Appendix C   Preparation of Written Material

Effective engineering requires good communication skills. Documentation and presentation of results are two important aspects of computational aerodynamics. This requires good use of both text and graphics. This appendix provides guidelines for student aerodynamicists. The first impression you make on the job is extremely important. Learn and practice good written communication. That is the way bosses "up-the-line" will see your work. You cannot do good written work without practice. This is especially true in aerodynamics, where good plots are crucial. You can't play in the band or on the basketball team without developing skills through practice. It is even more important to a career to develop good graphics skills while you are in school.

Text: Analysis and calculations must be documented with enough detail to settle any question that arises long after the calculations are made. This includes defining the precise version of the code used, the configuration geometric description, grid details, program input and output. Often questions arise (sometimes years later) where the documentation is insufficient to figure out with certainty exactly what happened. Few of us can remember specific details even after a few months, and particularly when being grilled because something doesn't "look right" (this is the situation when the flight test data arrives). Two personal examples from wind tunnel testing include inadequate documentation of the exact details of transition fixing and the sign convention for deflection of surfaces (at high angle-of-attack it may not be at all obvious what effect a "plus" or "minus" deflection would produce on the aerodynamic results). Good documentation is also crucial since a typical set of computations might cost many hundreds of thousands of dollars, and the results might be examined for effects that weren't of specific interest when the initial calculations were made. An unfortunate, but frequent, occurrence in practice is that the time and budget expire before the reporting is completed. Since the report is done last, budget overruns frequently result in poor final documentation. It is best if the documentation can be put together while the computations are being conducted. Computational aerodynamics work should copy wind tunnel test procedures and maintain a test notebook. This approach can minimize the problem.

When writing a memo describing the results be accurate, neat and precise. In a page or two, outline the problem, what you did to resolve it, and your conclusion. What do the results mean? What are the implications for your organization? Provide key figures together with the description of how you arrived at your conclusion. Additional details should be included in an appendix, possibly with limited distribution. When writing your memo or report provide specifics, not generalities, *i.e.*, rather than "greater than," say "12% greater than." What do the results mean? When writing the analysis, ***do not*** simply provide tables of numbers and demand that the reader do the interpretation. You must tell the reader exactly what you think the results mean. The conclusion to be drawn from the each figure must be precisely stated. Providing computer program output and expecting someone else (your boss or your teacher) to examine and interpret the results ***is totally unacceptable***. This is the difference between an engineer and an engineering aide.

Plots and Graphs: To make good plots using the computer, you must understand how a plot is supposed to be made. Hand plotting defines the standards. When plotting by hand use real graph paper. For *A* size (8 1/2 x 11) plots this means K&E* Cat. No. 46 1327 for 10x10 to the half inch, and an equivalent type for 10x10 to the centimeter. There is an equivalent catalog number for *B* size paper.** This is Albanene tracing paper. It is the paper that was actually used in engineering work, and it's expensive. The University Bookstore will stock this graph paper until it's no longer available (I think they keep it separated, stored under my name). You should use it carefully, and not waste it. With high quality tracing paper, where the grid is readily visible on the back side, you plot on the back. This allows you to make erasures and produces a better looking plot. Orange graph paper is standard, and generally works better with copy machines, especially when you plot on the back. Before computer data bases were used, tracing paper allowed you to keep reference data on a set of plots and easily overlay other results for comparison (remembering to allow for overlay comparisons by using the same scale for your graphs).

Always draw the axis well inside the border, leaving room for labels inside the border of the paper. Labels should be well inside the page margins. In reports, figure titles go on the bottom. For overhead presentations, the figure titles go on the top. Data plots should contain at least:

- Reference area, reference chord and span as appropriate (include units).
- Moment reference center location.
- Reynolds number, Mach number, and transition information.
- Configuration identification.

If the plots are not portrait style, and must be turned to use landscape style, make sure that they are attached properly. This means placing the bottom of the figure on the right hand side of the paper. This is exactly opposite the way output for landscape plots is output from printers. However, this is the way it must be done.

Use proper scales: Use of "Bastard Scales" is grounds for bad grades in class and much, much worse on the job. This means using the "1,2, or 5 rule". It simply says that the smallest division on the axis of the plot must be easily read. Major ticks should be separated by an

* This paper is very high quality paper. With computers replacing hand plotting, this paper is being discontinued by K&E. Most art supplies stores (sometimes erroneously also claiming to be engineering supply stores) don't stock good graph paper. Cheap paper will not be transparent, preventing easy tracing from one plot to another.

** Wind tunnel data, especially drag polars, are often plotted on *B* size paper (11 x 17).

increment that is an even multiple of 1, 2 or 5. For example, 10, 0.2, 50 and 0.001 are all good increments between major ticks because it makes interpolation between ticks easy. Increments of 40, 25, 0.125 and 60 are poor choices of increments, and don't obey the 1,2, or 5 rule. The Boeing Scale Selection Rules chart illustrates the rule, and our version of it* is included as Fig. C-1. Label plots neatly and fully. Use good line work. In putting lines on the page, use straight edges and ship's curves to connect points, *no freehand lines*. Ship's curves and not French curves are used by aeronautical engineers when working with force and moment data. Some engineering supply catalogs call them aeronautical engineering curves. Today, pressure distributions are usually plotted directly by computer software because of the density of data. The University Bookstore stocks at least the most common size ship's curve. As a young engineer, I was told that if the wind tunnel data didn't fit the ship's curve, the data were wrong. More often than not this has indeed turned out to be the case!

Drag polars are traditionally plotted with C_D on the abscissa or *X*-axis, and C_L on the ordinate or *Y*-axis. Moment curves are frequently included with the C_L-α curve. Figure C-2 provides an example of typical force and moment data plots. The moment axis is plotted from positive to negative, also shown in the figure. This allows the engineer to rotate the graph and examine C_m-C_l in a "normal" way to see the slope. Study the scales on the plot. Also, the drag, moment, and lift results typically require the use of different scales.

The traditional way to plot data and results of calculations was to use symbols for data, and a solid line for calculated results. Recently, and very unfortunately, this style has been reversed when comparing force and moment data. Experimental data may be much more detailed than the computations, which may have been computed at only one or two angles of attack. Nevertheless, I object to using lines for data, and believe that the actual data points should be shown. When comparing pressure distributions, calculations should always be represented by lines, and the experimental data shown as symbols. Also, recall that in aeronautics C_p is plotted with the negative scale upward. Figure C-3 provides a typical example of a C_p plot. When connecting data with curves, they ***must*** pass through the data points. Connect complicated data with straight lines, as shown in Fig. C-4. If the data points are dense, or a theory is used to compare with data, you don't need to draw lines between points (curves that don't go through data points are assumed to be theoretical results).

More comments on proper plots and graphs are contained in the engineering graphics text, by Giesecke, *eat al*. (Ref. C-1). The engineer traditionally puts his initials and date in the lower right hand corner of the plot. One problem frequently arises with plot labeling. In reports, the figure titles go on the bottom. On view graphs and slides the figure titles go on the top. Many graphics

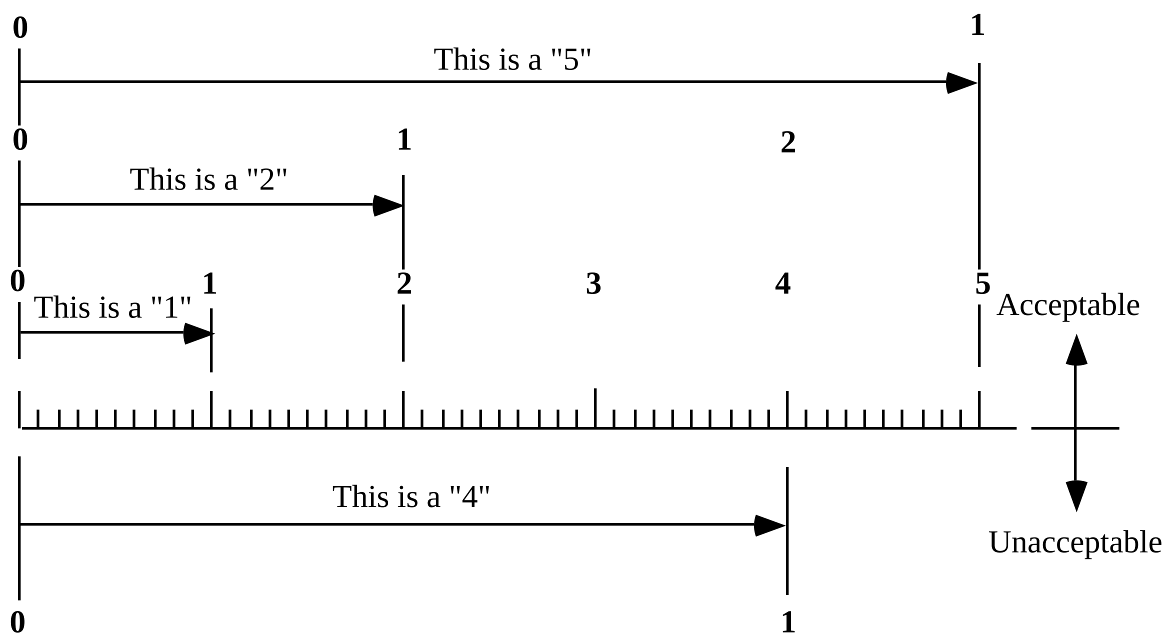
* This "improvement" was conceived by Joel Grassmeyer. It still requires some study.

packages are oriented toward placing the titles on the top. This is unacceptable in engineering reports. Finally, *tables* are labeled on the top for both reports and presentations.

Engineering plots made using your computer must be of engineering quality. To do this you have to understand the requirements given above for hand plots, and should have made enough graphs by hand to be able to identify problems in the computer generated graphs. For force and moment data it is often easier to make plots by hand than to figure out how to get your plotting package to do a good job. Typical problems include poor scale selection, poor quality printout, not being to invert the axis direction, and inability to print the experimental data as symbols and the theory as lines. Another problem that arises is the use of color. While color is important, it presents a major problem if the report is going to be copied for distribution. Most engineering reports don't make routine use of color— yet (electronic reports will make color much easier to distribute).

Reference

C-1 Giesecke, F.E., Mitchell, A., Spencer, H.C., Hill, I.L., Loving, R.O., and Dygdon, J.T., *Principles of Engineering Graphics*, Macmillan Publishing Cop., 1990, pap. 591-613.



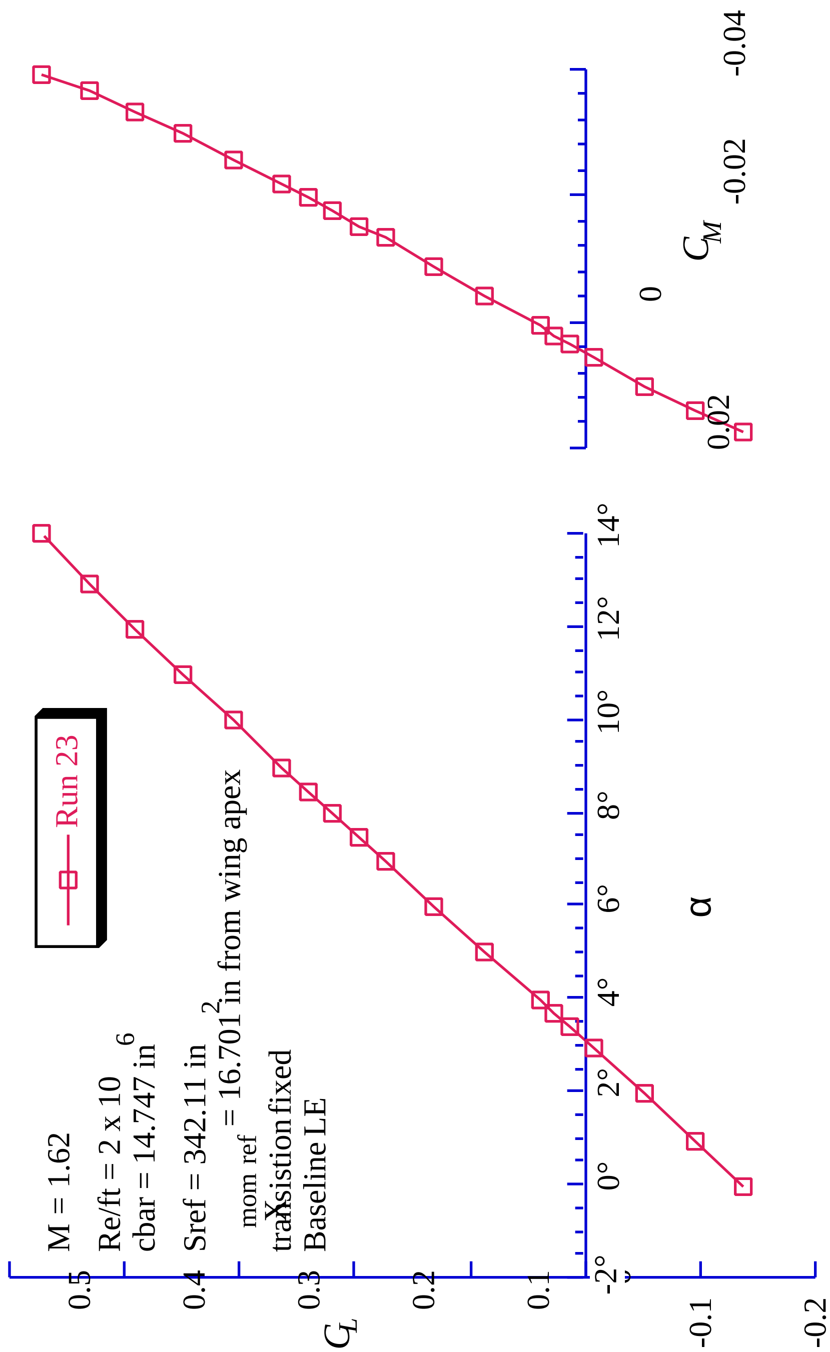
Minor subdivisions of 1, 2, or 5 allow easy interpolation, and are the only acceptable values. A minor division of 4, for example, is very difficult to use.

Scale selection rules for engineering graphs

Originally devised by H.C. Higgins, The Boeing Company, re-interpreted for these notes.

Figure C-1. Boeing scale selection chart
(based on a figure in the *AIAA Student Journal*, April, 1971)

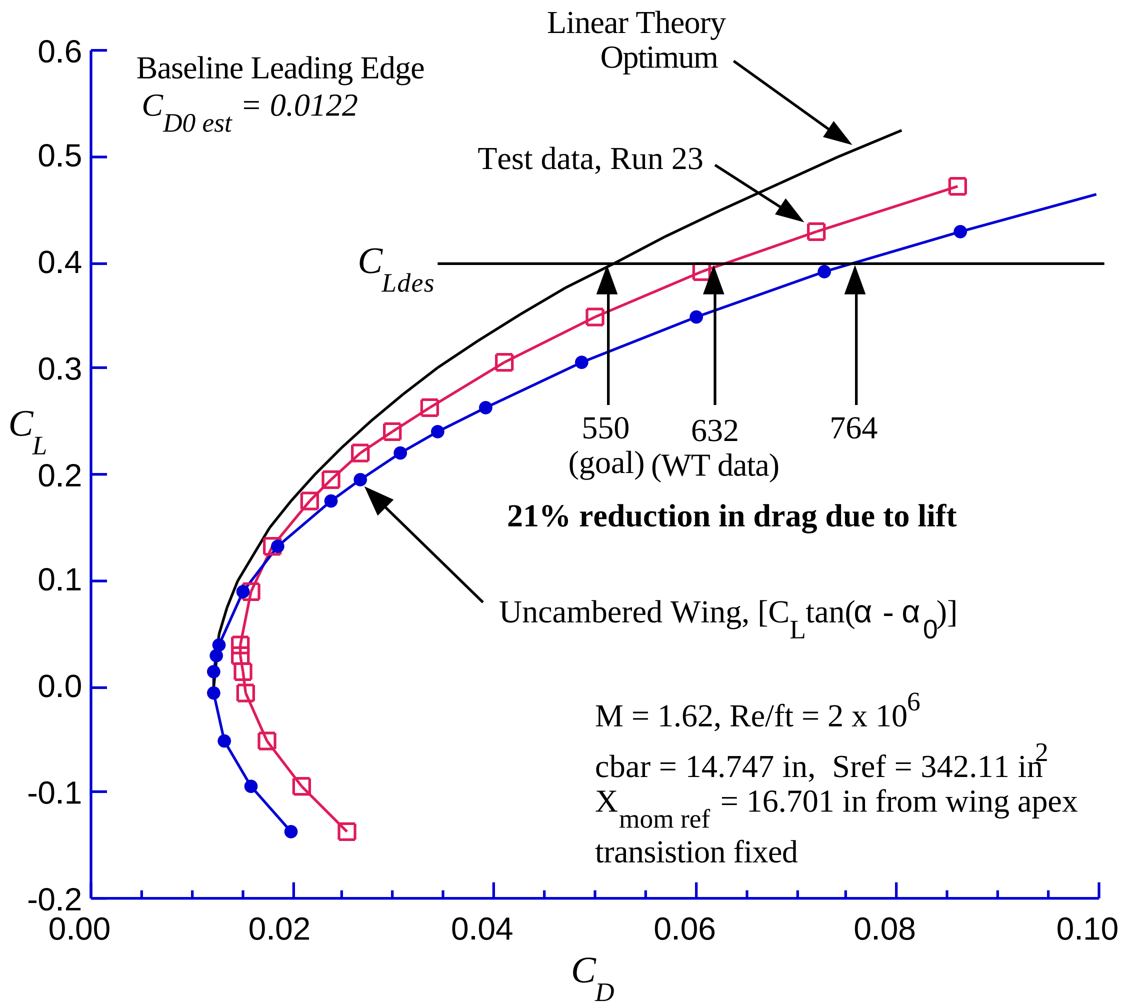
from Grumman Aero Report No. 393-82-02, April, 1982, “Experimental Pressure Distributions and Aerodynamic Characteristics of a Demonstration Wing for a Wing Concept for Supersonic Maneuvering,” by W.H. Mason



a) lift and moment

Figure C-2. Examples of wind tunnel data plots.

from Grumman Aero Report No. 393-82-02, April, 1982, “Experimental Pressure Distributions and Aerodynamic Characteristics of a Demonstration Wing for a Wing Concept for Supersonic Maneuvering,” by W.H. Mason



Drag Performance of a Demonstration Wing for Supersonic Maneuvering

b) drag polar

Figure C-2. Concluded.

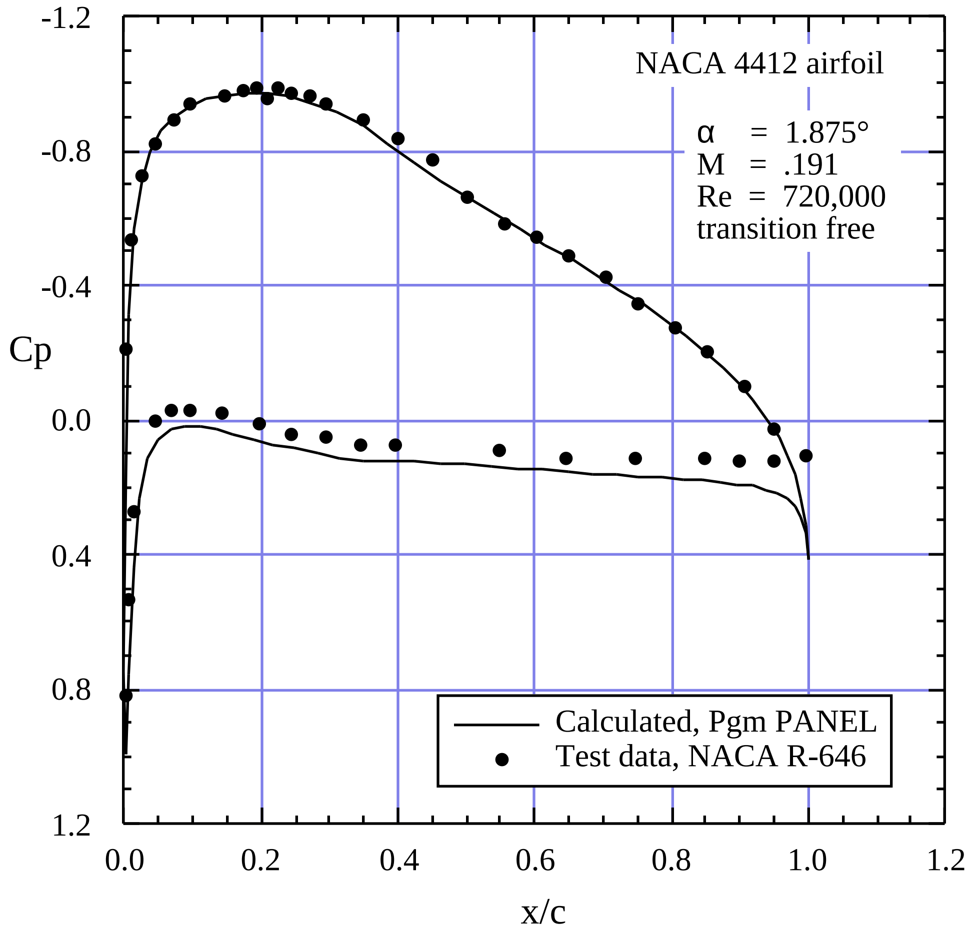


Figure C-3. Example of pressure distribution plot.

from Grumman Memo EG-ARDYN-86-051, 1986.

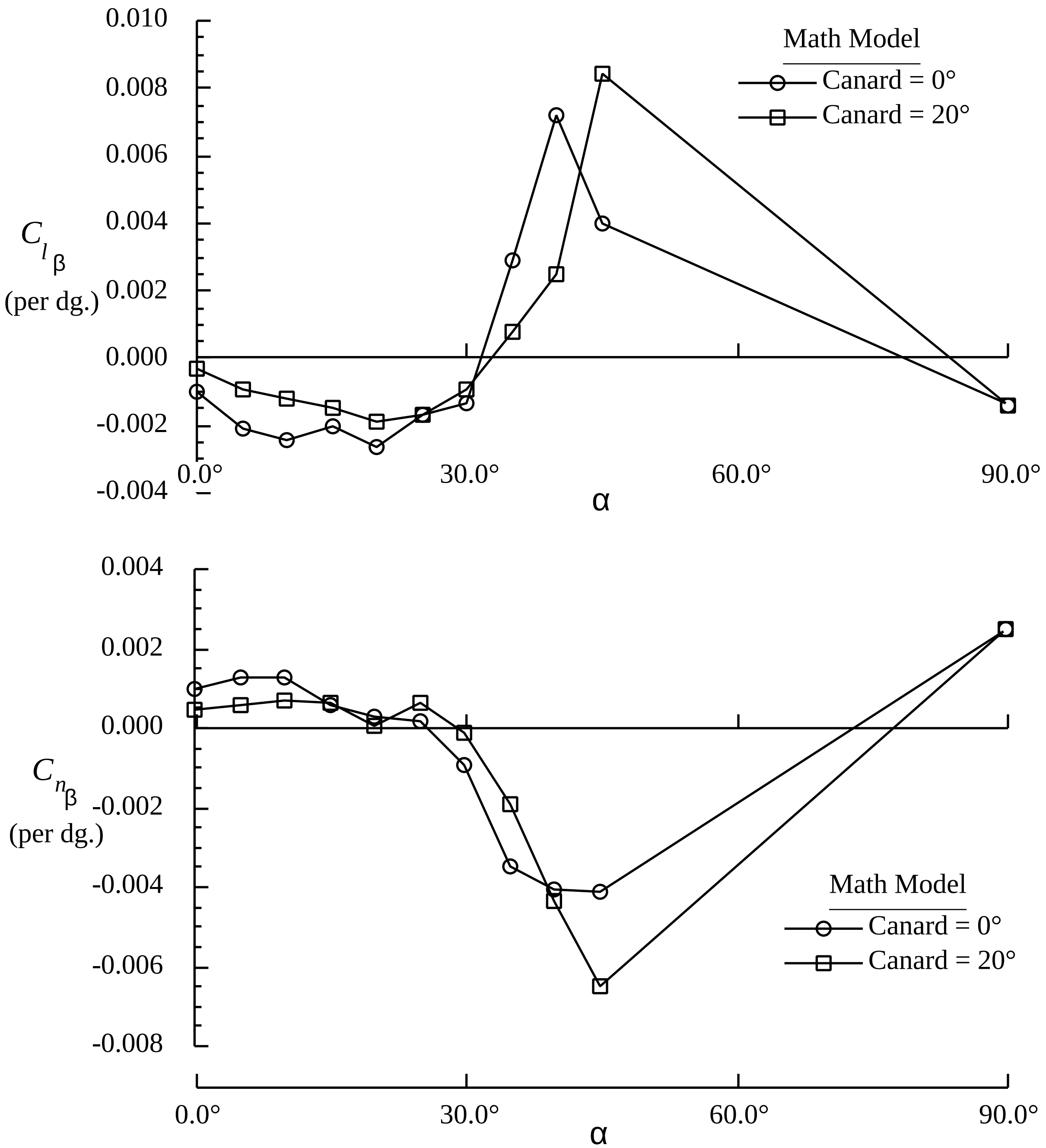


Figure C-4. Example of plotting complicated experimental data.