
| 0.39252 | -0.00605 |
| 0.44679 | -0.00410 |
| 0.50182 | -0.00228 |
| 0.55694 | -0.00065 |
| 0.61147 | 0.00074 |
| 0.66472 | 0.00186 |
| 0.71602 | 0.00268 |
| 0.76475 | 0.00320 |
| 0.81027 | 0.00342 |
| 0.85202 | 0.00337 |
| 0.88944 | 0.00307 |
| 0.92205 | 0.00258 |
| 0.94942 | 0.00196 |
| 0.97118 | 0.00132 |
| 0.98705 | 0.00071 |
| 0.99674 | 0.00021 |
| 1.00000 | 0.00000 |

**E387**

actual model A

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00009 |
| 0.99504 | 0.00095 |
| 0.98857 | 0.00194 |
| 0.98221 | 0.00295 |
| 0.97326 | 0.00432 |
| 0.96536 | 0.00547 |
| 0.95657 | 0.00679 |
| 0.94747 | 0.00807 |
| 0.93717 | 0.00960 |
| 0.92293 | 0.01174 |
| 0.90675 | 0.01418 |
| 0.88693 | 0.01708 |
| 0.86653 | 0.02009 |
| 0.83877 | 0.02424 |
| 0.80202 | 0.02969 |
| 0.76503 | 0.03515 |
| 0.72297 | 0.04144 |
| 0.66059 | 0.05062 |
| 0.60074 | 0.05897 |
| 0.54060 | 0.06640 |
| 0.47469 | 0.07305 |
| 0.41020 | 0.07733 |
| 0.35069 | 0.07854 |
| 0.28881 | 0.07694 |
| 0.22593 | 0.07209 |
| 0.18765 | 0.06751 |
| 0.15252 | 0.06202 |
| 0.12592 | 0.05690 |
| 0.10024 | 0.05108 |
| 0.08543 | 0.04710 |
| 0.07148 | 0.04284 |
| 0.05827 | 0.03825 |
| 0.04699 | 0.03386 |
| 0.03772 | 0.02981 |
| 0.02835 | 0.02503 |
| 0.02078 | 0.02043 |
| 0.01472 | 0.01639 |
| 0.00861 | 0.01171 |
| 0.00180 | 0.00468 |
| 0.00267 | -0.00568 |
| 0.00683 | -0.00775 |
| 0.01289 | -0.00957 |
| 0.01923 | -0.01107 |
| 0.02737 | -0.01261 |
| 0.03552 | -0.01390 |
| 0.04178 | -0.01472 |
| 0.05075 | -0.01564 |
| 0.06433 | -0.01656 |
| 0.08169 | -0.01728 |
| 0.10196 | -0.01767 |
| 0.13171 | -0.01766 |
| 0.16440 | -0.01716 |
| 0.20232 | -0.01623 |
| 0.24433 | -0.01495 |
| 0.30493 | -0.01288 |
| 0.36410 | -0.01068 |
| 0.42605 | -0.00820 |
| 0.48404 | -0.00599 |
| 0.54791 | -0.00384 |
| 0.61294 | -0.00200 |
| 0.67779 | -0.00036 |
| 0.74350 | 0.00102 |
| 0.78240 | 0.00166 |
| 0.81865 | 0.00199 |
| 0.85388 | 0.00216 |
| 0.90937 | 0.00192 |
| 0.92880 | 0.00148 |
| 0.94537 | 0.00117 |
| 0.96059 | 0.00074 |
| 0.97265 | 0.00047 |
| 0.98401 | 0.00019 |
| 0.99037 | -0.00006 |
| 1.00000 | 0.00009 |

**FX 63-137**

smoothed

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99572 | 0.00226 |
| 0.98296 | 0.00822 |
| 0.96194 | 0.01642 |
| 0.93301 | 0.02581 |
| 0.89668 | 0.03615 |
| 0.85355 | 0.04757 |
| 0.80438 | 0.06001 |
| 0.75000 | 0.07305 |
| 0.69134 | 0.08596 |
| 0.62941 | 0.09788 |
| 0.56526 | 0.10799 |
| 0.50000 | 0.11562 |
| 0.43474 | 0.12031 |
| 0.37059 | 0.12180 |
| 0.33928 | 0.12130 |
| 0.30866 | 0.11998 |
| 0.27886 | 0.11785 |
| 0.25000 | 0.11492 |
| 0.22221 | 0.11122 |
| 0.19562 | 0.10680 |
| 0.17033 | 0.10168 |
| 0.14645 | 0.09591 |
| 0.12408 | 0.08955 |
| 0.10332 | 0.08270 |
| 0.08427 | 0.07552 |
| 0.06699 | 0.06812 |
| 0.05156 | 0.06052 |
| 0.03806 | 0.05264 |
| 0.02653 | 0.04430 |
| 0.01704 | 0.03548 |
| 0.00961 | 0.02636 |
| 0.00428 | 0.01742 |
| 0.00107 | 0.00926 |
| 0.00000 | 0.00241 |
| 0.00107 | -0.00296 |
| 0.00428 | -0.00702 |
| 0.00961 | -0.01016 |
| 0.01704 | -0.01275 |
| 0.02653 | -0.01503 |
| 0.03806 | -0.01706 |
| 0.05156 | -0.01879 |
| 0.06699 | -0.02018 |
| 0.08427 | -0.02123 |
| 0.10332 | -0.02199 |
| 0.12408 | -0.02248 |
| 0.14645 | -0.02272 |
| 0.17033 | -0.02267 |
| 0.19562 | -0.02230 |
| 0.22221 | -0.02157 |
| 0.25000 | -0.02043 |
| 0.27886 | -0.01884 |
| 0.30866 | -0.01675 |
| 0.33928 | -0.01418 |
| 0.37059 | -0.01118 |
| 0.43474 | -0.00421 |
| 0.50000 | 0.00341 |
| 0.56526 | 0.01092 |
| 0.62941 | 0.01760 |
| 0.69134 | 0.02287 |
| 0.75000 | 0.02629 |
| 0.80438 | 0.02758 |
| 0.85355 | 0.02661 |
| 0.89668 | 0.02343 |
| 0.93301 | 0.01841 |
| 0.96194 | 0.01229 |
| 0.98296 | 0.00623 |
| 0.99572 | 0.00170 |
| 1.00000 | 0.00000 |

**FX 63-137**

actual model B

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00031 |
| 0.99932 | 0.00044 |
| 0.99504 | 0.00274 |
| 0.98879 | 0.00563 |
| 0.98146 | 0.00870 |
| 0.97492 | 0.01125 |
| 0.97500 | 0.01122 |
| 0.95693 | 0.01772 |
| 0.94531 | 0.02170 |
| 0.93349 | 0.02551 |
| 0.92051 | 0.02950 |
| 0.90331 | 0.03452 |
| 0.88636 | 0.03932 |
| 0.86782 | 0.04434 |
| 0.84997 | 0.04899 |
| 0.82203 | 0.05604 |
| 0.79002 | 0.06384 |
| 0.74876 | 0.07337 |
| 0.70670 | 0.08250 |
| 0.64448 | 0.09460 |
| 0.58299 | 0.10468 |
| 0.52087 | 0.11253 |
| 0.45837 | 0.11780 |
| 0.39446 | 0.11992 |
| 0.33408 | 0.11893 |
| 0.26817 | 0.11430 |
| 0.21284 | 0.10703 |
| 0.16606 | 0.09778 |
| 0.13272 | 0.08908 |
| 0.11672 | 0.08415 |
| 0.09989 | 0.07839 |
| 0.08201 | 0.07147 |
| 0.06895 | 0.06576 |
| 0.05624 | 0.05945 |
| 0.04500 | 0.05306 |
| 0.03324 | 0.04519 |
| 0.02382 | 0.03770 |
| 0.01858 | 0.03276 |
| 0.01147 | 0.02467 |
| 0.00517 | 0.01503 |
| 0.00552 | 0.01565 |
| 0.00152 | 0.00669 |
| 0.00081 | 0.00488 |
| 0.00291 | -0.00946 |
| 0.00702 | -0.01301 |
| 0.01268 | -0.01618 |
| 0.01865 | -0.01839 |
| 0.02609 | -0.02033 |
| 0.03367 | -0.02177 |
| 0.04433 | -0.02320 |
| 0.06261 | -0.02489 |
| 0.08313 | -0.02614 |
| 0.11482 | -0.02708 |
| 0.14881 | -0.02720 |
| 0.19042 | -0.02643 |
| 0.23870 | -0.02454 |
| 0.30207 | -0.02062 |
| 0.36557 | -0.01479 |
| 0.42496 | -0.00814 |
| 0.48817 | -0.00064 |
| 0.54911 | 0.00654 |
| 0.61046 | 0.01349 |
| 0.67309 | 0.01971 |
| 0.73663 | 0.02402 |
| 0.77968 | 0.02563 |
| 0.81868 | 0.02589 |
| 0.85321 | 0.02493 |
| 0.87115 | 0.02390 |

| | |
|---|---|
| 0.88864 | 0.02243 |
| 0.90527 | 0.02047 |
| 0.91935 | 0.01849 |
| 0.93295 | 0.01621 |
| 0.94633 | 0.01363 |
| 0.95557 | 0.01169 |
| 0.96543 | 0.00937 |
| 0.97486 | 0.00695 |
| 0.98453 | 0.00421 |
| 0.99236 | 0.00182 |
| 0.99933 | -0.00044 |
| 1.00000 | 0.00031 |

**FX 74-CL5-140 MOD**
smoothed model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00009 |
| 0.99754 | 0.00189 |
| 0.99070 | 0.00624 |
| 0.98037 | 0.01150 |
| 0.96698 | 0.01741 |
| 0.95044 | 0.02402 |
| 0.93064 | 0.03188 |
| 0.90775 | 0.04001 |
| 0.88202 | 0.04848 |
| 0.85370 | 0.05718 |
| 0.82309 | 0.06616 |
| 0.79048 | 0.07549 |
| 0.75616 | 0.08510 |
| 0.72043 | 0.09482 |
| 0.68359 | 0.10446 |
| 0.64594 | 0.11385 |
| 0.60778 | 0.12287 |
| 0.56937 | 0.13137 |
| 0.53099 | 0.13916 |
| 0.49265 | 0.14604 |
| 0.45435 | 0.15177 |
| 0.41638 | 0.15606 |
| 0.37887 | 0.15868 |
| 0.34204 | 0.15944 |
| 0.30609 | 0.15820 |
| 0.27120 | 0.15493 |
| 0.23760 | 0.14964 |
| 0.20549 | 0.14243 |
| 0.17504 | 0.13344 |
| 0.14648 | 0.12292 |
| 0.11999 | 0.11110 |
| 0.09576 | 0.09826 |
| 0.07395 | 0.08459 |
| 0.05468 | 0.07030 |
| 0.03811 | 0.05576 |
| 0.02433 | 0.04145 |
| 0.01338 | 0.02769 |
| 0.00548 | 0.01518 |
| 0.00098 | 0.00518 |
| 0.00000 | -0.00021 |
| 0.00098 | -0.00435 |
| 0.00548 | -0.00787 |
| 0.01338 | -0.00871 |
| 0.02433 | -0.00754 |
| 0.03811 | -0.00539 |
| 0.05468 | -0.00292 |
| 0.07395 | -0.00022 |
| 0.09576 | 0.00270 |
| 0.11999 | 0.00584 |
| 0.14648 | 0.00921 |
| 0.17504 | 0.01279 |
| 0.20549 | 0.01651 |
| 0.23760 | 0.02030 |
| 0.27120 | 0.02410 |
| 0.30609 | 0.02786 |
| 0.34204 | 0.03152 |
| 0.37887 | 0.03503 |
| 0.41638 | 0.03832 |
| 0.45435 | 0.04134 |
| 0.49265 | 0.04400 |
| 0.53099 | 0.04624 |
| 0.56937 | 0.04801 |
| 0.60778 | 0.04925 |
| 0.64594 | 0.04992 |
| 0.68359 | 0.04997 |
| 0.72043 | 0.04936 |
| 0.75616 | 0.04807 |
| 0.79048 | 0.04608 |
| 0.82309 | 0.04334 |
| 0.85370 | 0.03978 |
| 0.88202 | 0.03537 |
| 0.90775 | 0.03013 |
| 0.93064 | 0.02434 |
| 0.95044 | 0.01851 |
| 0.96698 | 0.01290 |
| 0.98037 | 0.00756 |
| 0.99070 | 0.00319 |
| 0.99754 | 0.00068 |
| 1.00000 | -0.00003 |

**FX 74-CL5-140 MOD**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00141 |
| 0.99816 | 0.00077 |
| 0.99280 | 0.00383 |
| 0.98718 | 0.00678 |
| 0.97934 | 0.01058 |
| 0.97052 | 0.01453 |
| 0.96308 | 0.01761 |
| 0.95544 | 0.02063 |
| 0.94685 | 0.02397 |
| 0.93789 | 0.02737 |
| 0.92887 | 0.03069 |
| 0.91876 | 0.03426 |
| 0.90950 | 0.03743 |
| 0.89922 | 0.04089 |
| 0.88378 | 0.04588 |
| 0.86905 | 0.05049 |
| 0.85360 | 0.05507 |
| 0.84069 | 0.05884 |
| 0.80768 | 0.06835 |
| 0.77501 | 0.07760 |
| 0.74687 | 0.08540 |
| 0.70547 | 0.09655 |
| 0.66612 | 0.10668 |
| 0.61967 | 0.11797 |
| 0.57861 | 0.12719 |
| 0.52217 | 0.13872 |
| 0.46313 | 0.14873 |
| 0.40939 | 0.15502 |
| 0.35552 | 0.15787 |
| 0.29881 | 0.15647 |
| 0.24982 | 0.15052 |
| 0.21251 | 0.14297 |
| 0.14857 | 0.12269 |
| 0.13038 | 0.11492 |
| 0.10868 | 0.10440 |
| 0.08477 | 0.09084 |
| 0.07267 | 0.08299 |
| 0.05717 | 0.07159 |
| 0.04571 | 0.06209 |
| 0.03546 | 0.05260 |
| 0.02545 | 0.04222 |
| 0.01818 | 0.03369 |
| 0.01305 | 0.02691 |
| 0.00703 | 0.01758 |
| 0.00348 | 0.01099 |
| 0.00088 | 0.00462 |
| 0.00021 | 0.00186 |
| 0.00010 | -0.00128 |
| 0.00200 | -0.00571 |
| 0.00668 | -0.00833 |
| 0.01274 | -0.00872 |
| 0.02070 | -0.00783 |
| 0.03086 | -0.00640 |
| 0.04204 | -0.00485 |
| 0.04204 | -0.00485 |
| 0.06956 | -0.00104 |
| 0.08794 | 0.00136 |
| 0.09851 | 0.00269 |
| 0.11525 | 0.00476 |
| 0.14318 | 0.00820 |
| 0.17209 | 0.01174 |
| 0.19558 | 0.01447 |
| 0.24186 | 0.01984 |
| 0.28294 | 0.02443 |
| 0.34451 | 0.03054 |
| 0.40135 | 0.03567 |
| 0.45829 | 0.04028 |
| 0.51318 | 0.04381 |
| 0.57902 | 0.04675 |
| 0.63677 | 0.04815 |
| 0.66945 | 0.04838 |
| 0.70611 | 0.04792 |
| 0.75147 | 0.04660 |
| 0.79027 | 0.04442 |
| 0.82706 | 0.04129 |
| 0.85262 | 0.03834 |
| 0.87659 | 0.03477 |
| 0.89444 | 0.03150 |
| 0.91070 | 0.02793 |
| 0.92553 | 0.02425 |
| 0.93432 | 0.02187 |
| 0.94510 | 0.01870 |
| 0.95758 | 0.01480 |
| 0.96875 | 0.01103 |
| 0.98026 | 0.00665 |
| 0.98685 | 0.00377 |
| 0.99646 | -0.00076 |
| 1.00000 | -0.00141 |

**GEMINI**
smoothed model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00014 |
| 0.99754 | 0.00151 |
| 0.99070 | 0.00419 |
| 0.98037 | 0.00623 |
| 0.96698 | 0.00919 |
| 0.95044 | 0.01300 |
| 0.93064 | 0.01720 |
| 0.90775 | 0.02213 |
| 0.88202 | 0.02757 |
| 0.85370 | 0.03335 |
| 0.82309 | 0.03944 |
| 0.79048 | 0.04581 |
| 0.75616 | 0.05236 |
| 0.72043 | 0.05893 |
| 0.68359 | 0.06539 |
| 0.64594 | 0.07161 |
| 0.60778 | 0.07745 |
| 0.56937 | 0.08278 |
| 0.53099 | 0.08745 |
| 0.49265 | 0.09138 |
| 0.45435 | 0.09455 |
| 0.41638 | 0.09689 |
| 0.37887 | 0.09835 |
| 0.34204 | 0.09886 |
| 0.30609 | 0.09832 |
| 0.27120 | 0.09666 |
| 0.23760 | 0.09383 |
| 0.20549 | 0.08982 |
| 0.17504 | 0.08469 |
| 0.14648 | 0.07851 |
| 0.11999 | 0.07137 |
| 0.09576 | 0.06334 |
| 0.07395 | 0.05453 |
| 0.05468 | 0.04523 |
| 0.03811 | 0.03610 |
| 0.02433 | 0.02764 |
| 0.01338 | 0.01975 |
| 0.00548 | 0.01212 |
| 0.00098 | 0.00497 |
| 0.00000 | 0.00001 |
| 0.00098 | -0.00493 |
| 0.00548 | -0.01164 |
| 0.01338 | -0.01784 |
| 0.02433 | -0.02329 |
| 0.03811 | -0.02826 |
| 0.05468 | -0.03288 |
| 0.07395 | -0.03724 |
| 0.09576 | -0.04136 |
| 0.11999 | -0.04512 |
| 0.14648 | -0.04825 |
| 0.17504 | -0.05067 |
| 0.20549 | -0.05246 |
| 0.23760 | -0.05376 |
| 0.27120 | -0.05461 |
| 0.30609 | -0.05501 |
| 0.34204 | -0.05493 |
| 0.37887 | -0.05433 |
| 0.41638 | -0.05323 |
| 0.45435 | -0.05162 |
| 0.49265 | -0.04955 |
| 0.53099 | -0.04709 |

| | |
|---|---|
| 0.56937 | -0.04430 |
| 0.60778 | -0.04124 |
| 0.64594 | -0.03798 |
| 0.68359 | -0.03461 |
| 0.72043 | -0.03121 |
| 0.75616 | -0.02782 |
| 0.79048 | -0.02446 |
| 0.82309 | -0.02118 |
| 0.85370 | -0.01802 |
| 0.88202 | -0.01506 |
| 0.90775 | -0.01233 |
| 0.93064 | -0.00987 |
| 0.95044 | -0.00778 |
| 0.96698 | -0.00638 |
| 0.98037 | -0.00522 |
| 0.99070 | -0.00344 |
| 0.99754 | -0.00117 |
| 1.00000 | -0.00001 |

**GEMINI**

actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00075 |
| 0.99908 | 0.00273 |
| 0.99605 | 0.00405 |
| 0.99168 | 0.00502 |
| 0.98664 | 0.00622 |
| 0.97874 | 0.00822 |
| 0.96932 | 0.01028 |
| 0.96083 | 0.01213 |
| 0.94912 | 0.01471 |
| 0.93709 | 0.01726 |
| 0.92481 | 0.01978 |
| 0.90932 | 0.02328 |
| 0.89417 | 0.02643 |
| 0.87998 | 0.02942 |
| 0.84901 | 0.03568 |
| 0.81705 | 0.04191 |
| 0.78888 | 0.04740 |
| 0.74459 | 0.05575 |
| 0.70218 | 0.06344 |
| 0.65948 | 0.07063 |
| 0.61604 | 0.07737 |
| 0.56044 | 0.08502 |
| 0.50545 | 0.09148 |
| 0.44769 | 0.09629 |
| 0.38932 | 0.09870 |
| 0.33216 | 0.09991 |
| 0.27457 | 0.09810 |
| 0.23045 | 0.09380 |
| 0.19098 | 0.08847 |
| 0.16333 | 0.08320 |
| 0.13497 | 0.07639 |
| 0.10705 | 0.06800 |
| 0.09455 | 0.06359 |
| 0.08178 | 0.05860 |
| 0.06854 | 0.05269 |
| 0.05628 | 0.04664 |
| 0.04304 | 0.03937 |
| 0.02848 | 0.03051 |
| 0.02029 | 0.02517 |
| 0.01347 | 0.02022 |
| 0.00665 | 0.01355 |
| 0.00347 | 0.00914 |
| 0.00138 | 0.00573 |
| 0.00224 | -0.00749 |
| 0.00576 | -0.01212 |
| 0.00958 | -0.01550 |
| 0.01818 | -0.02044 |
| 0.02489 | -0.02351 |
| 0.03421 | -0.02702 |
| 0.04612 | -0.03060 |
| 0.06079 | -0.03431 |
| 0.07669 | -0.03771 |
| 0.09104 | -0.04043 |
| 0.10322 | -0.04255 |
| 0.12623 | -0.04588 |
| 0.14307 | -0.04789 |
| 0.17180 | -0.05041 |
| 0.20230 | -0.05225 |
| 0.24452 | -0.05360 |
| 0.28864 | -0.05443 |
| 0.34340 | -0.05470 |
| 0.40117 | -0.05347 |
| 0.45750 | -0.05121 |
| 0.51287 | -0.04801 |
| 0.57232 | -0.04378 |
| 0.62644 | -0.03936 |
| 0.66966 | -0.03551 |
| 0.71376 | -0.03145 |
| 0.75569 | -0.02757 |
| 0.79793 | -0.02342 |
| 0.82795 | -0.02034 |
| 0.86258 | -0.01677 |
| 0.89339 | -0.01359 |
| 0.91038 | -0.01176 |
| 0.92357 | -0.01031 |
| 0.93966 | -0.00865 |
| 0.95225 | -0.00734 |
| 0.96343 | -0.00624 |
| 0.97683 | -0.00492 |
| 0.98975 | -0.00378 |
| 0.99921 | -0.00273 |
| 1.00000 | 0.00075 |

**GM15**

smoothed model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00006 |
| 0.99754 | 0.00114 |
| 0.99070 | 0.00356 |
| 0.98037 | 0.00616 |
| 0.96698 | 0.00865 |
| 0.95044 | 0.01149 |
| 0.93064 | 0.01516 |
| 0.90775 | 0.01969 |
| 0.88202 | 0.02474 |
| 0.85370 | 0.03001 |
| 0.82309 | 0.03524 |
| 0.79048 | 0.04030 |
| 0.75616 | 0.04511 |
| 0.72043 | 0.04963 |
| 0.68359 | 0.05386 |
| 0.64594 | 0.05779 |
| 0.60778 | 0.06140 |
| 0.56937 | 0.06467 |
| 0.53099 | 0.06751 |
| 0.49265 | 0.06988 |
| 0.45435 | 0.07172 |
| 0.41638 | 0.07295 |
| 0.37887 | 0.07352 |
| 0.34204 | 0.07339 |
| 0.30609 | 0.07255 |
| 0.27120 | 0.07097 |
| 0.23760 | 0.06866 |
| 0.20549 | 0.06561 |
| 0.17504 | 0.06182 |
| 0.14648 | 0.05731 |
| 0.11999 | 0.05210 |
| 0.09576 | 0.04629 |
| 0.07395 | 0.04003 |
| 0.05468 | 0.03354 |
| 0.03811 | 0.02698 |
| 0.02433 | 0.02052 |
| 0.01338 | 0.01433 |
| 0.00548 | 0.00852 |
| 0.00098 | 0.00322 |
| 0.00000 | -0.00019 |
| 0.00098 | -0.00312 |
| 0.00548 | -0.00634 |
| 0.01338 | -0.00868 |
| 0.02433 | -0.01036 |
| 0.03811 | -0.01150 |
| 0.05468 | -0.01210 |
| 0.07395 | -0.01207 |
| 0.09576 | -0.01136 |
| 0.11999 | -0.00996 |
| 0.14648 | -0.00785 |
| 0.17504 | -0.00510 |
| 0.20549 | -0.00179 |
| 0.23760 | 0.00191 |
| 0.27120 | 0.00586 |
| 0.30609 | 0.00988 |
| 0.34204 | 0.01379 |
| 0.37887 | 0.01741 |
| 0.41638 | 0.02060 |
| 0.45435 | 0.02324 |
| 0.49265 | 0.02526 |
| 0.53099 | 0.02661 |
| 0.56937 | 0.02732 |
| 0.60778 | 0.02740 |
| 0.64594 | 0.02692 |
| 0.68359 | 0.02594 |
| 0.72043 | 0.02456 |
| 0.75616 | 0.02287 |
| 0.79048 | 0.02088 |
| 0.82309 | 0.01858 |
| 0.85370 | 0.01598 |
| 0.88202 | 0.01317 |
| 0.90775 | 0.01033 |
| 0.93064 | 0.00765 |
| 0.95044 | 0.00528 |
| 0.96698 | 0.00332 |
| 0.98037 | 0.00179 |
| 0.99070 | 0.00075 |
| 0.99754 | 0.00017 |
| 1.00000 | -0.00001 |

**GM15**

actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00153 |
| 0.99539 | 0.00116 |
| 0.98862 | 0.00264 |
| 0.98057 | 0.00402 |
| 0.97155 | 0.00594 |
| 0.95658 | 0.00878 |
| 0.94418 | 0.01143 |
| 0.93171 | 0.01364 |
| 0.91581 | 0.01630 |
| 0.89757 | 0.01997 |
| 0.88410 | 0.02301 |
| 0.85174 | 0.02964 |
| 0.82229 | 0.03442 |
| 0.79060 | 0.03884 |
| 0.74898 | 0.04494 |
| 0.70735 | 0.05047 |
| 0.66514 | 0.05535 |
| 0.62046 | 0.05914 |
| 0.56279 | 0.06420 |
| 0.51025 | 0.06836 |
| 0.45558 | 0.07133 |
| 0.39572 | 0.07301 |
| 0.33961 | 0.07258 |
| 0.28096 | 0.07109 |
| 0.23556 | 0.06865 |
| 0.18840 | 0.06385 |
| 0.15957 | 0.05955 |
| 0.13405 | 0.05505 |
| 0.10701 | 0.04930 |
| 0.09233 | 0.04536 |
| 0.07702 | 0.04098 |
| 0.06153 | 0.03601 |
| 0.05063 | 0.03216 |
| 0.04017 | 0.02804 |
| 0.02829 | 0.02250 |
| 0.02132 | 0.01883 |
| 0.01500 | 0.01537 |
| 0.00842 | 0.01098 |
| 0.00385 | 0.00725 |
| 0.00167 | 0.00406 |
| 0.00000 | -0.00011 |
| 0.00399 | -0.00628 |
| 0.00781 | -0.00744 |
| 0.01570 | -0.00888 |
| 0.02268 | -0.01002 |
| 0.03116 | -0.01102 |
| 0.04716 | -0.01198 |
| 0.06033 | -0.01208 |
| 0.07504 | -0.01193 |
| 0.08895 | -0.01171 |
| 0.10477 | -0.01108 |
| 0.12022 | -0.01004 |
| 0.14641 | -0.00794 |
| 0.17578 | -0.00523 |
| 0.20395 | -0.00226 |
| 0.24788 | 0.00282 |
| 0.29626 | 0.00853 |
| 0.34919 | 0.01424 |
| 0.40288 | 0.01903 |
| 0.46307 | 0.02355 |
| 0.51862 | 0.02613 |
| 0.57584 | 0.02678 |
| 0.63110 | 0.02605 |
| 0.67619 | 0.02462 |
| 0.72014 | 0.02343 |
| 0.76444 | 0.02159 |

| | |
|---|---|
| 0.80748 | 0.01935 |
| 0.83766 | 0.01578 |
| 0.86986 | 0.01314 |
| 0.90304 | 0.00973 |
| 0.91751 | 0.00771 |
| 0.93202 | 0.00616 |
| 0.95024 | 0.00412 |
| 0.96279 | 0.00217 |
| 0.97394 | 0.00103 |
| 0.98610 | -0.00010 |
| 0.99283 | -0.00114 |
| 1.00000 | -0.00153 |

**GM15 (reflexed fla**
actual model
reflexed flap

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00108 |
| 0.99768 | 0.00163 |
| 0.99175 | 0.00226 |
| 0.98572 | 0.00287 |
| 0.97308 | 0.00411 |
| 0.95989 | 0.00541 |
| 0.94798 | 0.00634 |
| 0.93450 | 0.00746 |
| 0.91824 | 0.00877 |
| 0.90389 | 0.00998 |
| 0.88952 | 0.01163 |
| 0.85723 | 0.01514 |
| 0.82155 | 0.01777 |
| 0.79312 | 0.01885 |
| 0.75021 | 0.02068 |
| 0.70598 | 0.02216 |
| 0.66364 | 0.02436 |
| 0.61958 | 0.03012 |
| 0.56287 | 0.03802 |
| 0.50630 | 0.04505 |
| 0.45206 | 0.05049 |
| 0.39478 | 0.05465 |
| 0.33826 | 0.05690 |
| 0.28324 | 0.05801 |
| 0.23720 | 0.05776 |
| 0.19531 | 0.05558 |
| 0.16463 | 0.05260 |
| 0.13575 | 0.04900 |
| 0.10962 | 0.04475 |
| 0.09613 | 0.04188 |
| 0.08282 | 0.03866 |
| 0.06530 | 0.03414 |
| 0.05167 | 0.03007 |
| 0.04019 | 0.02614 |
| 0.02474 | 0.01961 |
| 0.01699 | 0.01587 |
| 0.00813 | 0.01062 |
| 0.00123 | 0.00324 |
| 0.00000 | 0.00008 |
| 0.00440 | -0.00611 |
| 0.01068 | -0.00817 |
| 0.01743 | -0.00963 |
| 0.02538 | -0.01110 |
| 0.03147 | -0.01204 |
| 0.04506 | -0.01353 |
| 0.05847 | -0.01439 |
| 0.07130 | -0.01468 |
| 0.08313 | -0.01522 |
| 0.09799 | -0.01544 |
| 0.11476 | -0.01532 |
| 0.14018 | -0.01471 |
| 0.17005 | -0.01340 |
| 0.20018 | -0.01164 |
| 0.24453 | -0.00875 |
| 0.29261 | -0.00535 |
| 0.34669 | -0.00214 |
| 0.40380 | 0.00016 |
| 0.46250 | 0.00185 |
| 0.51368 | 0.00160 |
| 0.57249 | -0.00017 |
| 0.62846 | -0.00386 |
| 0.67683 | -0.00687 |
| 0.71743 | -0.00421 |
| 0.75938 | -0.00197 |
| 0.80531 | 0.00043 |
| 0.83507 | 0.00051 |
| 0.86859 | 0.00083 |
| 0.90278 | 0.00027 |
| 0.91757 | -0.00014 |
| 0.93247 | -0.00034 |
| 0.94659 | -0.00058 |
| 0.96192 | -0.00100 |
| 0.97236 | -0.00112 |
| 0.98319 | -0.00154 |
| 0.99262 | -0.00162 |
| 1.00000 | -0.00108 |

**J5012**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99726 | 0.00043 |
| 0.98907 | 0.00169 |
| 0.97553 | 0.00377 |
| 0.95677 | 0.00659 |
| 0.93301 | 0.01009 |
| 0.90451 | 0.01416 |
| 0.87157 | 0.01870 |
| 0.83457 | 0.02357 |
| 0.79389 | 0.02864 |
| 0.75000 | 0.03377 |
| 0.70337 | 0.03880 |
| 0.65451 | 0.04359 |
| 0.60396 | 0.04800 |
| 0.55226 | 0.05189 |
| 0.50000 | 0.05514 |
| 0.44774 | 0.05763 |
| 0.39604 | 0.05928 |
| 0.34549 | 0.06000 |
| 0.29663 | 0.05975 |
| 0.25000 | 0.05849 |
| 0.20611 | 0.05621 |
| 0.16544 | 0.05294 |
| 0.12843 | 0.04871 |
| 0.09549 | 0.04359 |
| 0.06699 | 0.03766 |
| 0.04323 | 0.03102 |
| 0.02447 | 0.02380 |
| 0.01093 | 0.01612 |
| 0.00274 | 0.00814 |
| 0.00000 | 0.00000 |
| 0.00274 | -0.00814 |
| 0.01093 | -0.01612 |
| 0.02447 | -0.02380 |
| 0.04323 | -0.03102 |
| 0.06699 | -0.03766 |
| 0.09549 | -0.04359 |
| 0.12843 | -0.04871 |
| 0.16543 | -0.05294 |
| 0.20611 | -0.05621 |
| 0.25000 | -0.05849 |
| 0.29663 | -0.05975 |
| 0.34549 | -0.06000 |
| 0.39604 | -0.05928 |
| 0.44774 | -0.05763 |
| 0.50000 | -0.05514 |
| 0.55226 | -0.05189 |
| 0.60396 | -0.04800 |
| 0.65451 | -0.04359 |
| 0.70337 | -0.03880 |
| 0.75000 | -0.03377 |
| 0.79389 | -0.02864 |
| 0.83456 | -0.02357 |
| 0.87157 | -0.01870 |
| 0.90451 | -0.01416 |
| 0.93301 | -0.01009 |
| 0.95677 | -0.00659 |
| 0.97553 | -0.00377 |
| 0.98907 | -0.00169 |
| 0.99726 | -0.00043 |
| 1.00000 | 0.00000 |

**J5012**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00043 |
| 0.99683 | 0.00325 |
| 0.99236 | 0.00410 |
| 0.98621 | 0.00473 |
| 0.97933 | 0.00565 |
| 0.97334 | 0.00642 |
| 0.96802 | 0.00702 |
| 0.96016 | 0.00805 |
| 0.95092 | 0.00920 |
| 0.93935 | 0.01065 |
| 0.91244 | 0.01407 |
| 0.89213 | 0.01708 |
| 0.87168 | 0.02010 |
| 0.84330 | 0.02397 |
| 0.80711 | 0.02853 |
| 0.72530 | 0.03722 |
| 0.66130 | 0.04362 |
| 0.59952 | 0.04832 |
| 0.53716 | 0.05309 |
| 0.47185 | 0.05714 |
| 0.41102 | 0.05843 |
| 0.34700 | 0.05953 |
| 0.28532 | 0.05833 |
| 0.22125 | 0.05623 |
| 0.18379 | 0.05339 |
| 0.14666 | 0.05010 |
| 0.11503 | 0.04572 |
| 0.08233 | 0.03939 |
| 0.05940 | 0.03400 |
| 0.04376 | 0.02942 |
| 0.03116 | 0.02492 |
| 0.02167 | 0.02092 |
| 0.01453 | 0.01745 |
| 0.00688 | 0.01256 |
| 0.00164 | 0.00605 |
| 0.00038 | -0.00286 |
| 0.00304 | -0.00814 |
| 0.00744 | -0.01239 |
| 0.01340 | -0.01656 |
| 0.01769 | -0.01911 |
| 0.02600 | -0.02334 |
| 0.03675 | -0.02786 |
| 0.05076 | -0.03222 |
| 0.06808 | -0.03608 |
| 0.08714 | -0.03943 |
| 0.11804 | -0.04439 |
| 0.14686 | -0.04810 |
| 0.18075 | -0.05138 |
| 0.23136 | -0.05512 |
| 0.28906 | -0.05784 |
| 0.35629 | -0.05804 |
| 0.41865 | -0.05705 |
| 0.48118 | -0.05473 |
| 0.54428 | -0.05096 |
| 0.60641 | -0.04598 |
| 0.66791 | -0.04046 |
| 0.72858 | -0.03435 |
| 0.77346 | -0.02874 |
| 0.81109 | -0.02476 |
| 0.84578 | -0.01999 |
| 0.87596 | -0.01571 |
| 0.89291 | -0.01356 |
| 0.91593 | -0.01139 |
| 0.93072 | -0.01000 |
| 0.94686 | -0.00851 |
| 0.95756 | -0.00780 |
| 0.96603 | -0.00721 |
| 0.97488 | -0.00634 |
| 0.98317 | -0.00510 |
| 0.99140 | -0.00347 |
| 0.99921 | -0.00151 |
| 1.00000 | 0.00043 |

**K3311**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.95000 | 0.01043 |
| 0.90000 | 0.02009 |
| 0.85000 | 0.02931 |
| 0.80000 | 0.03842 |
| 0.75000 | 0.04670 |
| 0.70000 | 0.05476 |
| 0.65000 | 0.06170 |
| 0.60000 | 0.06895 |
| 0.55000 | 0.07485 |
| 0.50000 | 0.07966 |
| 0.45000 | 0.08347 |
| 0.40000 | 0.08618 |
| 0.35000 | 0.08702 |
| 0.30000 | 0.08595 |
| 0.25000 | 0.08310 |
| 0.20000 | 0.07776 |
| 0.15000 | 0.06966 |
| 0.10000 | 0.05748 |

| | |
|---|---|
| 0.08000 | 0.05130 |
| 0.06000 | 0.04412 |
| 0.04000 | 0.03498 |
| 0.02000 | 0.02327 |
| 0.01000 | 0.01563 |
| 0.00000 | 0.00000 |
| 0.01000 | -0.01036 |
| 0.02000 | -0.01285 |
| 0.04000 | -0.01635 |
| 0.06000 | -0.01896 |
| 0.08000 | -0.02045 |
| 0.10000 | -0.02169 |
| 0.15000 | -0.02387 |
| 0.20000 | -0.02492 |
| 0.25000 | -0.02468 |
| 0.30000 | -0.02405 |
| 0.35000 | -0.02260 |
| 0.40000 | -0.02113 |
| 0.45000 | -0.01883 |
| 0.50000 | -0.01608 |
| 0.55000 | -0.01327 |
| 0.60000 | -0.01053 |
| 0.65000 | -0.00812 |
| 0.70000 | -0.00592 |
| 0.75000 | -0.00396 |
| 0.80000 | -0.00232 |
| 0.85000 | -0.00121 |
| 0.90000 | -0.00051 |
| 0.95000 | -0.00054 |
| 1.00000 | 0.00000 |

**K3311**
smoothed

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99754 | 0.00055 |
| 0.99070 | 0.00206 |
| 0.98037 | 0.00428 |
| 0.96698 | 0.00706 |
| 0.95044 | 0.01040 |
| 0.93064 | 0.01430 |
| 0.90775 | 0.01871 |
| 0.88202 | 0.02357 |
| 0.85370 | 0.02879 |
| 0.82309 | 0.03430 |
| 0.79048 | 0.03999 |
| 0.75616 | 0.04575 |
| 0.72043 | 0.05150 |
| 0.68359 | 0.05713 |
| 0.64594 | 0.06257 |
| 0.60778 | 0.06772 |
| 0.56937 | 0.07246 |
| 0.53099 | 0.07666 |
| 0.49265 | 0.08025 |
| 0.45435 | 0.08315 |
| 0.41638 | 0.08525 |
| 0.37887 | 0.08647 |
| 0.34204 | 0.08674 |
| 0.30609 | 0.08604 |
| 0.27120 | 0.08436 |
| 0.23760 | 0.08174 |
| 0.20549 | 0.07821 |
| 0.17504 | 0.07381 |
| 0.14648 | 0.06861 |
| 0.11999 | 0.06267 |
| 0.09576 | 0.05609 |
| 0.07395 | 0.04899 |
| 0.05468 | 0.04147 |
| 0.03811 | 0.03372 |
| 0.02433 | 0.02593 |
| 0.01338 | 0.01829 |
| 0.00548 | 0.01100 |
| 0.00098 | 0.00432 |
| 0.00000 | 0.00000 |
| 0.00098 | -0.00381 |
| 0.00548 | -0.00822 |
| 0.01338 | -0.01171 |
| 0.02433 | -0.01444 |
| 0.03811 | -0.01666 |
| 0.05468 | -0.01859 |
| 0.07395 | -0.02033 |
| 0.09576 | -0.02189 |
| 0.11999 | -0.02320 |
| 0.14648 | -0.02422 |
| 0.17504 | -0.02491 |
| 0.20549 | -0.02525 |
| 0.23760 | -0.02524 |
| 0.27120 | -0.02490 |
| 0.30609 | -0.02424 |
| 0.34204 | -0.02329 |
| 0.37887 | -0.02207 |
| 0.41638 | -0.02057 |
| 0.45435 | -0.01879 |
| 0.49265 | -0.01679 |
| 0.53099 | -0.01466 |
| 0.56937 | -0.01253 |
| 0.60778 | -0.01049 |
| 0.64594 | -0.00859 |
| 0.68359 | -0.00686 |
| 0.72043 | -0.00531 |
| 0.75616 | -0.00396 |
| 0.79048 | -0.00283 |
| 0.82309 | -0.00195 |
| 0.85370 | -0.00132 |
| 0.88202 | -0.00094 |
| 0.90775 | -0.00074 |
| 0.93064 | -0.00067 |
| 0.95044 | -0.00063 |
| 0.96698 | -0.00057 |
| 0.98037 | -0.00044 |
| 0.99070 | -0.00026 |
| 0.99754 | -0.00008 |
| 1.00000 | 0.00000 |

**K3311**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00003 |
| 0.99939 | 0.00056 |
| 0.99529 | 0.00107 |
| 0.99173 | 0.00173 |
| 0.98800 | 0.00241 |
| 0.98235 | 0.00350 |
| 0.97586 | 0.00452 |
| 0.96889 | 0.00574 |
| 0.96170 | 0.00711 |
| 0.95409 | 0.00856 |
| 0.94155 | 0.01100 |
| 0.92927 | 0.01326 |
| 0.91421 | 0.01626 |
| 0.88981 | 0.02080 |
| 0.87119 | 0.02451 |
| 0.84401 | 0.02951 |
| 0.80879 | 0.03576 |
| 0.76896 | 0.04246 |
| 0.72532 | 0.04963 |
| 0.65974 | 0.05985 |
| 0.60050 | 0.06780 |
| 0.54235 | 0.07445 |
| 0.47337 | 0.08056 |
| 0.41661 | 0.08425 |
| 0.35294 | 0.08572 |
| 0.28951 | 0.08457 |
| 0.22964 | 0.08037 |
| 0.18578 | 0.07492 |
| 0.14442 | 0.06769 |
| 0.11920 | 0.06178 |
| 0.09024 | 0.05352 |
| 0.07182 | 0.04722 |
| 0.05559 | 0.04064 |
| 0.04140 | 0.03416 |
| 0.03141 | 0.02924 |
| 0.02214 | 0.02376 |
| 0.01532 | 0.01912 |
| 0.00759 | 0.01280 |
| 0.00303 | 0.00794 |
| 0.00009 | 0.00133 |
| 0.00082 | -0.00414 |
| 0.00471 | -0.00837 |
| 0.01331 | -0.01180 |
| 0.01986 | -0.01340 |
| 0.02925 | -0.01529 |
| 0.04276 | -0.01744 |
| 0.05520 | -0.01904 |
| 0.07022 | -0.02053 |
| 0.09125 | -0.02225 |
| 0.12022 | -0.02396 |
| 0.15193 | -0.02512 |
| 0.19496 | -0.02572 |
| 0.23624 | -0.02561 |
| 0.30577 | -0.02450 |
| 0.36754 | -0.02317 |
| 0.42753 | -0.02084 |
| 0.48901 | -0.01772 |
| 0.55276 | -0.01393 |
| 0.61363 | -0.01064 |
| 0.67612 | -0.00737 |
| 0.73888 | -0.00509 |
| 0.78249 | -0.00331 |
| 0.81868 | -0.00231 |
| 0.85742 | -0.00167 |
| 0.88673 | -0.00146 |
| 0.90460 | -0.00132 |
| 0.92704 | -0.00119 |
| 0.94406 | -0.00115 |
| 0.95318 | -0.00120 |
| 0.96388 | -0.00112 |
| 0.97228 | -0.00108 |
| 0.98062 | -0.00091 |
| 0.98641 | -0.00080 |
| 0.99166 | -0.00084 |
| 0.99800 | -0.00056 |
| 1.00000 | 0.00003 |

**M06-13-128**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99896 | 0.00015 |
| 0.99152 | 0.00088 |
| 0.97756 | 0.00198 |
| 0.95718 | 0.00370 |
| 0.93068 | 0.00631 |
| 0.89849 | 0.01002 |
| 0.86112 | 0.01499 |
| 0.81923 | 0.02139 |
| 0.77354 | 0.02930 |
| 0.72493 | 0.03878 |
| 0.67434 | 0.04980 |
| 0.62288 | 0.06225 |
| 0.57180 | 0.07584 |
| 0.52265 | 0.09002 |
| 0.47756 | 0.10309 |
| 0.43510 | 0.11094 |
| 0.39263 | 0.11489 |
| 0.35032 | 0.11617 |
| 0.30873 | 0.11531 |
| 0.26838 | 0.11256 |
| 0.22975 | 0.10814 |
| 0.19328 | 0.10220 |
| 0.15942 | 0.09487 |
| 0.12857 | 0.08605 |
| 0.10057 | 0.07583 |
| 0.07558 | 0.06460 |
| 0.05382 | 0.05305 |
| 0.03551 | 0.04122 |
| 0.02083 | 0.02960 |
| 0.00994 | 0.01862 |
| 0.00296 | 0.00878 |
| 0.00098 | 0.00452 |
| 0.00005 | 0.00087 |
| 0.00030 | -0.00183 |
| 0.00233 | -0.00372 |
| 0.01203 | -0.00669 |
| 0.02803 | -0.00901 |
| 0.04987 | -0.01077 |
| 0.07718 | -0.01203 |
| 0.10959 | -0.01287 |
| 0.14667 | -0.01333 |
| 0.18796 | -0.01349 |
| 0.23296 | -0.01339 |
| 0.28111 | -0.01308 |
| 0.33185 | -0.01260 |
| 0.38456 | -0.01200 |
| 0.43862 | -0.01129 |
| 0.49338 | -0.01053 |
| 0.54820 | -0.00972 |
| 0.60242 | -0.00890 |
| 0.65541 | -0.00809 |
| 0.70652 | -0.00729 |
| 0.75516 | -0.00652 |
| 0.80073 | -0.00577 |
| 0.84269 | -0.00506 |
| 0.88053 | -0.00437 |
| 0.91379 | -0.00370 |
| 0.94205 | -0.00302 |
| 0.96496 | -0.00228 |
| 0.98232 | -0.00147 |
| 0.99393 | -0.00073 |

| | |
|---|---|
| 0.99942 | -0.00014 |
| 1.00000 | 0.00000 |

**M06-13-128**
actual model B

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00013 |
| 0.99991 | 0.00090 |
| 0.99740 | 0.00124 |
| 0.99257 | 0.00149 |
| 0.98566 | 0.00162 |
| 0.97902 | 0.00196 |
| 0.96956 | 0.00242 |
| 0.96139 | 0.00305 |
| 0.95256 | 0.00383 |
| 0.94342 | 0.00472 |
| 0.93006 | 0.00616 |
| 0.91687 | 0.00765 |
| 0.90392 | 0.00925 |
| 0.88712 | 0.01146 |
| 0.86530 | 0.01451 |
| 0.84546 | 0.01744 |
| 0.81718 | 0.02197 |
| 0.78112 | 0.02819 |
| 0.74243 | 0.03529 |
| 0.69893 | 0.04428 |
| 0.64065 | 0.05777 |
| 0.58100 | 0.07280 |
| 0.51924 | 0.09047 |
| 0.46121 | 0.10537 |
| 0.39966 | 0.11277 |
| 0.32971 | 0.11417 |
| 0.26768 | 0.11073 |
| 0.20710 | 0.10258 |
| 0.17032 | 0.09508 |
| 0.14567 | 0.08875 |
| 0.12535 | 0.08252 |
| 0.10647 | 0.07575 |
| 0.08239 | 0.06552 |
| 0.06396 | 0.05623 |
| 0.05228 | 0.04960 |
| 0.03982 | 0.04178 |
| 0.03050 | 0.03527 |
| 0.02092 | 0.02762 |
| 0.01126 | 0.01820 |
| 0.00491 | 0.01044 |
| 0.00032 | 0.00263 |
| 0.00347 | -0.00885 |
| 0.00859 | -0.01029 |
| 0.01784 | -0.01219 |
| 0.03226 | -0.01399 |
| 0.05462 | -0.01559 |
| 0.08276 | -0.01664 |
| 0.11168 | -0.01712 |
| 0.16316 | -0.01750 |
| 0.22105 | -0.01733 |
| 0.27285 | -0.01695 |
| 0.33585 | -0.01621 |
| 0.39924 | -0.01526 |
| 0.46002 | -0.01418 |
| 0.52606 | -0.01287 |
| 0.58351 | -0.01167 |
| 0.64698 | -0.01036 |
| 0.70823 | -0.00913 |
| 0.74706 | -0.00844 |
| 0.78928 | -0.00765 |
| 0.82743 | -0.00701 |
| 0.85713 | -0.00651 |
| 0.89265 | -0.00579 |
| 0.91175 | -0.00536 |
| 0.93322 | -0.00478 |
| 0.94441 | -0.00440 |
| 0.95421 | -0.00399 |
| 0.96515 | -0.00344 |
| 0.97685 | -0.00279 |
| 0.98503 | -0.00227 |
| 0.99239 | -0.00166 |
| 0.99927 | -0.00090 |
| 1.00000 | 0.00013 |

**MA409**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00070 |
| 0.95000 | 0.01246 |
| 0.90000 | 0.02308 |
| 0.80000 | 0.04015 |
| 0.70000 | 0.05236 |
| 0.65000 | 0.06154 |
| 0.55000 | 0.06543 |
| 0.50000 | 0.06945 |
| 0.45000 | 0.07186 |
| 0.40000 | 0.07391 |
| 0.35000 | 0.07434 |
| 0.30000 | 0.07398 |
| 0.25000 | 0.07302 |
| 0.20000 | 0.06925 |
| 0.15000 | 0.06421 |
| 0.10000 | 0.05673 |
| 0.07500 | 0.05132 |
| 0.05000 | 0.04479 |
| 0.02500 | 0.03500 |
| 0.01250 | 0.02831 |
| 0.00000 | 0.01749 |
| 0.01250 | 0.00878 |
| 0.02500 | 0.00437 |
| 0.05000 | 0.00082 |
| 0.07500 | 0.00022 |
| 0.10000 | 0.00000 |
| 0.15000 | 0.00122 |
| 0.20000 | 0.00280 |
| 0.25000 | 0.00514 |
| 0.30000 | 0.00789 |
| 0.35000 | 0.01031 |
| 0.40000 | 0.01229 |
| 0.45000 | 0.01424 |
| 0.50000 | 0.01499 |
| 0.55000 | 0.01525 |
| 0.60000 | 0.01536 |
| 0.70000 | 0.01384 |
| 0.80000 | 0.01107 |
| 0.90000 | 0.00704 |
| 0.95000 | 0.00355 |
| 1.00000 | 0.00000 |

**MA409**
smoothed

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00034 |
| 0.99754 | 0.00094 |
| 0.99070 | 0.00259 |
| 0.98037 | 0.00498 |
| 0.96698 | 0.00793 |
| 0.95044 | 0.01136 |
| 0.93064 | 0.01521 |
| 0.90775 | 0.01937 |
| 0.88202 | 0.02373 |
| 0.85370 | 0.02817 |
| 0.82309 | 0.03261 |
| 0.79048 | 0.03694 |
| 0.75616 | 0.04112 |
| 0.72043 | 0.04505 |
| 0.68359 | 0.04869 |
| 0.64594 | 0.05198 |
| 0.60778 | 0.05486 |
| 0.56937 | 0.05732 |
| 0.53099 | 0.05933 |
| 0.49265 | 0.06089 |
| 0.45435 | 0.06202 |
| 0.41638 | 0.06270 |
| 0.37887 | 0.06291 |
| 0.34204 | 0.06260 |
| 0.30609 | 0.06172 |
| 0.27120 | 0.06025 |
| 0.23760 | 0.05819 |
| 0.20549 | 0.05555 |
| 0.17504 | 0.05234 |
| 0.14648 | 0.04859 |
| 0.11999 | 0.04433 |
| 0.09576 | 0.03961 |
| 0.07395 | 0.03450 |
| 0.05468 | 0.02913 |
| 0.03811 | 0.02369 |
| 0.02433 | 0.01831 |
| 0.01338 | 0.01305 |
| 0.00548 | 0.00797 |
| 0.00098 | 0.00318 |
| 0.00000 | -0.00004 |
| 0.00098 | -0.00302 |
| 0.00548 | -0.00664 |
| 0.01338 | -0.00968 |
| 0.02433 | -0.01213 |
| 0.03811 | -0.01400 |
| 0.05468 | -0.01527 |
| 0.07395 | -0.01590 |
| 0.09576 | -0.01589 |
| 0.11999 | -0.01527 |
| 0.14648 | -0.01416 |
| 0.17504 | -0.01264 |
| 0.20549 | -0.01081 |
| 0.23760 | -0.00875 |
| 0.27120 | -0.00653 |
| 0.30609 | -0.00421 |
| 0.34204 | -0.00186 |
| 0.37887 | 0.00039 |
| 0.41638 | 0.00245 |
| 0.45435 | 0.00422 |
| 0.49265 | 0.00565 |
| 0.53099 | 0.00674 |
| 0.56937 | 0.00754 |
| 0.60778 | 0.00808 |
| 0.64594 | 0.00837 |
| 0.68359 | 0.00844 |
| 0.72043 | 0.00830 |
| 0.75616 | 0.00798 |
| 0.79048 | 0.00749 |
| 0.82309 | 0.00687 |
| 0.85370 | 0.00613 |
| 0.88202 | 0.00529 |
| 0.90775 | 0.00439 |
| 0.93064 | 0.00347 |
| 0.95044 | 0.00256 |
| 0.96698 | 0.00170 |
| 0.98037 | 0.00093 |
| 0.99070 | 0.00028 |
| 0.99754 | -0.00018 |
| 1.00000 | -0.00036 |

**MA409**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00018 |
| 0.99720 | 0.00043 |
| 0.99175 | 0.00133 |
| 0.98504 | 0.00240 |
| 0.97808 | 0.00336 |
| 0.97095 | 0.00424 |
| 0.96274 | 0.00536 |
| 0.95052 | 0.00716 |
| 0.94205 | 0.00843 |
| 0.92669 | 0.01072 |
| 0.91083 | 0.01322 |
| 0.89909 | 0.01491 |
| 0.86881 | 0.01946 |
| 0.84319 | 0.02298 |
| 0.81288 | 0.02684 |
| 0.77221 | 0.03143 |
| 0.72759 | 0.03588 |
| 0.67018 | 0.04107 |
| 0.61345 | 0.04551 |
| 0.55514 | 0.04947 |
| 0.49831 | 0.05310 |
| 0.44066 | 0.05540 |
| 0.38248 | 0.05684 |
| 0.33651 | 0.05671 |
| 0.29551 | 0.05636 |
| 0.25040 | 0.05530 |
| 0.21036 | 0.05254 |
| 0.17822 | 0.04967 |
| 0.14297 | 0.04628 |
| 0.11363 | 0.04257 |
| 0.09503 | 0.03950 |
| 0.08197 | 0.03694 |
| 0.06768 | 0.03368 |
| 0.05445 | 0.03018 |
| 0.04538 | 0.02745 |
| 0.03432 | 0.02377 |
| 0.02440 | 0.01984 |
| 0.01444 | 0.01477 |
| 0.00787 | 0.01033 |
| 0.00213 | 0.00509 |
| 0.00043 | 0.00228 |
| 0.00055 | -0.00262 |

| | |
|---|---|
| 0.00328 | -0.00600 |
| 0.00830 | -0.00907 |
| 0.01423 | -0.01167 |
| 0.01996 | -0.01369 |
| 0.02550 | -0.01504 |
| 0.03360 | -0.01635 |
| 0.04220 | -0.01731 |
| 0.05421 | -0.01795 |
| 0.06552 | -0.01827 |
| 0.08973 | -0.01834 |
| 0.10067 | -0.01821 |
| 0.11201 | -0.01798 |
| 0.13732 | -0.01725 |
| 0.16378 | -0.01619 |
| 0.19399 | -0.01505 |
| 0.23873 | -0.01281 |
| 0.28061 | -0.01034 |
| 0.33952 | -0.00702 |
| 0.39707 | -0.00433 |
| 0.45727 | -0.00184 |
| 0.51627 | -0.00082 |
| 0.57355 | -0.00006 |
| 0.62624 | 0.00021 |
| 0.67937 | 0.00048 |
| 0.72125 | 0.00013 |
| 0.76715 | -0.00014 |
| 0.81282 | -0.00015 |
| 0.84246 | -0.00012 |
| 0.87766 | -0.00015 |
| 0.91173 | -0.00071 |
| 0.92537 | -0.00084 |
| 0.94213 | -0.00111 |
| 0.95522 | -0.00122 |
| 0.96880 | -0.00129 |
| 0.97824 | -0.00111 |
| 0.98517 | -0.00084 |
| 0.99321 | -0.00043 |
| 1.00000 | -0.00018 |

**MB253515**
smoothed

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.95000 | 0.01032 |
| 0.90000 | 0.02033 |
| 0.85000 | 0.03052 |
| 0.80000 | 0.04079 |
| 0.75000 | 0.05095 |
| 0.70000 | 0.06078 |
| 0.65000 | 0.07005 |
| 0.60000 | 0.07849 |
| 0.55000 | 0.08582 |
| 0.50000 | 0.09174 |
| 0.45000 | 0.09602 |
| 0.42500 | 0.09748 |
| 0.40000 | 0.09847 |
| 0.37500 | 0.09898 |
| 0.35000 | 0.09904 |
| 0.32500 | 0.09868 |
| 0.30000 | 0.09788 |
| 0.27500 | 0.09660 |
| 0.25000 | 0.09473 |
| 0.22500 | 0.09211 |
| 0.20000 | 0.08861 |
| 0.17500 | 0.08410 |
| 0.15000 | 0.07844 |
| 0.12500 | 0.07146 |
| 0.10000 | 0.06296 |
| 0.08750 | 0.05807 |
| 0.07500 | 0.05274 |
| 0.06250 | 0.04696 |
| 0.05000 | 0.04072 |
| 0.03750 | 0.03393 |
| 0.02500 | 0.02636 |
| 0.01000 | 0.01521 |
| 0.00000 | -0.00041 |
| 0.01000 | -0.01223 |
| 0.02500 | -0.01809 |
| 0.03750 | -0.02159 |
| 0.05000 | -0.02461 |
| 0.06250 | -0.02739 |
| 0.07500 | -0.03001 |
| 0.08750 | -0.03246 |
| 0.10000 | -0.03472 |
| 0.12500 | -0.03861 |
| 0.15000 | -0.04175 |
| 0.17500 | -0.04425 |
| 0.20000 | -0.04622 |
| 0.22500 | -0.04776 |
| 0.25000 | -0.04892 |
| 0.27500 | -0.04974 |
| 0.30000 | -0.05026 |
| 0.32500 | -0.05052 |
| 0.35000 | -0.05054 |
| 0.37500 | -0.05035 |
| 0.40000 | -0.04997 |
| 0.42500 | -0.04941 |
| 0.45000 | -0.04866 |
| 0.50000 | -0.04660 |
| 0.55000 | -0.04383 |
| 0.60000 | -0.04036 |
| 0.65000 | -0.03628 |
| 0.70000 | -0.03169 |
| 0.75000 | -0.02669 |
| 0.80000 | -0.02144 |
| 0.85000 | -0.01606 |
| 0.90000 | -0.01070 |
| 0.95000 | -0.00544 |
| 1.00000 | 0.00000 |

**MB253515**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00039 |
| 0.99967 | 0.00028 |
| 0.99635 | 0.00105 |
| 0.99240 | 0.00188 |
| 0.98505 | 0.00339 |
| 0.96759 | 0.00686 |
| 0.95867 | 0.00870 |
| 0.94980 | 0.01051 |
| 0.94010 | 0.01252 |
| 0.92969 | 0.01462 |
| 0.91530 | 0.01751 |
| 0.89377 | 0.02198 |
| 0.86433 | 0.02796 |
| 0.83562 | 0.03381 |
| 0.80168 | 0.04070 |
| 0.75958 | 0.04923 |
| 0.71819 | 0.05753 |
| 0.65931 | 0.06879 |
| 0.59687 | 0.07943 |
| 0.53642 | 0.08808 |
| 0.47578 | 0.09452 |
| 0.41397 | 0.09840 |
| 0.34916 | 0.09961 |
| 0.28574 | 0.09767 |
| 0.22234 | 0.09218 |
| 0.18314 | 0.08621 |
| 0.15247 | 0.07959 |
| 0.13478 | 0.07485 |
| 0.11301 | 0.06803 |
| 0.09509 | 0.06148 |
| 0.07437 | 0.05274 |
| 0.05843 | 0.04511 |
| 0.05001 | 0.04073 |
| 0.04097 | 0.03571 |
| 0.03239 | 0.03061 |
| 0.02467 | 0.02569 |
| 0.01653 | 0.02010 |
| 0.01034 | 0.01534 |
| 0.00788 | 0.01322 |
| 0.00339 | 0.00843 |
| 0.00107 | 0.00457 |
| 0.00085 | -0.00400 |
| 0.00374 | -0.00842 |
| 0.00764 | -0.01150 |
| 0.01331 | -0.01442 |
| 0.01999 | -0.01703 |
| 0.02801 | -0.01969 |
| 0.03626 | -0.02207 |
| 0.04648 | -0.02474 |
| 0.05763 | -0.02737 |
| 0.06963 | -0.02994 |
| 0.08657 | -0.03320 |
| 0.11740 | -0.03817 |
| 0.15010 | -0.04229 |
| 0.18899 | -0.04588 |
| 0.23249 | -0.04847 |
| 0.29430 | -0.05009 |
| 0.35640 | -0.05059 |
| 0.41879 | -0.04988 |
| 0.48450 | -0.04778 |
| 0.54388 | -0.04475 |
| 0.60626 | -0.04041 |
| 0.66912 | -0.03497 |
| 0.72901 | -0.02908 |
| 0.77184 | -0.02465 |
| 0.81297 | -0.02029 |
| 0.84465 | -0.01688 |
| 0.87527 | -0.01358 |
| 0.89709 | -0.01126 |
| 0.91763 | -0.00905 |
| 0.93436 | -0.00715 |
| 0.94645 | -0.00588 |
| 0.95786 | -0.00478 |
| 0.96817 | -0.00367 |
| 0.97570 | -0.00279 |
| 0.98410 | -0.00189 |
| 0.99163 | -0.00108 |
| 0.99875 | -0.00028 |
| 1.00000 | 0.00039 |

**MH45**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99669 | -0.00010 |
| 0.98669 | -0.00021 |
| 0.97013 | 0.00016 |
| 0.94746 | 0.00130 |
| 0.91917 | 0.00332 |
| 0.88574 | 0.00629 |
| 0.84775 | 0.01028 |
| 0.80590 | 0.01536 |
| 0.76107 | 0.02140 |
| 0.71405 | 0.02803 |
| 0.66547 | 0.03488 |
| 0.61587 | 0.04154 |
| 0.56569 | 0.04768 |
| 0.51532 | 0.05306 |
| 0.46516 | 0.05755 |
| 0.41564 | 0.06108 |
| 0.36723 | 0.06358 |
| 0.32039 | 0.06498 |
| 0.27558 | 0.06523 |
| 0.23318 | 0.06425 |
| 0.19353 | 0.06203 |
| 0.15691 | 0.05862 |
| 0.12363 | 0.05410 |
| 0.09395 | 0.04858 |
| 0.06813 | 0.04218 |
| 0.04634 | 0.03500 |
| 0.02867 | 0.02722 |
| 0.01520 | 0.01906 |
| 0.00588 | 0.01088 |
| 0.00079 | 0.00326 |
| 0.00000 | 0.00000 |
| 0.00068 | -0.00279 |
| 0.00641 | -0.00788 |
| 0.01781 | -0.01310 |
| 0.03421 | -0.01814 |
| 0.05531 | -0.02277 |
| 0.08085 | -0.02678 |
| 0.11065 | -0.02991 |
| 0.14460 | -0.03206 |
| 0.18252 | -0.03329 |
| 0.22408 | -0.03366 |
| 0.26891 | -0.03330 |
| 0.31654 | -0.03229 |
| 0.36646 | -0.03073 |
| 0.41816 | -0.02875 |
| 0.47104 | -0.02646 |
| 0.52449 | -0.02399 |
| 0.57786 | -0.02143 |
| 0.63049 | -0.01888 |
| 0.68174 | -0.01640 |
| 0.73095 | -0.01403 |
| 0.77754 | -0.01179 |
| 0.82094 | -0.00971 |
| 0.86062 | -0.00782 |
| 0.89607 | -0.00613 |
| 0.92686 | -0.00465 |
| 0.95259 | -0.00334 |
| 0.97293 | -0.00219 |
| 0.98770 | -0.00113 |
| 0.99683 | -0.00031 |
| 1.00000 | 0.00000 |

**MH45**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00012 |
| 0.99827 | 0.00179 |
| 0.99520 | 0.00212 |
| 0.99240 | 0.00228 |
| 0.98841 | 0.00249 |
| 0.98497 | 0.00284 |
| 0.98013 | 0.00313 |
| 0.97530 | 0.00344 |
| 0.96638 | 0.00399 |
| 0.95793 | 0.00447 |
| 0.94952 | 0.00495 |
| 0.93930 | 0.00558 |
| 0.92778 | 0.00656 |
| 0.91818 | 0.00749 |
| 0.90665 | 0.00855 |
| 0.89505 | 0.00971 |
| 0.87743 | 0.01142 |
| 0.86049 | 0.01322 |
| 0.82591 | 0.01754 |
| 0.79821 | 0.02126 |
| 0.75602 | 0.02736 |
| 0.71415 | 0.03362 |
| 0.58275 | 0.05127 |
| 0.51906 | 0.05841 |
| 0.46381 | 0.06373 |
| 0.40971 | 0.06769 |
| 0.35884 | 0.06985 |
| 0.29253 | 0.07056 |
| 0.25072 | 0.06980 |
| 0.20946 | 0.06760 |
| 0.18011 | 0.06517 |
| 0.15412 | 0.06223 |
| 0.12930 | 0.05861 |
| 0.11007 | 0.05512 |
| 0.09501 | 0.05198 |
| 0.08431 | 0.04948 |
| 0.07168 | 0.04616 |
| 0.06060 | 0.04275 |
| 0.04926 | 0.03858 |
| 0.03750 | 0.03343 |
| 0.02705 | 0.02794 |
| 0.02012 | 0.02358 |
| 0.01364 | 0.01864 |
| 0.00843 | 0.01365 |
| 0.00477 | 0.00938 |
| 0.00086 | 0.00247 |
| 0.00004 | 0.00053 |
| 0.00631 | -0.00670 |
| 0.01189 | -0.00959 |
| 0.01834 | -0.01249 |
| 0.02381 | -0.01471 |
| 0.03119 | -0.01721 |
| 0.03888 | -0.01939 |
| 0.05568 | -0.02307 |
| 0.07078 | -0.02561 |
| 0.08371 | -0.02746 |
| 0.09714 | -0.02909 |
| 0.11366 | -0.03073 |
| 0.12732 | -0.03177 |
| 0.15294 | -0.03319 |
| 0.18046 | -0.03405 |
| 0.21002 | -0.03435 |
| 0.24978 | -0.03405 |
| 0.29382 | -0.03321 |
| 0.35002 | -0.03175 |
| 0.40632 | -0.03007 |
| 0.46453 | -0.02806 |
| 0.57671 | -0.02373 |
| 0.63115 | -0.02151 |
| 0.67494 | -0.01962 |
| 0.71782 | -0.01783 |
| 0.75959 | -0.01606 |
| 0.80331 | -0.01402 |
| 0.83434 | -0.01230 |
| 0.86386 | -0.01047 |
| 0.89378 | -0.00855 |
| 0.91042 | -0.00743 |
| 0.92210 | -0.00656 |
| 0.93479 | -0.00566 |
| 0.94721 | -0.00491 |
| 0.95882 | -0.00420 |
| 0.97087 | -0.00347 |
| 0.98152 | -0.00281 |
| 0.98921 | -0.00236 |
| 0.99814 | -0.00179 |
| 1.00000 | -0.00012 |

**NACA 0009**
smoothed

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99572 | 0.00057 |
| 0.98296 | 0.00218 |
| 0.96194 | 0.00463 |
| 0.93301 | 0.00770 |
| 0.89668 | 0.01127 |
| 0.85355 | 0.01522 |
| 0.80438 | 0.01945 |
| 0.75000 | 0.02384 |
| 0.69134 | 0.02823 |
| 0.62941 | 0.03247 |
| 0.56526 | 0.03638 |
| 0.50000 | 0.03978 |
| 0.43474 | 0.04248 |
| 0.37059 | 0.04431 |
| 0.33928 | 0.04484 |
| 0.30866 | 0.04509 |
| 0.27886 | 0.04504 |
| 0.25000 | 0.04466 |
| 0.22221 | 0.04397 |
| 0.19562 | 0.04295 |
| 0.17033 | 0.04161 |
| 0.14645 | 0.03994 |
| 0.12408 | 0.03795 |
| 0.10332 | 0.03564 |
| 0.08427 | 0.03305 |
| 0.06699 | 0.03023 |
| 0.05156 | 0.02720 |
| 0.03806 | 0.02395 |
| 0.02653 | 0.02039 |
| 0.01704 | 0.01646 |
| 0.00961 | 0.01214 |
| 0.00428 | 0.00767 |
| 0.00107 | 0.00349 |
| 0.00000 | 0.00000 |
| 0.00107 | -0.00349 |
| 0.00428 | -0.00767 |
| 0.00961 | -0.01214 |
| 0.01704 | -0.01646 |
| 0.02653 | -0.02039 |
| 0.03806 | -0.02395 |
| 0.05156 | -0.02720 |
| 0.06699 | -0.03023 |
| 0.08427 | -0.03305 |
| 0.10332 | -0.03564 |
| 0.12408 | -0.03795 |
| 0.14645 | -0.03994 |
| 0.17033 | -0.04161 |
| 0.19562 | -0.04295 |
| 0.22221 | -0.04397 |
| 0.25000 | -0.04466 |
| 0.27886 | -0.04504 |
| 0.30866 | -0.04509 |
| 0.33928 | -0.04484 |
| 0.37059 | -0.04431 |
| 0.43474 | -0.04248 |
| 0.50000 | -0.03978 |
| 0.56526 | -0.03638 |
| 0.62941 | -0.03247 |
| 0.69134 | -0.02823 |
| 0.75000 | -0.02384 |
| 0.80438 | -0.01945 |
| 0.85355 | -0.01522 |
| 0.89668 | -0.01127 |
| 0.93301 | -0.00770 |
| 0.96194 | -0.00463 |
| 0.98296 | -0.00218 |
| 0.99572 | -0.00057 |
| 1.00000 | 0.00000 |

**NACA 0009**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00050 |
| 0.99995 | 0.00019 |
| 0.99646 | 0.00079 |
| 0.98599 | 0.00056 |
| 0.97854 | 0.00072 |
| 0.97088 | 0.00136 |
| 0.96416 | 0.00178 |
| 0.95695 | 0.00244 |
| 0.94678 | 0.00324 |
| 0.93607 | 0.00430 |
| 0.92414 | 0.00558 |
| 0.90698 | 0.00748 |
| 0.88511 | 0.00991 |
| 0.86640 | 0.01188 |
| 0.83604 | 0.01503 |
| 0.80165 | 0.01848 |
| 0.76079 | 0.02237 |
| 0.71497 | 0.02614 |
| 0.65763 | 0.03029 |
| 0.60092 | 0.03413 |
| 0.53019 | 0.03828 |
| 0.47423 | 0.04098 |
| 0.40460 | 0.04382 |
| 0.34168 | 0.04563 |
| 0.28447 | 0.04619 |
| 0.22228 | 0.04526 |
| 0.18469 | 0.04365 |
| 0.15708 | 0.04208 |
| 0.13481 | 0.04056 |
| 0.11586 | 0.03882 |
| 0.09458 | 0.03635 |
| 0.07376 | 0.03302 |
| 0.05901 | 0.02992 |
| 0.04663 | 0.02681 |
| 0.03764 | 0.02415 |
| 0.02896 | 0.02122 |
| 0.01889 | 0.01749 |
| 0.01131 | 0.01404 |
| 0.00493 | 0.00973 |
| 0.00024 | 0.00229 |
| 0.00016 | -0.00186 |
| 0.00234 | -0.00712 |
| 0.00552 | -0.01011 |
| 0.01021 | -0.01281 |
| 0.01601 | -0.01515 |
| 0.02354 | -0.01736 |
| 0.03397 | -0.01983 |
| 0.04585 | -0.02250 |
| 0.05700 | -0.02476 |
| 0.07278 | -0.02793 |
| 0.09495 | -0.03167 |
| 0.12545 | -0.03591 |
| 0.15443 | -0.03857 |
| 0.19641 | -0.04115 |
| 0.23971 | -0.04292 |
| 0.29860 | -0.04391 |
| 0.36369 | -0.04298 |
| 0.42318 | -0.04107 |
| 0.48687 | -0.03833 |
| 0.55039 | -0.03483 |
| 0.61023 | -0.03131 |
| 0.67169 | -0.02741 |
| 0.73278 | -0.02369 |
| 0.77620 | -0.02086 |
| 0.81736 | -0.01802 |
| 0.85242 | -0.01533 |
| 0.87831 | -0.01306 |
| 0.89724 | -0.01154 |
| 0.91881 | -0.00944 |
| 0.93434 | -0.00832 |
| 0.94931 | -0.00701 |
| 0.96153 | -0.00585 |
| 0.97091 | -0.00518 |
| 0.98726 | -0.00288 |
| 0.99218 | -0.00166 |
| 1.00008 | -0.00019 |
| 1.00000 | -0.00050 |

**NACA 6409**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99732 | 0.00084 |
| 0.98930 | 0.00333 |
| 0.97603 | 0.00737 |
| 0.95760 | 0.01284 |
| 0.93423 | 0.01954 |
| 0.90615 | 0.02724 |
| 0.87357 | 0.03571 |
| 0.83690 | 0.04464 |
| 0.79647 | 0.05378 |

| | |
|---|---|
| 0.75272 | 0.06283 |
| 0.70608 | 0.07153 |
| 0.65710 | 0.07961 |
| 0.60627 | 0.08684 |
| 0.55413 | 0.09302 |
| 0.50132 | 0.09796 |
| 0.44840 | 0.10152 |
| 0.39590 | 0.10360 |
| 0.34367 | 0.10352 |
| 0.29315 | 0.10086 |
| 0.24502 | 0.09584 |
| 0.19988 | 0.08874 |
| 0.15830 | 0.07992 |
| 0.12080 | 0.06982 |
| 0.08780 | 0.05889 |
| 0.05968 | 0.04762 |
| 0.03677 | 0.03646 |
| 0.01920 | 0.02581 |
| 0.00720 | 0.01603 |
| 0.00080 | 0.00737 |
| 0.00000 | 0.00000 |
| 0.00467 | -0.00573 |
| 0.01467 | -0.00956 |
| 0.02973 | -0.01157 |
| 0.04970 | -0.01192 |
| 0.07428 | -0.01080 |
| 0.10317 | -0.00844 |
| 0.13607 | -0.00513 |
| 0.17257 | -0.00119 |
| 0.21235 | 0.00307 |
| 0.25498 | 0.00729 |
| 0.30012 | 0.01112 |
| 0.34730 | 0.01425 |
| 0.39618 | 0.01639 |
| 0.44707 | 0.01772 |
| 0.49868 | 0.01871 |
| 0.55040 | 0.01925 |
| 0.60167 | 0.01929 |
| 0.65193 | 0.01880 |
| 0.70065 | 0.01780 |
| 0.74728 | 0.01634 |
| 0.79130 | 0.01451 |
| 0.83223 | 0.01241 |
| 0.86957 | 0.01017 |
| 0.90288 | 0.00791 |
| 0.93180 | 0.00576 |
| 0.95593 | 0.00383 |
| 0.97503 | 0.00221 |
| 0.98883 | 0.00101 |
| 0.99722 | 0.00025 |
| 1.00000 | 0.00000 |

**NACA 6409**

actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00049 |
| 0.99074 | 0.00359 |
| 0.98429 | 0.00559 |
| 0.97730 | 0.00769 |
| 0.97242 | 0.00909 |
| 0.96508 | 0.01099 |
| 0.95596 | 0.01341 |
| 0.94591 | 0.01594 |
| 0.93629 | 0.01827 |
| 0.92590 | 0.02077 |
| 0.91387 | 0.02419 |
| 0.90369 | 0.02679 |
| 0.89095 | 0.02985 |
| 0.87619 | 0.03339 |
| 0.84472 | 0.04098 |
| 0.81153 | 0.04855 |
| 0.78438 | 0.05442 |
| 0.73987 | 0.06314 |
| 0.69754 | 0.07091 |
| 0.65769 | 0.07766 |
| 0.61251 | 0.08448 |
| 0.56042 | 0.09112 |
| 0.50220 | 0.09713 |
| 0.44575 | 0.10148 |
| 0.38914 | 0.10386 |
| 0.33272 | 0.10332 |
| 0.27353 | 0.09971 |
| 0.23447 | 0.09569 |
| 0.18910 | 0.08827 |
| 0.16203 | 0.08230 |
| 0.13640 | 0.07561 |
| 0.11046 | 0.06759 |
| 0.09637 | 0.06281 |
| 0.08404 | 0.05832 |
| 0.07102 | 0.05295 |
| 0.05713 | 0.04639 |
| 0.04597 | 0.04041 |
| 0.03371 | 0.03331 |
| 0.02399 | 0.02739 |
| 0.01574 | 0.02162 |
| 0.00813 | 0.01477 |
| 0.00108 | 0.00498 |
| 0.00004 | 0.00089 |
| 0.00632 | -0.00897 |
| 0.01049 | -0.01087 |
| 0.01966 | -0.01274 |
| 0.02611 | -0.01335 |
| 0.03332 | -0.01372 |
| 0.05037 | -0.01406 |
| 0.06540 | -0.01292 |
| 0.08015 | -0.01232 |
| 0.09344 | -0.01166 |
| 0.10750 | -0.01057 |
| 0.12194 | -0.00915 |
| 0.14880 | -0.00638 |
| 0.17622 | -0.00281 |
| 0.20133 | 0.00043 |
| 0.24547 | 0.00525 |
| 0.28357 | 0.00872 |
| 0.33882 | 0.01219 |
| 0.39755 | 0.01521 |
| 0.45392 | 0.01640 |
| 0.51068 | 0.01714 |
| 0.56779 | 0.01734 |
| 0.62390 | 0.01695 |
| 0.67127 | 0.01619 |
| 0.71437 | 0.01508 |
| 0.75797 | 0.01355 |
| 0.80075 | 0.01137 |
| 0.83002 | 0.00970 |
| 0.86288 | 0.00739 |
| 0.89353 | 0.00555 |
| 0.91073 | 0.00440 |
| 0.92427 | 0.00362 |
| 0.94065 | 0.00233 |
| 0.95459 | 0.00137 |
| 0.96742 | 0.00039 |
| 0.97864 | -0.00042 |
| 0.98835 | -0.00088 |
| 1.00000 | 0.00049 |

**NACA 64A010**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.95000 | 0.00540 |
| 0.90000 | 0.01063 |
| 0.85000 | 0.01583 |
| 0.80000 | 0.02102 |
| 0.75000 | 0.02620 |
| 0.70000 | 0.03124 |
| 0.65000 | 0.03597 |
| 0.60000 | 0.04021 |
| 0.55000 | 0.04387 |
| 0.50000 | 0.04683 |
| 0.45000 | 0.04893 |
| 0.40000 | 0.04995 |
| 0.35000 | 0.04968 |
| 0.30000 | 0.04837 |
| 0.25000 | 0.04608 |
| 0.20000 | 0.04274 |
| 0.18000 | 0.04106 |
| 0.16000 | 0.03918 |
| 0.14000 | 0.03707 |
| 0.12000 | 0.03471 |
| 0.10000 | 0.03201 |
| 0.09000 | 0.03052 |
| 0.08000 | 0.02892 |
| 0.07000 | 0.02720 |
| 0.06000 | 0.02535 |
| 0.05000 | 0.02331 |
| 0.04000 | 0.02103 |
| 0.03000 | 0.01842 |
| 0.02000 | 0.01529 |
| 0.01000 | 0.01117 |
| 0.00950 | 0.01091 |
| 0.00900 | 0.01065 |
| 0.00850 | 0.01037 |
| 0.00800 | 0.01010 |
| 0.00750 | 0.00980 |
| 0.00700 | 0.00950 |
| 0.00650 | 0.00919 |
| 0.00600 | 0.00886 |
| 0.00550 | 0.00851 |
| 0.00500 | 0.00815 |
| 0.00450 | 0.00776 |
| 0.00400 | 0.00735 |
| 0.00350 | 0.00690 |
| 0.00300 | 0.00642 |
| 0.00250 | 0.00588 |
| 0.00225 | 0.00559 |
| 0.00200 | 0.00528 |
| 0.00175 | 0.00495 |
| 0.00150 | 0.00459 |
| 0.00125 | 0.00421 |
| 0.00100 | 0.00377 |
| 0.00075 | 0.00327 |
| 0.00050 | 0.00268 |
| 0.00025 | 0.00189 |
| 0.00000 | 0.00000 |
| 0.00025 | -0.00189 |
| 0.00050 | -0.00268 |
| 0.00075 | -0.00327 |
| 0.00100 | -0.00377 |
| 0.00125 | -0.00421 |
| 0.00150 | -0.00459 |
| 0.00175 | -0.00495 |
| 0.00200 | -0.00528 |
| 0.00225 | -0.00559 |
| 0.00250 | -0.00588 |
| 0.00300 | -0.00642 |
| 0.00350 | -0.00690 |
| 0.00400 | -0.00735 |
| 0.00450 | -0.00776 |
| 0.00500 | -0.00815 |
| 0.00550 | -0.00851 |
| 0.00600 | -0.00886 |
| 0.00650 | -0.00919 |
| 0.00700 | -0.00950 |
| 0.00750 | -0.00980 |
| 0.00800 | -0.01010 |
| 0.00850 | -0.01037 |
| 0.00900 | -0.01065 |
| 0.00950 | -0.01091 |
| 0.01000 | -0.01117 |
| 0.02000 | -0.01529 |
| 0.03000 | -0.01842 |
| 0.04000 | -0.02103 |
| 0.05000 | -0.02331 |
| 0.06000 | -0.02535 |
| 0.07000 | -0.02720 |
| 0.08000 | -0.02892 |
| 0.09000 | -0.03052 |
| 0.10000 | -0.03201 |
| 0.12000 | -0.03471 |
| 0.14000 | -0.03707 |
| 0.16000 | -0.03918 |
| 0.18000 | -0.04106 |
| 0.20000 | -0.04274 |
| 0.25000 | -0.04608 |
| 0.30000 | -0.04837 |
| 0.35000 | -0.04968 |
| 0.40000 | -0.04995 |
| 0.45000 | -0.04893 |
| 0.50000 | -0.04683 |
| 0.55000 | -0.04387 |
| 0.60000 | -0.04021 |
| 0.65000 | -0.03597 |
| 0.70000 | -0.03124 |
| 0.75000 | -0.02620 |
| 0.80000 | -0.02102 |
| 0.85000 | -0.01583 |
| 0.90000 | -0.01063 |
| 0.95000 | -0.00540 |
| 1.00000 | 0.00000 |

**NACA 64A010**

actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00038 |
| 0.99992 | 0.00071 |
| 0.99608 | 0.00136 |
| 0.99029 | 0.00194 |

| | |
|---|---|
| 0.98300 | 0.00256 |
| 0.97367 | 0.00324 |
| 0.96164 | 0.00442 |
| 0.94893 | 0.00598 |
| 0.94062 | 0.00705 |
| 0.93106 | 0.00812 |
| 0.91739 | 0.00965 |
| 0.90021 | 0.01152 |
| 0.88131 | 0.01346 |
| 0.86043 | 0.01561 |
| 0.82848 | 0.01885 |
| 0.78218 | 0.02331 |
| 0.73276 | 0.02762 |
| 0.67337 | 0.03289 |
| 0.60978 | 0.03816 |
| 0.54964 | 0.04264 |
| 0.48886 | 0.04635 |
| 0.42787 | 0.04825 |
| 0.36190 | 0.04894 |
| 0.30447 | 0.04817 |
| 0.24276 | 0.04568 |
| 0.20023 | 0.04283 |
| 0.16052 | 0.03945 |
| 0.13601 | 0.03698 |
| 0.11091 | 0.03407 |
| 0.08643 | 0.03071 |
| 0.07408 | 0.02883 |
| 0.06265 | 0.02681 |
| 0.05240 | 0.02467 |
| 0.03856 | 0.02136 |
| 0.02957 | 0.01878 |
| 0.02001 | 0.01543 |
| 0.01370 | 0.01286 |
| 0.00695 | 0.00942 |
| 0.00169 | 0.00466 |
| 0.00063 | 0.00286 |
| 0.00047 | -0.00243 |
| 0.00227 | -0.00537 |
| 0.00660 | -0.00890 |
| 0.01230 | -0.01209 |
| 0.02183 | -0.01627 |
| 0.03003 | -0.01901 |
| 0.04119 | -0.02206 |
| 0.05047 | -0.02425 |
| 0.06368 | -0.02705 |
| 0.08151 | -0.03033 |
| 0.10171 | -0.03340 |
| 0.13017 | -0.03702 |
| 0.15982 | -0.04030 |
| 0.19836 | -0.04365 |
| 0.23931 | -0.04648 |
| 0.30199 | -0.04944 |
| 0.36475 | -0.05084 |
| 0.42555 | -0.05029 |
| 0.55070 | -0.04390 |
| 0.61418 | -0.03926 |
| 0.67674 | -0.03356 |
| 0.73809 | -0.02754 |
| 0.78083 | -0.02328 |
| 0.82019 | -0.01922 |
| 0.85473 | -0.01566 |
| 0.88422 | -0.01252 |
| 0.90343 | -0.01061 |
| 0.92075 | -0.00880 |
| 0.93800 | -0.00705 |
| 0.95323 | -0.00547 |
| 0.96391 | -0.00438 |
| 0.97343 | -0.00334 |
| 0.98189 | -0.00233 |
| 0.98877 | -0.00175 |
| 0.99866 | -0.00071 |
| 1.00000 | 0.00038 |

**R140**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.97241 | 0.00414 |
| 0.94482 | 0.00760 |
| 0.91826 | 0.01182 |
| 0.88965 | 0.01565 |
| 0.86206 | 0.02015 |
| 0.83448 | 0.02416 |
| 0.80689 | 0.02709 |
| 0.77931 | 0.03140 |
| 0.75172 | 0.03485 |
| 0.72413 | 0.03795 |
| 0.69696 | 0.04130 |
| 0.66957 | 0.04435 |
| 0.64174 | 0.04761 |
| 0.61391 | 0.05075 |
| 0.58783 | 0.05308 |
| 0.56174 | 0.05565 |
| 0.53304 | 0.05826 |
| 0.50435 | 0.06070 |
| 0.47913 | 0.06174 |
| 0.45217 | 0.06313 |
| 0.42261 | 0.06456 |
| 0.39304 | 0.06428 |
| 0.36696 | 0.06450 |
| 0.34087 | 0.06378 |
| 0.31035 | 0.06266 |
| 0.28275 | 0.06067 |
| 0.25517 | 0.05880 |
| 0.22759 | 0.05659 |
| 0.20000 | 0.05328 |
| 0.17783 | 0.05087 |
| 0.16087 | 0.04870 |
| 0.14435 | 0.04613 |
| 0.13103 | 0.04334 |
| 0.11724 | 0.04072 |
| 0.10345 | 0.03830 |
| 0.08965 | 0.03512 |
| 0.07586 | 0.03224 |
| 0.06207 | 0.02899 |
| 0.04826 | 0.02512 |
| 0.03448 | 0.02098 |
| 0.02759 | 0.01835 |
| 0.02069 | 0.01546 |
| 0.01379 | 0.01208 |
| 0.00690 | 0.00760 |
| 0.00348 | 0.00414 |
| 0.00000 | 0.00000 |
| 0.00348 | -0.00415 |
| 0.00690 | -0.00760 |
| 0.01379 | -0.01160 |
| 0.02069 | -0.01491 |
| 0.02759 | -0.01753 |
| 0.03448 | -0.01933 |
| 0.04826 | -0.02278 |
| 0.06261 | -0.02609 |
| 0.07652 | -0.02957 |
| 0.09043 | -0.03131 |
| 0.10348 | -0.03391 |
| 0.11739 | -0.03565 |
| 0.13304 | -0.03826 |
| 0.14696 | -0.04000 |
| 0.16174 | -0.04174 |
| 0.17696 | -0.04304 |
| 0.20000 | -0.04570 |
| 0.22759 | -0.04845 |
| 0.25517 | -0.05107 |
| 0.28522 | -0.05304 |
| 0.31035 | -0.05397 |
| 0.33793 | -0.05498 |
| 0.36552 | -0.05529 |
| 0.39310 | -0.05572 |
| 0.42068 | -0.05526 |
| 0.44827 | -0.05471 |
| 0.47586 | -0.05384 |
| 0.50344 | -0.05255 |
| 0.53043 | -0.05130 |
| 0.55862 | -0.04936 |
| 0.58621 | -0.04695 |
| 0.61379 | -0.04454 |
| 0.64130 | -0.04174 |
| 0.66913 | -0.03913 |
| 0.69655 | -0.03668 |
| 0.72431 | -0.03451 |
| 0.75172 | -0.03134 |
| 0.77931 | -0.02831 |
| 0.80870 | -0.02435 |
| 0.83448 | -0.02139 |
| 0.86206 | -0.01781 |
| 0.88870 | -0.01470 |
| 0.91724 | -0.01128 |
| 0.94482 | -0.00760 |
| 0.97241 | -0.00415 |
| 1.00000 | 0.00000 |

**R140**
smoothed model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99000 | 0.00155 |
| 0.98000 | 0.00300 |
| 0.97000 | 0.00440 |
| 0.95000 | 0.00718 |
| 0.92500 | 0.01070 |
| 0.90000 | 0.01431 |
| 0.87500 | 0.01798 |
| 0.85000 | 0.02162 |
| 0.82500 | 0.02516 |
| 0.80000 | 0.02855 |
| 0.77500 | 0.03181 |
| 0.75000 | 0.03494 |
| 0.72500 | 0.03798 |
| 0.70000 | 0.04095 |
| 0.67500 | 0.04386 |
| 0.65000 | 0.04668 |
| 0.62500 | 0.04941 |
| 0.60000 | 0.05202 |
| 0.57500 | 0.05448 |
| 0.55000 | 0.05679 |
| 0.52500 | 0.05891 |
| 0.50000 | 0.06081 |
| 0.47500 | 0.06242 |
| 0.45000 | 0.06367 |
| 0.42500 | 0.06448 |
| 0.40000 | 0.06482 |
| 0.37500 | 0.06470 |
| 0.35000 | 0.06414 |
| 0.32500 | 0.06319 |
| 0.30000 | 0.06191 |
| 0.27500 | 0.06031 |
| 0.25000 | 0.05840 |
| 0.22500 | 0.05616 |
| 0.20000 | 0.05353 |
| 0.17500 | 0.05044 |
| 0.15000 | 0.04676 |
| 0.12500 | 0.04241 |
| 0.10000 | 0.03747 |
| 0.09000 | 0.03537 |
| 0.08000 | 0.03318 |
| 0.07000 | 0.03088 |
| 0.06000 | 0.02842 |
| 0.05000 | 0.02573 |
| 0.04000 | 0.02269 |
| 0.03000 | 0.01918 |
| 0.02000 | 0.01499 |
| 0.01000 | 0.00994 |
| 0.00500 | 0.00676 |
| 0.00250 | 0.00468 |
| 0.00200 | 0.00416 |
| 0.00150 | 0.00359 |
| 0.00100 | 0.00292 |
| 0.00075 | 0.00252 |
| 0.00050 | 0.00205 |
| 0.00025 | 0.00145 |
| 0.00000 | 0.00000 |
| 0.00025 | -0.00145 |
| 0.00050 | -0.00205 |
| 0.00075 | -0.00251 |
| 0.00100 | -0.00290 |
| 0.00150 | -0.00357 |
| 0.00200 | -0.00413 |
| 0.00250 | -0.00463 |
| 0.00500 | -0.00664 |
| 0.01000 | -0.00966 |
| 0.02000 | -0.01422 |
| 0.03000 | -0.01781 |
| 0.04000 | -0.02076 |
| 0.05000 | -0.02332 |
| 0.06000 | -0.02562 |
| 0.07000 | -0.02774 |
| 0.08000 | -0.02972 |
| 0.09000 | -0.03157 |
| 0.10000 | -0.03330 |
| 0.12500 | -0.03710 |
| 0.15000 | -0.04035 |
| 0.17500 | -0.04330 |
| 0.20000 | -0.04603 |
| 0.22500 | -0.04850 |
| 0.25000 | -0.05066 |
| 0.27500 | -0.05244 |
| 0.30000 | -0.05384 |
| 0.32500 | -0.05486 |
| 0.35000 | -0.05551 |
| 0.37500 | -0.05583 |

| | |
|---|---|
| 0.40000 | -0.05583 |
| 0.42500 | -0.05552 |
| 0.45000 | -0.05493 |
| 0.47500 | -0.05409 |
| 0.50000 | -0.05300 |
| 0.52500 | -0.05166 |
| 0.55000 | -0.05001 |
| 0.57500 | -0.04806 |
| 0.60000 | -0.04588 |
| 0.62500 | -0.04357 |
| 0.65000 | -0.04126 |
| 0.67500 | -0.03896 |
| 0.70000 | -0.03665 |
| 0.72500 | -0.03422 |
| 0.75000 | -0.03160 |
| 0.77500 | -0.02877 |
| 0.80000 | -0.02578 |
| 0.82500 | -0.02269 |
| 0.85000 | -0.01959 |
| 0.87500 | -0.01650 |
| 0.90000 | -0.01342 |
| 0.92500 | -0.01032 |
| 0.95000 | -0.00713 |
| 0.97000 | -0.00445 |
| 0.98000 | -0.00304 |
| 0.99000 | -0.00156 |
| 1.00000 | 0.00000 |

**R140**
actual model A

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00059 |
| 0.99965 | 0.00026 |
| 0.99623 | 0.00163 |
| 0.99185 | 0.00277 |
| 0.98676 | 0.00375 |
| 0.97845 | 0.00509 |
| 0.96744 | 0.00680 |
| 0.95733 | 0.00860 |
| 0.94609 | 0.01083 |
| 0.92986 | 0.01394 |
| 0.91258 | 0.01658 |
| 0.88866 | 0.01996 |
| 0.86201 | 0.02370 |
| 0.83519 | 0.02732 |
| 0.80907 | 0.03075 |
| 0.78207 | 0.03434 |
| 0.74293 | 0.03883 |
| 0.71258 | 0.04263 |
| 0.68103 | 0.04619 |
| 0.65171 | 0.04922 |
| 0.62178 | 0.05206 |
| 0.58465 | 0.05577 |
| 0.55078 | 0.05870 |
| 0.52023 | 0.06093 |
| 0.48449 | 0.06258 |
| 0.44969 | 0.06408 |
| 0.41973 | 0.06481 |
| 0.38880 | 0.06494 |
| 0.33882 | 0.06440 |
| 0.30226 | 0.06308 |
| 0.26226 | 0.06030 |
| 0.23109 | 0.05745 |
| 0.20504 | 0.05438 |
| 0.17673 | 0.05054 |
| 0.14442 | 0.04532 |
| 0.12115 | 0.04101 |
| 0.10240 | 0.03738 |
| 0.08552 | 0.03371 |
| 0.07159 | 0.03024 |
| 0.05916 | 0.02677 |
| 0.04793 | 0.02335 |
| 0.03906 | 0.02045 |
| 0.02693 | 0.01609 |
| 0.01800 | 0.01249 |
| 0.01165 | 0.00948 |
| 0.00593 | 0.00579 |
| 0.00248 | 0.00241 |
| 0.00189 | 0.00211 |
| 0.00254 | -0.00246 |
| 0.00689 | -0.00647 |
| 0.01002 | -0.00871 |
| 0.01449 | -0.01105 |
| 0.01978 | -0.01340 |
| 0.02778 | -0.01636 |
| 0.03482 | -0.01871 |
| 0.04838 | -0.02261 |
| 0.06221 | -0.02592 |
| 0.07400 | -0.02835 |
| 0.08696 | -0.03065 |
| 0.10175 | -0.03301 |
| 0.12901 | -0.03686 |
| 0.14666 | -0.03914 |
| 0.16805 | -0.04192 |
| 0.18516 | -0.04391 |
| 0.20600 | -0.04610 |
| 0.23145 | -0.04851 |
| 0.30230 | -0.05302 |
| 0.35298 | -0.05479 |
| 0.40558 | -0.05535 |
| 0.45837 | -0.05471 |
| 0.49218 | -0.05349 |
| 0.53051 | -0.05156 |
| 0.57601 | -0.04864 |
| 0.61836 | -0.04519 |
| 0.66369 | -0.04102 |
| 0.70022 | -0.03732 |
| 0.73779 | -0.03313 |
| 0.77187 | -0.02916 |
| 0.81100 | -0.02452 |
| 0.83916 | -0.02115 |
| 0.86371 | -0.01822 |
| 0.88391 | -0.01581 |
| 0.89942 | -0.01396 |
| 0.91718 | -0.01189 |
| 0.92802 | -0.01066 |
| 0.93542 | -0.00975 |
| 0.94490 | -0.00862 |
| 0.95722 | -0.00676 |
| 0.96778 | -0.00537 |
| 0.97684 | -0.00417 |
| 0.98362 | -0.00304 |
| 0.99007 | -0.00197 |
| 0.99475 | -0.00120 |
| 0.99920 | -0.00026 |
| 1.00000 | 0.00059 |

**RG15**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99671 | 0.00054 |
| 0.98726 | 0.00229 |
| 0.97237 | 0.00514 |
| 0.95248 | 0.00865 |
| 0.92764 | 0.01254 |
| 0.89810 | 0.01685 |
| 0.86427 | 0.02152 |
| 0.82660 | 0.02644 |
| 0.78557 | 0.03149 |
| 0.74165 | 0.03654 |
| 0.69537 | 0.04146 |
| 0.64723 | 0.04612 |
| 0.59778 | 0.05039 |
| 0.54753 | 0.05414 |
| 0.49702 | 0.05727 |
| 0.44676 | 0.05966 |
| 0.39727 | 0.06123 |
| 0.34902 | 0.06190 |
| 0.30248 | 0.06162 |
| 0.25809 | 0.06036 |
| 0.21624 | 0.05810 |
| 0.17730 | 0.05486 |
| 0.14161 | 0.05068 |
| 0.10945 | 0.04564 |
| 0.08108 | 0.03985 |
| 0.05673 | 0.03343 |
| 0.03658 | 0.02654 |
| 0.02076 | 0.01935 |
| 0.00932 | 0.01214 |
| 0.00235 | 0.00526 |
| 0.00000 | 0.00000 |
| 0.00002 | -0.00048 |
| 0.00336 | -0.00534 |
| 0.01247 | -0.01006 |
| 0.02670 | -0.01436 |
| 0.04596 | -0.01811 |
| 0.07010 | -0.02123 |
| 0.09896 | -0.02372 |
| 0.13224 | -0.02559 |
| 0.16963 | -0.02688 |
| 0.21073 | -0.02762 |
| 0.25509 | -0.02785 |
| 0.30221 | -0.02762 |
| 0.35156 | -0.02696 |
| 0.40257 | -0.02590 |
| 0.45463 | -0.02446 |
| 0.50713 | -0.02262 |
| 0.55944 | -0.02025 |
| 0.61128 | -0.01717 |
| 0.66244 | -0.01366 |
| 0.71237 | -0.01015 |
| 0.76037 | -0.00691 |
| 0.80575 | -0.00413 |
| 0.84779 | -0.00192 |
| 0.88583 | -0.00034 |
| 0.91925 | 0.00062 |
| 0.94748 | 0.00101 |
| 0.97003 | 0.00097 |
| 0.98652 | 0.00064 |
| 0.99660 | 0.00021 |
| 1.00000 | 0.00000 |

**RG15**
actual model B

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00033 |
| 0.99956 | 0.00118 |
| 0.99473 | 0.00194 |
| 0.98944 | 0.00265 |
| 0.98943 | 0.00265 |
| 0.97727 | 0.00430 |
| 0.97079 | 0.00511 |
| 0.96327 | 0.00619 |
| 0.95678 | 0.00708 |
| 0.94778 | 0.00832 |
| 0.93797 | 0.00973 |
| 0.92548 | 0.01145 |
| 0.91565 | 0.01286 |
| 0.90042 | 0.01510 |
| 0.88394 | 0.01737 |
| 0.86128 | 0.02047 |
| 0.83160 | 0.02408 |
| 0.79274 | 0.02870 |
| 0.74504 | 0.03408 |
| 0.67182 | 0.04179 |
| 0.60574 | 0.04798 |
| 0.54068 | 0.05272 |
| 0.47840 | 0.05632 |
| 0.42204 | 0.05880 |
| 0.36113 | 0.06010 |
| 0.29558 | 0.05989 |
| 0.24179 | 0.05839 |
| 0.19037 | 0.05533 |
| 0.14441 | 0.05079 |
| 0.11430 | 0.04672 |
| 0.08978 | 0.04230 |
| 0.06762 | 0.03708 |
| 0.05259 | 0.03266 |
| 0.04127 | 0.02877 |
| 0.03461 | 0.02616 |
| 0.02632 | 0.02257 |
| 0.01572 | 0.01667 |
| 0.00896 | 0.01183 |
| 0.00504 | 0.00833 |
| 0.00053 | 0.00233 |
| 0.00000 | 0.00006 |
| 0.00126 | -0.00358 |
| 0.00465 | -0.00659 |
| 0.01036 | -0.00976 |
| 0.01793 | -0.01259 |
| 0.02427 | -0.01439 |
| 0.03202 | -0.01614 |
| 0.03918 | -0.01745 |
| 0.04919 | -0.01900 |
| 0.05726 | -0.02003 |
| 0.06704 | -0.02116 |
| 0.07736 | -0.02220 |
| 0.09648 | -0.02387 |
| 0.12009 | -0.02549 |
| 0.15500 | -0.02702 |
| 0.19367 | -0.02803 |
| 0.24011 | -0.02865 |
| 0.30056 | -0.02884 |
| 0.36303 | -0.02793 |
| 0.42108 | -0.02646 |
| 0.48527 | -0.02469 |

| | |
|---|---|
| 0.55188 | -0.02231 |
| 0.61282 | -0.01943 |
| 0.67555 | -0.01523 |
| 0.73370 | -0.01074 |
| 0.78255 | -0.00729 |
| 0.82186 | -0.00512 |
| 0.85361 | -0.00373 |
| 0.87921 | -0.00283 |
| 0.90302 | -0.00227 |
| 0.92365 | -0.00197 |
| 0.93681 | -0.00188 |
| 0.94866 | -0.00170 |
| 0.95838 | -0.00153 |
| 0.96695 | -0.00119 |
| 0.97573 | -0.00126 |
| 0.98606 | -0.00145 |
| 0.99231 | -0.00145 |
| 0.99920 | -0.00118 |
| 1.00000 | -0.00033 |

**S1210**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99837 | 0.00101 |
| 0.99398 | 0.00397 |
| 0.98753 | 0.00832 |
| 0.97908 | 0.01317 |
| 0.96811 | 0.01811 |
| 0.95437 | 0.02328 |
| 0.93796 | 0.02874 |
| 0.91898 | 0.03443 |
| 0.89754 | 0.04032 |
| 0.87376 | 0.04637 |
| 0.84779 | 0.05254 |
| 0.81980 | 0.05879 |
| 0.78997 | 0.06506 |
| 0.75851 | 0.07130 |
| 0.72561 | 0.07747 |
| 0.69151 | 0.08349 |
| 0.65642 | 0.08932 |
| 0.62058 | 0.09490 |
| 0.58423 | 0.10016 |
| 0.54763 | 0.10505 |
| 0.51105 | 0.10948 |
| 0.47473 | 0.11335 |
| 0.43891 | 0.11653 |
| 0.40378 | 0.11892 |
| 0.36955 | 0.12046 |
| 0.33652 | 0.12091 |
| 0.30456 | 0.12000 |
| 0.27347 | 0.11784 |
| 0.24341 | 0.11462 |
| 0.21445 | 0.11047 |
| 0.18681 | 0.10556 |
| 0.16069 | 0.09994 |
| 0.13622 | 0.09362 |
| 0.11351 | 0.08672 |
| 0.09269 | 0.07932 |
| 0.07388 | 0.07149 |
| 0.05719 | 0.06332 |
| 0.04282 | 0.05484 |
| 0.03068 | 0.04593 |
| 0.02054 | 0.03672 |
| 0.01239 | 0.02755 |
| 0.00626 | 0.01866 |
| 0.00217 | 0.01030 |
| 0.00016 | 0.00277 |
| 0.00023 | -0.00345 |
| 0.00337 | -0.00773 |
| 0.01034 | -0.01070 |
| 0.02071 | -0.01324 |
| 0.03417 | -0.01529 |
| 0.05052 | -0.01685 |
| 0.06959 | -0.01786 |
| 0.09118 | -0.01830 |
| 0.11512 | -0.01810 |
| 0.14119 | -0.01715 |
| 0.16911 | -0.01524 |
| 0.19906 | -0.01183 |
| 0.23157 | -0.00697 |
| 0.26670 | -0.00124 |
| 0.30427 | 0.00504 |
| 0.34404 | 0.01158 |
| 0.38575 | 0.01814 |
| 0.42909 | 0.02446 |
| 0.47370 | 0.03032 |
| 0.51919 | 0.03551 |
| 0.56515 | 0.03986 |
| 0.61113 | 0.04320 |
| 0.65666 | 0.04543 |
| 0.70127 | 0.04646 |
| 0.74446 | 0.04625 |
| 0.78575 | 0.04479 |
| 0.82465 | 0.04214 |
| 0.86071 | 0.03837 |
| 0.89349 | 0.03364 |
| 0.92255 | 0.02809 |
| 0.94754 | 0.02192 |
| 0.96791 | 0.01530 |
| 0.98299 | 0.00890 |
| 0.99284 | 0.00390 |
| 0.99828 | 0.00095 |
| 1.00000 | 0.00000 |

**S1210**

actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00013 |
| 0.99811 | 0.00094 |
| 0.99327 | 0.00382 |
| 0.98860 | 0.00623 |
| 0.98320 | 0.00875 |
| 0.97511 | 0.01220 |
| 0.96703 | 0.01544 |
| 0.95475 | 0.02010 |
| 0.94579 | 0.02318 |
| 0.93445 | 0.02695 |
| 0.92541 | 0.02975 |
| 0.91267 | 0.03349 |
| 0.89739 | 0.03771 |
| 0.88726 | 0.04036 |
| 0.86978 | 0.04470 |
| 0.84462 | 0.05056 |
| 0.81905 | 0.05619 |
| 0.78199 | 0.06393 |
| 0.74332 | 0.07152 |
| 0.70412 | 0.07876 |
| 0.64019 | 0.08959 |
| 0.58116 | 0.09838 |
| 0.51830 | 0.10638 |
| 0.45991 | 0.11242 |
| 0.39930 | 0.11681 |
| 0.33861 | 0.11829 |
| 0.26775 | 0.11516 |
| 0.20457 | 0.10701 |
| 0.16745 | 0.09969 |
| 0.12519 | 0.08872 |
| 0.09391 | 0.07821 |
| 0.06982 | 0.06801 |
| 0.05786 | 0.06189 |
| 0.04457 | 0.05380 |
| 0.03633 | 0.04791 |
| 0.02944 | 0.04232 |
| 0.02202 | 0.03546 |
| 0.01391 | 0.02653 |
| 0.00972 | 0.02090 |
| 0.00362 | 0.00974 |
| 0.00230 | 0.00629 |
| 0.00185 | -0.00554 |
| 0.00763 | -0.01127 |
| 0.01687 | -0.01493 |
| 0.02535 | -0.01671 |
| 0.03157 | -0.01762 |
| 0.04450 | -0.01902 |
| 0.05676 | -0.01987 |
| 0.08545 | -0.02075 |
| 0.10512 | -0.02075 |
| 0.13856 | -0.01978 |
| 0.16539 | -0.01790 |
| 0.20815 | -0.01272 |
| 0.24922 | -0.00626 |
| 0.30895 | 0.00352 |
| 0.36788 | 0.01310 |
| 0.43344 | 0.02266 |
| 0.49644 | 0.03030 |
| 0.55937 | 0.03653 |
| 0.61487 | 0.04070 |
| 0.67785 | 0.04314 |
| 0.73767 | 0.04325 |
| 0.77928 | 0.04170 |
| 0.81769 | 0.03910 |
| 0.83794 | 0.03725 |
| 0.85523 | 0.03546 |
| 0.87291 | 0.03326 |
| 0.89185 | 0.03042 |
| 0.90942 | 0.02729 |
| 0.92714 | 0.02352 |
| 0.94273 | 0.01954 |
| 0.95734 | 0.01512 |
| 0.96766 | 0.01155 |
| 0.97714 | 0.00798 |
| 0.98589 | 0.00448 |
| 0.99269 | 0.00165 |
| 1.00099 | -0.00094 |
| 1.00000 | -0.00013 |

**S1223**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99838 | 0.00126 |
| 0.99417 | 0.00494 |
| 0.98825 | 0.01037 |
| 0.98075 | 0.01646 |
| 0.97111 | 0.02250 |
| 0.95884 | 0.02853 |
| 0.94389 | 0.03476 |
| 0.92639 | 0.04116 |
| 0.90641 | 0.04768 |
| 0.88406 | 0.05427 |
| 0.85947 | 0.06089 |
| 0.83277 | 0.06749 |
| 0.80412 | 0.07402 |
| 0.77369 | 0.08044 |
| 0.74166 | 0.08671 |
| 0.70823 | 0.09277 |
| 0.67360 | 0.09859 |
| 0.63798 | 0.10412 |
| 0.60158 | 0.10935 |
| 0.56465 | 0.11425 |
| 0.52744 | 0.11881 |
| 0.49025 | 0.12303 |
| 0.45340 | 0.12683 |
| 0.41721 | 0.13011 |
| 0.38193 | 0.13271 |
| 0.34777 | 0.13447 |
| 0.31488 | 0.13526 |
| 0.28347 | 0.13505 |
| 0.25370 | 0.13346 |
| 0.22541 | 0.13037 |
| 0.19846 | 0.12594 |
| 0.17286 | 0.12026 |
| 0.14863 | 0.11355 |
| 0.12591 | 0.10598 |
| 0.10482 | 0.09770 |
| 0.08545 | 0.08879 |
| 0.06789 | 0.07940 |
| 0.05223 | 0.06965 |
| 0.03855 | 0.05968 |
| 0.02694 | 0.04966 |
| 0.01755 | 0.03961 |
| 0.01028 | 0.02954 |
| 0.00495 | 0.01969 |
| 0.00155 | 0.01033 |
| 0.00005 | 0.00178 |
| 0.00044 | -0.00561 |
| 0.00264 | -0.01120 |
| 0.00789 | -0.01427 |
| 0.01718 | -0.01550 |
| 0.03006 | -0.01584 |
| 0.04627 | -0.01532 |
| 0.06561 | -0.01404 |
| 0.08787 | -0.01202 |
| 0.11282 | -0.00925 |
| 0.14020 | -0.00563 |
| 0.17006 | -0.00075 |
| 0.20278 | 0.00535 |
| 0.23840 | 0.01213 |
| 0.27673 | 0.01928 |
| 0.31750 | 0.02652 |
| 0.36044 | 0.03358 |
| 0.40519 | 0.04021 |
| 0.45139 | 0.04618 |
| 0.49860 | 0.05129 |
| 0.54639 | 0.05534 |
| 0.59428 | 0.05820 |
| 0.64176 | 0.05976 |
| 0.68832 | 0.05994 |

| | |
|---|---|
| 0.73344 | 0.05872 |
| 0.77660 | 0.05612 |
| 0.81729 | 0.05219 |
| 0.85500 | 0.04706 |
| 0.88928 | 0.04088 |
| 0.91966 | 0.03387 |
| 0.94573 | 0.02624 |
| 0.96693 | 0.01822 |
| 0.98255 | 0.01060 |
| 0.99268 | 0.00468 |
| 0.99825 | 0.00115 |
| 1.00000 | 0.00000 |

**S1223**

actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00013 |
| 0.99720 | 0.00333 |
| 0.99187 | 0.00839 |
| 0.98689 | 0.01260 |
| 0.98075 | 0.01692 |
| 0.97339 | 0.02127 |
| 0.96293 | 0.02660 |
| 0.95370 | 0.03080 |
| 0.94176 | 0.03581 |
| 0.92548 | 0.04204 |
| 0.91053 | 0.04728 |
| 0.88969 | 0.05399 |
| 0.87178 | 0.05924 |
| 0.84496 | 0.06638 |
| 0.81744 | 0.07305 |
| 0.78334 | 0.08061 |
| 0.74802 | 0.08779 |
| 0.71868 | 0.09328 |
| 0.68153 | 0.09976 |
| 0.65038 | 0.10483 |
| 0.61072 | 0.11087 |
| 0.59071 | 0.11368 |
| 0.56407 | 0.11720 |
| 0.53542 | 0.12074 |
| 0.50578 | 0.12419 |
| 0.47863 | 0.12718 |
| 0.44641 | 0.13039 |
| 0.41610 | 0.13304 |
| 0.38752 | 0.13509 |
| 0.35962 | 0.13665 |
| 0.32854 | 0.13771 |
| 0.29648 | 0.13794 |
| 0.26356 | 0.13679 |
| 0.23263 | 0.13393 |
| 0.21283 | 0.13114 |
| 0.19561 | 0.12802 |
| 0.17473 | 0.12336 |
| 0.15733 | 0.11868 |
| 0.14032 | 0.11348 |
| 0.12497 | 0.10819 |
| 0.11009 | 0.10247 |
| 0.09550 | 0.09613 |
| 0.08018 | 0.08863 |
| 0.06800 | 0.08199 |
| 0.04897 | 0.07000 |
| 0.03568 | 0.05999 |
| 0.02846 | 0.05369 |
| 0.01989 | 0.04487 |
| 0.01503 | 0.03884 |
| 0.01082 | 0.03257 |
| 0.00706 | 0.02587 |
| 0.00482 | 0.02100 |
| 0.00221 | 0.01365 |
| 0.00080 | 0.00745 |
| 0.00019 | 0.00286 |
| 0.00005 | -0.00138 |
| 0.00083 | -0.00593 |
| 0.00139 | -0.00690 |
| 0.00312 | -0.00872 |
| 0.00790 | -0.01068 |
| 0.01449 | -0.01150 |
| 0.02138 | -0.01185 |
| 0.03330 | -0.01196 |
| 0.04627 | -0.01153 |
| 0.06389 | -0.01040 |
| 0.08117 | -0.00888 |
| 0.10354 | -0.00663 |
| 0.12948 | -0.00369 |
| 0.16404 | 0.00134 |
| 0.20100 | 0.00781 |
| 0.25115 | 0.01690 |
| 0.29610 | 0.02479 |
| 0.33392 | 0.03100 |
| 0.38160 | 0.03816 |
| 0.43006 | 0.04455 |
| 0.47940 | 0.05004 |
| 0.52654 | 0.05432 |
| 0.57684 | 0.05747 |
| 0.63172 | 0.05939 |
| 0.67649 | 0.05980 |
| 0.71559 | 0.05921 |
| 0.73675 | 0.05844 |
| 0.76333 | 0.05703 |
| 0.78942 | 0.05506 |
| 0.80947 | 0.05310 |
| 0.83028 | 0.05062 |
| 0.86994 | 0.04446 |
| 0.89924 | 0.03838 |
| 0.92149 | 0.03274 |
| 0.94479 | 0.02561 |
| 0.95707 | 0.02117 |
| 0.97177 | 0.01493 |
| 0.98900 | 0.00570 |
| 0.99231 | 0.00363 |
| 0.99800 | -0.00013 |
| 1.00000 | -0.00178 |

**S6062**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99680 | 0.00020 |
| 0.98733 | 0.00088 |
| 0.97184 | 0.00225 |
| 0.95072 | 0.00438 |
| 0.92441 | 0.00730 |
| 0.89341 | 0.01095 |
| 0.85821 | 0.01522 |
| 0.81934 | 0.01994 |
| 0.77733 | 0.02496 |
| 0.73267 | 0.03005 |
| 0.68588 | 0.03506 |
| 0.63746 | 0.03978 |
| 0.58788 | 0.04408 |
| 0.53767 | 0.04783 |
| 0.48734 | 0.05093 |
| 0.43737 | 0.05323 |
| 0.38823 | 0.05467 |
| 0.34037 | 0.05520 |
| 0.29424 | 0.05479 |
| 0.25026 | 0.05344 |
| 0.20882 | 0.05117 |
| 0.17033 | 0.04804 |
| 0.13513 | 0.04409 |
| 0.10353 | 0.03938 |
| 0.07580 | 0.03401 |
| 0.05216 | 0.02810 |
| 0.03276 | 0.02178 |
| 0.01774 | 0.01528 |
| 0.00715 | 0.00884 |
| 0.00107 | 0.00295 |
| 0.00045 | -0.00181 |
| 0.00563 | -0.00607 |
| 0.01601 | -0.01033 |
| 0.03144 | -0.01419 |
| 0.05180 | -0.01752 |
| 0.07696 | -0.02024 |
| 0.10672 | -0.02234 |
| 0.14083 | -0.02382 |
| 0.17897 | -0.02471 |
| 0.22075 | -0.02507 |
| 0.26575 | -0.02494 |
| 0.31346 | -0.02440 |
| 0.36335 | -0.02349 |
| 0.41486 | -0.02225 |
| 0.46742 | -0.02074 |
| 0.52041 | -0.01900 |
| 0.57326 | -0.01706 |
| 0.62537 | -0.01496 |
| 0.67617 | -0.01273 |
| 0.72513 | -0.01044 |
| 0.77171 | -0.00816 |
| 0.81540 | -0.00600 |
| 0.85566 | -0.00409 |
| 0.89194 | -0.00252 |
| 0.92370 | -0.00135 |
| 0.95045 | -0.00056 |
| 0.97178 | -0.00012 |
| 0.98733 | 0.00004 |
| 0.99681 | 0.00003 |
| 1.00000 | 0.00000 |

**S6062**

actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00092 |
| 0.99997 | 0.00020 |
| 0.99555 | 0.00067 |
| 0.99025 | 0.00168 |
| 0.98554 | 0.00280 |
| 0.98014 | 0.00351 |
| 0.97341 | 0.00458 |
| 0.96579 | 0.00571 |
| 0.95450 | 0.00743 |
| 0.94397 | 0.00897 |
| 0.92361 | 0.01213 |
| 0.91191 | 0.01364 |
| 0.89484 | 0.01595 |
| 0.87825 | 0.01823 |
| 0.85084 | 0.02165 |
| 0.83656 | 0.02334 |
| 0.81613 | 0.02577 |
| 0.80349 | 0.02728 |
| 0.79097 | 0.02869 |
| 0.76233 | 0.03191 |
| 0.74745 | 0.03352 |
| 0.72867 | 0.03555 |
| 0.71127 | 0.03747 |
| 0.68297 | 0.04031 |
| 0.65020 | 0.04330 |
| 0.62252 | 0.04550 |
| 0.59974 | 0.04718 |
| 0.57271 | 0.04917 |
| 0.54433 | 0.05103 |
| 0.51966 | 0.05257 |
| 0.49053 | 0.05397 |
| 0.45887 | 0.05522 |
| 0.42424 | 0.05619 |
| 0.39420 | 0.05666 |
| 0.36300 | 0.05675 |
| 0.32813 | 0.05627 |
| 0.29729 | 0.05528 |
| 0.27385 | 0.05417 |
| 0.23959 | 0.05204 |
| 0.21505 | 0.05024 |
| 0.18806 | 0.04784 |
| 0.16310 | 0.04515 |
| 0.13883 | 0.04209 |
| 0.12001 | 0.03941 |
| 0.10503 | 0.03710 |
| 0.09032 | 0.03456 |
| 0.07110 | 0.03058 |
| 0.05662 | 0.02684 |
| 0.04802 | 0.02436 |
| 0.03936 | 0.02162 |
| 0.02960 | 0.01831 |
| 0.02130 | 0.01526 |
| 0.01444 | 0.01217 |
| 0.00802 | 0.00838 |
| 0.00432 | 0.00562 |
| 0.00072 | -0.00228 |
| 0.00106 | -0.00277 |
| 0.00373 | -0.00688 |
| 0.00585 | -0.00892 |
| 0.00907 | -0.01074 |
| 0.01530 | -0.01336 |
| 0.02055 | -0.01486 |
| 0.02545 | -0.01591 |
| 0.03810 | -0.01816 |
| 0.05334 | -0.02016 |
| 0.07060 | -0.02192 |
| 0.08929 | -0.02339 |
| 0.11283 | -0.02480 |
| 0.14143 | -0.02602 |
| 0.17509 | -0.02667 |
| 0.21077 | -0.02666 |
| 0.24782 | -0.02619 |
| 0.30981 | -0.02468 |
| 0.36414 | -0.02279 |
| 0.41468 | -0.02087 |
| 0.47090 | -0.01854 |
| 0.52194 | -0.01630 |

| | |
|---|---|
| 0.57581 | -0.01355 |
| 0.63128 | -0.01072 |
| 0.67090 | -0.00877 |
| 0.71094 | -0.00702 |
| 0.75430 | -0.00509 |
| 0.79276 | -0.00317 |
| 0.83080 | -0.00144 |
| 0.87524 | 0.00005 |
| 0.90758 | 0.00110 |
| 0.92690 | 0.00138 |
| 0.94413 | 0.00165 |
| 0.95833 | 0.00182 |
| 0.96951 | 0.00163 |
| 0.97956 | 0.00151 |
| 0.98827 | 0.00133 |
| 0.99585 | 0.00133 |
| 1.00000 | -0.00092 |

**S7012**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99819 | 0.00024 |
| 0.99294 | 0.00104 |
| 0.98451 | 0.00231 |
| 0.97296 | 0.00392 |
| 0.95833 | 0.00586 |
| 0.94077 | 0.00817 |
| 0.92044 | 0.01080 |
| 0.89749 | 0.01372 |
| 0.87210 | 0.01689 |
| 0.84445 | 0.02029 |
| 0.81474 | 0.02386 |
| 0.78318 | 0.02757 |
| 0.74999 | 0.03138 |
| 0.71540 | 0.03524 |
| 0.67965 | 0.03909 |
| 0.64298 | 0.04287 |
| 0.60563 | 0.04654 |
| 0.56785 | 0.05002 |
| 0.52988 | 0.05324 |
| 0.49193 | 0.05615 |
| 0.45426 | 0.05870 |
| 0.41710 | 0.06081 |
| 0.38070 | 0.06241 |
| 0.34520 | 0.06335 |
| 0.31071 | 0.06360 |
| 0.27741 | 0.06319 |
| 0.24543 | 0.06209 |
| 0.21486 | 0.06033 |
| 0.18590 | 0.05795 |
| 0.15865 | 0.05496 |
| 0.13326 | 0.05143 |
| 0.10983 | 0.04738 |
| 0.08846 | 0.04287 |
| 0.06926 | 0.03798 |
| 0.05229 | 0.03274 |
| 0.03759 | 0.02728 |
| 0.02525 | 0.02167 |
| 0.01528 | 0.01605 |
| 0.00773 | 0.01058 |
| 0.00266 | 0.00542 |
| 0.00007 | 0.00087 |
| 0.00069 | -0.00278 |
| 0.00486 | -0.00600 |
| 0.01208 | -0.00918 |
| 0.02223 | -0.01220 |
| 0.03523 | -0.01495 |
| 0.05102 | -0.01739 |
| 0.06952 | -0.01950 |
| 0.09065 | -0.02126 |
| 0.11428 | -0.02265 |
| 0.14032 | -0.02368 |
| 0.16861 | -0.02436 |
| 0.19900 | -0.02471 |
| 0.23131 | -0.02474 |
| 0.26535 | -0.02448 |
| 0.30091 | -0.02396 |
| 0.33778 | -0.02318 |
| 0.37572 | -0.02220 |
| 0.41449 | -0.02101 |
| 0.45383 | -0.01965 |
| 0.49348 | -0.01813 |
| 0.53316 | -0.01644 |
| 0.57261 | -0.01453 |
| 0.61171 | -0.01227 |
| 0.65044 | -0.00978 |
| 0.68859 | -0.00732 |
| 0.72582 | -0.00504 |
| 0.76182 | -0.00300 |
| 0.79628 | -0.00128 |
| 0.82889 | 0.00010 |
| 0.85936 | 0.00112 |
| 0.88743 | 0.00178 |
| 0.91283 | 0.00211 |
| 0.93533 | 0.00214 |
| 0.95473 | 0.00192 |
| 0.97084 | 0.00153 |
| 0.98352 | 0.00105 |
| 0.99266 | 0.00055 |
| 0.99816 | 0.00016 |
| 1.00000 | 0.00000 |

**S7012**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00024 |
| 0.99990 | 0.00045 |
| 0.99580 | 0.00110 |
| 0.99052 | 0.00164 |
| 0.98306 | 0.00219 |
| 0.97378 | 0.00295 |
| 0.96520 | 0.00372 |
| 0.95453 | 0.00479 |
| 0.94108 | 0.00613 |
| 0.92357 | 0.00813 |
| 0.89856 | 0.01071 |
| 0.87495 | 0.01333 |
| 0.84892 | 0.01626 |
| 0.81563 | 0.02012 |
| 0.77729 | 0.02448 |
| 0.73367 | 0.02949 |
| 0.67295 | 0.03588 |
| 0.60982 | 0.04226 |
| 0.54845 | 0.04805 |
| 0.48627 | 0.05325 |
| 0.42203 | 0.05747 |
| 0.36132 | 0.06026 |
| 0.29858 | 0.06102 |
| 0.23934 | 0.05963 |
| 0.19735 | 0.05688 |
| 0.15534 | 0.05266 |
| 0.12433 | 0.04829 |
| 0.10986 | 0.04572 |
| 0.09582 | 0.04289 |
| 0.08643 | 0.04080 |
| 0.07630 | 0.03837 |
| 0.05400 | 0.03204 |
| 0.04526 | 0.02901 |
| 0.03654 | 0.02564 |
| 0.02727 | 0.02166 |
| 0.02128 | 0.01884 |
| 0.01711 | 0.01665 |
| 0.01203 | 0.01351 |
| 0.00697 | 0.00952 |
| 0.00469 | 0.00711 |
| 0.00300 | 0.00526 |
| 0.00219 | -0.00443 |
| 0.00616 | -0.00745 |
| 0.01068 | -0.00992 |
| 0.01468 | -0.01158 |
| 0.01962 | -0.01322 |
| 0.02676 | -0.01520 |
| 0.03620 | -0.01736 |
| 0.04772 | -0.01941 |
| 0.04752 | -0.01938 |
| 0.07539 | -0.02251 |
| 0.09520 | -0.02407 |
| 0.12888 | -0.02592 |
| 0.15977 | -0.02698 |
| 0.19904 | -0.02753 |
| 0.23819 | -0.02729 |
| 0.30247 | -0.02631 |
| 0.36215 | -0.02488 |
| 0.42815 | -0.02294 |
| 0.49299 | -0.02065 |
| 0.55294 | -0.01787 |
| 0.61399 | -0.01442 |
| 0.67478 | -0.01052 |
| 0.73552 | -0.00680 |
| 0.78148 | -0.00428 |
| 0.82002 | -0.00242 |
| 0.85315 | -0.00103 |
| 0.88282 | -0.00019 |
| 0.90308 | 0.00026 |
| 0.92552 | 0.00047 |
| 0.95235 | 0.00069 |
| 0.96396 | 0.00054 |
| 0.97523 | 0.00034 |
| 0.98339 | -0.00005 |
| 0.99099 | -0.00036 |
| 0.99862 | -0.00045 |
| 1.00000 | 0.00024 |

**S7055**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99808 | 0.00023 |
| 0.99243 | 0.00104 |
| 0.98327 | 0.00251 |
| 0.97083 | 0.00464 |
| 0.95526 | 0.00738 |
| 0.93671 | 0.01073 |
| 0.91539 | 0.01470 |
| 0.89155 | 0.01924 |
| 0.86543 | 0.02431 |
| 0.83728 | 0.02981 |
| 0.80738 | 0.03565 |
| 0.77601 | 0.04169 |
| 0.74337 | 0.04770 |
| 0.70958 | 0.05354 |
| 0.67484 | 0.05920 |
| 0.63934 | 0.06454 |
| 0.60327 | 0.06949 |
| 0.56688 | 0.07399 |
| 0.53032 | 0.07791 |
| 0.49374 | 0.08125 |
| 0.45740 | 0.08391 |
| 0.42142 | 0.08584 |
| 0.38601 | 0.08706 |
| 0.35133 | 0.08749 |
| 0.31754 | 0.08713 |
| 0.28483 | 0.08599 |
| 0.25332 | 0.08404 |
| 0.22311 | 0.08132 |
| 0.19440 | 0.07787 |
| 0.16729 | 0.07370 |
| 0.14189 | 0.06891 |
| 0.11833 | 0.06352 |
| 0.09668 | 0.05760 |
| 0.07705 | 0.05125 |
| 0.05952 | 0.04455 |
| 0.04413 | 0.03761 |
| 0.03097 | 0.03054 |
| 0.02008 | 0.02346 |
| 0.01148 | 0.01655 |
| 0.00524 | 0.00998 |
| 0.00139 | 0.00398 |
| 0.00007 | -0.00091 |
| 0.00214 | -0.00493 |
| 0.00762 | -0.00871 |
| 0.01587 | -0.01193 |
| 0.02720 | -0.01436 |
| 0.04175 | -0.01620 |
| 0.05938 | -0.01763 |
| 0.07995 | -0.01870 |
| 0.10333 | -0.01944 |
| 0.12935 | -0.01989 |
| 0.15784 | -0.02009 |
| 0.18857 | -0.02006 |
| 0.22132 | -0.01980 |
| 0.25590 | -0.01927 |
| 0.29218 | -0.01849 |
| 0.32993 | -0.01757 |
| 0.36889 | -0.01656 |
| 0.40878 | -0.01551 |
| 0.44933 | -0.01445 |
| 0.49021 | -0.01338 |
| 0.53116 | -0.01230 |
| 0.57188 | -0.01123 |
| 0.61212 | -0.01018 |
| 0.65160 | -0.00914 |
| 0.69009 | -0.00813 |
| 0.72734 | -0.00716 |
| 0.76303 | -0.00622 |
| 0.79681 | -0.00533 |
| 0.82841 | -0.00450 |
| 0.85793 | -0.00373 |

| | |
|---|---|
| 0.88544 | -0.00301 |
| 0.91063 | -0.00235 |
| 0.93322 | -0.00175 |
| 0.95293 | -0.00124 |
| 0.96949 | -0.00080 |
| 0.98266 | -0.00046 |
| 0.99224 | -0.00020 |
| 0.99805 | -0.00005 |
| 1.00000 | 0.00000 |

**S7055**

actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00040 |
| 0.99562 | 0.00203 |
| 0.99010 | 0.00284 |
| 0.98345 | 0.00397 |
| 0.97668 | 0.00506 |
| 0.96982 | 0.00632 |
| 0.96240 | 0.00763 |
| 0.95470 | 0.00905 |
| 0.94683 | 0.01044 |
| 0.93714 | 0.01212 |
| 0.92450 | 0.01445 |
| 0.91234 | 0.01666 |
| 0.90178 | 0.01871 |
| 0.88154 | 0.02256 |
| 0.86177 | 0.02643 |
| 0.83545 | 0.03185 |
| 0.79854 | 0.03912 |
| 0.76066 | 0.04651 |
| 0.72058 | 0.05398 |
| 0.66018 | 0.06405 |
| 0.60023 | 0.07286 |
| 0.53588 | 0.07980 |
| 0.47323 | 0.08473 |
| 0.41034 | 0.08802 |
| 0.34779 | 0.08827 |
| 0.28557 | 0.08628 |
| 0.22639 | 0.08189 |
| 0.18440 | 0.07689 |
| 0.14489 | 0.07040 |
| 0.12239 | 0.06522 |
| 0.10318 | 0.05983 |
| 0.08536 | 0.05384 |
| 0.07289 | 0.04896 |
| 0.06069 | 0.04381 |
| 0.04943 | 0.03870 |
| 0.03860 | 0.03320 |
| 0.02930 | 0.02774 |
| 0.02098 | 0.02225 |
| 0.01432 | 0.01724 |
| 0.00716 | 0.01110 |
| 0.00294 | 0.00641 |
| 0.00005 | -0.00085 |
| 0.00025 | -0.00185 |
| 0.00422 | -0.00712 |
| 0.00819 | -0.00946 |
| 0.01368 | -0.01173 |
| 0.01940 | -0.01365 |
| 0.02561 | -0.01527 |
| 0.03578 | -0.01721 |
| 0.04885 | -0.01892 |
| 0.05964 | -0.02005 |
| 0.07697 | -0.02144 |
| 0.09621 | -0.02215 |
| 0.12762 | -0.02249 |
| 0.15810 | -0.02285 |
| 0.19891 | -0.02277 |
| 0.24187 | -0.02203 |
| 0.30328 | -0.01968 |
| 0.36843 | -0.01772 |
| 0.43049 | -0.01599 |
| 0.49304 | -0.01422 |
| 0.55200 | -0.01265 |
| 0.61392 | -0.01127 |
| 0.67063 | -0.00971 |
| 0.73894 | -0.00781 |
| 0.78119 | -0.00628 |
| 0.82139 | -0.00528 |
| 0.85601 | -0.00448 |
| 0.88476 | -0.00359 |
| 0.90230 | -0.00292 |
| 0.92436 | -0.00225 |
| 0.93865 | -0.00180 |
| 0.95219 | -0.00156 |
| 0.96302 | -0.00127 |
| 0.97314 | -0.00124 |
| 0.98332 | -0.00121 |
| 0.99112 | -0.00125 |
| 0.99936 | -0.00105 |
| 1.00000 | 0.00040 |

**S8052**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99803 | 0.00018 |
| 0.99231 | 0.00079 |
| 0.98301 | 0.00181 |
| 0.97022 | 0.00330 |
| 0.95412 | 0.00533 |
| 0.93491 | 0.00790 |
| 0.91280 | 0.01104 |
| 0.88804 | 0.01472 |
| 0.86087 | 0.01891 |
| 0.83155 | 0.02357 |
| 0.80036 | 0.02863 |
| 0.76759 | 0.03400 |
| 0.73351 | 0.03957 |
| 0.69841 | 0.04524 |
| 0.66259 | 0.05083 |
| 0.62635 | 0.05617 |
| 0.58984 | 0.06088 |
| 0.55299 | 0.06482 |
| 0.51588 | 0.06814 |
| 0.47873 | 0.07081 |
| 0.44169 | 0.07283 |
| 0.40501 | 0.07423 |
| 0.36887 | 0.07498 |
| 0.33344 | 0.07511 |
| 0.29896 | 0.07461 |
| 0.26560 | 0.07351 |
| 0.23357 | 0.07182 |
| 0.20304 | 0.06957 |
| 0.17422 | 0.06676 |
| 0.14727 | 0.06341 |
| 0.12234 | 0.05951 |
| 0.09956 | 0.05510 |
| 0.07907 | 0.05012 |
| 0.06085 | 0.04458 |
| 0.04493 | 0.03864 |
| 0.03140 | 0.03234 |
| 0.02025 | 0.02579 |
| 0.01165 | 0.01916 |
| 0.00552 | 0.01240 |
| 0.00163 | 0.00569 |
| 0.00001 | -0.00037 |
| 0.00147 | -0.00540 |
| 0.00651 | -0.00985 |
| 0.01471 | -0.01427 |
| 0.02583 | -0.01860 |
| 0.03977 | -0.02271 |
| 0.05642 | -0.02654 |
| 0.07569 | -0.03003 |
| 0.09749 | -0.03316 |
| 0.12169 | -0.03590 |
| 0.14818 | -0.03824 |
| 0.17678 | -0.04018 |
| 0.20735 | -0.04171 |
| 0.23970 | -0.04283 |
| 0.27364 | -0.04354 |
| 0.30896 | -0.04385 |
| 0.34545 | -0.04377 |
| 0.38288 | -0.04331 |
| 0.42100 | -0.04248 |
| 0.45957 | -0.04127 |
| 0.49834 | -0.03967 |
| 0.53702 | -0.03758 |
| 0.57556 | -0.03494 |
| 0.61389 | -0.03185 |
| 0.65181 | -0.02843 |
| 0.68916 | -0.02481 |
| 0.72568 | -0.02116 |
| 0.76113 | -0.01762 |
| 0.79518 | -0.01433 |
| 0.82751 | -0.01136 |
| 0.85782 | -0.00876 |
| 0.88581 | -0.00656 |
| 0.91121 | -0.00475 |
| 0.93377 | -0.00330 |
| 0.95325 | -0.00218 |
| 0.96950 | -0.00128 |
| 0.98246 | -0.00056 |
| 0.99204 | -0.00011 |
| 0.99798 | 0.00002 |
| 1.00000 | 0.00000 |

**SD6060**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99661 | 0.00023 |
| 0.98660 | 0.00108 |
| 0.97033 | 0.00283 |
| 0.94829 | 0.00559 |
| 0.92100 | 0.00941 |
| 0.88905 | 0.01419 |
| 0.85301 | 0.01977 |
| 0.81346 | 0.02595 |
| 0.77096 | 0.03248 |
| 0.72602 | 0.03912 |
| 0.67917 | 0.04563 |
| 0.63091 | 0.05177 |
| 0.58174 | 0.05738 |
| 0.53222 | 0.06225 |
| 0.48283 | 0.06606 |
| 0.43386 | 0.06866 |
| 0.38566 | 0.07003 |
| 0.33862 | 0.07020 |
| 0.29316 | 0.06922 |
| 0.24976 | 0.06715 |
| 0.20883 | 0.06402 |
| 0.17076 | 0.05988 |
| 0.13589 | 0.05480 |
| 0.10456 | 0.04887 |
| 0.07700 | 0.04218 |
| 0.05344 | 0.03486 |
| 0.03399 | 0.02710 |
| 0.01879 | 0.01913 |
| 0.00790 | 0.01132 |
| 0.00148 | 0.00411 |
| 0.00025 | -0.00159 |
| 0.00495 | -0.00647 |
| 0.01525 | -0.01148 |
| 0.03068 | -0.01612 |
| 0.05114 | -0.02025 |
| 0.07648 | -0.02381 |
| 0.10645 | -0.02678 |
| 0.14078 | -0.02919 |
| 0.17909 | -0.03105 |
| 0.22096 | -0.03238 |
| 0.26592 | -0.03321 |
| 0.31347 | -0.03354 |
| 0.36306 | -0.03338 |
| 0.41413 | -0.03273 |
| 0.46614 | -0.03159 |
| 0.51852 | -0.02995 |
| 0.57073 | -0.02784 |
| 0.62223 | -0.02527 |
| 0.67254 | -0.02231 |
| 0.72116 | -0.01906 |
| 0.76761 | -0.01568 |
| 0.81133 | -0.01236 |
| 0.85176 | -0.00922 |
| 0.88838 | -0.00638 |
| 0.92070 | -0.00399 |
| 0.94818 | -0.00214 |
| 0.97032 | -0.00090 |
| 0.98661 | -0.00024 |
| 0.99662 | -0.00002 |
| 1.00000 | 0.00000 |

**SD6060**

actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00005 |
| 0.99445 | 0.00158 |
| 0.98915 | 0.00189 |
| 0.98274 | 0.00233 |
| 0.97632 | 0.00280 |
| 0.96840 | 0.00349 |
| 0.96021 | 0.00427 |
| 0.95108 | 0.00523 |
| 0.93972 | 0.00652 |
| 0.92543 | 0.00819 |
| 0.90947 | 0.01034 |

| | |
|---|---|
| 0.88641 | 0.01350 |
| 0.86803 | 0.01621 |
| 0.83804 | 0.02061 |
| 0.80333 | 0.02566 |
| 0.76548 | 0.03134 |
| 0.72844 | 0.03684 |
| 0.66218 | 0.04601 |
| 0.60211 | 0.05343 |
| 0.54017 | 0.05990 |
| 0.47817 | 0.06478 |
| 0.41464 | 0.06785 |
| 0.35251 | 0.06896 |
| 0.29323 | 0.06788 |
| 0.22973 | 0.06474 |
| 0.18531 | 0.06100 |
| 0.14689 | 0.05603 |
| 0.11633 | 0.05056 |
| 0.08752 | 0.04407 |
| 0.06241 | 0.03708 |
| 0.04904 | 0.03258 |
| 0.04040 | 0.02962 |
| 0.02969 | 0.02475 |
| 0.02245 | 0.02092 |
| 0.01453 | 0.01602 |
| 0.00633 | 0.00922 |
| 0.00062 | 0.00191 |
| 0.00047 | -0.00164 |
| 0.00103 | -0.00245 |
| 0.00459 | -0.00592 |
| 0.01135 | -0.01002 |
| 0.01901 | -0.01298 |
| 0.02524 | -0.01491 |
| 0.03464 | -0.01737 |
| 0.04704 | -0.01998 |
| 0.05625 | -0.02151 |
| 0.07464 | -0.02396 |
| 0.09503 | -0.02628 |
| 0.12572 | -0.02867 |
| 0.15720 | -0.03022 |
| 0.19690 | -0.03144 |
| 0.23471 | -0.03216 |
| 0.29580 | -0.03320 |
| 0.36138 | -0.03322 |
| 0.42232 | -0.03252 |
| 0.48560 | -0.03125 |
| 0.54849 | -0.02919 |
| 0.60979 | -0.02634 |
| 0.67166 | -0.02206 |
| 0.73181 | -0.01757 |
| 0.77283 | -0.01466 |
| 0.81335 | -0.01179 |
| 0.84864 | -0.00910 |
| 0.87676 | -0.00685 |
| 0.89785 | -0.00525 |
| 0.91888 | -0.00360 |
| 0.93566 | -0.00252 |
| 0.94851 | -0.00172 |
| 0.96113 | -0.00127 |
| 0.97256 | -0.00092 |
| 0.98297 | -0.00083 |
| 0.98875 | -0.00080 |
| 0.99902 | -0.00080 |
| 1.00000 | -0.00005 |

**SD7003**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99681 | 0.00031 |
| 0.98745 | 0.00132 |
| 0.97235 | 0.00310 |
| 0.95193 | 0.00547 |
| 0.92639 | 0.00824 |
| 0.89600 | 0.01139 |
| 0.86112 | 0.01494 |
| 0.82224 | 0.01884 |
| 0.77985 | 0.02304 |
| 0.73449 | 0.02744 |
| 0.68673 | 0.03197 |
| 0.63717 | 0.03649 |
| 0.58641 | 0.04086 |
| 0.53499 | 0.04494 |
| 0.48350 | 0.04859 |
| 0.43249 | 0.05171 |
| 0.38250 | 0.05415 |
| 0.33405 | 0.05581 |
| 0.28760 | 0.05658 |
| 0.24358 | 0.05639 |
| 0.20240 | 0.05518 |
| 0.16442 | 0.05292 |
| 0.12993 | 0.04961 |
| 0.09921 | 0.04526 |
| 0.07244 | 0.03993 |
| 0.04978 | 0.03372 |
| 0.03130 | 0.02677 |
| 0.01702 | 0.01932 |
| 0.00697 | 0.01172 |
| 0.00127 | 0.00438 |
| 0.00025 | -0.00186 |
| 0.00457 | -0.00741 |
| 0.01408 | -0.01285 |
| 0.02839 | -0.01759 |
| 0.04763 | -0.02141 |
| 0.07182 | -0.02438 |
| 0.10073 | -0.02660 |
| 0.13407 | -0.02809 |
| 0.17150 | -0.02888 |
| 0.21268 | -0.02900 |
| 0.25719 | -0.02852 |
| 0.30456 | -0.02752 |
| 0.35426 | -0.02608 |
| 0.40572 | -0.02428 |
| 0.45837 | -0.02217 |
| 0.51161 | -0.01980 |
| 0.56484 | -0.01723 |
| 0.61748 | -0.01450 |
| 0.66898 | -0.01167 |
| 0.71883 | -0.00887 |
| 0.76644 | -0.00628 |
| 0.81118 | -0.00403 |
| 0.85241 | -0.00220 |
| 0.88957 | -0.00082 |
| 0.92210 | 0.00008 |
| 0.94952 | 0.00052 |
| 0.97134 | 0.00057 |
| 0.98718 | 0.00037 |
| 0.99679 | 0.00011 |
| 1.00001 | 0.00000 |

**SD7003**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00009 |
| 0.99930 | 0.00181 |
| 0.99484 | 0.00228 |
| 0.98973 | 0.00282 |
| 0.98540 | 0.00319 |
| 0.98022 | 0.00377 |
| 0.97396 | 0.00438 |
| 0.96788 | 0.00494 |
| 0.96124 | 0.00560 |
| 0.94962 | 0.00669 |
| 0.93592 | 0.00810 |
| 0.92019 | 0.00954 |
| 0.89956 | 0.01165 |
| 0.87889 | 0.01356 |
| 0.84842 | 0.01648 |
| 0.81369 | 0.01979 |
| 0.77486 | 0.02353 |
| 0.73262 | 0.02755 |
| 0.67067 | 0.03331 |
| 0.60737 | 0.03899 |
| 0.54734 | 0.04392 |
| 0.48510 | 0.04838 |
| 0.42437 | 0.05202 |
| 0.36209 | 0.05478 |
| 0.30006 | 0.05629 |
| 0.23709 | 0.05612 |
| 0.19703 | 0.05464 |
| 0.17634 | 0.05336 |
| 0.15254 | 0.05138 |
| 0.12780 | 0.04869 |
| 0.11036 | 0.04624 |
| 0.09384 | 0.04344 |
| 0.07961 | 0.04058 |
| 0.06546 | 0.03722 |
| 0.05047 | 0.03289 |
| 0.04069 | 0.02953 |
| 0.03243 | 0.02625 |
| 0.02599 | 0.02342 |
| 0.02034 | 0.02069 |
| 0.01552 | 0.01802 |
| 0.01027 | 0.01445 |
| 0.00624 | 0.01081 |
| 0.00244 | 0.00612 |
| 0.00104 | 0.00377 |
| 0.00031 | -0.00204 |
| 0.00347 | -0.00683 |
| 0.00885 | -0.01060 |
| 0.01755 | -0.01436 |
| 0.02766 | -0.01756 |
| 0.03904 | -0.02054 |
| 0.05200 | -0.02324 |
| 0.06315 | -0.02501 |
| 0.07902 | -0.02678 |
| 0.10100 | -0.02841 |
| 0.12878 | -0.02970 |
| 0.16084 | -0.03050 |
| 0.19924 | -0.03067 |
| 0.24389 | -0.03013 |
| 0.30555 | -0.02867 |
| 0.36704 | -0.02680 |
| 0.43136 | -0.02445 |
| 0.49027 | -0.02195 |
| 0.55287 | -0.01896 |
| 0.61685 | -0.01558 |
| 0.67653 | -0.01223 |
| 0.74123 | -0.00858 |
| 0.78341 | -0.00630 |
| 0.82176 | -0.00428 |
| 0.85838 | -0.00238 |
| 0.88440 | -0.00133 |
| 0.90074 | -0.00064 |
| 0.91928 | -0.00014 |
| 0.93834 | 0.00002 |
| 0.95147 | -0.00006 |
| 0.96668 | -0.00043 |
| 0.97836 | -0.00097 |
| 0.98828 | -0.00152 |
| 0.99431 | -0.00177 |
| 1.00002 | -0.00181 |
| 1.00000 | -0.00009 |

**SD7032**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99674 | 0.00048 |
| 0.98712 | 0.00204 |
| 0.97155 | 0.00485 |
| 0.95054 | 0.00894 |
| 0.92464 | 0.01420 |
| 0.89436 | 0.02041 |
| 0.86021 | 0.02731 |
| 0.82264 | 0.03460 |
| 0.78208 | 0.04199 |
| 0.73892 | 0.04925 |
| 0.69356 | 0.05620 |
| 0.64646 | 0.06270 |
| 0.59812 | 0.06861 |
| 0.54902 | 0.07381 |
| 0.49967 | 0.07816 |
| 0.45058 | 0.08154 |
| 0.40222 | 0.08385 |
| 0.35506 | 0.08500 |
| 0.30953 | 0.08493 |
| 0.26604 | 0.08359 |
| 0.22499 | 0.08096 |
| 0.18671 | 0.07703 |
| 0.15146 | 0.07182 |
| 0.11948 | 0.06548 |
| 0.09105 | 0.05809 |
| 0.06627 | 0.04976 |
| 0.04524 | 0.04078 |
| 0.02812 | 0.03145 |
| 0.01502 | 0.02206 |
| 0.00606 | 0.01293 |
| 0.00115 | 0.00448 |
| 0.00038 | -0.00223 |
| 0.00532 | -0.00701 |
| 0.01649 | -0.01088 |
| 0.03308 | -0.01403 |
| 0.05491 | -0.01635 |
| 0.08180 | -0.01787 |
| 0.11351 | -0.01862 |
| 0.14974 | -0.01867 |
| 0.19010 | -0.01810 |
| 0.23420 | -0.01699 |

| | |
|---|---|
| 0.28153 | -0.01547 |
| 0.33154 | -0.01363 |
| 0.38364 | -0.01152 |
| 0.43724 | -0.00922 |
| 0.49176 | -0.00678 |
| 0.54659 | -0.00430 |
| 0.60112 | -0.00190 |
| 0.65469 | 0.00030 |
| 0.70664 | 0.00224 |
| 0.75634 | 0.00379 |
| 0.80313 | 0.00485 |
| 0.84635 | 0.00535 |
| 0.88534 | 0.00526 |
| 0.91942 | 0.00458 |
| 0.94797 | 0.00350 |
| 0.97054 | 0.00226 |
| 0.98684 | 0.00113 |
| 0.99670 | 0.00030 |
| 1.00000 | 0.00000 |

**SD7032**

actual model D

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00035 |
| 0.99864 | 0.00040 |
| 0.99665 | 0.00110 |
| 0.99353 | 0.00185 |
| 0.98888 | 0.00276 |
| 0.98259 | 0.00379 |
| 0.97541 | 0.00481 |
| 0.96809 | 0.00616 |
| 0.96252 | 0.00712 |
| 0.94859 | 0.00980 |
| 0.93704 | 0.01181 |
| 0.92652 | 0.01367 |
| 0.91821 | 0.01508 |
| 0.90582 | 0.01711 |
| 0.89075 | 0.01972 |
| 0.85677 | 0.02607 |
| 0.82499 | 0.03159 |
| 0.79355 | 0.03686 |
| 0.75266 | 0.04431 |
| 0.71060 | 0.05136 |
| 0.66862 | 0.05770 |
| 0.62429 | 0.06346 |
| 0.56871 | 0.06980 |
| 0.51073 | 0.07533 |
| 0.45314 | 0.07952 |
| 0.39660 | 0.08205 |
| 0.34046 | 0.08289 |
| 0.28613 | 0.08208 |
| 0.24396 | 0.07994 |
| 0.19704 | 0.07609 |
| 0.17147 | 0.07271 |
| 0.14238 | 0.06773 |
| 0.11459 | 0.06170 |
| 0.09965 | 0.05761 |
| 0.08841 | 0.05421 |
| 0.07620 | 0.05025 |
| 0.06239 | 0.04531 |
| 0.04837 | 0.03948 |
| 0.03818 | 0.03453 |
| 0.02912 | 0.02965 |
| 0.01986 | 0.02401 |
| 0.01227 | 0.01814 |
| 0.00787 | 0.01368 |
| 0.00240 | 0.00633 |
| 0.00023 | -0.00192 |
| 0.00280 | -0.00679 |
| 0.00928 | -0.01148 |
| 0.01264 | -0.01250 |
| 0.01846 | -0.01399 |
| 0.02881 | -0.01573 |
| 0.04723 | -0.01785 |
| 0.06062 | -0.01903 |
| 0.07656 | -0.02001 |
| 0.09187 | -0.02064 |
| 0.10349 | -0.02099 |
| 0.12003 | -0.02144 |
| 0.14868 | -0.02176 |
| 0.17685 | -0.02145 |
| 0.20472 | -0.02073 |
| 0.24431 | -0.01943 |
| 0.28925 | -0.01764 |
| 0.33962 | -0.01591 |
| 0.40103 | -0.01330 |
| 0.45698 | -0.01036 |
| 0.51631 | -0.00740 |
| 0.57476 | -0.00438 |
| 0.62875 | -0.00132 |
| 0.67810 | 0.00055 |
| 0.71802 | 0.00157 |
| 0.75935 | 0.00282 |
| 0.80501 | 0.00420 |
| 0.83600 | 0.00481 |
| 0.86820 | 0.00511 |
| 0.89605 | 0.00491 |
| 0.90948 | 0.00457 |
| 0.92313 | 0.00380 |
| 0.94075 | 0.00277 |
| 0.95357 | 0.00173 |
| 0.96655 | 0.00116 |
| 0.97922 | 0.00045 |
| 0.99036 | -0.00013 |
| 0.99484 | -0.00029 |
| 0.99844 | -0.00040 |
| 1.00000 | -0.00035 |

**SD7032**

actual model E

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | -0.00002 |
| 0.99604 | 0.00103 |
| 0.99174 | 0.00144 |
| 0.98543 | 0.00239 |
| 0.97848 | 0.00360 |
| 0.97068 | 0.00492 |
| 0.96224 | 0.00654 |
| 0.95405 | 0.00821 |
| 0.94438 | 0.01010 |
| 0.93313 | 0.01232 |
| 0.91812 | 0.01539 |
| 0.90203 | 0.01859 |
| 0.87770 | 0.02327 |
| 0.85205 | 0.02816 |
| 0.81421 | 0.03526 |
| 0.77184 | 0.04269 |
| 0.72898 | 0.04973 |
| 0.66868 | 0.05901 |
| 0.60720 | 0.06737 |
| 0.54130 | 0.07453 |
| 0.47884 | 0.07969 |
| 0.41734 | 0.08315 |
| 0.35286 | 0.08482 |
| 0.29265 | 0.08421 |
| 0.22164 | 0.07990 |
| 0.18166 | 0.07543 |
| 0.15363 | 0.07095 |
| 0.12851 | 0.06583 |
| 0.10848 | 0.06109 |
| 0.09024 | 0.05614 |
| 0.07700 | 0.05214 |
| 0.06371 | 0.04780 |
| 0.05270 | 0.04356 |
| 0.03901 | 0.03705 |
| 0.02749 | 0.03063 |
| 0.01674 | 0.02342 |
| 0.00879 | 0.01664 |
| 0.00034 | 0.00322 |
| 0.00040 | -0.00360 |
| 0.00455 | -0.00953 |
| 0.01247 | -0.01281 |
| 0.02075 | -0.01447 |
| 0.02898 | -0.01573 |
| 0.05026 | -0.01875 |
| 0.06704 | -0.01997 |
| 0.08723 | -0.02055 |
| 0.11218 | -0.02087 |
| 0.14554 | -0.02052 |
| 0.18027 | -0.01982 |
| 0.23716 | -0.01833 |
| 0.29788 | -0.01643 |
| 0.36224 | -0.01440 |
| 0.42552 | -0.01213 |
| 0.48858 | -0.01002 |
| 0.54975 | -0.00763 |
| 0.61762 | -0.00501 |
| 0.67933 | -0.00296 |
| 0.74312 | -0.00116 |
| 0.78526 | 0.00013 |
| 0.82732 | 0.00111 |
| 0.86321 | 0.00139 |
| 0.89349 | 0.00146 |
| 0.91412 | 0.00119 |
| 0.93708 | 0.00083 |
| 0.95104 | 0.00026 |
| 0.96729 | -0.00036 |
| 0.98134 | -0.00078 |
| 0.99034 | -0.00083 |
| 0.99826 | -0.00055 |
| 1.00000 | -0.00002 |

**SD7037**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99672 | 0.00042 |
| 0.98707 | 0.00180 |
| 0.97146 | 0.00436 |
| 0.95041 | 0.00811 |
| 0.92450 | 0.01295 |
| 0.89425 | 0.01865 |
| 0.86015 | 0.02490 |
| 0.82261 | 0.03141 |
| 0.78201 | 0.03788 |
| 0.73865 | 0.04413 |
| 0.69294 | 0.05011 |
| 0.64539 | 0.05572 |
| 0.59655 | 0.06085 |
| 0.54693 | 0.06538 |
| 0.49706 | 0.06917 |
| 0.44745 | 0.07211 |
| 0.39862 | 0.07410 |
| 0.35101 | 0.07504 |
| 0.30508 | 0.07488 |
| 0.26125 | 0.07358 |
| 0.21989 | 0.07113 |
| 0.18137 | 0.06754 |
| 0.14601 | 0.06286 |
| 0.11410 | 0.05715 |
| 0.08586 | 0.05049 |
| 0.06146 | 0.04300 |
| 0.04102 | 0.03486 |
| 0.02462 | 0.02632 |
| 0.01232 | 0.01770 |
| 0.00418 | 0.00936 |
| 0.00021 | 0.00185 |
| 0.00127 | -0.00393 |
| 0.00806 | -0.00839 |
| 0.02038 | -0.01227 |
| 0.03800 | -0.01541 |
| 0.06074 | -0.01777 |
| 0.08844 | -0.01934 |
| 0.12084 | -0.02017 |
| 0.15765 | -0.02032 |
| 0.19850 | -0.01987 |
| 0.24296 | -0.01891 |
| 0.29055 | -0.01754 |
| 0.34071 | -0.01586 |
| 0.39288 | -0.01396 |
| 0.44643 | -0.01190 |
| 0.50074 | -0.00976 |
| 0.55519 | -0.00760 |
| 0.60914 | -0.00549 |
| 0.66197 | -0.00349 |
| 0.71305 | -0.00168 |
| 0.76178 | -0.00014 |
| 0.80752 | 0.00104 |
| 0.84964 | 0.00182 |
| 0.88756 | 0.00220 |
| 0.92071 | 0.00218 |
| 0.94859 | 0.00185 |
| 0.97077 | 0.00132 |
| 0.98690 | 0.00071 |
| 0.99671 | 0.00021 |
| 1.00000 | 0.00000 |

**SD7037**

actual model A

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00010 |
| 0.99939 | 0.00020 |
| 0.99527 | 0.00090 |
| 0.99014 | 0.00163 |
| 0.98353 | 0.00263 |
| 0.97403 | 0.00417 |
| 0.96261 | 0.00617 |

| | |
|---|---|
| 0.95155 | 0.00837 |
| 0.93611 | 0.01114 |
| 0.92040 | 0.01426 |
| 0.89570 | 0.01832 |
| 0.87523 | 0.02168 |
| 0.84954 | 0.02595 |
| 0.81473 | 0.03151 |
| 0.77445 | 0.03798 |
| 0.73371 | 0.04426 |
| 0.67283 | 0.05179 |
| 0.60966 | 0.05842 |
| 0.54617 | 0.06407 |
| 0.48282 | 0.06857 |
| 0.42115 | 0.07073 |
| 0.35717 | 0.07218 |
| 0.29557 | 0.07174 |
| 0.23162 | 0.06859 |
| 0.18963 | 0.06476 |
| 0.14693 | 0.05875 |
| 0.11775 | 0.05343 |
| 0.08713 | 0.04632 |
| 0.06452 | 0.03971 |
| 0.05084 | 0.03504 |
| 0.03697 | 0.02983 |
| 0.02726 | 0.02581 |
| 0.01915 | 0.02154 |
| 0.01227 | 0.01678 |
| 0.00792 | 0.01314 |
| 0.00381 | 0.00873 |
| 0.00201 | 0.00608 |
| 0.00106 | 0.00411 |
| 0.00000 | -0.00114 |
| 0.00104 | -0.00405 |
| 0.00523 | -0.00834 |
| 0.01049 | -0.01095 |
| 0.01641 | -0.01278 |
| 0.02217 | -0.01413 |
| 0.03130 | -0.01547 |
| 0.04393 | -0.01670 |
| 0.05396 | -0.01754 |
| 0.07175 | -0.01882 |
| 0.09250 | -0.02009 |
| 0.12402 | -0.02118 |
| 0.15728 | -0.02178 |
| 0.19785 | -0.02160 |
| 0.23954 | -0.02063 |
| 0.30173 | -0.01914 |
| 0.36573 | -0.01710 |
| 0.42758 | -0.01477 |
| 0.48907 | -0.01271 |
| 0.55079 | -0.01026 |
| 0.61275 | -0.00788 |
| 0.67713 | -0.00581 |
| 0.74024 | -0.00400 |
| 0.78350 | -0.00276 |
| 0.82467 | -0.00189 |
| 0.86111 | -0.00124 |
| 0.89018 | -0.00112 |
| 0.91028 | -0.00083 |
| 0.93140 | -0.00068 |
| 0.94733 | -0.00051 |
| 0.96292 | -0.00036 |
| 0.97465 | -0.00027 |
| 0.98378 | -0.00029 |
| 0.99008 | -0.00028 |
| 0.99745 | -0.00020 |
| 1.00000 | 0.00010 |

**SD7037**
actual model B

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00024 |
| 0.99970 | 0.00101 |
| 0.99598 | 0.00202 |
| 0.99205 | 0.00266 |
| 0.98502 | 0.00365 |
| 0.97716 | 0.00484 |
| 0.96931 | 0.00617 |
| 0.96189 | 0.00740 |
| 0.95176 | 0.00908 |
| 0.93747 | 0.01138 |
| 0.92491 | 0.01353 |
| 0.90813 | 0.01654 |
| 0.89082 | 0.01969 |
| 0.87337 | 0.02265 |
| 0.84839 | 0.02689 |
| 0.82124 | 0.03133 |
| 0.77629 | 0.03808 |
| 0.73714 | 0.04373 |
| 0.67533 | 0.05168 |
| 0.61304 | 0.05864 |
| 0.55026 | 0.06448 |
| 0.48609 | 0.06920 |
| 0.42380 | 0.07261 |
| 0.36212 | 0.07430 |
| 0.29770 | 0.07411 |
| 0.23632 | 0.07153 |
| 0.19389 | 0.06803 |
| 0.15198 | 0.06297 |
| 0.12033 | 0.05764 |
| 0.09461 | 0.05214 |
| 0.07954 | 0.04827 |
| 0.06942 | 0.04532 |
| 0.05672 | 0.04144 |
| 0.04558 | 0.03723 |
| 0.03513 | 0.03261 |
| 0.02605 | 0.02761 |
| 0.01987 | 0.02350 |
| 0.01370 | 0.01882 |
| 0.01022 | 0.01598 |
| 0.00719 | 0.01306 |
| 0.00167 | 0.00588 |
| 0.00022 | 0.00212 |
| 0.00211 | -0.00668 |
| 0.00487 | -0.00914 |
| 0.01007 | -0.01186 |
| 0.01523 | -0.01365 |
| 0.02322 | -0.01605 |
| 0.02997 | -0.01761 |
| 0.04075 | -0.01936 |
| 0.05077 | -0.02039 |
| 0.06403 | -0.02134 |
| 0.07854 | -0.02223 |
| 0.09895 | -0.02280 |
| 0.13065 | -0.02300 |
| 0.15845 | -0.02281 |
| 0.20002 | -0.02238 |
| 0.24292 | -0.02137 |
| 0.30574 | -0.01912 |
| 0.36946 | -0.01644 |
| 0.43210 | -0.01382 |
| 0.49408 | -0.01144 |
| 0.55674 | -0.00899 |
| 0.61627 | -0.00666 |
| 0.68273 | -0.00401 |
| 0.74376 | -0.00163 |
| 0.78840 | -0.00022 |
| 0.82871 | 0.00066 |
| 0.86231 | 0.00116 |
| 0.89094 | 0.00125 |
| 0.90746 | 0.00133 |
| 0.92920 | 0.00109 |
| 0.94526 | 0.00087 |
| 0.95938 | 0.00051 |
| 0.97400 | 0.00017 |
| 0.98276 | -0.00013 |
| 0.99226 | -0.00073 |
| 0.99963 | -0.00101 |
| 1.00000 | 0.00024 |

**SD8000**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99674 | 0.00030 |
| 0.98711 | 0.00130 |
| 0.97148 | 0.00321 |
| 0.95032 | 0.00607 |
| 0.92413 | 0.00984 |
| 0.89343 | 0.01434 |
| 0.85871 | 0.01936 |
| 0.82042 | 0.02466 |
| 0.77899 | 0.03000 |
| 0.73481 | 0.03521 |
| 0.68831 | 0.04017 |
| 0.63998 | 0.04478 |
| 0.59034 | 0.04894 |
| 0.53991 | 0.05256 |
| 0.48921 | 0.05553 |
| 0.43875 | 0.05780 |
| 0.38905 | 0.05929 |
| 0.34062 | 0.05996 |
| 0.29395 | 0.05978 |
| 0.24951 | 0.05872 |
| 0.20775 | 0.05675 |
| 0.16906 | 0.05389 |
| 0.13380 | 0.05012 |
| 0.10229 | 0.04548 |
| 0.07476 | 0.04000 |
| 0.05142 | 0.03377 |
| 0.03238 | 0.02686 |
| 0.01766 | 0.01948 |
| 0.00729 | 0.01194 |
| 0.00136 | 0.00460 |
| 0.00022 | -0.00175 |
| 0.00440 | -0.00749 |
| 0.01370 | -0.01315 |
| 0.02780 | -0.01814 |
| 0.04677 | -0.02225 |
| 0.07058 | -0.02544 |
| 0.09914 | -0.02776 |
| 0.13219 | -0.02929 |
| 0.16941 | -0.03008 |
| 0.21041 | -0.03020 |
| 0.25477 | -0.02969 |
| 0.30202 | -0.02864 |
| 0.35163 | -0.02710 |
| 0.40307 | -0.02514 |
| 0.45576 | -0.02284 |
| 0.50913 | -0.02024 |
| 0.56263 | -0.01744 |
| 0.61566 | -0.01459 |
| 0.66757 | -0.01179 |
| 0.71773 | -0.00910 |
| 0.76556 | -0.00662 |
| 0.81047 | -0.00445 |
| 0.85185 | -0.00268 |
| 0.88910 | -0.00132 |
| 0.92170 | -0.00040 |
| 0.94916 | 0.00013 |
| 0.97105 | 0.00032 |
| 0.98700 | 0.00026 |
| 0.99673 | 0.00009 |
| 1.00001 | 0.00000 |

**SD8000**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00051 |
| 0.99900 | 0.00127 |
| 0.99466 | 0.00191 |
| 0.98934 | 0.00276 |
| 0.98377 | 0.00352 |
| 0.97797 | 0.00421 |
| 0.97139 | 0.00508 |
| 0.96266 | 0.00598 |
| 0.95123 | 0.00760 |
| 0.93681 | 0.00960 |
| 0.92195 | 0.01192 |
| 0.90020 | 0.01505 |
| 0.87714 | 0.01845 |
| 0.85101 | 0.02222 |
| 0.81648 | 0.02683 |
| 0.77368 | 0.03213 |
| 0.73223 | 0.03718 |
| 0.67079 | 0.04365 |
| 0.60486 | 0.04912 |
| 0.54669 | 0.05324 |
| 0.48480 | 0.05687 |
| 0.42339 | 0.05938 |
| 0.35904 | 0.06075 |
| 0.29645 | 0.06053 |
| 0.23380 | 0.05856 |
| 0.19549 | 0.05643 |
| 0.15215 | 0.05265 |
| 0.12015 | 0.04853 |
| 0.10415 | 0.04598 |
| 0.08874 | 0.04319 |
| 0.07551 | 0.04036 |
| 0.06034 | 0.03648 |
| 0.05324 | 0.03437 |
| 0.04460 | 0.03150 |
| 0.03627 | 0.02834 |
| 0.02778 | 0.02458 |
| 0.02165 | 0.02139 |
| 0.01569 | 0.01775 |
| 0.00865 | 0.01263 |
| 0.00485 | 0.00866 |

| | |
|---|---|
| 0.00064 | -0.00310 |
| 0.00268 | -0.00638 |
| 0.00629 | -0.00936 |
| 0.01227 | -0.01252 |
| 0.01719 | -0.01468 |
| 0.02222 | -0.01655 |
| 0.02657 | -0.01790 |
| 0.03833 | -0.02054 |
| 0.04884 | -0.02230 |
| 0.06105 | -0.02386 |
| 0.07541 | -0.02541 |
| 0.09852 | -0.02727 |
| 0.12534 | -0.02862 |
| 0.15997 | -0.02940 |
| 0.19782 | -0.02955 |
| 0.24327 | -0.02902 |
| 0.30405 | -0.02732 |
| 0.36741 | -0.02485 |
| 0.42792 | -0.02195 |
| 0.49041 | -0.01878 |
| 0.55391 | -0.01531 |
| 0.61699 | -0.01167 |
| 0.67610 | -0.00841 |
| 0.73884 | -0.00504 |
| 0.78108 | -0.00282 |
| 0.82102 | -0.00116 |
| 0.85989 | 0.00010 |
| 0.88821 | 0.00066 |
| 0.90521 | 0.00087 |
| 0.92671 | 0.00075 |
| 0.94213 | 0.00062 |
| 0.95687 | 0.00028 |
| 0.96956 | 0.00001 |
| 0.97878 | -0.00029 |
| 0.98453 | -0.00065 |
| 0.99052 | -0.00077 |
| 0.99846 | -0.00127 |
| 1.00000 | 0.00051 |

**SD8020**

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00000 |
| 0.99646 | 0.00027 |
| 0.98625 | 0.00131 |
| 0.97017 | 0.00330 |
| 0.94885 | 0.00591 |
| 0.92247 | 0.00876 |
| 0.89118 | 0.01188 |
| 0.85538 | 0.01532 |
| 0.81560 | 0.01908 |
| 0.77237 | 0.02308 |
| 0.72627 | 0.02722 |
| 0.67789 | 0.03135 |
| 0.62777 | 0.03535 |
| 0.57647 | 0.03909 |
| 0.52456 | 0.04246 |
| 0.47261 | 0.04536 |
| 0.42116 | 0.04770 |
| 0.37077 | 0.04938 |
| 0.32196 | 0.05034 |
| 0.27523 | 0.05051 |
| 0.23106 | 0.04982 |
| 0.18987 | 0.04824 |
| 0.15203 | 0.04574 |
| 0.11789 | 0.04233 |
| 0.08774 | 0.03802 |
| 0.06179 | 0.03287 |
| 0.04024 | 0.02697 |
| 0.02318 | 0.02041 |
| 0.01065 | 0.01345 |
| 0.00276 | 0.00645 |
| 0.00000 | 0.00000 |
| 0.00276 | -0.00645 |
| 0.01066 | -0.01345 |
| 0.02319 | -0.02041 |
| 0.04024 | -0.02697 |
| 0.06180 | -0.03287 |
| 0.08774 | -0.03802 |
| 0.11790 | -0.04233 |
| 0.15204 | -0.04574 |
| 0.18987 | -0.04824 |
| 0.23107 | -0.04982 |
| 0.27524 | -0.05051 |
| 0.32197 | -0.05034 |
| 0.37077 | -0.04938 |
| 0.42117 | -0.04769 |
| 0.47262 | -0.04536 |
| 0.52457 | -0.04246 |
| 0.57648 | -0.03908 |
| 0.62778 | -0.03534 |
| 0.67790 | -0.03135 |
| 0.72629 | -0.02722 |
| 0.77238 | -0.02308 |
| 0.81561 | -0.01907 |
| 0.85539 | -0.01532 |
| 0.89119 | -0.01188 |
| 0.92248 | -0.00876 |
| 0.94886 | -0.00591 |
| 0.97018 | -0.00330 |
| 0.98626 | -0.00131 |
| 0.99647 | -0.00027 |
| 1.00000 | 0.00000 |

**SD8020**
actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00011 |
| 0.99546 | 0.00173 |
| 0.99166 | 0.00204 |
| 0.98736 | 0.00239 |
| 0.98111 | 0.00284 |
| 0.97326 | 0.00346 |
| 0.96549 | 0.00406 |
| 0.95378 | 0.00509 |
| 0.93947 | 0.00648 |
| 0.92296 | 0.00797 |
| 0.90064 | 0.01003 |
| 0.88305 | 0.01164 |
| 0.85620 | 0.01421 |
| 0.81837 | 0.01774 |
| 0.77897 | 0.02135 |
| 0.73462 | 0.02528 |
| 0.67566 | 0.03030 |
| 0.61081 | 0.03524 |
| 0.55035 | 0.03943 |
| 0.48701 | 0.04337 |
| 0.41960 | 0.04683 |
| 0.35578 | 0.04908 |
| 0.29098 | 0.05021 |
| 0.23096 | 0.04966 |
| 0.19250 | 0.04838 |
| 0.16513 | 0.04683 |
| 0.14181 | 0.04497 |
| 0.11555 | 0.04230 |
| 0.09471 | 0.03947 |
| 0.07409 | 0.03594 |
| 0.05620 | 0.03208 |
| 0.04384 | 0.02876 |
| 0.03327 | 0.02534 |
| 0.02199 | 0.02080 |
| 0.01428 | 0.01681 |
| 0.00757 | 0.01239 |
| 0.00311 | 0.00799 |
| 0.00147 | 0.00536 |
| 0.00047 | -0.00298 |
| 0.00096 | -0.00428 |
| 0.00279 | -0.00745 |
| 0.00737 | -0.01163 |
| 0.01322 | -0.01524 |
| 0.01678 | -0.01716 |
| 0.02298 | -0.02022 |
| 0.02831 | -0.02247 |
| 0.03865 | -0.02621 |
| 0.05296 | -0.03047 |
| 0.06671 | -0.03381 |
| 0.09061 | -0.03838 |
| 0.12098 | -0.04271 |
| 0.14971 | -0.04583 |
| 0.19223 | -0.04893 |
| 0.23731 | -0.05068 |
| 0.29757 | -0.05124 |
| 0.36030 | -0.05009 |
| 0.42266 | -0.04822 |
| 0.48291 | -0.04564 |
| 0.55072 | -0.04195 |
| 0.61223 | -0.03786 |
| 0.66813 | -0.03355 |
| 0.73482 | -0.02784 |
| 0.78040 | -0.02364 |
| 0.81835 | -0.02010 |
| 0.85535 | -0.01637 |
| 0.88453 | -0.01350 |
| 0.90299 | -0.01163 |
| 0.92111 | -0.00969 |
| 0.93656 | -0.00809 |
| 0.95033 | -0.00657 |
| 0.96385 | -0.00508 |
| 0.97644 | -0.00373 |
| 0.98576 | -0.00269 |
| 0.99371 | -0.00177 |
| 0.99930 | -0.00111 |
| 1.00000 | 0.00011 |

**WASP**
smoothed model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00007 |
| 0.99754 | 0.00132 |
| 0.99070 | 0.00392 |
| 0.98037 | 0.00632 |
| 0.96698 | 0.00831 |
| 0.95044 | 0.01060 |
| 0.93064 | 0.01373 |
| 0.90775 | 0.01754 |
| 0.88202 | 0.02173 |
| 0.85370 | 0.02616 |
| 0.82309 | 0.03071 |
| 0.79048 | 0.03534 |
| 0.75616 | 0.04001 |
| 0.72043 | 0.04467 |
| 0.68359 | 0.04923 |
| 0.64594 | 0.05362 |
| 0.60778 | 0.05775 |
| 0.56937 | 0.06154 |
| 0.53099 | 0.06495 |
| 0.49265 | 0.06796 |
| 0.45435 | 0.07055 |
| 0.41638 | 0.07265 |
| 0.37887 | 0.07421 |
| 0.34204 | 0.07514 |
| 0.30609 | 0.07537 |
| 0.27120 | 0.07482 |
| 0.23760 | 0.07345 |
| 0.20549 | 0.07122 |
| 0.17504 | 0.06813 |
| 0.14648 | 0.06419 |
| 0.11999 | 0.05944 |
| 0.09576 | 0.05388 |
| 0.07395 | 0.04750 |
| 0.05468 | 0.04040 |
| 0.03811 | 0.03288 |
| 0.02433 | 0.02528 |
| 0.01338 | 0.01779 |
| 0.00548 | 0.01060 |
| 0.00098 | 0.00395 |
| 0.00000 | -0.00042 |
| 0.00098 | -0.00434 |
| 0.00548 | -0.00897 |
| 0.01338 | -0.01273 |
| 0.02433 | -0.01570 |
| 0.03811 | -0.01799 |
| 0.05468 | -0.01973 |
| 0.07395 | -0.02094 |
| 0.09576 | -0.02167 |
| 0.11999 | -0.02197 |
| 0.14648 | -0.02189 |
| 0.17504 | -0.02147 |
| 0.20549 | -0.02077 |
| 0.23760 | -0.01984 |
| 0.27120 | -0.01872 |
| 0.30609 | -0.01746 |
| 0.34204 | -0.01608 |
| 0.37887 | -0.01462 |
| 0.41638 | -0.01309 |
| 0.45435 | -0.01154 |
| 0.49265 | -0.01002 |
| 0.53099 | -0.00856 |
| 0.56937 | -0.00723 |
| 0.60778 | -0.00604 |
| 0.64594 | -0.00503 |
| 0.68359 | -0.00420 |
| 0.72043 | -0.00353 |
| 0.75616 | -0.00299 |
| 0.79048 | -0.00258 |
| 0.82309 | -0.00231 |
| 0.85370 | -0.00220 |
| 0.88202 | -0.00223 |

| | |
|---|---|
| 0.90775 | -0.00237 |
| 0.93064 | -0.00258 |
| 0.95044 | -0.00291 |
| 0.96698 | -0.00323 |
| 0.98037 | -0.00313 |
| 0.99070 | -0.00225 |
| 0.99754 | -0.00088 |
| 1.00000 | -0.00016 |

**WASP**

actual model

| $x/c$ | $y/c$ |
|---|---|
| 1.00000 | 0.00022 |
| 0.99989 | 0.00203 |
| 0.99585 | 0.00302 |
| 0.99190 | 0.00379 |
| 0.98579 | 0.00488 |
| 0.97399 | 0.00695 |
| 0.96060 | 0.00911 |
| 0.94952 | 0.01089 |
| 0.93443 | 0.01328 |
| 0.91987 | 0.01570 |
| 0.90601 | 0.01794 |
| 0.89170 | 0.02022 |
| 0.85854 | 0.02554 |
| 0.82573 | 0.03052 |
| 0.79503 | 0.03488 |
| 0.75211 | 0.04053 |
| 0.70872 | 0.04628 |
| 0.66522 | 0.05145 |
| 0.62163 | 0.05638 |
| 0.56465 | 0.06215 |
| 0.50733 | 0.06700 |
| 0.45447 | 0.07061 |
| 0.39619 | 0.07338 |
| 0.34099 | 0.07507 |
| 0.28274 | 0.07524 |
| 0.23843 | 0.07380 |
| 0.19210 | 0.07018 |
| 0.16650 | 0.06712 |
| 0.13833 | 0.06281 |
| 0.10969 | 0.05728 |
| 0.09819 | 0.05462 |
| 0.08388 | 0.05084 |
| 0.07039 | 0.04660 |
| 0.05665 | 0.04146 |
| 0.04371 | 0.03570 |
| 0.02744 | 0.02701 |
| 0.01496 | 0.01888 |
| 0.00498 | 0.01006 |
| 0.00027 | 0.00234 |
| 0.00073 | -0.00390 |
| 0.00431 | -0.00827 |
| 0.00993 | -0.01125 |
| 0.01686 | -0.01374 |
| 0.02494 | -0.01574 |
| 0.03330 | -0.01723 |
| 0.04439 | -0.01867 |
| 0.06175 | -0.02015 |
| 0.07602 | -0.02094 |
| 0.09099 | -0.02147 |
| 0.10561 | -0.02174 |
| 0.11860 | -0.02182 |
| 0.14807 | -0.02164 |
| 0.17424 | -0.02130 |
| 0.20582 | -0.02070 |
| 0.24853 | -0.01931 |
| 0.28925 | -0.01776 |
| 0.35038 | -0.01538 |
| 0.40203 | -0.01347 |
| 0.46036 | -0.01114 |
| 0.51593 | -0.00881 |
| 0.57793 | -0.00632 |
| 0.63048 | -0.00502 |
| 0.67423 | -0.00409 |
| 0.71664 | -0.00333 |
| 0.75867 | -0.00260 |
| 0.80236 | -0.00197 |
| 0.83345 | -0.00170 |
| 0.86509 | -0.00178 |
| 0.89302 | -0.00204 |
| 0.90911 | -0.00212 |
| 0.92227 | -0.00220 |
| 0.94096 | -0.00227 |
| 0.95520 | -0.00219 |
| 0.96798 | -0.00221 |
| 0.97706 | -0.00222 |
| 0.98496 | -0.00219 |
| 0.99773 | -0.00203 |
| 1.00000 | 0.00022 |

# Appendix B

# Airfoil Polar Data

All of the polar data shown in Chapter 4 is listed in this appendix and identified by airfoil name, figure number, and run number. This same data in addition to the four spanwise $C_d$ values used to obtain the average $C_d$ are included with the data distribution disk. Also included on the disk but not listed here is the lift data plotted in the $C_l$-$\alpha$ curves shown in Chapter 4.

**A18**
Fig. 4.3

Run: 278
$Re = 40400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.20 | 0.120 | 0.0257 |
| 0.88 | 0.329 | 0.0213 |
| 2.77 | 0.543 | 0.0371 |
| 5.00 | 0.839 | 0.0438 |
| 6.98 | 1.002 | 0.0346 |
| 9.01 | 1.101 | 0.0315 |
| 11.03 | 1.133 | 0.0632 |

Run: 161
$Re = 61300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.11 | 0.028 | 0.0235 |
| -0.22 | 0.220 | 0.0190 |
| 1.09 | 0.412 | 0.0212 |
| 2.39 | 0.594 | 0.0230 |
| 4.11 | 0.809 | 0.0251 |
| 5.96 | 0.964 | 0.0229 |
| 7.55 | 1.049 | 0.0268 |
| 9.08 | 1.127 | 0.0353 |
| 10.34 | 1.166 | 0.0439 |

Run: 163
$Re = 101700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.57 | 0.085 | 0.0188 |
| -0.41 | 0.270 | 0.0146 |
| 1.05 | 0.472 | 0.0156 |
| 2.77 | 0.655 | 0.0172 |
| 4.32 | 0.787 | 0.0166 |
| 5.88 | 0.917 | 0.0181 |
| 7.54 | 1.014 | 0.0264 |
| 8.94 | 1.090 | 0.0332 |
| 10.11 | 1.126 | 0.0404 |

Run: 165
$Re = 203800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.60 | 0.201 | 0.0131 |
| 0.12 | 0.389 | 0.0098 |
| 1.48 | 0.528 | 0.0095 |
| 2.88 | 0.674 | 0.0107 |
| 4.32 | 0.807 | 0.0127 |
| 5.54 | 0.900 | 0.0152 |
| 7.44 | 1.033 | 0.0215 |
| 8.86 | 1.117 | 0.0276 |
| 10.15 | 1.169 | 0.0351 |

Run: 521
$Re = 203800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.33 | -0.380 | 0.0668 |
| -3.43 | -0.095 | 0.0180 |

Run: 167
$Re = 303300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.42 | 0.124 | 0.0111 |
| -0.49 | 0.330 | 0.0104 |
| 0.89 | 0.476 | 0.0084 |
| 2.34 | 0.623 | 0.0088 |
| 4.22 | 0.789 | 0.0107 |
| 5.75 | 0.908 | 0.0152 |
| 7.87 | 1.064 | 0.0214 |
| 9.25 | 1.138 | 0.0260 |
| 10.21 | 1.171 | 0.0328 |

Run: 522
$Re = 304800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.39 | -0.338 | 0.0613 |
| -3.63 | -0.058 | 0.0139 |

**BE50**
Fig. 4.7

Run: 570
$Re = 60900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.74 | 0.032 | 0.0206 |
| -0.13 | 0.192 | 0.0165 |
| 1.35 | 0.442 | 0.0148 |
| 2.98 | 0.623 | 0.0196 |
| 4.51 | 0.763 | 0.0244 |
| 5.78 | 0.867 | 0.0214 |
| 7.45 | 0.993 | 0.0301 |
| 9.03 | 1.108 | 0.0326 |
| 10.51 | 1.188 | 0.0386 |

Run: 572
$Re = 101800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.48 | -0.132 | 0.0274 |
| -1.75 | 0.020 | 0.0178 |
| -0.28 | 0.238 | 0.0130 |
| 1.42 | 0.467 | 0.0131 |
| 3.45 | 0.655 | 0.0157 |
| 4.29 | 0.731 | 0.0171 |
| 5.97 | 0.876 | 0.0211 |
| 7.31 | 0.987 | 0.0247 |
| 9.21 | 1.131 | 0.0301 |
| 10.37 | 1.179 | 0.0367 |

Run: 574
$Re = 203100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.41 | -0.370 | 0.0690 |
| -3.12 | -0.091 | 0.0188 |
| -1.73 | 0.102 | 0.0127 |
| -0.44 | 0.247 | 0.0103 |
| 1.28 | 0.437 | 0.0092 |
| 2.80 | 0.591 | 0.0104 |
| 4.37 | 0.738 | 0.0129 |
| 5.71 | 0.860 | 0.0159 |
| 7.55 | 1.020 | 0.0191 |
| 8.82 | 1.114 | 0.0226 |
| 10.37 | 1.186 | 0.0335 |

Run: 576
$Re = 304800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.10 | -0.326 | 0.0608 |
| -3.44 | -0.089 | 0.0172 |
| -2.19 | 0.069 | 0.0120 |
| -0.34 | 0.264 | 0.0095 |
| 1.23 | 0.430 | 0.0080 |
| 2.90 | 0.597 | 0.0093 |
| 4.32 | 0.734 | 0.0112 |
| 6.20 | 0.917 | 0.0145 |
| 7.73 | 1.049 | 0.0174 |
| 9.17 | 1.140 | 0.0226 |
| 10.47 | 1.200 | 0.0307 |

**CH 10-48-13**
Fig. 4.11

Run: 156
$Re = 203200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 1.30 | 0.949 | 0.0202 |
| 2.30 | 1.040 | 0.0197 |
| 3.41 | 1.139 | 0.0194 |
| 5.17 | 1.283 | 0.0210 |
| 7.26 | 1.467 | 0.0242 |
| 9.52 | 1.647 | 0.0292 |
| 11.67 | 1.806 | 0.0363 |

Run: 560
$Re = 203900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.08 | 0.327 | 0.0535 |
| -0.48 | 0.693 | 0.0300 |

**E374 (B)**
Fig. 4.15

Run: 69
$Re = 61500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.39 | -0.439 | 0.0338 |
| -5.31 | -0.384 | 0.0287 |
| -4.28 | -0.324 | 0.0224 |
| -3.29 | -0.237 | 0.0167 |
| -2.32 | -0.159 | 0.0168 |
| -1.21 | -0.015 | 0.0191 |
| -0.19 | 0.105 | 0.0222 |
| 0.88 | 0.256 | 0.0264 |
| 1.84 | 0.364 | 0.0288 |
| 2.96 | 0.429 | 0.0332 |
| 3.90 | 0.521 | 0.0357 |
| 4.93 | 0.669 | 0.0354 |
| 5.99 | 0.786 | 0.0351 |
| 6.98 | 0.883 | 0.0302 |
| 7.97 | 0.952 | 0.0293 |
| 8.97 | 0.980 | 0.0318 |
| 9.98 | 1.013 | 0.0400 |

Run: 67
$Re = 102300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.23 | -0.303 | 0.0205 |
| -3.32 | -0.186 | 0.0158 |
| -2.25 | -0.013 | 0.0155 |
| -1.12 | 0.154 | 0.0194 |
| -0.25 | 0.239 | 0.0207 |
| 0.80 | 0.316 | 0.0230 |
| 1.83 | 0.400 | 0.0262 |
| 2.82 | 0.492 | 0.0284 |
| 3.98 | 0.608 | 0.0291 |
| 5.00 | 0.709 | 0.0242 |
| 5.94 | 0.802 | 0.0213 |
| 6.99 | 0.900 | 0.0200 |
| 7.99 | 0.942 | 0.0264 |
| 8.92 | 0.967 | 0.0340 |
| 9.98 | 1.002 | 0.0452 |

Run: 503
$Re = 102200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.38 | -0.468 | 0.0320 |
| -5.39 | -0.425 | 0.0252 |
| -4.36 | -0.337 | 0.0203 |

Run: 502
$Re = 153100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.45 | -0.475 | 0.0291 |
| -5.26 | -0.389 | 0.0201 |
| -4.27 | -0.240 | 0.0162 |
| -3.13 | -0.101 | 0.0127 |
| -2.23 | -0.032 | 0.0131 |
| -1.10 | 0.083 | 0.0146 |
| -0.21 | 0.238 | 0.0144 |
| 0.84 | 0.334 | 0.0152 |
| 1.80 | 0.419 | 0.0162 |
| 2.91 | 0.523 | 0.0176 |
| 3.94 | 0.621 | 0.0179 |
| 4.87 | 0.712 | 0.0171 |
| 5.88 | 0.806 | 0.0164 |
| 7.00 | 0.902 | 0.0176 |
| 8.02 | 0.938 | 0.0267 |
| 9.00 | 0.974 | 0.0334 |
| 9.97 | 1.004 | 0.0416 |

Run: 65
$Re = 204000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.38 | -0.449 | 0.0221 |
| -5.33 | -0.311 | 0.0168 |
| -4.29 | -0.180 | 0.0135 |
| -3.30 | -0.098 | 0.0116 |
| -2.29 | -0.023 | 0.0110 |
| -1.22 | 0.080 | 0.0117 |
| -0.17 | 0.236 | 0.0115 |
| 0.83 | 0.338 | 0.0121 |
| 1.78 | 0.421 | 0.0128 |
| 2.82 | 0.517 | 0.0135 |
| 3.85 | 0.615 | 0.0138 |
| 4.97 | 0.726 | 0.0138 |
| 5.90 | 0.813 | 0.0140 |
| 6.89 | 0.886 | 0.0164 |
| 7.93 | 0.922 | 0.0242 |
| 8.94 | 0.961 | 0.0304 |
| 9.95 | 0.993 | 0.0393 |

Run: 63
$Re = 304900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.37 | -0.416 | 0.0195 |
| -5.29 | -0.289 | 0.0146 |
| -4.14 | -0.192 | 0.0127 |
| -3.08 | -0.099 | 0.0108 |
| -2.11 | -0.013 | 0.0092 |
| -1.05 | 0.079 | 0.0094 |
| -0.02 | 0.194 | 0.0091 |
| 1.02 | 0.352 | 0.0098 |
| 2.06 | 0.453 | 0.0102 |
| 3.06 | 0.551 | 0.0107 |
| 4.06 | 0.652 | 0.0111 |
| 5.13 | 0.756 | 0.0112 |
| 6.05 | 0.838 | 0.0121 |

| | | |
|---|---|---|
| 6.93 | 0.891 | 0.0164 |
| 8.00 | 0.940 | 0.0228 |
| 9.08 | 0.986 | 0.0289 |
| 10.10 | 1.016 | 0.0374 |

## E387 (A)

Fig. 4.19

Run: 209
$Re = 61500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.36 | -0.255 | 0.0425 |
| -3.71 | -0.127 | 0.0248 |
| -2.12 | 0.059 | 0.0240 |
| -0.68 | 0.250 | 0.0237 |
| 0.92 | 0.439 | 0.0296 |
| 2.58 | 0.611 | 0.0346 |
| 4.17 | 0.769 | 0.0400 |
| 5.40 | 0.880 | 0.0421 |
| 6.98 | 1.026 | 0.0415 |
| 8.80 | 1.183 | 0.0287 |
| 10.13 | 1.201 | 0.0437 |

Run: 211
$Re = 101800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.37 | -0.294 | 0.0471 |
| -3.61 | -0.067 | 0.0229 |
| -2.04 | 0.146 | 0.0167 |
| -0.49 | 0.311 | 0.0170 |
| 0.81 | 0.436 | 0.0195 |
| 2.45 | 0.590 | 0.0221 |
| 3.85 | 0.721 | 0.0229 |
| 5.60 | 0.890 | 0.0229 |
| 6.91 | 1.014 | 0.0226 |
| 8.68 | 1.150 | 0.0251 |
| 10.10 | 1.169 | 0.0422 |

Run: 555
$Re = 152700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.30 | -0.296 | 0.0491 |
| -3.46 | -0.030 | 0.0191 |
| -2.11 | 0.103 | 0.0141 |
| -0.50 | 0.258 | 0.0120 |
| 0.83 | 0.398 | 0.0132 |
| 2.53 | 0.577 | 0.0157 |
| 4.06 | 0.732 | 0.0179 |
| 5.64 | 0.887 | 0.0182 |
| 7.05 | 1.018 | 0.0184 |
| 8.63 | 1.126 | 0.0245 |
| 10.02 | 1.159 | 0.0385 |

Run: 213
$Re = 203800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.65 | -0.145 | 0.0237 |
| -3.35 | -0.010 | 0.0158 |
| -1.97 | 0.121 | 0.0119 |
| -0.37 | 0.281 | 0.0104 |
| 1.27 | 0.454 | 0.0116 |
| 2.67 | 0.599 | 0.0130 |
| 4.23 | 0.761 | 0.0142 |
| 5.59 | 0.893 | 0.0149 |
| 7.23 | 1.042 | 0.0163 |
| 8.77 | 1.127 | 0.0259 |
| 10.16 | 1.164 | 0.0378 |

Run: 215
$Re = 305200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.45 | -0.235 | 0.0406 |
| -3.92 | -0.077 | 0.0163 |
| -2.24 | 0.085 | 0.0116 |
| -0.24 | 0.289 | 0.0085 |
| 1.04 | 0.429 | 0.0092 |
| 2.53 | 0.587 | 0.0100 |
| 4.07 | 0.748 | 0.0113 |
| 5.93 | 0.931 | 0.0125 |
| 6.93 | 1.013 | 0.0140 |
| 8.44 | 1.103 | 0.0212 |
| 9.91 | 1.156 | 0.0322 |

## FX 63-137 (B)

Fig. 4.23

Run: 159
$Re = 102100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.05 | -0.019 | 0.0481 |
| -3.74 | 0.174 | 0.0382 |
| -2.87 | 0.289 | 0.0364 |
| -1.91 | 0.398 | 0.0364 |
| -0.58 | 0.494 | 0.0441 |
| 0.36 | 0.563 | 0.0510 |
| 1.28 | 0.619 | 0.0538 |
| 2.26 | 0.677 | 0.0590 |
| 3.46 | 0.772 | 0.0657 |
| 4.39 | 1.007 | 0.0498 |
| 5.62 | 1.211 | 0.0378 |
| 6.50 | 1.304 | 0.0351 |
| 7.49 | 1.397 | 0.0336 |
| 8.31 | 1.459 | 0.0336 |
| 9.68 | 1.558 | 0.0337 |
| 10.53 | 1.608 | 0.0365 |
| 11.40 | 1.646 | 0.0403 |
| 12.96 | 1.677 | 0.0513 |

Run: 154
$Re = 204000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.79 | 0.144 | 0.0265 |
| -4.74 | 0.264 | 0.0203 |
| -3.65 | 0.379 | 0.0175 |
| -2.54 | 0.509 | 0.0155 |
| -1.62 | 0.604 | 0.0159 |
| -0.43 | 0.725 | 0.0173 |
| 0.85 | 0.854 | 0.0183 |
| 1.40 | 0.907 | 0.0185 |
| 2.61 | 1.024 | 0.0192 |
| 3.97 | 1.155 | 0.0194 |
| 4.65 | 1.213 | 0.0194 |
| 5.86 | 1.318 | 0.0194 |
| 6.74 | 1.401 | 0.0201 |
| 8.25 | 1.518 | 0.0217 |
| 9.10 | 1.574 | 0.0237 |
| 10.47 | 1.641 | 0.0284 |
| 10.66 | 1.647 | 0.0297 |
| 11.93 | 1.672 | 0.0366 |
| 12.82 | 1.671 | 0.0456 |

Run: 506
$Re = 254900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.29 | 0.084 | 0.0312 |
| -4.91 | 0.241 | 0.0184 |
| -3.88 | 0.355 | 0.0158 |
| -2.75 | 0.483 | 0.0135 |
| -1.82 | 0.587 | 0.0136 |
| -0.75 | 0.694 | 0.0144 |
| 0.23 | 0.790 | 0.0151 |
| 1.23 | 0.886 | 0.0158 |
| 2.32 | 0.995 | 0.0164 |
| 3.34 | 1.094 | 0.0167 |
| 4.32 | 1.183 | 0.0171 |
| 5.33 | 1.271 | 0.0173 |
| 6.46 | 1.363 | 0.0176 |
| 7.47 | 1.446 | 0.0186 |
| 8.30 | 1.503 | 0.0199 |
| 9.46 | 1.574 | 0.0233 |
| 10.47 | 1.625 | 0.0267 |
| 11.56 | 1.657 | 0.0330 |

Run: 511
$Re = 306300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.82 | 0.144 | 0.0207 |
| -4.87 | 0.249 | 0.0167 |
| -3.85 | 0.363 | 0.0146 |
| -2.80 | 0.481 | 0.0127 |
| -1.75 | 0.599 | 0.0123 |
| -0.73 | 0.704 | 0.0129 |
| 0.32 | 0.807 | 0.0136 |
| 1.33 | 0.907 | 0.0143 |
| 2.33 | 1.008 | 0.0147 |
| 3.34 | 1.104 | 0.0151 |
| 4.42 | 1.212 | 0.0156 |
| 5.43 | 1.300 | 0.0163 |
| 6.39 | 1.371 | 0.0163 |
| 7.46 | 1.454 | 0.0175 |
| 8.49 | 1.522 | 0.0195 |
| 9.53 | 1.583 | 0.0225 |
| 10.51 | 1.628 | 0.0262 |
| 11.49 | 1.657 | 0.0321 |

## FX 74-CL5-140 MOD

Fig. 4.27

Run: 185
$Re = 202800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.81 | 0.607 | 0.0401 |
| -0.49 | 0.852 | 0.0279 |
| 1.18 | 1.036 | 0.0246 |
| 2.68 | 1.181 | 0.0235 |
| 4.23 | 1.320 | 0.0264 |
| 5.57 | 1.433 | 0.0288 |
| 7.38 | 1.576 | 0.0328 |
| 9.00 | 1.692 | 0.0369 |
| 10.43 | 1.784 | 0.0410 |

## GEMINI

Fig. 4.31

Run: 217
$Re = 102300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -7.00 | -0.521 | 0.0270 |
| -3.28 | -0.074 | 0.0156 |
| -2.71 | -0.028 | 0.0170 |
| -1.08 | 0.101 | 0.0171 |
| 0.55 | 0.360 | 0.0203 |
| 2.07 | 0.504 | 0.0186 |
| 3.63 | 0.624 | 0.0196 |
| 5.12 | 0.755 | 0.0240 |
| 6.43 | 0.859 | 0.0261 |
| 8.27 | 1.007 | 0.0289 |
| 9.60 | 1.111 | 0.0299 |
| 11.02 | 1.197 | 0.0324 |
| 12.63 | 1.179 | 0.0409 |

Run: 219
$Re = 204100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -7.04 | -0.391 | 0.0189 |
| -5.60 | -0.269 | 0.0148 |
| -3.85 | -0.138 | 0.0119 |
| -2.47 | -0.022 | 0.0119 |
| -1.14 | 0.103 | 0.0120 |
| 0.38 | 0.251 | 0.0124 |
| 2.10 | 0.477 | 0.0125 |
| 3.55 | 0.641 | 0.0137 |
| 5.14 | 0.773 | 0.0160 |
| 7.03 | 0.937 | 0.0200 |
| 8.19 | 1.033 | 0.0217 |
| 9.76 | 1.137 | 0.0229 |
| 11.10 | 1.136 | 0.0342 |
| 12.65 | 1.093 | 0.0538 |

Run: 221
$Re = 306100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.76 | -0.291 | 0.0146 |
| -4.53 | -0.193 | 0.0122 |
| -2.47 | -0.020 | 0.0106 |
| -1.29 | 0.093 | 0.0103 |
| 0.76 | 0.310 | 0.0103 |
| 2.07 | 0.452 | 0.0114 |
| 3.58 | 0.634 | 0.0134 |
| 5.22 | 0.793 | 0.0136 |
| 6.85 | 0.938 | 0.0163 |
| 8.25 | 1.056 | 0.0178 |
| 9.57 | 1.113 | 0.0200 |
| 11.22 | 1.111 | 0.0351 |

## GM15

Fig. 4.36

Run: 404
$Re = 40900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.61 | -0.072 | 0.0504 |
| -1.52 | 0.160 | 0.0271 |
| 0.66 | 0.368 | 0.0235 |
| 2.60 | 0.594 | 0.0233 |
| 4.59 | 0.869 | 0.0320 |

| | | |
|---|---|---|
| 6.81 | 1.086 | 0.0286 |
| 8.73 | 1.179 | 0.0286 |
| 9.92 | 1.239 | 0.0292 |

Run: 405
$Re = 39200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 10.95 | 1.257 | 0.0507 |

Run: 401
$Re = 61300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.59 | -0.033 | 0.0399 |
| -1.91 | 0.166 | 0.0217 |
| -0.38 | 0.316 | 0.0216 |
| 1.07 | 0.471 | 0.0186 |
| 2.71 | 0.720 | 0.0226 |
| 4.26 | 0.910 | 0.0235 |
| 5.72 | 1.029 | 0.0221 |
| 7.32 | 1.163 | 0.0227 |
| 8.93 | 1.236 | 0.0308 |
| 10.35 | 1.281 | 0.0471 |
| 11.93 | 1.300 | 0.0622 |

Run: 395
$Re = 102000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -0.01 | 0.431 | 0.0177 |
| 1.62 | 0.669 | 0.0176 |
| 3.11 | 0.832 | 0.0172 |
| 4.54 | 0.957 | 0.0180 |
| 6.13 | 1.093 | 0.0200 |
| 7.56 | 1.190 | 0.0242 |
| 9.09 | 1.241 | 0.0385 |
| 10.57 | 1.286 | 0.0513 |
| 12.41 | 1.296 | 0.0925 |

Run: 396
$Re = 102400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.49 | 0.224 | 0.0184 |

Run: 397
$Re = 101900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.46 | 0.022 | 0.0320 |

Run: 399
$Re = 202700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.42 | 0.118 | 0.0175 |
| -1.26 | 0.392 | 0.0115 |
| -0.44 | 0.495 | 0.0113 |
| 1.53 | 0.688 | 0.0104 |
| 2.76 | 0.809 | 0.0112 |
| 4.74 | 1.004 | 0.0138 |
| 5.84 | 1.094 | 0.0160 |
| 7.63 | 1.197 | 0.0266 |
| 9.11 | 1.263 | 0.0371 |
| 10.55 | 1.290 | 0.0530 |

## GM15

Fig. 4.38

Run: 409
$Re = 61000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.87 | -0.348 | 0.0578 |
| -0.25 | -0.174 | 0.0289 |
| 1.23 | -0.027 | 0.0187 |
| 2.53 | 0.114 | 0.0139 |
| 4.21 | 0.326 | 0.0133 |
| 5.62 | 0.469 | 0.0153 |
| 7.29 | 0.640 | 0.0206 |
| 8.77 | 0.774 | 0.0232 |
| 10.38 | 0.877 | 0.0260 |
| 11.83 | 0.988 | 0.0274 |
| 13.45 | 1.072 | 0.0379 |

Run: 407
$Re = 101900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.89 | -0.343 | 0.0464 |
| -0.11 | -0.155 | 0.0196 |
| 1.34 | -0.020 | 0.0146 |
| 2.73 | 0.138 | 0.0119 |
| 4.22 | 0.289 | 0.0133 |
| 5.65 | 0.435 | 0.0162 |
| 7.29 | 0.594 | 0.0191 |
| 8.74 | 0.738 | 0.0190 |
| 10.44 | 0.893 | 0.0209 |
| 11.85 | 0.985 | 0.0322 |
| 13.46 | 1.067 | 0.0511 |

Run: 412
$Re = 203400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.70 | -0.282 | 0.0298 |
| 0.12 | -0.090 | 0.0153 |
| 1.51 | -0.002 | 0.0134 |
| 3.10 | 0.165 | 0.0120 |
| 4.56 | 0.312 | 0.0120 |
| 5.95 | 0.485 | 0.0121 |
| 7.48 | 0.645 | 0.0125 |
| 9.11 | 0.802 | 0.0147 |
| 10.66 | 0.928 | 0.0223 |
| 11.98 | 1.020 | 0.0310 |
| 13.54 | 1.084 | 0.0529 |

Run: 414
$Re = 304400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.95 | -0.307 | 0.0408 |
| -0.46 | -0.150 | 0.0166 |
| 2.07 | 0.056 | 0.0123 |
| 3.04 | 0.186 | 0.0113 |
| 4.57 | 0.346 | 0.0100 |
| 6.12 | 0.511 | 0.0099 |
| 7.57 | 0.655 | 0.0107 |
| 9.02 | 0.795 | 0.0127 |
| 10.52 | 0.920 | 0.0191 |
| 12.42 | 1.056 | 0.0323 |
| 13.78 | 1.107 | 0.0642 |

## K3311

Fig. 4.45

Run: 126
$Re = 61600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.24 | -0.238 | 0.0323 |
| -2.71 | -0.079 | 0.0255 |
| -1.19 | 0.090 | 0.0184 |
| 0.57 | 0.341 | 0.0240 |
| 1.89 | 0.497 | 0.0280 |
| 3.67 | 0.653 | 0.0375 |
| 5.05 | 0.770 | 0.0416 |
| 6.78 | 0.920 | 0.0485 |
| 8.28 | 1.084 | 0.0401 |
| 9.86 | 1.205 | 0.0336 |
| 11.20 | 1.220 | 0.0473 |

Run: 124
$Re = 102200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.09 | -0.167 | 0.0263 |
| -2.54 | 0.068 | 0.0194 |
| -1.21 | 0.181 | 0.0152 |
| 0.43 | 0.400 | 0.0157 |
| 2.12 | 0.571 | 0.0183 |
| 3.59 | 0.722 | 0.0201 |
| 5.18 | 0.885 | 0.0214 |
| 6.82 | 1.049 | 0.0231 |
| 8.24 | 1.192 | 0.0239 |
| 9.75 | 1.271 | 0.0278 |
| 11.21 | 1.269 | 0.0452 |

Run: 122
$Re = 203300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.79 | -0.299 | 0.0428 |
| -4.11 | -0.106 | 0.0201 |
| -2.55 | 0.038 | 0.0144 |
| -1.08 | 0.172 | 0.0107 |
| 0.40 | 0.342 | 0.0100 |
| 2.17 | 0.537 | 0.0114 |
| 3.51 | 0.683 | 0.0129 |
| 5.20 | 0.858 | 0.0144 |
| 6.58 | 0.992 | 0.0157 |
| 8.13 | 1.127 | 0.0177 |
| 9.83 | 1.191 | 0.0292 |
| 11.17 | 1.186 | 0.0462 |

Run: 120
$Re = 305100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.62 | -0.243 | 0.0358 |
| -4.28 | -0.119 | 0.0195 |
| -2.78 | 0.019 | 0.0138 |
| -1.00 | 0.193 | 0.0092 |
| 0.47 | 0.358 | 0.0082 |
| 2.10 | 0.535 | 0.0094 |
| 3.50 | 0.678 | 0.0104 |
| 5.24 | 0.854 | 0.0120 |
| 6.81 | 1.001 | 0.0132 |
| 8.14 | 1.101 | 0.0162 |
| 10.03 | 1.164 | 0.0293 |
| 11.65 | 1.164 | 0.0530 |

## M06-13-128 (B)

Fig. 4.49

Run: 197
$Re = 203800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.63 | -0.054 | 0.0464 |
| -2.61 | 0.051 | 0.0393 |
| -1.65 | 0.138 | 0.0409 |
| -0.41 | 0.219 | 0.0503 |
| 0.35 | 0.259 | 0.0557 |
| 1.50 | 0.331 | 0.0621 |
| 2.49 | 0.387 | 0.0706 |
| 3.56 | 0.452 | 0.0796 |

Run: 201
$Re = 203900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 4.22 | 0.496 | 0.0837 |
| 5.49 | 0.606 | 0.0919 |
| 6.54 | 0.789 | 0.0834 |
| 7.43 | 0.947 | 0.0610 |
| 8.34 | 1.076 | 0.0441 |
| 9.41 | 1.210 | 0.0329 |
| 10.48 | 1.334 | 0.0258 |
| 11.58 | 1.437 | 0.0250 |
| 12.49 | 1.487 | 0.0283 |

Run: 199
$Re = 305200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.87 | -0.114 | 0.0444 |
| -2.46 | 0.043 | 0.0306 |
| -1.59 | 0.137 | 0.0290 |
| -0.72 | 0.230 | 0.0314 |
| 0.43 | 0.353 | 0.0344 |
| 1.62 | 0.467 | 0.0392 |

Run: 200
$Re = 306200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 1.62 | 0.468 | 0.0390 |
| 2.34 | 0.538 | 0.0401 |
| 3.65 | 0.672 | 0.0378 |
| 4.33 | 0.741 | 0.0353 |
| 5.39 | 0.850 | 0.0319 |
| 6.52 | 0.969 | 0.0282 |
| 7.41 | 1.062 | 0.0257 |
| 8.48 | 1.174 | 0.0230 |
| 9.43 | 1.273 | 0.0208 |
| 10.49 | 1.380 | 0.0183 |
| 11.51 | 1.456 | 0.0201 |
| 12.50 | 1.471 | 0.0411 |

## MA409

Fig. 4.53

Run: 301
$Re = 41000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.98 | -0.007 | 0.0214 |
| 0.16 | 0.218 | 0.0169 |
| 2.10 | 0.428 | 0.0186 |
| 4.30 | 0.750 | 0.0215 |
| 6.34 | 0.905 | 0.0263 |
| 8.20 | 1.017 | 0.0306 |
| 10.32 | 1.067 | 0.0764 |

Run: 177
$Re = 61200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.71 | -0.097 | 0.0244 |
| -1.11 | 0.039 | 0.0140 |
| 0.56 | 0.202 | 0.0156 |
| 2.02 | 0.389 | 0.0179 |
| 3.25 | 0.579 | 0.0185 |
| 4.88 | 0.717 | 0.0159 |
| 6.34 | 0.835 | 0.0206 |

| | | |
|---|---|---|
| 7.96 | 0.925 | 0.0316 |
| 9.56 | 0.998 | 0.0462 |

Run: 179
$Re = 102100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.38 | -0.255 | 0.0264 |
| -2.61 | -0.106 | 0.0186 |
| -1.24 | 0.021 | 0.0147 |
| 0.31 | 0.173 | 0.0109 |
| 1.81 | 0.417 | 0.0139 |
| 3.29 | 0.581 | 0.0148 |
| 5.06 | 0.734 | 0.0155 |
| 6.41 | 0.841 | 0.0197 |
| 8.23 | 0.945 | 0.0315 |
| 9.43 | 0.998 | 0.0432 |

Run: 181
$Re = 203100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.40 | -0.251 | 0.0175 |
| -2.82 | -0.118 | 0.0145 |
| -1.45 | 0.038 | 0.0113 |
| -0.03 | 0.226 | 0.0092 |
| 1.71 | 0.414 | 0.0092 |
| 3.29 | 0.574 | 0.0102 |
| 4.70 | 0.703 | 0.0122 |
| 6.12 | 0.819 | 0.0164 |
| 7.57 | 0.917 | 0.0232 |
| 9.22 | 1.006 | 0.0375 |

Run: 183
$Re = 304300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.68 | -0.280 | 0.0145 |
| -3.14 | -0.140 | 0.0142 |
| -1.43 | 0.070 | 0.0087 |
| 0.00 | 0.240 | 0.0081 |
| 1.61 | 0.407 | 0.0072 |
| 3.48 | 0.590 | 0.0092 |
| 4.77 | 0.702 | 0.0113 |
| 6.20 | 0.820 | 0.0149 |
| 7.99 | 0.950 | 0.0233 |
| 9.38 | 1.023 | 0.0352 |

Run: 523
$Re = 303500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.08 | -0.447 | 0.0677 |

## MH45

Fig. 4.60

Run: 112
$Re = 61300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.22 | -0.193 | 0.0184 |
| -1.62 | 0.015 | 0.0190 |
| -0.06 | 0.250 | 0.0224 |
| 1.45 | 0.393 | 0.0298 |
| 2.97 | 0.536 | 0.0314 |
| 4.49 | 0.655 | 0.0292 |
| 6.04 | 0.794 | 0.0254 |
| 7.56 | 0.913 | 0.0271 |
| 9.07 | 1.010 | 0.0326 |
| 10.61 | 1.090 | 0.0412 |

Run: 526
$Re = 61200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.20 | -0.466 | 0.0321 |
| -4.66 | -0.314 | 0.0209 |

Run: 114
$Re = 102000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.94 | -0.153 | 0.0124 |
| -1.40 | 0.081 | 0.0135 |
| 0.16 | 0.224 | 0.0171 |
| 1.48 | 0.341 | 0.0196 |
| 3.33 | 0.516 | 0.0181 |
| 4.68 | 0.650 | 0.0183 |
| 6.16 | 0.789 | 0.0207 |
| 7.62 | 0.910 | 0.0250 |
| 9.26 | 1.025 | 0.0309 |
| 10.66 | 1.093 | 0.0401 |
| 12.34 | 1.099 | 0.0474 |

Run: 527
$Re = 101900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.11 | -0.488 | 0.0260 |
| -4.67 | -0.352 | 0.0176 |

Run: 116
$Re = 203500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.00 | -0.168 | 0.0123 |
| -1.64 | -0.048 | 0.0106 |
| -0.04 | 0.151 | 0.0109 |
| 1.47 | 0.307 | 0.0114 |
| 3.22 | 0.495 | 0.0121 |
| 4.67 | 0.651 | 0.0139 |
| 6.13 | 0.800 | 0.0163 |
| 7.72 | 0.940 | 0.0197 |
| 9.25 | 1.052 | 0.0254 |
| 10.61 | 1.125 | 0.0310 |
| 12.25 | 1.109 | 0.0456 |

Run: 528
$Re = 203700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.63 | -0.335 | 0.0148 |

Run: 529
$Re = 202800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.17 | -0.508 | 0.0209 |

Run: 118
$Re = 304800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.92 | -0.178 | 0.0114 |
| -1.45 | -0.031 | 0.0096 |
| 0.14 | 0.164 | 0.0089 |
| 1.48 | 0.317 | 0.0089 |
| 3.02 | 0.490 | 0.0099 |
| 4.49 | 0.648 | 0.0113 |
| 6.27 | 0.832 | 0.0138 |
| 7.65 | 0.959 | 0.0168 |
| 9.34 | 1.097 | 0.0219 |
| 10.72 | 1.163 | 0.0274 |

Run: 530
$Re = 304700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.07 | -0.502 | 0.0190 |
| -4.49 | -0.355 | 0.0145 |

## NACA 6409

Fig. 4.67

Run: 187
$Re = 61400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.80 | -0.005 | 0.0628 |
| -1.14 | 0.240 | 0.0386 |
| 0.26 | 0.454 | 0.0383 |
| 2.07 | 0.649 | 0.0391 |
| 3.32 | 0.770 | 0.0430 |
| 4.98 | 0.911 | 0.0509 |

Run: 189
$Re = 101800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.68 | 0.196 | 0.0389 |
| -1.01 | 0.436 | 0.0240 |
| 0.25 | 0.565 | 0.0213 |
| 1.97 | 0.729 | 0.0203 |
| 3.32 | 0.858 | 0.0214 |
| 5.07 | 1.009 | 0.0235 |
| 6.45 | 1.132 | 0.0243 |
| 8.10 | 1.265 | 0.0255 |
| 9.70 | 1.383 | 0.0285 |

Run: 191
$Re = 203100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.89 | 0.285 | 0.0193 |
| -1.38 | 0.437 | 0.0150 |
| 0.21 | 0.602 | 0.0145 |
| 1.66 | 0.744 | 0.0135 |
| 3.32 | 0.903 | 0.0147 |
| 4.95 | 1.059 | 0.0157 |
| 6.94 | 1.238 | 0.0179 |
| 8.08 | 1.328 | 0.0197 |
| 10.10 | 1.426 | 0.0239 |
| 11.30 | 1.406 | 0.0314 |

## NACA 64A010

Fig. 4.72

Run: 244
$Re = 61700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.06 | -0.577 | 0.0226 |
| -4.30 | -0.445 | 0.0174 |
| -2.72 | -0.333 | 0.0177 |
| -1.17 | -0.043 | 0.0196 |
| 0.32 | 0.031 | 0.0116 |
| 1.84 | 0.145 | 0.0179 |
| 3.17 | 0.388 | 0.0171 |
| 4.69 | 0.519 | 0.0195 |
| 6.50 | 0.650 | 0.0289 |
| 7.90 | 0.732 | 0.0434 |

Run: 246
$Re = 101700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.29 | -0.649 | 0.0237 |
| -4.27 | -0.515 | 0.0135 |
| -2.71 | -0.389 | 0.0132 |
| -1.22 | -0.222 | 0.0149 |
| 0.12 | -0.017 | 0.0102 |
| 1.70 | 0.220 | 0.0142 |
| 3.36 | 0.387 | 0.0139 |
| 4.70 | 0.483 | 0.0163 |
| 6.39 | 0.600 | 0.0276 |
| 7.67 | 0.682 | 0.0413 |

Run: 248
$Re = 203100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.07 | -0.605 | 0.0162 |
| -4.39 | -0.488 | 0.0108 |
| -2.73 | -0.346 | 0.0097 |
| -1.10 | -0.153 | 0.0108 |
| 0.08 | -0.001 | 0.0112 |
| 1.65 | 0.185 | 0.0108 |
| 3.42 | 0.400 | 0.0107 |
| 4.65 | 0.489 | 0.0146 |
| 6.08 | 0.598 | 0.0201 |
| 7.72 | 0.715 | 0.0364 |

Run: 250
$Re = 304800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.25 | -0.632 | 0.0151 |
| -4.27 | -0.479 | 0.0102 |
| -2.53 | -0.309 | 0.0086 |
| -0.87 | -0.087 | 0.0082 |
| 0.36 | 0.031 | 0.0079 |
| 1.67 | 0.159 | 0.0082 |
| 3.28 | 0.366 | 0.0090 |
| 4.64 | 0.484 | 0.0129 |
| 6.19 | 0.607 | 0.0182 |
| 7.74 | 0.719 | 0.0331 |

## R140 (A)

Fig. 4.76

Run: 203
$Re = 102000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.02 | -0.461 | 0.0178 |
| -2.47 | -0.369 | 0.0182 |
| -0.91 | -0.067 | 0.0163 |
| 0.55 | 0.174 | 0.0185 |
| 2.13 | 0.407 | 0.0201 |
| 3.65 | 0.511 | 0.0191 |
| 4.98 | 0.593 | 0.0162 |
| 6.55 | 0.653 | 0.0227 |
| 8.25 | 0.734 | 0.0334 |
| 9.52 | 0.788 | 0.0453 |

Run: 531
$Re = 102200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.77 | -0.583 | 0.0247 |

Run: 205
$Re = 203500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.62 | -0.548 | 0.0198 |
| -4.07 | -0.432 | 0.0147 |
| -2.70 | -0.273 | 0.0105 |
| -0.96 | -0.092 | 0.0107 |
| 0.36 | 0.024 | 0.0106 |
| 2.01 | 0.211 | 0.0124 |
| 3.84 | 0.465 | 0.0130 |
| 5.12 | 0.564 | 0.0172 |
| 6.46 | 0.626 | 0.0217 |
| 8.28 | 0.715 | 0.0319 |
| 9.54 | 0.786 | 0.0489 |

Run: 207
$Re = 305200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.71 | -0.558 | 0.0189 |
| -3.85 | -0.358 | 0.0120 |
| -2.65 | -0.243 | 0.0096 |
| -0.44 | -0.047 | 0.0090 |
| 0.59 | 0.044 | 0.0089 |
| 2.13 | 0.204 | 0.0092 |
| 3.39 | 0.362 | 0.0101 |
| 5.10 | 0.559 | 0.0165 |
| 6.45 | 0.629 | 0.0199 |
| 8.03 | 0.705 | 0.0282 |
| 9.60 | 0.803 | 0.0526 |

## RG15 (B)

Fig. 4.80

Run: 85
$Re = 61400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.86 | -0.454 | 0.0526 |
| -4.98 | -0.310 | 0.0284 |
| -3.58 | -0.197 | 0.0199 |
| -1.93 | -0.074 | 0.0155 |
| -0.34 | 0.089 | 0.0147 |
| 1.12 | 0.255 | 0.0175 |
| 2.75 | 0.519 | 0.0187 |
| 4.23 | 0.674 | 0.0200 |
| 5.65 | 0.786 | 0.0212 |
| 7.29 | 0.901 | 0.0273 |
| 8.84 | 0.991 | 0.0357 |
| 10.23 | 1.046 | 0.0493 |

Run: 83
$Re = 101500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.44 | -0.430 | 0.0379 |
| -4.96 | -0.310 | 0.0234 |
| -3.47 | -0.184 | 0.0149 |
| -2.04 | -0.064 | 0.0124 |
| -0.47 | 0.085 | 0.0125 |
| 1.10 | 0.335 | 0.0163 |
| 2.62 | 0.527 | 0.0151 |
| 4.10 | 0.654 | 0.0158 |
| 5.65 | 0.793 | 0.0183 |
| 7.21 | 0.907 | 0.0241 |
| 8.75 | 0.994 | 0.0319 |
| 10.26 | 1.055 | 0.0505 |

Run: 550
$Re = 152500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.07 | -0.430 | 0.0309 |
| -5.10 | -0.348 | 0.0217 |
| -4.13 | -0.264 | 0.0169 |
| -3.25 | -0.186 | 0.0138 |
| -2.02 | -0.082 | 0.0127 |
| -1.28 | -0.015 | 0.0122 |
| 0.04 | 0.174 | 0.0110 |
| 0.92 | 0.311 | 0.0104 |
| 2.01 | 0.426 | 0.0109 |
| 2.90 | 0.513 | 0.0119 |
| 4.06 | 0.626 | 0.0126 |
| 5.10 | 0.723 | 0.0143 |
| 5.94 | 0.793 | 0.0169 |
| 7.14 | 0.888 | 0.0213 |
| 8.19 | 0.954 | 0.0243 |
| 8.96 | 0.997 | 0.0304 |
| 9.98 | 1.040 | 0.0415 |

Run: 81
$Re = 203500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.45 | -0.444 | 0.0321 |
| -5.09 | -0.330 | 0.0181 |
| -3.53 | -0.191 | 0.0132 |
| -1.98 | -0.035 | 0.0115 |
| -0.47 | 0.162 | 0.0096 |
| 1.13 | 0.342 | 0.0094 |
| 2.67 | 0.495 | 0.0098 |
| 4.19 | 0.638 | 0.0115 |
| 5.73 | 0.774 | 0.0147 |
| 7.26 | 0.891 | 0.0193 |
| 8.75 | 0.979 | 0.0270 |
| 10.29 | 1.040 | 0.0421 |

Run: 79
$Re = 304200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.49 | -0.458 | 0.0336 |
| -5.13 | -0.345 | 0.0155 |
| -3.66 | -0.204 | 0.0127 |
| -2.16 | -0.015 | 0.0093 |
| -0.56 | 0.162 | 0.0085 |
| 0.93 | 0.321 | 0.0077 |
| 2.56 | 0.500 | 0.0082 |
| 4.05 | 0.652 | 0.0101 |
| 5.59 | 0.790 | 0.0131 |
| 7.14 | 0.916 | 0.0164 |
| 8.75 | 1.023 | 0.0240 |
| 10.34 | 1.093 | 0.0380 |

## S822

Fig. 4.84

Run: 416
$Re = 102400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -7.19 | -0.710 | 0.0249 |
| -4.28 | -0.385 | 0.0242 |
| -2.75 | -0.267 | 0.0284 |
| -1.39 | -0.212 | 0.0315 |
| 0.09 | -0.112 | 0.0336 |
| 1.60 | 0.035 | 0.0357 |
| 3.19 | 0.187 | 0.0441 |
| 4.64 | 0.338 | 0.0533 |
| 6.38 | 0.751 | 0.0329 |
| 7.89 | 0.964 | 0.0221 |
| 9.44 | 1.062 | 0.0261 |
| 10.93 | 1.074 | 0.0396 |

Run: 417
$Re = 102500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 12.42 | 1.115 | 0.0510 |

Run: 419
$Re = 204500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -7.68 | -0.553 | 0.0192 |
| -5.90 | -0.376 | 0.0177 |
| -4.42 | -0.231 | 0.0176 |
| -3.12 | -0.103 | 0.0191 |
| -1.57 | 0.047 | 0.0211 |
| 0.07 | 0.202 | 0.0232 |
| 1.53 | 0.340 | 0.0240 |
| 3.02 | 0.493 | 0.0228 |
| 4.57 | 0.652 | 0.0195 |
| 6.11 | 0.836 | 0.0165 |
| 7.75 | 0.966 | 0.0166 |
| 9.08 | 1.032 | 0.0226 |
| 10.64 | 1.075 | 0.0336 |
| 12.10 | 1.107 | 0.0467 |

Run: 437
$Re = 306500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -8.40 | -0.578 | 0.0156 |
| -6.48 | -0.410 | 0.0134 |
| -5.04 | -0.273 | 0.0126 |
| -3.55 | -0.121 | 0.0128 |
| -2.05 | 0.039 | 0.0133 |
| -0.45 | 0.208 | 0.0139 |
| 1.38 | 0.415 | 0.0145 |
| 2.75 | 0.563 | 0.0148 |
| 4.63 | 0.753 | 0.0140 |
| 5.95 | 0.864 | 0.0136 |
| 7.55 | 0.956 | 0.0156 |
| 8.89 | 1.027 | 0.0205 |
| 10.39 | 1.089 | 0.0293 |
| 12.12 | 1.141 | 0.0414 |

Run: 435
$Re = 408100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -8.07 | -0.555 | 0.0135 |
| -6.53 | -0.417 | 0.0119 |
| -5.16 | -0.281 | 0.0110 |
| -3.49 | -0.107 | 0.0110 |
| -1.97 | 0.058 | 0.0110 |
| -0.52 | 0.221 | 0.0112 |
| 1.15 | 0.407 | 0.0113 |
| 2.58 | 0.564 | 0.0113 |
| 4.22 | 0.736 | 0.0115 |
| 5.87 | 0.884 | 0.0119 |
| 7.88 | 0.975 | 0.0172 |
| 9.42 | 1.044 | 0.0231 |
| 10.80 | 1.101 | 0.0308 |
| 12.34 | 1.145 | 0.0413 |

Run: 420
$Re = 509100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.84 | -0.028 | 0.0100 |

Run: 421
$Re = 506800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.20 | 0.154 | 0.0098 |

Run: 422
$Re = 510700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 0.52 | 0.350 | 0.0096 |

Run: 423
$Re = 511500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 1.67 | 0.474 | 0.0095 |

Run: 424
$Re = 511400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 3.56 | 0.683 | 0.0097 |

Run: 425
$Re = 508300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 4.83 | 0.807 | 0.0099 |

Run: 426
$Re = 509500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 6.20 | 0.911 | 0.0115 |

Run: 427
$Re = 509900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 7.83 | 0.979 | 0.0166 |

Run: 428
$Re = 509600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 9.21 | 1.028 | 0.0216 |

Run: 429
$Re = 511200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 10.84 | 1.090 | 0.0294 |

Run: 430
$Re = 510400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 12.85 | 1.161 | 0.0435 |

Run: 431
$Re = 509100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.11 | -0.287 | 0.0100 |

Run: 432
$Re = 506700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -7.99 | -0.578 | 0.0126 |

Run: 433
$Re = 506800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -8.77 | -0.642 | 0.0140 |

**S823**
Fig. 4.88

Run: 454
$Re = 103000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.64 | -0.034 | 0.0492 |
| -0.13 | 0.108 | 0.0449 |
| 1.54 | 0.289 | 0.0435 |
| 2.97 | 0.429 | 0.0448 |
| 4.35 | 0.603 | 0.0406 |
| 5.98 | 0.770 | 0.0384 |
| 7.56 | 0.917 | 0.0332 |
| 9.21 | 1.064 | 0.0319 |
| 10.56 | 1.159 | 0.0306 |
| 12.21 | 1.166 | 0.0436 |

Run: 457
$Re = 204900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.19 | -0.096 | 0.0214 |
| -1.46 | 0.079 | 0.0199 |
| 0.40 | 0.283 | 0.0191 |
| 1.53 | 0.409 | 0.0196 |
| 3.05 | 0.579 | 0.0205 |
| 4.67 | 0.750 | 0.0205 |
| 6.12 | 0.891 | 0.0214 |
| 7.66 | 1.029 | 0.0215 |
| 9.31 | 1.151 | 0.0239 |
| 10.67 | 1.180 | 0.0341 |
| 12.17 | 1.151 | 0.0658 |

Run: 458
$Re = 205800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.74 | -0.229 | 0.0230 |

Run: 461
$Re = 307400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.90 | -0.269 | 0.0172 |
| -3.28 | -0.114 | 0.0168 |
| -1.85 | 0.040 | 0.0163 |
| -0.21 | 0.223 | 0.0159 |
| 1.30 | 0.397 | 0.0154 |
| 2.84 | 0.571 | 0.0155 |
| 4.44 | 0.742 | 0.0162 |
| 5.97 | 0.895 | 0.0169 |
| 7.50 | 1.029 | 0.0183 |
| 9.21 | 1.140 | 0.0219 |
| 10.79 | 1.161 | 0.0369 |

Run: 462
$Re = 306400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.85 | -0.357 | 0.0177 |

Run: 465
$Re = 408800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -7.86 | -0.563 | 0.0182 |

Run: 464
$Re = 410100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -7.83 | -0.562 | 0.0181 |
| -6.34 | -0.413 | 0.0154 |
| -4.79 | -0.271 | 0.0148 |
| -3.27 | -0.123 | 0.0148 |
| -1.76 | 0.043 | 0.0145 |
| -0.22 | 0.222 | 0.0141 |
| 1.38 | 0.407 | 0.0134 |
| 2.82 | 0.574 | 0.0133 |
| 4.43 | 0.748 | 0.0137 |
| 5.95 | 0.898 | 0.0147 |
| 7.47 | 1.028 | 0.0161 |
| 9.03 | 1.117 | 0.0208 |
| 10.51 | 1.141 | 0.0338 |

Run: 466
$Re = 509400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.51 | -0.129 | 0.0137 |

Run: 467
$Re = 513200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.55 | 0.092 | 0.0136 |

Run: 468
$Re = 511300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -0.36 | 0.224 | 0.0133 |

Run: 469
$Re = 510700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 1.47 | 0.436 | 0.0125 |

Run: 470
$Re = 513600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 2.75 | 0.582 | 0.0125 |

Run: 471
$Re = 513500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 4.40 | 0.757 | 0.0128 |

Run: 472
$Re = 510800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 6.01 | 0.913 | 0.0140 |

Run: 473
$Re = 510900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 7.61 | 1.043 | 0.0160 |

Run: 474
$Re = 512000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 9.04 | 1.117 | 0.0206 |

Run: 475
$Re = 512300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 10.42 | 1.140 | 0.0353 |

Run: 477
$Re = 508500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.75 | -0.266 | 0.0138 |

**S1210**
Fig. 4.92

Run: 129
$Re = 102600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.98 | 0.354 | 0.0320 |
| -3.04 | 0.532 | 0.0272 |
| -2.05 | 0.677 | 0.0244 |
| -0.96 | 0.787 | 0.0276 |
| -0.02 | 0.868 | 0.0272 |
| 1.08 | 0.972 | 0.0307 |
| 2.02 | 1.061 | 0.0305 |
| 3.07 | 1.161 | 0.0319 |
| 4.22 | 1.248 | 0.0322 |
| 5.19 | 1.322 | 0.0348 |
| 6.32 | 1.414 | 0.0377 |
| 7.12 | 1.473 | 0.0391 |
| 8.24 | 1.563 | 0.0387 |
| 9.35 | 1.639 | 0.0399 |
| 10.16 | 1.687 | 0.0388 |
| 11.18 | 1.735 | 0.0391 |

Run: 492
$Re = 102700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 12.24 | 1.715 | 0.0463 |

Run: 488
$Re = 153000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.83 | 0.426 | 0.0228 |
| -2.89 | 0.596 | 0.0175 |
| -1.84 | 0.707 | 0.0175 |
| -0.79 | 0.807 | 0.0183 |
| 0.19 | 0.901 | 0.0207 |
| 1.38 | 1.014 | 0.0220 |
| 2.31 | 1.104 | 0.0231 |
| 3.12 | 1.177 | 0.0241 |
| 4.12 | 1.263 | 0.0248 |
| 5.30 | 1.356 | 0.0269 |
| 6.32 | 1.435 | 0.0286 |
| 7.32 | 1.510 | 0.0300 |
| 8.14 | 1.567 | 0.0308 |
| 9.45 | 1.656 | 0.0321 |
| 10.28 | 1.703 | 0.0334 |
| 11.23 | 1.735 | 0.0366 |
| 12.27 | 1.752 | 0.0436 |

Run: 131
$Re = 204100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.15 | 0.451 | 0.0197 |
| -3.16 | 0.590 | 0.0149 |
| -2.19 | 0.694 | 0.0148 |
| -1.16 | 0.792 | 0.0160 |
| -0.03 | 0.903 | 0.0173 |
| 0.90 | 0.991 | 0.0182 |
| 1.93 | 1.092 | 0.0190 |
| 2.91 | 1.182 | 0.0200 |
| 3.97 | 1.276 | 0.0210 |
| 5.07 | 1.362 | 0.0214 |
| 6.13 | 1.451 | 0.0229 |
| 7.12 | 1.530 | 0.0242 |
| 8.13 | 1.602 | 0.0255 |
| 9.33 | 1.685 | 0.0274 |
| 10.43 | 1.737 | 0.0304 |
| 11.61 | 1.759 | 0.0370 |

Run: 490
$Re = 254400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.14 | 0.428 | 0.0178 |
| -3.13 | 0.572 | 0.0136 |
| -2.17 | 0.685 | 0.0134 |
| -1.11 | 0.787 | 0.0146 |
| -0.06 | 0.890 | 0.0157 |
| 1.00 | 0.995 | 0.0165 |
| 2.03 | 1.096 | 0.0173 |
| 3.00 | 1.186 | 0.0182 |
| 4.06 | 1.283 | 0.0191 |
| 5.00 | 1.359 | 0.0192 |
| 6.13 | 1.450 | 0.0203 |
| 7.16 | 1.533 | 0.0214 |
| 8.14 | 1.607 | 0.0227 |
| 9.37 | 1.688 | 0.0247 |
| 10.20 | 1.724 | 0.0271 |
| 11.23 | 1.751 | 0.0324 |

Run: 491
$Re = 253400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 12.26 | 1.774 | 0.0393 |

Run: 495
$Re = 305500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.10 | 0.297 | 0.0211 |
| -4.11 | 0.449 | 0.0156 |
| -3.06 | 0.587 | 0.0124 |
| -2.04 | 0.697 | 0.0125 |
| -1.04 | 0.793 | 0.0136 |
| 0.00 | 0.898 | 0.0147 |
| 0.99 | 0.995 | 0.0152 |
| 2.07 | 1.102 | 0.0162 |
| 3.07 | 1.198 | 0.0168 |
| 4.11 | 1.292 | 0.0176 |
| 5.12 | 1.380 | 0.0179 |
| 6.14 | 1.460 | 0.0186 |
| 7.10 | 1.533 | 0.0197 |
| 8.19 | 1.615 | 0.0211 |
| 9.11 | 1.672 | 0.0226 |
| 10.19 | 1.724 | 0.0261 |
| 11.22 | 1.753 | 0.0318 |
| 12.23 | 1.771 | 0.0396 |

**S1223**
Fig. 4.96

Run: 134
$Re = 102100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.30 | 0.384 | 0.0687 |
| -2.53 | 0.752 | 0.0355 |
| -1.01 | 0.937 | 0.0247 |
| -0.03 | 1.037 | 0.0269 |
| 0.89 | 1.120 | 0.0311 |
| 1.73 | 1.193 | 0.0324 |
| 2.56 | 1.267 | 0.0341 |
| 3.69 | 1.343 | 0.0375 |
| 4.82 | 1.423 | 0.0426 |
| 5.70 | 1.485 | 0.0475 |

| | | |
|---|---|---|
| 6.68 | 1.536 | 0.0548 |

Run: 590
$Re = 152600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.31 | 0.779 | 0.0275 |
| -0.83 | 0.948 | 0.0219 |
| 0.73 | 1.115 | 0.0246 |
| 2.89 | 1.313 | 0.0291 |

Run: 598
$Re = 152900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 3.91 | 1.399 | 0.0311 |
| 5.22 | 1.502 | 0.0360 |
| 6.83 | 1.617 | 0.0413 |
| 8.60 | 1.729 | 0.0493 |
| 9.89 | 1.803 | 0.0556 |
| 11.41 | 1.883 | 0.0623 |

Run: 136
$Re = 203800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.84 | 0.587 | 0.0437 |
| -1.47 | 0.903 | 0.0207 |
| -0.02 | 1.070 | 0.0211 |
| 0.64 | 1.129 | 0.0221 |
| 1.80 | 1.235 | 0.0237 |
| 2.96 | 1.341 | 0.0252 |
| 3.74 | 1.396 | 0.0257 |
| 4.72 | 1.473 | 0.0280 |
| 6.22 | 1.582 | 0.0318 |
| 6.86 | 1.627 | 0.0333 |
| 7.88 | 1.696 | 0.0364 |

Run: 588
$Re = 203600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 8.86 | 1.765 | 0.0391 |
| 10.12 | 1.840 | 0.0422 |
| 11.05 | 1.892 | 0.0450 |
| 11.81 | 1.935 | 0.0465 |
| 13.11 | 2.003 | 0.0491 |
| 13.90 | 2.042 | 0.0509 |
| 15.13 | 2.091 | 0.0542 |

Run: 594
$Re = 254600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.05 | 0.443 | 0.0573 |
| -1.08 | 0.936 | 0.0185 |
| 0.45 | 1.105 | 0.0194 |
| 1.92 | 1.240 | 0.0221 |
| 3.45 | 1.376 | 0.0237 |
| 5.09 | 1.497 | 0.0259 |
| 6.60 | 1.610 | 0.0290 |
| 8.14 | 1.719 | 0.0320 |
| 9.53 | 1.811 | 0.0353 |
| 11.34 | 1.920 | 0.0398 |
| 12.87 | 2.003 | 0.0425 |
| 14.52 | 2.076 | 0.0473 |

Run: 597
$Re = 305300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.69 | 0.638 | 0.0425 |
| -1.03 | 0.953 | 0.0184 |
| 0.46 | 1.116 | 0.0182 |
| 2.02 | 1.259 | 0.0209 |
| 3.57 | 1.398 | 0.0226 |
| 5.07 | 1.510 | 0.0242 |
| 6.57 | 1.624 | 0.0268 |
| 8.17 | 1.743 | 0.0300 |
| 9.65 | 1.844 | 0.0330 |
| 11.17 | 1.939 | 0.0363 |
| 12.79 | 2.029 | 0.0401 |
| 14.68 | 2.080 | 0.0445 |
| 16.32 | 2.114 | 0.0544 |

## S1223
Fig. 4.98

Run: 370
$Re = 203800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -0.45 | 0.962 | 0.0329 |
| 1.75 | 1.161 | 0.0372 |
| 3.75 | 1.319 | 0.0406 |
| 5.81 | 1.475 | 0.0465 |
| 7.66 | 1.595 | 0.0520 |
| 9.87 | 1.727 | 0.0608 |

## S1223
Fig. 4.101

Run: 517
$Re = 203500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -0.42 | 1.243 | 0.0270 |
| 3.59 | 1.589 | 0.0332 |
| 7.78 | 1.842 | 0.0426 |

## S6062
Fig. 4.105

Run: 142
$Re = 101800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.98 | -0.216 | 0.0186 |
| -2.17 | -0.048 | 0.0124 |
| -0.61 | 0.090 | 0.0107 |
| 0.75 | 0.244 | 0.0135 |
| 2.38 | 0.510 | 0.0146 |
| 3.52 | 0.621 | 0.0145 |
| 5.31 | 0.773 | 0.0166 |
| 7.00 | 0.876 | 0.0293 |
| 8.28 | 0.951 | 0.0424 |

Run: 140
$Re = 202900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.86 | -0.480 | 0.0567 |
| -2.91 | -0.108 | 0.0123 |
| -2.59 | -0.072 | 0.0113 |
| -0.77 | 0.140 | 0.0093 |
| 0.56 | 0.311 | 0.0084 |
| 2.44 | 0.519 | 0.0091 |
| 3.73 | 0.651 | 0.0105 |
| 5.48 | 0.780 | 0.0169 |
| 6.72 | 0.866 | 0.0237 |

Run: 532
$Re = 203000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.21 | -0.242 | 0.0156 |
| 8.68 | 0.989 | 0.0460 |

Run: 138
$Re = 305100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.55 | -0.344 | 0.0179 |
| -3.93 | -0.197 | 0.0131 |
| -2.57 | -0.039 | 0.0093 |
| -0.83 | 0.178 | 0.0074 |
| 0.59 | 0.325 | 0.0069 |
| 2.56 | 0.531 | 0.0082 |
| 3.74 | 0.641 | 0.0093 |
| 5.73 | 0.794 | 0.0168 |
| 7.22 | 0.906 | 0.0248 |
| 8.60 | 0.997 | 0.0494 |

## S7012
Fig. 4.109

Run: 94
$Re = 61400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.83 | -0.432 | 0.0394 |
| -4.33 | -0.308 | 0.0252 |
| -2.80 | -0.167 | 0.0171 |
| -1.31 | -0.036 | 0.0127 |
| 0.10 | 0.109 | 0.0113 |
| 1.72 | 0.393 | 0.0180 |
| 3.48 | 0.579 | 0.0245 |
| 4.81 | 0.696 | 0.0189 |
| 6.32 | 0.827 | 0.0243 |
| 7.84 | 0.949 | 0.0274 |
| 9.54 | 1.048 | 0.0387 |
| 10.94 | 1.081 | 0.0588 |

Run: 92
$Re = 101700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.88 | -0.468 | 0.0348 |
| -4.40 | -0.331 | 0.0201 |
| -2.91 | -0.190 | 0.0144 |
| -1.31 | -0.049 | 0.0104 |
| 0.23 | 0.188 | 0.0122 |
| 1.76 | 0.373 | 0.0142 |
| 3.28 | 0.524 | 0.0160 |
| 4.75 | 0.670 | 0.0173 |
| 6.38 | 0.832 | 0.0186 |
| 7.94 | 0.959 | 0.0249 |
| 9.48 | 1.039 | 0.0414 |
| 10.97 | 1.079 | 0.0659 |

Run: 565
$Re = 152800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.95 | -0.447 | 0.0276 |
| -4.15 | -0.280 | 0.0167 |
| -2.55 | -0.128 | 0.0113 |
| -1.12 | 0.028 | 0.0099 |
| 0.56 | 0.234 | 0.0098 |
| 1.96 | 0.379 | 0.0115 |
| 3.42 | 0.536 | 0.0131 |
| 5.13 | 0.714 | 0.0145 |
| 6.69 | 0.864 | 0.0171 |
| 8.03 | 0.956 | 0.0252 |
| 9.57 | 1.039 | 0.0383 |

Run: 90
$Re = 203200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.93 | -0.450 | 0.0229 |
| -4.42 | -0.310 | 0.0159 |
| -2.88 | -0.157 | 0.0112 |
| -1.40 | 0.007 | 0.0091 |
| 0.33 | 0.196 | 0.0077 |
| 1.75 | 0.351 | 0.0096 |
| 3.34 | 0.525 | 0.0111 |
| 4.74 | 0.671 | 0.0124 |
| 6.41 | 0.836 | 0.0146 |
| 7.91 | 0.949 | 0.0223 |
| 9.44 | 1.036 | 0.0343 |
| 10.94 | 1.071 | 0.0588 |

Run: 88
$Re = 304700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.85 | -0.458 | 0.0198 |
| -4.23 | -0.299 | 0.0129 |
| -2.78 | -0.149 | 0.0099 |
| -1.18 | 0.042 | 0.0078 |
| 0.13 | 0.165 | 0.0079 |
| 1.68 | 0.345 | 0.0079 |
| 3.30 | 0.528 | 0.0091 |
| 4.87 | 0.702 | 0.0105 |
| 6.47 | 0.857 | 0.0131 |
| 7.85 | 0.969 | 0.0198 |
| 9.55 | 1.070 | 0.0315 |
| 11.02 | 1.118 | 0.0605 |

## S7055
Fig. 4.113

Run: 152
$Re = 61200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.54 | -0.212 | 0.0342 |
| -2.73 | 0.008 | 0.0284 |
| -0.93 | 0.184 | 0.0237 |
| 0.40 | 0.352 | 0.0284 |
| 2.32 | 0.565 | 0.0316 |
| 3.48 | 0.688 | 0.0352 |
| 5.27 | 0.870 | 0.0362 |
| 6.55 | 0.985 | 0.0341 |
| 8.30 | 1.122 | 0.0366 |
| 9.63 | 1.213 | 0.0332 |

Run: 547
$Re = 61600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| 11.88 | 1.209 | 0.0578 |

Run: 150
$Re = 102300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.43 | -0.105 | 0.0265 |
| -2.40 | 0.134 | 0.0203 |
| -0.92 | 0.284 | 0.0197 |
| 0.45 | 0.426 | 0.0214 |
| 2.34 | 0.610 | 0.0224 |
| 3.56 | 0.728 | 0.0222 |

| | | |
|---|---|---|
| 5.39 | 0.909 | 0.0204 |
| 6.66 | 1.023 | 0.0224 |
| 7.96 | 1.130 | 0.0259 |
| 9.89 | 1.227 | 0.0346 |

Run: 537
$Re = 153200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.63 | -0.079 | 0.0216 |
| -2.65 | 0.103 | 0.0165 |
| -1.04 | 0.261 | 0.0143 |
| 0.44 | 0.400 | 0.0146 |
| 1.91 | 0.549 | 0.0156 |
| 3.47 | 0.710 | 0.0165 |
| 5.01 | 0.869 | 0.0175 |
| 6.51 | 1.011 | 0.0190 |
| 8.06 | 1.128 | 0.0218 |
| 9.73 | 1.206 | 0.0322 |

Run: 148
$Re = 203900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.08 | 0.163 | 0.0133 |
| -0.82 | 0.279 | 0.0114 |
| 0.48 | 0.417 | 0.0122 |
| 2.42 | 0.621 | 0.0128 |
| 3.74 | 0.758 | 0.0136 |
| 5.21 | 0.907 | 0.0144 |
| 7.10 | 1.076 | 0.0176 |
| 8.30 | 1.160 | 0.0214 |
| 9.59 | 1.195 | 0.0304 |

Run: 535
$Re = 203700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.49 | -0.079 | 0.0190 |

Run: 548
$Re = 203000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.92 | 0.072 | 0.0151 |

Run: 146
$Re = 304700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -1.06 | 0.242 | 0.0097 |
| 0.37 | 0.397 | 0.0094 |
| 2.11 | 0.583 | 0.0100 |
| 4.00 | 0.784 | 0.0112 |
| 5.19 | 0.900 | 0.0123 |
| 6.43 | 1.011 | 0.0140 |
| 8.11 | 1.136 | 0.0189 |
| 10.10 | 1.177 | 0.0375 |

Run: 534
$Re = 304700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.49 | -0.111 | 0.0166 |

Run: 577
$Re = 305100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -2.96 | 0.054 | 0.0131 |

## SD6060

Fig. 4.117

Run: 77
$Re = 61300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.14 | -0.440 | 0.0293 |
| -5.15 | -0.363 | 0.0228 |
| -4.24 | -0.296 | 0.0208 |
| -3.21 | -0.213 | 0.0150 |
| -2.15 | -0.119 | 0.0130 |
| -1.17 | -0.035 | 0.0123 |
| -0.10 | 0.117 | 0.0191 |
| 0.97 | 0.280 | 0.0221 |
| 1.87 | 0.406 | 0.0242 |
| 3.10 | 0.543 | 0.0299 |
| 4.05 | 0.637 | 0.0290 |
| 4.95 | 0.710 | 0.0274 |
| 6.01 | 0.805 | 0.0248 |
| 7.05 | 0.901 | 0.0247 |
| 8.02 | 0.967 | 0.0252 |
| 9.09 | 1.023 | 0.0328 |
| 10.06 | 1.068 | 0.0434 |

Run: 75
$Re = 102300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.07 | -0.451 | 0.0256 |
| -5.29 | -0.396 | 0.0211 |
| -4.17 | -0.316 | 0.0173 |
| -3.24 | -0.235 | 0.0158 |
| -2.32 | -0.137 | 0.0153 |
| -1.20 | 0.043 | 0.0162 |
| -0.09 | 0.203 | 0.0171 |
| 0.85 | 0.297 | 0.0189 |
| 1.94 | 0.402 | 0.0204 |
| 2.93 | 0.491 | 0.0213 |
| 3.94 | 0.582 | 0.0197 |
| 5.05 | 0.690 | 0.0181 |
| 6.00 | 0.775 | 0.0189 |
| 7.05 | 0.869 | 0.0199 |
| 8.00 | 0.939 | 0.0235 |
| 9.02 | 0.987 | 0.0328 |
| 10.04 | 1.015 | 0.0404 |

Run: 442
$Re = 152800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.22 | -0.460 | 0.0238 |
| -4.31 | -0.313 | 0.0184 |
| -3.05 | -0.147 | 0.0135 |
| -1.44 | 0.001 | 0.0133 |
| -0.05 | 0.188 | 0.0137 |
| 1.65 | 0.342 | 0.0136 |
| 3.28 | 0.511 | 0.0141 |
| 4.72 | 0.656 | 0.0143 |
| 6.27 | 0.806 | 0.0158 |
| 7.76 | 0.927 | 0.0208 |
| 9.17 | 0.993 | 0.0325 |
| 10.72 | 1.025 | 0.0502 |

Run: 540
$Re = 153000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.02 | -0.462 | 0.0233 |
| -5.03 | -0.398 | 0.0191 |
| -4.07 | -0.303 | 0.0179 |
| -2.80 | -0.130 | 0.0133 |
| -1.78 | -0.028 | 0.0132 |
| -0.96 | 0.026 | 0.0138 |
| 0.12 | 0.196 | 0.0133 |
| 1.13 | 0.280 | 0.0129 |
| 2.18 | 0.383 | 0.0135 |
| 3.26 | 0.495 | 0.0141 |
| 4.29 | 0.598 | 0.0139 |
| 5.21 | 0.691 | 0.0145 |
| 6.25 | 0.787 | 0.0155 |
| 7.43 | 0.887 | 0.0192 |
| 8.21 | 0.936 | 0.0235 |
| 9.28 | 0.981 | 0.0332 |
| 10.70 | 1.013 | 0.0500 |

Run: 73
$Re = 203700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.08 | -0.436 | 0.0198 |
| -5.26 | -0.371 | 0.0176 |
| -4.36 | -0.253 | 0.0149 |
| -3.20 | -0.126 | 0.0116 |
| -2.26 | -0.054 | 0.0107 |
| -1.17 | 0.035 | 0.0096 |
| -0.22 | 0.120 | 0.0087 |
| 0.96 | 0.267 | 0.0111 |
| 2.02 | 0.378 | 0.0112 |
| 2.84 | 0.461 | 0.0114 |
| 3.89 | 0.573 | 0.0113 |
| 5.09 | 0.700 | 0.0124 |
| 6.00 | 0.785 | 0.0133 |
| 7.04 | 0.876 | 0.0169 |
| 8.01 | 0.942 | 0.0220 |
| 9.02 | 0.988 | 0.0300 |
| 10.08 | 1.018 | 0.0402 |

Run: 71
$Re = 305000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.10 | -0.433 | 0.0184 |
| -4.61 | -0.277 | 0.0135 |
| -3.96 | -0.218 | 0.0123 |
| -2.88 | -0.124 | 0.0103 |
| -1.89 | -0.038 | 0.0093 |
| -0.89 | 0.049 | 0.0089 |
| 0.07 | 0.134 | 0.0082 |
| 1.23 | 0.292 | 0.0087 |
| 2.25 | 0.400 | 0.0088 |
| 3.18 | 0.500 | 0.0092 |
| 4.18 | 0.605 | 0.0097 |
| 5.20 | 0.709 | 0.0104 |
| 6.21 | 0.803 | 0.0131 |
| 7.31 | 0.892 | 0.0174 |
| 8.36 | 0.957 | 0.0230 |
| 9.26 | 0.997 | 0.0293 |
| 10.27 | 1.020 | 0.0397 |

## SD7003

Fig. 4.121

Run: 169
$Re = 61400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.84 | -0.304 | 0.0250 |
| -2.92 | -0.151 | 0.0155 |
| -1.61 | -0.041 | 0.0128 |
| -0.10 | 0.111 | 0.0135 |
| 1.66 | 0.374 | 0.0137 |
| 3.02 | 0.517 | 0.0140 |
| 4.59 | 0.656 | 0.0181 |
| 6.07 | 0.787 | 0.0209 |
| 7.71 | 0.916 | 0.0289 |
| 9.18 | 1.019 | 0.0339 |

Run: 171
$Re = 102200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.76 | -0.343 | 0.0180 |
| -3.20 | -0.192 | 0.0144 |
| -1.54 | -0.053 | 0.0101 |
| 0.01 | 0.106 | 0.0091 |
| 1.33 | 0.326 | 0.0119 |
| 3.11 | 0.494 | 0.0145 |
| 4.41 | 0.619 | 0.0158 |
| 6.17 | 0.788 | 0.0197 |
| 7.55 | 0.907 | 0.0254 |
| 9.23 | 1.017 | 0.0387 |
| 10.55 | 1.066 | 0.0603 |

Run: 173
$Re = 203400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.65 | -0.326 | 0.0138 |
| -2.85 | -0.144 | 0.0108 |
| -1.67 | -0.032 | 0.0093 |
| 0.02 | 0.162 | 0.0076 |
| 1.53 | 0.321 | 0.0090 |
| 3.05 | 0.479 | 0.0107 |
| 4.66 | 0.645 | 0.0130 |
| 5.97 | 0.773 | 0.0156 |
| 7.49 | 0.909 | 0.0204 |
| 9.04 | 1.022 | 0.0288 |
| 10.50 | 1.101 | 0.0411 |

Run: 175
$Re = 304700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.27 | -0.290 | 0.0114 |
| -2.96 | -0.154 | 0.0100 |
| -1.67 | -0.021 | 0.0080 |
| 0.24 | 0.173 | 0.0073 |
| 1.72 | 0.335 | 0.0080 |
| 3.24 | 0.503 | 0.0098 |
| 4.70 | 0.657 | 0.0117 |
| 6.06 | 0.788 | 0.0138 |
| 7.77 | 0.941 | 0.0193 |
| 9.07 | 1.040 | 0.0250 |
| 10.59 | 1.122 | 0.0362 |

Run: 533
$Re = 303400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.28 | -0.506 | 0.0167 |

## SD7032 (D)

Fig. 4.125

Run: 235
$Re = 60900$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.82 | -0.104 | 0.0299 |
| -2.19 | 0.072 | 0.0184 |
| -0.68 | 0.255 | 0.0186 |
| 0.83 | 0.444 | 0.0281 |
| 2.87 | 0.698 | 0.0319 |
| 4.04 | 0.814 | 0.0316 |
| 5.58 | 0.954 | 0.0328 |

| | | |
|---|---|---|
| 7.08 | 1.069 | 0.0365 |
| 8.59 | 1.185 | 0.0319 |
| 10.23 | 1.266 | 0.0452 |
| 11.51 | 1.325 | 0.0498 |

Run: 237
$Re = 101800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.61 | -0.047 | 0.0234 |
| -1.90 | 0.217 | 0.0175 |
| -0.49 | 0.382 | 0.0173 |
| 1.09 | 0.553 | 0.0188 |
| 2.47 | 0.686 | 0.0183 |
| 4.03 | 0.836 | 0.0187 |
| 5.51 | 0.975 | 0.0212 |
| 7.03 | 1.111 | 0.0243 |
| 8.61 | 1.240 | 0.0281 |
| 10.26 | 1.328 | 0.0339 |
| 11.66 | 1.346 | 0.0483 |
| 13.16 | 1.341 | 0.0558 |

Run: 543
$Re = 152800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.64 | 0.014 | 0.0185 |
| -1.77 | 0.234 | 0.0133 |
| -0.12 | 0.385 | 0.0124 |
| 1.01 | 0.502 | 0.0135 |
| 2.62 | 0.670 | 0.0143 |
| 4.23 | 0.840 | 0.0150 |
| 5.60 | 0.972 | 0.0170 |
| 7.26 | 1.116 | 0.0208 |
| 8.68 | 1.231 | 0.0252 |
| 10.19 | 1.312 | 0.0316 |
| 11.55 | 1.330 | 0.0425 |

Run: 239
$Re = 203800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.07 | 0.017 | 0.0163 |
| -1.98 | 0.231 | 0.0122 |
| -0.40 | 0.379 | 0.0104 |
| 0.94 | 0.524 | 0.0112 |
| 2.60 | 0.703 | 0.0117 |
| 4.08 | 0.853 | 0.0134 |
| 5.69 | 1.008 | 0.0154 |
| 7.08 | 1.128 | 0.0186 |
| 8.62 | 1.248 | 0.0228 |
| 10.20 | 1.323 | 0.0301 |
| 11.69 | 1.352 | 0.0417 |

Run: 241
$Re = 304300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -3.87 | 0.032 | 0.0139 |
| -2.48 | 0.165 | 0.0113 |
| -0.86 | 0.340 | 0.0093 |
| 0.71 | 0.497 | 0.0084 |
| 2.38 | 0.675 | 0.0095 |
| 3.62 | 0.797 | 0.0107 |
| 5.55 | 0.987 | 0.0131 |
| 7.21 | 1.133 | 0.0160 |
| 9.09 | 1.265 | 0.0217 |
| 10.50 | 1.329 | 0.0286 |
| 11.92 | 1.355 | 0.0384 |

## SD7032 (E)

Fig. 4.129

Run: 356
$Re = 203400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.38 | -0.026 | 0.0193 |
| -2.47 | 0.154 | 0.0144 |
| -0.94 | 0.306 | 0.0122 |
| 0.73 | 0.471 | 0.0113 |
| 2.00 | 0.605 | 0.0116 |
| 3.41 | 0.745 | 0.0124 |
| 5.32 | 0.925 | 0.0149 |
| 6.83 | 1.054 | 0.0174 |
| 8.07 | 1.151 | 0.0195 |
| 9.84 | 1.253 | 0.0269 |
| 11.07 | 1.295 | 0.0348 |
| 12.47 | 1.295 | 0.0613 |

## SD7037 (A)

Fig. 4.133

Run: 104
$Re = 61300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.19 | -0.234 | 0.0365 |
| -3.12 | -0.158 | 0.0261 |
| -1.80 | -0.044 | 0.0206 |
| -0.02 | 0.130 | 0.0169 |
| 1.38 | 0.326 | 0.0212 |
| 3.10 | 0.604 | 0.0237 |
| 4.52 | 0.742 | 0.0217 |
| 6.02 | 0.877 | 0.0205 |
| 7.69 | 1.008 | 0.0239 |
| 9.04 | 1.078 | 0.0283 |
| 10.54 | 1.143 | 0.0397 |

Run: 223
$Re = 101800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.49 | -0.294 | 0.0325 |
| -2.79 | -0.121 | 0.0216 |
| -1.59 | 0.037 | 0.0158 |
| 0.17 | 0.270 | 0.0153 |
| 1.79 | 0.483 | 0.0162 |
| 3.26 | 0.625 | 0.0171 |
| 4.78 | 0.762 | 0.0158 |
| 6.31 | 0.895 | 0.0181 |
| 7.82 | 1.015 | 0.0226 |
| 9.35 | 1.085 | 0.0330 |
| 10.72 | 1.145 | 0.0440 |

Run: 225
$Re = 203600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.28 | -0.171 | 0.0217 |
| -2.87 | -0.010 | 0.0151 |
| -1.17 | 0.166 | 0.0099 |
| 0.17 | 0.304 | 0.0086 |
| 1.63 | 0.461 | 0.0098 |
| 3.25 | 0.626 | 0.0106 |
| 4.84 | 0.771 | 0.0123 |
| 6.47 | 0.914 | 0.0158 |
| 7.89 | 1.010 | 0.0215 |
| 9.36 | 1.094 | 0.0290 |
| 10.81 | 1.157 | 0.0395 |

Run: 227
$Re = 304400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.68 | -0.185 | 0.0213 |
| -2.88 | -0.002 | 0.0135 |
| -1.39 | 0.139 | 0.0101 |
| -0.01 | 0.285 | 0.0077 |
| 1.71 | 0.469 | 0.0078 |
| 3.00 | 0.596 | 0.0086 |
| 5.12 | 0.799 | 0.0115 |
| 6.48 | 0.914 | 0.0143 |
| 7.99 | 1.015 | 0.0198 |
| 9.43 | 1.104 | 0.0260 |
| 10.87 | 1.164 | 0.0356 |

## SD7037 (B)

Fig. 4.137

Run: 102
$Re = 61000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.35 | -0.180 | 0.0302 |
| -2.88 | -0.085 | 0.0234 |
| -1.25 | 0.054 | 0.0149 |
| 0.27 | 0.230 | 0.0181 |
| 1.85 | 0.490 | 0.0230 |
| 3.40 | 0.660 | 0.0277 |
| 5.00 | 0.799 | 0.0278 |
| 6.32 | 0.917 | 0.0275 |
| 8.22 | 1.041 | 0.0319 |
| 9.36 | 1.123 | 0.0373 |
| 11.10 | 1.199 | 0.0460 |

Run: 100
$Re = 102200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.18 | -0.229 | 0.0268 |
| -2.88 | -0.119 | 0.0192 |
| -1.35 | 0.052 | 0.0157 |
| 0.31 | 0.310 | 0.0163 |
| 1.75 | 0.497 | 0.0176 |
| 3.25 | 0.640 | 0.0177 |
| 5.01 | 0.800 | 0.0188 |
| 6.29 | 0.916 | 0.0210 |
| 8.07 | 1.065 | 0.0282 |
| 9.37 | 1.146 | 0.0327 |
| 11.04 | 1.221 | 0.0396 |

Run: 582
$Re = 152600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.03 | -0.302 | 0.0322 |
| -2.54 | -0.033 | 0.0148 |
| -0.95 | 0.189 | 0.0125 |
| 0.57 | 0.356 | 0.0118 |
| 2.08 | 0.510 | 0.0112 |
| 3.76 | 0.687 | 0.0136 |
| 5.21 | 0.827 | 0.0154 |
| 6.79 | 0.967 | 0.0183 |
| 8.68 | 1.116 | 0.0251 |
| 9.81 | 1.185 | 0.0309 |
| 11.27 | 1.241 | 0.0380 |

Run: 98
$Re = 203600$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.25 | -0.211 | 0.0224 |
| -2.77 | 0.005 | 0.0138 |
| -0.99 | 0.212 | 0.0104 |
| 0.20 | 0.331 | 0.0101 |
| 1.75 | 0.496 | 0.0105 |
| 3.46 | 0.679 | 0.0116 |
| 4.95 | 0.828 | 0.0136 |
| 6.50 | 0.972 | 0.0161 |
| 7.91 | 1.086 | 0.0202 |
| 9.58 | 1.196 | 0.0264 |
| 11.02 | 1.263 | 0.0323 |

Run: 96
$Re = 304300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.87 | -0.370 | 0.0570 |
| -4.55 | -0.196 | 0.0159 |
| -2.90 | 0.007 | 0.0121 |
| -1.42 | 0.163 | 0.0104 |
| 0.17 | 0.315 | 0.0078 |
| 1.93 | 0.507 | 0.0083 |
| 3.59 | 0.681 | 0.0098 |
| 5.02 | 0.823 | 0.0118 |
| 6.60 | 0.965 | 0.0145 |
| 8.20 | 1.091 | 0.0185 |
| 9.45 | 1.175 | 0.0224 |
| 11.16 | 1.258 | 0.0292 |

## SD8000

Fig. 4.141

Run: 325
$Re = 61200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.55 | -0.354 | 0.0300 |
| -3.88 | -0.207 | 0.0209 |
| -2.36 | -0.078 | 0.0145 |
| -0.81 | 0.066 | 0.0164 |
| 0.80 | 0.246 | 0.0150 |
| 2.28 | 0.482 | 0.0158 |
| 3.96 | 0.686 | 0.0186 |
| 5.34 | 0.797 | 0.0218 |
| 6.94 | 0.933 | 0.0226 |
| 8.34 | 1.025 | 0.0306 |
| 9.99 | 1.116 | 0.0378 |
| 11.49 | 1.123 | 0.0719 |

Run: 327
$Re = 101700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.62 | -0.368 | 0.0243 |
| -3.68 | -0.201 | 0.0154 |
| -2.22 | -0.076 | 0.0125 |
| -0.85 | 0.047 | 0.0126 |
| 0.82 | 0.263 | 0.0151 |
| 2.29 | 0.506 | 0.0161 |
| 3.97 | 0.658 | 0.0143 |
| 5.47 | 0.791 | 0.0183 |
| 7.10 | 0.921 | 0.0247 |
| 8.51 | 1.026 | 0.0301 |
| 10.07 | 1.106 | 0.0458 |

Run: 329
$Re = 202800$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -5.50 | -0.349 | 0.0170 |
| -3.76 | -0.191 | 0.0134 |
| -2.30 | -0.046 | 0.0112 |
| -0.72 | 0.177 | 0.0094 |
| 0.79 | 0.349 | 0.0092 |
| 2.20 | 0.491 | 0.0101 |
| 3.83 | 0.655 | 0.0112 |
| 5.24 | 0.785 | 0.0145 |
| 6.83 | 0.921 | 0.0192 |
| 8.34 | 1.032 | 0.0243 |
| 9.80 | 1.117 | 0.0326 |

Run: 331
$Re = 304300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.39 | -0.420 | 0.0187 |
| -3.59 | -0.149 | 0.0123 |
| -2.19 | 0.034 | 0.0079 |
| -0.59 | 0.206 | 0.0076 |
| 0.82 | 0.338 | 0.0076 |
| 2.47 | 0.512 | 0.0083 |
| 4.16 | 0.681 | 0.0108 |
| 5.56 | 0.812 | 0.0138 |
| 7.65 | 0.992 | 0.0187 |
| 8.59 | 1.063 | 0.0225 |
| 10.32 | 1.159 | 0.0326 |
| 11.54 | 1.189 | 0.0448 |

## SD8020
Fig. 4.145

Run: 252
$Re = 61400$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.45 | -0.633 | 0.0255 |
| -4.93 | -0.509 | 0.0181 |
| -3.36 | -0.352 | 0.0178 |
| -1.81 | -0.097 | 0.0178 |
| -0.29 | 0.031 | 0.0138 |
| 1.17 | 0.107 | 0.0201 |
| 2.72 | 0.366 | 0.0139 |
| 4.37 | 0.513 | 0.0175 |
| 5.88 | 0.635 | 0.0205 |
| 7.39 | 0.743 | 0.0283 |

Run: 254
$Re = 101700$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.55 | -0.704 | 0.0184 |
| -5.03 | -0.562 | 0.0148 |
| -3.32 | -0.407 | 0.0135 |
| -1.81 | -0.237 | 0.0125 |
| -0.41 | -0.001 | 0.0102 |
| 1.21 | 0.144 | 0.0127 |
| 2.69 | 0.303 | 0.0140 |
| 4.10 | 0.423 | 0.0161 |
| 5.68 | 0.561 | 0.0183 |
| 7.27 | 0.679 | 0.0256 |
| 8.89 | 0.783 | 0.0408 |

Run: 256
$Re = 203500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.41 | -0.659 | 0.0134 |
| -4.95 | -0.529 | 0.0110 |
| -3.43 | -0.387 | 0.0099 |
| -1.62 | -0.221 | 0.0087 |
| -0.33 | -0.042 | 0.0087 |
| 1.21 | 0.147 | 0.0079 |
| 2.58 | 0.287 | 0.0101 |
| 4.30 | 0.444 | 0.0123 |
| 5.77 | 0.574 | 0.0153 |
| 7.30 | 0.697 | 0.0212 |
| 8.86 | 0.807 | 0.0298 |

Run: 258
$Re = 305200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.77 | -0.699 | 0.0139 |
| -4.75 | -0.514 | 0.0097 |
| -3.27 | -0.371 | 0.0087 |
| -1.73 | -0.206 | 0.0074 |
| -0.22 | -0.033 | 0.0074 |
| 1.18 | 0.101 | 0.0087 |
| 2.61 | 0.280 | 0.0091 |
| 4.45 | 0.454 | 0.0114 |
| 5.69 | 0.565 | 0.0136 |
| 7.24 | 0.696 | 0.0184 |
| 8.86 | 0.815 | 0.0261 |

## SD8020
Fig. 4.148

Run: 287
$Re = 61200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.44 | -0.619 | 0.0254 |
| -4.64 | -0.474 | 0.0207 |
| -2.59 | -0.286 | 0.0160 |
| -0.49 | -0.041 | 0.0146 |
| 1.58 | 0.230 | 0.0161 |
| 3.58 | 0.410 | 0.0157 |
| 5.63 | 0.583 | 0.0217 |
| 6.61 | 0.647 | 0.0232 |
| 7.78 | 0.728 | 0.0287 |
| 8.66 | 0.774 | 0.0388 |

Run: 289
$Re = 203500$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -6.53 | -0.657 | 0.0189 |
| -4.58 | -0.477 | 0.0159 |
| -2.61 | -0.272 | 0.0163 |
| -0.50 | -0.053 | 0.0170 |
| 1.56 | 0.143 | 0.0164 |
| 3.62 | 0.357 | 0.0169 |
| 5.68 | 0.553 | 0.0204 |
| 6.73 | 0.640 | 0.0239 |
| 7.76 | 0.721 | 0.0282 |
| 8.79 | 0.790 | 0.0337 |

## WASP
Fig. 4.152

Run: 229
$Re = 61200$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.30 | -0.187 | 0.0294 |
| -2.62 | -0.047 | 0.0214 |
| -1.01 | 0.106 | 0.0173 |
| 0.38 | 0.318 | 0.0217 |
| 1.99 | 0.554 | 0.0218 |
| 3.34 | 0.676 | 0.0236 |
| 4.92 | 0.807 | 0.0310 |
| 6.68 | 0.952 | 0.0365 |
| 8.13 | 1.066 | 0.0405 |
| 9.62 | 1.166 | 0.0385 |
| 11.24 | 1.238 | 0.0472 |

Run: 144
$Re = 102000$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.18 | -0.211 | 0.0245 |
| -2.44 | -0.054 | 0.0193 |
| -0.87 | 0.167 | 0.0129 |
| 0.23 | 0.346 | 0.0144 |
| 2.05 | 0.543 | 0.0159 |
| 3.63 | 0.685 | 0.0171 |
| 5.23 | 0.832 | 0.0192 |
| 7.07 | 0.999 | 0.0235 |
| 8.20 | 1.085 | 0.0265 |
| 9.87 | 1.201 | 0.0296 |

Run: 231
$Re = 203300$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.02 | -0.175 | 0.0182 |
| -2.65 | 0.006 | 0.0132 |
| -0.29 | 0.288 | 0.0092 |
| 0.40 | 0.355 | 0.0095 |
| 2.63 | 0.588 | 0.0115 |
| 3.50 | 0.675 | 0.0123 |
| 5.11 | 0.830 | 0.0145 |
| 6.63 | 0.971 | 0.0170 |
| 8.26 | 1.106 | 0.0201 |
| 9.79 | 1.195 | 0.0270 |
| 11.09 | 1.219 | 0.0393 |

Run: 233
$Re = 305100$

| $\alpha$ | $C_l$ | $C_d$ |
|---|---|---|
| -4.31 | -0.175 | 0.0154 |
| -2.53 | 0.049 | 0.0109 |
| -1.03 | 0.201 | 0.0090 |
| 0.90 | 0.400 | 0.0084 |
| 2.22 | 0.543 | 0.0095 |
| 3.60 | 0.680 | 0.0106 |
| 5.06 | 0.822 | 0.0124 |
| 6.46 | 0.956 | 0.0142 |
| 8.11 | 1.094 | 0.0173 |
| 9.51 | 1.184 | 0.0227 |
| 11.24 | 1.224 | 0.0377 |

# Appendix C

# UIUC Low-Speed Airfoil Tests Manifesto

*The UIUC Low-Speed Airfoil Tests Manifesto which appears below is a modified version of the initial announcement of the wind-tunnel test program written in December 1993. At the risk of being redundant with respect to what was included in the Preface, most of the original content of the announcement is retained. For recent information on the UIUC LSATs, please see the latest bulletin available from either the coordinator at the address given or from* `http://uxh.cso.uiuc.edu/~selig` *on the World Wide Web.*

We are searching for a group of experienced modelers to build a variety of airfoil wind-tunnel models for tests at the University of Illinois at Urbana-Champaign (UIUC). A low-speed, low-turbulence wind tunnel has been instrumented to take lift and drag measurements on airfoils at low speeds over the Reynolds number range from 40,000 to 500,000 (40k to 500k). The scope of the airfoil wind-tunnel tests will be limited only by the number of wind-tunnel models provided and the amount of funding received. Hopefully, the proposed modeler-supported airfoil test program will become self-sustaining. Your support and help of any kind will be acknowledged in reports on the project to be published through SoarTech Publications (Herk Stokely). We plan to publish the results through SoarTech frequently—possibly twice per year.

A similar undertaking (with substantial support from modelers) was started by Michael Selig, John Donovan and the late David Fraser in 1987 at Princeton University. In a two year period, over 60 various low-speed airfoils were wind-tunnel tested, involving over 1200 hours of wind-tunnel test time. The results were published in SoarTech 8 in 1989, and many of the new airfoil designs produced and tested during the program are now widely used on R/C sailplanes. As of November 1993, over 2200 copies of SoarTech 8 are in circulation worldwide. SoarTech 8 is available from

SoarTech Publications
c/o H.A. Stokely
1504 N. Horseshoe Circle
Virginia Beach, VA 23451
*e-mail: herkstok@aol.com*

At the present time, there is a need for new airfoils for R/C sailplanes. For example, R/C handlaunch soaring is booming, but few good airfoils (e.g., E387 and SD7037) presently exist for such sailplanes. Sailplanes for the new F3J competition are just beginning to evolve, and new airfoils will probably be required. What will they look like? In the past, only a few airfoils (e.g., HQ 1.5/8.5, RG15 and SD7003) have been favored for F3B competition. In shape, handling and performance the SD7003 is quite different from the other airfoils mentioned. These significant differences suggest that it may be possible to design new airfoils that have better overall characteristics for F3B competition. In addition to the design and wind-tunnel testing of new airfoils, several existing airfoils should be tested. The SD7037 and RG15 are quite popular and often used with flaps. The flap effectiveness of these airfoils should be quantified through wind-tunnel tests, and the results should be used in the design of new airfoils.

There is also a need for new airfoils for R/C sport, aerobatic, and electric planes, as well as R/C helicopters. Often, NACA airfoils are used for these applications, but as compared with airfoils that could be designed today, many of the NACA airfoils (which were designed decades ago mostly by trial and error) are inferior. At the time the NACA airfoils were designed, little was known about the complex aerodynamics of airfoils operating at low Reynolds numbers. (Airfoils with small chords at low speeds, such as those on model aircraft, are said to operate in the low Reynolds number flight regime). In recent years, much has been learned about low Reynolds number aerodynamics, and this knowledge has successfully been applied to the design of new airfoils for R/C sailplanes, ushering in a new era in R/C soaring. Overall, R/C sailplane performance has improved dramatically. Older airfoils are no longer used. R/C power aircraft performance could likewise be dramatically improved through the use of newly designed, specially tailored airfoils.

Unique airfoil design requirements also exist for other categories of model aircraft. For example, FAI free flight aircraft (which incorporate both a powered launch segment and gliding flight) operate over a wide range of speeds. In the past, many airfoils with good performance characteristics have been designed for FAI free flight. These airfoils should be wind-tunnel tested to quantify their performance. The results gleaned from the tests could then be applied in the design process in an effort to develop new airfoils with improved performance. Also, the Society of Automotive Engineers (SAE) sponsors an annual model airplane design competition in which university student teams design, build and fly an R/C cargo aircraft. The record cargo weight that has been carried now stands at 24 3/4 lb for a model with a 60-size engine and 1200 $in^2$ total projected area. Conceivably, this record could be broken by an aircraft with an airfoil (or airfoils) specifically designed for the competition. Clearly, the need for new airfoils and data on existing airfoils is not limited just to R/C sailplanes, but applies to any type of model aircraft where better handling qualities and overall performance are desired.

Other topics of interest include the effects of turbulators and contour accuracy. Are boundary layer trips simply "repairs" to otherwise bad airfoils, or can trips be integrated with the airfoil and result in improvements over, say, the SD7037? The Princeton tests began to address this issue, but many questions still remain. For example, what is the best trip height for a given airfoil? Also, what is the best trip geometry, where should the trip be located for best performance, and what type of airfoils respond best to trips? The Princeton tests also shed some light on how accurate airfoils must be in order to achieve expected performance, but a more systematic effort should be made to test the best airfoils for sensitivity to contour accuracy. Also, we are interested in designing and testing families of airfoils for use in, say, transitioning from one airfoil at the root to a different airfoil at the tip. It is unlikely that the best performance can be obtained from a single airfoil used along the entire wing span. This is especially true for flying wings. Companion airfoils for blending should be designed for use with the most popular existing airfoils, e.g., SD7037 and RG15. It is expected that the practice of blending airfoils along the span will become much more popular than it is today. In an effort to maximize low Reynolds number airfoil performance for model aircraft, all of these topics should be addressed.

Overall, the UIUC test objectives will be to design and wind-tunnel test new airfoils for each category of aircraft listed above and also to examine the effects of flaps, turbulators and contour accuracy. We are especially interested in testing existing airfoils that are known to have superior performance. Wind-tunnel data on such airfoils will be used during the design of new and better airfoils. If you believe that we have overlooked an important area, we would be interested in your input and may consider expanding the scope of the project. The number of airfoil models to be tested has not been predefined; rather, it will be depend on the level of interest and support from the modeling community.

The wind-tunnel models should have a 33 5/8 in span with a 12 in chord and can either be built-up or foam core. To insure a uniform contour, the built-up models need to be fully sheeted. For the foam core models, we may be able to supply two 12 inch chord wing templates. The surface finish can either be fiberglass or monokote; however, we are interested in the effects of surface finish and will consider testing models with non-smooth surfaces. The models will be attached to the wind-tunnel balance by standard model wing rods. Standard model construction techniques should provide the necessary strength (supporting 15–20 lb of lift when pinned at both ends). The brass tubing and collars for the models will be supplied along with full-scale plots and/or coordinates of the airfoil, if requested. (Please contact us before starting any construction on a wind-tunnel model.)

The airfoils will be tested in the UIUC open-circuit $3 \times 4$ ft subsonic wind tunnel. The turbulence intensity level is minimal and more than sufficient to ensure good flow integrity at low Reynolds numbers. The experimental apparatus

used at Princeton will be modified for the UIUC tests. Lift and drag measurements for each airfoil will be taken at Reynolds numbers of 60k, 100k, 200k and 300k. In some instances, it may be possible to take limited data over an expanded range (40k–500k). The lift characteristics will be determined through force-balance measurements, while the drag will be evaluated by the momentum method through the use of pitot-static probes traversed through the airfoil wake at several spanwise locations. We are also interested in airfoil pitching moment measurements, but the current apparatus does not have such a capability. However, a pitching moment balance has been recently designed and should provide pitching moment data in the near future.

If you are interested in building wind-tunnel models for the tests or wish to request information, please write, fax or send e-mail to the coordinator

UIUC LSATs Coordinator
c/o Prof. Michael Selig
Dept. of Aeronautical and Astronautical Eng.
University of Illinois at Urbana-Champaign
306 Talbot Laboratory, 104 S. Wright St.
Urbana, IL 61801-2935
*e-mail: uiuclsats@opus.aae.uiuc.edu*
fax: (217) 244-0720

The program will be self-sustaining so long as funds are made available for equipment maintenance/upgrades and graduate student stipend support and tuition and fees (approximately $16,000/yr per student). The initial goal is to raise enough money to support at least two graduate students for a three year period. It is envisioned that a small level of support from a large number of modeling enthusiasts could sustain the airfoil design wind-tunnel test program indefinitely. The impact on model aviation could be tremendous. Donations can be mailed to

Prof. Michael Selig
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Please make checks payable to "University of Illinois, AAE Dept." Also, please write on the check "Selig — Wind Tunnel Testing/AAE Unrestricted Funds," and provide a letter stating that your contribution is to be used by Prof. Selig and his group of students (both undergraduate and graduate) in support of the airfoil wind-tunnel tests. Finally, for a suggested donation of $18 in US, Canada, and Mexico (or $22 in other countries) you can receive a UIUC LSATs white short-sleeve shirt. All proceeds will go toward the continuation of the project.