Appendix

C

Technical Graphics Guidelines
Preparation of Plots, Tables, and Equations[14]

General Preparation

Like all aspects of technical writing, the preparation of plots, figures, tables, and other graphics elements is expected to portray professionalism and clarity of communication. Even if your text is lucid and well-written, your report will be considered of poor quality if your graphics are ill-prepared or ambiguous. Therefore, all graphics included in your technical writing, regardless of the format, shall abide by these common-sense guidelines.

First Things First

If you are using Microsoft Excel to prepare your plots, you must take note. This is because the "default" scatter plot in Excel is a terrible format to use, violating almost every rule for preparing plots. Therefore, you must invest a significant amount of time to change the formatting and thus the look of your graph. In particular, Excel defaults to the following 11 things that are completely unacceptable with regards to technical data presentation:

1) The background is non-white. This quickly runs your printer dry and, more importantly, can make it difficult to see details on your plot. Change the background to white.
2) The plot area is framed by a gray border. This should be black, to clearly define the plotting area. Alternatively, this can be eliminated altogether (i.e., axes lines only on the plot).
3) The graph area is framed by a black border. This should be eliminated because it is unnecessary.
4) There are gridlines. These should be removed because they detract from the plot details and trends. Instead, include tick marks along your axes to demark the major and minor increments.
5) The legend squeezes out usable plot area. If you don't need a legend, then don't use one. If you need one, overlay it on a non-critical part of the plot area.
6) The legend text is ambiguous. You must give the data series meaning.
7) The title squeezes out usable plot area. Eliminate this. Every plot is captioned in a technical report, so a plot title is extraneous. This is usually true for PowerPoint presentations, as well.
8) The "automatic" axis limits and increments are usually poor representatives for the data selected. Change these using the guidelines on page 69.
9) The data points are connected with a "smoothed line." This is the phoniest aspect of Excel! Note how the smoothed line apparently predicts a false maximum at x = 8. If you use a line, then just "connect the dots" with straight line segments because this preserves the true trend.
10) The symbols are usually too small. Furthermore, the symbols and lines are usually color-coded in such a way that photocopying makes the data series seem ambiguous. Follow the guidelines on page 70 to select the symbol size, shape, and coloring.

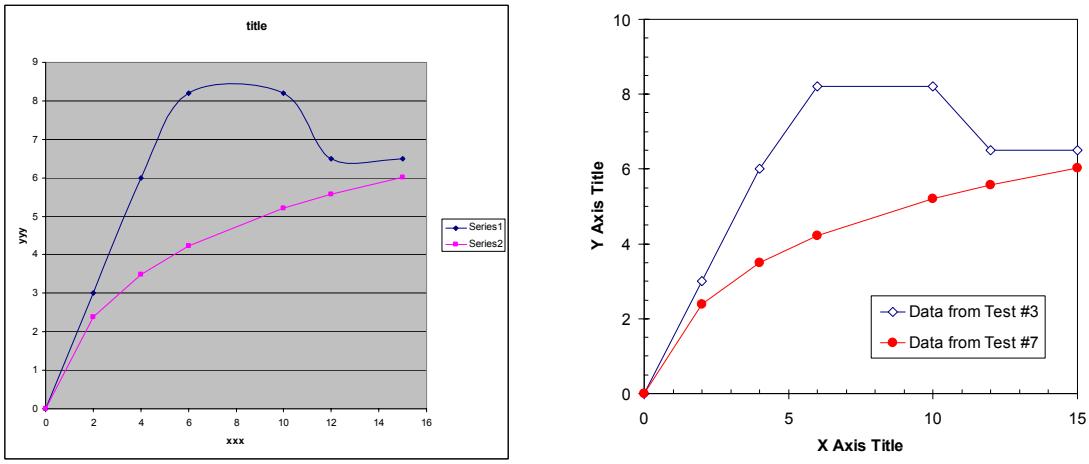
[14] Compiled from USNA's *Report Writing Handbook* (adapted from the USNTPS handbook, *The Write Stuff),* dated August 1999; USNA's *Technical Report Writing Guide* (adapted from USAFA guidelines and prepared for students in the Astronautics Track); and W.H. Mason's unpublished *Applied Computational Aerodynamics* (http://www.aoe.vt.edu/~mason/Mason_f/CAtxtTop.html), Appendix C.

11) The font is usually far too small. Once reduced to fit within the document, these fonts can be unreadable. Make the fonts larger.[15]

Excel Examples

The problems with Excel are illustrated in the two examples shown in Figure 26. The graph on the left uses all of the unacceptable Excel default formats. It is terrible as a scientific figure and will receive zero credit in a technical report. By contrast, the graph on the right shows the same data with all of the Excel problems corrected. This results in an acceptable presentation of the data. You should carefully study the differences between these two plots if you will be using Excel to plot your data.

If you will be regularly using Excel to prepare your plots, then you should consider creating a custom template of your own default formats. This can be accomplished by setting up a properly-formatted scatter plot and then accessing (from the standard Excel toolbar) Chart > Chart Type > Custom Types. Then you can select from "User-defined" chart types to add your own customized default chart. When you hit the "Add" button, it will save the current plot in your list of chart types. Make sure to click the "Set as default chart" button to complete the task. From now on, every graph will default to the formatting you defined.



• Figure 26. An unacceptable Excel plot (left) and a satisfactory one (right)

General Guidelines for Figures and Tables

These guidelines relate to the general use of figures and tables in technical writing:

1) The category "figure" includes graphs, charts, illustrations, photographs, diagrams, or schematics. Figures are numbered and captioned below the figure. The only time a title or caption appears above the figure is in a presentation slide.

2) The category "table" involves data arranged in tabular form. Tables are numbered and captioned above the table.

3) Orient the figure or table so that it is read in the same orientation as a page of text. Large illustrations may be rotated so that the top of the figure is along the left margin of the page (Note: this is upside-down compared to the landscape output from a printer).

4) Figure and table captions should be brief, but descriptive. Avoid lengthy captions with too much detail. Avoid using abbreviations or symbols in the caption text, unless is it absolutely necessary. The caption should all be on the same line, with normal capitalization (avoid all caps). **The caption must remain with the table or figure, not on the previous/next page!**

[15] Besides, your instructor may have less-than-perfect eyesight!

5) Annotate the table or figure with reference information relating to the data. This could be the test article model and/or serial number, the test Mach and Reynolds numbers, the material used, etc. Use annotation to make it clear what is being presented, but don't be redundant with the figure caption. Refer to the graphs in this document for examples of how to annotate figures.

6) The table or figure should appear close to the place it is referenced in the text, with the following priority:

   a. On the same page following the first reference, or
   b. On the same page, visible from the reference point, or
   c. At the top of the following page, or
   d. In an appendix.

7) Every table and figure <u>must</u> <u>be</u> <u>referenced</u> in the text. If it's not, then it doesn't belong in the report. The exception is material that appears in the appendices. In this case, the figures or tables can be referred to in bulk (e.g., "Appendix B includes the raw data plots for the lift coefficient.").

8) If the table or figure is not your own, you <u>must</u> cite its source! Do this at the end of the caption.

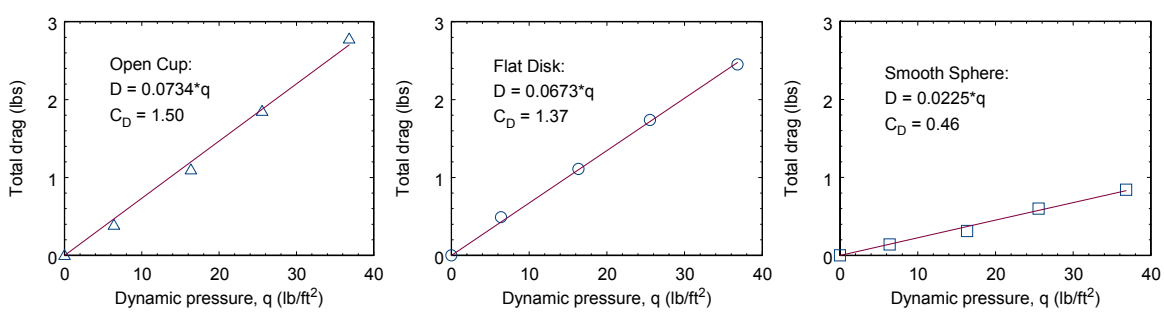
9) Figures and tables are numbered consecutively using Arabic numerals (e.g., "Figure 1," "Table 2," etc.). They should also appear in the report consecutively. A separate numbering sequence shall be used for figures and tables.

10) Figures and tables in the appendices are numbered consecutively using Arabic numerals preceded by the appendix letter (e.g., "Figure A.1," "Table B.2," etc.).

11) Use an appropriate number of significant digits in numerical information presented in figures and tables. This extends to reference information, axis labels, and legends.

Formatting Plots

When comparing several plots showing the same type of data, it is preferable to include all data series on one set of axes, but it is not always possible or practical. One huge plot may become inundated with too much information. In this case, make separate graphs but make them as uniform as possible. Make all plots the same size with the same axes limits using consistent symbols, lines, and/or colors. Sometimes, this means that some of the graphs will have a lot of seemingly wasted plot area. However, this is acceptable because it allows for instantaneous "eyeball" comparison between the different plots. See Figure 27 for an example of uniform scaling between several plots.



• Figure 27. An example of uniform axis scaling for comparison purposes

Proper Scales and Increments

It is important to select the proper scales and increments when setting up plotting axes. In particular, you should pay special attention to the major and minor tick mark increments along each axis. You should follow the so-called "1-2-5 rule." This rule basically states that the smallest division on a plot's axis must be easily read. This is accomplished by creating axis divisions and subdivisions, as indicated by major and

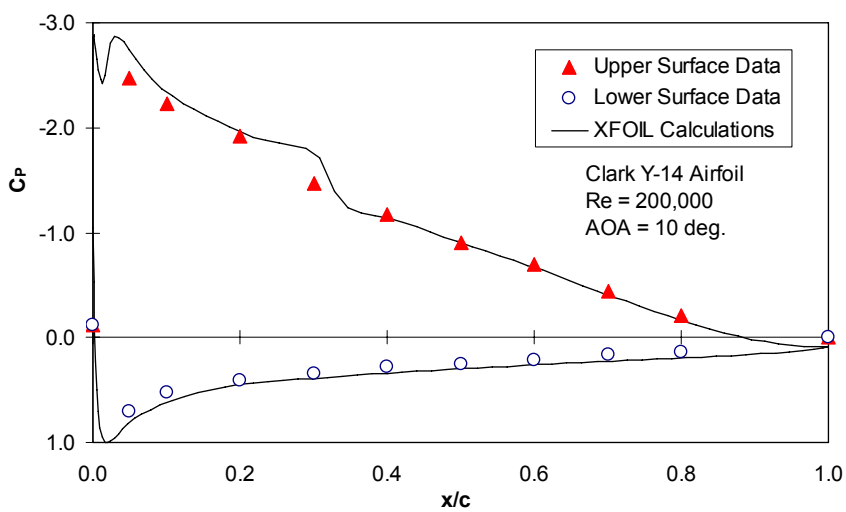
minor tick marks, that are separated by an order of magnitude of 1, 2, or 5 (i.e., 1, 2, or 5 x 10^n). By following this rule, data can be easily interpolated between tick marks. Some good examples of major and minor tick mark increments are 10, 0.2, 50, and 0.001. Some poor choices are 40, 25, 0.125, and 60, because they do not follow the 1-2-5 rule.

When setting up a graph's plotting limits, you should use common sense. The limits should include the range of interest without too much extra space (the exception is when you have a series of identical plots, with varying data). It is common to hold loosely to the 1-2-5 rule when setting up axis limits.

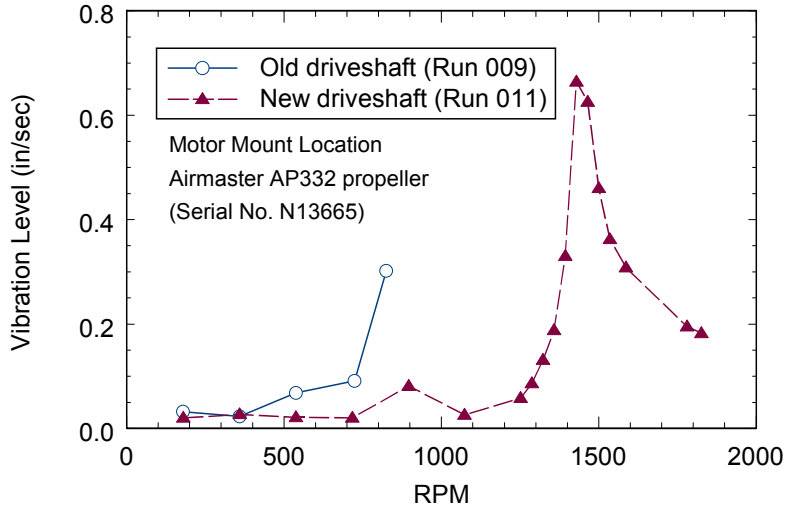
Selection of Symbols and Lines

The use of line/symbol combinations can signify a lot about your data. Proper use will help facilitate quick comparisons and make conclusions clear. Follow these guidelines to help you:

- The choice for symbol/line/color combinations should be consistent throughout the report or presentation. For example, if lift coefficient data for the NACA 0012 with zero flaps is represented by red, filled triangles connected by a solid line, then maintain this combination throughout the rest of the plots: drag polar, pitching moment coefficient, and L/D ratio.
- Maintain a consistency in the ordering of the data, as presented in the plot legend. Keep this order throughout a series of data plots. And if possible, select an ordering that roughly mimics the data in the plots (i.e., the data series on top, in the middle, and on the bottom should be reflected in the legend in the same orientation).
- If experimental data is being compared to theoretical calculations (including CFD or simulation results), use the accepted convention: experimental data is indicated by symbols (no lines) and theoretical data is indicated by lines (no symbols). The legend should also clearly discriminate the two data series, as is shown in Figure 28.
- If plotting complicated data, you might want to "connect the dots" to clarify the trends, even if multiple series of experimental data are included. In this case, it may be useful to change the line type as well: solid, dashed, dotted, etc. See Figure 29 for details.



• Figure 28. A plot comparing experimental data (symbols) with theoretical results (line)



• Figure 29. Plotting complicated experimental data for comparison

The Use of Color

The most important aspect to remember when selecting symbol/line combinations is that the color may not be transmitted accurately. This is especially true if the report is photocopied, during which a beautiful, color-coded chart or plot may be quickly reduced to an ambiguous mass of similar-looking symbols and lines (i.e., "junk"). Excel is especially good at auto-selecting color schemes that all look the same after photocopying.

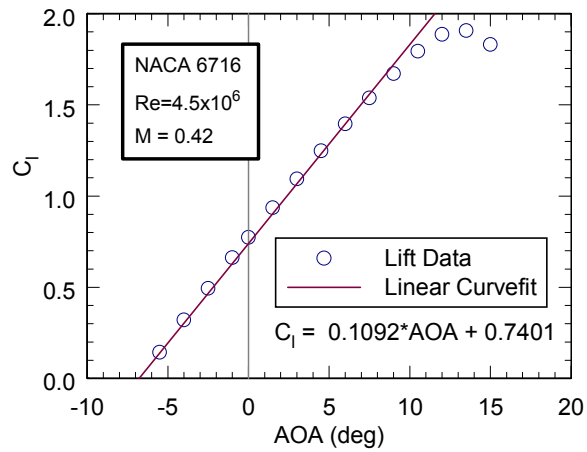
In short, it is permissible to use color in reports and presentations, but your results, analysis, and conclusions **SHOULD NOT BE TOTALLY DEPENDENT** on an accurate color facsimile of the figure. In other words, follow these basic guidelines to distinguish your data in other ways:

- Alternate between open and filled symbols for alternating data series.
- Alternate between dark hues and medium hues. As an example, magenta photocopies as a medium gray color. Avoid using the lightest colors like yellow and cyan, because these won't show up on a photocopy at all.

Data Trends

When plotting experimental data, only use a trend line (or curvefit) that accurately represents the theoretical trend! This means that the "smoothed line" function in Microsoft Excel is completely inappropriate for scientific and engineering plotting, because it represents no physical aspect of the data.

As an example, consider experimental lift coefficients plotted against the angle of attack for an airfoil. Suppose you are required to determine the lift curve slope and then interpolate the function to get α_{L_0}. It makes no sense to fit a quadratic trendline through the data, even if the nonlinear stall region is included. The theoretical relationship between lift coefficient and AOA is linear at low-to-moderate angles of attack, so a linear curvefit should be used. If you're using an Excel linear trendline, make sure to create the trendline only from the data points that are in the linear region. Figure 30 shows the proper use and format of a linear curvefit (or trendline) and how the information can be presented on the plot. Remember that if you use the wrong data points to determine something like the airfoil lift curve slope, then all your subsequent results and conclusions are in error!



• Figure 30. Proper use of linear curvefit information

In some situations, the linear trendline may differ from the linear theory, so make sure you present the context of the problem appropriately. A trendline uses the acquired experimental data to create a best-fit linear function through the points; it only requires the original set of data. Linear theory involves another data series representing the theoretical relationship (in other words, a second dataset). Therefore, the slopes of these two elements may differ; do not confuse the two.

Formatting Tables

Tables are used to present the numerical value of data for comparison and/or calculation. The purpose of a table is to present a more-inclusive presentation of the data than is discussed in the text. In other words, one or two critical data points might be discussed in detail in the text, but the table shows all 8 data points. Table 14 depicts an example of a data table.

• Table 14. A properly-formatted data table.

Balloon Weight Component Measurements

C (in)	Volume (ft^3)	$W_{envelope}$ (lb)	$W_{payload}$ (lb)	W_{total} (lb)
-	0	-	-	-
66.75	2.91	0.1004	0.0886	0.1890
80.60	5.12	0.0715	0.2684	0.3399
92.00	7.61	0.1003	0.3815	0.4818
99.10	9.51	0.0986	0.4930	0.5916
110.70	13.26	0.1094	0.7618	0.8712
116.25	15.35	0.1048	0.8918	0.9966
-	20	-	-	-

Follow these general guidelines when preparing a data table:

1) Consider if a graph is better suited to present your data.

2) You should use “open table” formatting. In other words, there is no box around the whole table. There are also no horizontal lines except to delineate the column headings. Lastly, the columns are all separated by vertical lines.

3) Tables should be clear, concise, and easy to read. Do not include too much information in one table. Sometimes, two smaller tables are better than one large one.

4) Don’t leave blank cells in a table. Use dashes to represent omitted data.

5) Tables may be used to present raw data. These tables should be included in the Appendix.

6) Tables represented reduced data can be included within the body of the report. If this data is already represented by a graph, you may want to consider putting the table in the Appendix.

7) Include units in the column or row headings.

Formatting Equations

It is expected that equations are included in most technical reports or presentations. Because they usually require a little more preparation than typing characters at the keyboard, they are considered with the graphical elements of a technical report. There are only a few basic guidelines for properly using equations:

1) Use an equation editor (e.g., MathType). These are usually built into word processing applications. DO NOT type out equations using text and symbols (i.e., -, +, *, /, ^, etc.).

2) Keep the equation all on one line, if possible.

3) Every equation should be referenced in the text. If it’s not, then it shouldn’t be in the report.

4) You should number your equations with Arabic numerals. If possible, place the equation number on the same line as the equation, aligned with the right margin. In Microsoft Word, this is impossible, so put it on the next line and right-justify it.

5) Define symbols immediately following the equation unless they are already defined in the List of Symbols.

An example of Bernoulli’s equation should appear all on one line in a report, like this:

$$p_t = p_s + \frac{1}{2}\rho U_\infty^2 \qquad \text{Equation 1}$$

…or like this:

$$p_t = p_s + \frac{1}{2}\rho U_\infty^2 \qquad (13.1)$$

Alternatively, the equation and label can be staggered on two separate lines, like this:

$$p_t = p_s + \frac{1}{2}\rho U_\infty^2$$

Equation 2

…or like this:

$$p_t = p_s + \frac{1}{2}\rho U_\infty^2$$

(13.2)