DATA PRESENTATION

Presentation of data is an essential function of engineering documentation. Errors or carelessness in the reproduction of equations, construction of tables, inclusion of computer printouts, and—particularly—citing of data in text can make documentation work ineffective or even meaningless.

Guidelines for the effective presentation of data are provided in the following paragraphs.

EQUATIONS

An equation is a shorthand way of expressing a relationship or a process. It is like jargon; when we use this language with those who understand it, we have simplified communication enormously. How many words would it take to express the following:

$$\sigma_x^2 = \frac{1}{n}\left\{\sum_{i=1}^{n} X_i^2 - n\overline{X}^2\right\} \tag{1}$$

On the other hand, what possible meaning does it have for the uninitiated?

Equations are significant in topical reports, articles, and books dealing with the derivation of relationships and generalizations from empirical data. We must, of course, explain the relationship and its derivation in the text of the report: this is what we did to get the data, this is how we manipulated and analyzed it, this is what it looked like (graph), and—then—this is the resulting function. Long derivations, or series of equations, may be put in an appendix with only the most important ones included in the body of the report.

An equation may be used in a manual or other instructional material to help the reader understand the principle behind a device or a process. However, we must consider carefully just how much principle this specific audience needs, and, on the other hand, where we approach overkill (and resulting confusion).

Also, a manual user may need an equation to derive a number that is required for operation of the equipment or process. For example, the user must solve for x in the equation $x = 1.25\sqrt{A}$, and then set an instrument using the value obtained. Equations employed for purposes like this should be simple and clearly explained in text, keeping in mind the mathematical and technical ability of the potential user. If the function is not a simple one, it is better to substitute a

This article is based on the *Handbook for Preparing Engineering Documents,* IEEE Press, 1996, pp. 107–118, 205–206, 296–301, © 1996 IEEE.

Text Explanation

> Testing was performed off site on 856 samples in 199X. Only 16 percent (133 samples) of the 856 samples passed the first test. 84 percent (723 samples) of the original 856 failed the evaluation at a cost of $107,727. The failed samples were submitted for a second test with an 80-percent acceptance rate. The remaining 20 percent of the samples that failed the second test cost $38,304, for a total first- and second-test failure cost of $146,031.
>
> In contrast, the on-site testing facility has tested 677 samples during the current year. Projections of the 199Y testing activities have been performed so the cost can be more accurately compared.
>
> The 856 projected samples subjected to the first test rendered a 91-percent (776 samples) acceptance. The remaining 9 percent (80 samples) failed, costing $5,280. The first-test failures were submitted to the second test, in which 52 percent (41 samples) were accepted. The balance (48 percent, 39 samples) of the samples also failed the second test at a cost of $4,563 or a total cost for first- and second-test failure of $9,843.

Table Explanation

Testing	Number of	First-Test Failures			Second-Test Failures			Total Failure
Agency	Samples Tested	Number	Percent	Cost ($)	Number	Percent	Cost ($)	Cost ($)
Off site	856	723	84	107,727	144	20	38,304	146,031
On site	856[a]	80	9	5,280	39	48	4,563	9,843

[a] Projected on the basis of current year-to-date testing.

Figure 1. Example of reduction of text to table.

graph of the function (with a full grid) and instructions for finding the needed value from the curve.

There are two ways to set equations in a document: *inline* and *displayed.* (Inline equations are also called *shilling* equations.) An inline equation is shown in the preceding paragraph. Inline equations are usually short, uncomplicated expressions, with few or no outsized symbols (like summation signs and braces) which would introduce a nonstandard line spacing. Fractional and quotient expressions in these equations are written in shilling form, that is, with the slash symbol: $x/y = 1/2\ (a + b)$. They should never be broken at the end of a line; if a break is unavoidable, the equation should be displayed. An equation that is too long to fit on one line, even if displayed, should break at an operation sign (for example, *plus* or *minus*). The operation sign should be repeated on the next line for readability. All lines of the same equation should be aligned flush left under the operation sign.

The first equation shown in this article [Eq. (1)] is a displayed equation; that is, it is set on a line by itself. If there are several equations in a work (say, more than three) and a need to refer to them in text, they should be numbered (like tables and figures). The equation number is often set in parentheses at the right-hand margin.

When a displayed equation is introduced in text, it is good practice to use an introductory sentence, followed by a colon, and then insert the displayed item:

> The relationship between *x* and *y* is shown by the following equation:
>
> $$x = A + 2y$$

It is sometimes preferable to use, instead, whatever punctuation would be logical if the action of the equation were not displayed—that is, described in words, rather than mathematically. For instance,

> Solving for *y* gives
>
> $$y = (A - x)/2$$
>
> and this is the definition of the horizontal scale shown in Fig. 4-1.

Chemical equations are treated in much the same way as mathematical equations.

Most of today's word processing programs give all of us the capability to set complex mathematical material with incredible ease and with precision.

It is well worth the engineer's while to learn to use whatever equation software is available. The average typist/word processing operator is likely to make errors of content in this kind of work. But the engineer understands the function of summation signs and limits; integrals; over- and underbars; delimiters like parentheses, brackets, and braces; as well as Greek letters and other symbols. With today's word processing programs, it is much easier to enter this information ourselves than to explain calculus, often handwritten, to a word processing operator.

TABLES

Like an equation, a table can save a lot of words, as shown by Fig. 1. In this case, an engineer wrote out the text explanation in longhand and gave it to the group secretary to type. Many hours and much discussion/argument later, his colleagues finally understood what the engineer was saying, and one of them constructed the table explanation.

The table is easier to comprehend. It shows the large difference in the costs of off-site and on-site testing more emphatically. And it takes up less space/less of the reader's time.

Tables, like graphs and equations, are ways we show relationships in engineering documentation. Tables, in fact, show multiple relationships. The table in Fig. 1 may be used to discern the relationship between first-test failure and second-test failure at the two testing agencies, to compare rates of failure between the agencies, and of course to compare costs.

A table communicates information better than text when the following conditions are present:

- There is more than one set of related data.
- The data sets reference the same parameters—for instance, meter readings (on the same unit-of-measurement scale) at various locations, or time intervals.
- There is reason to be interested in comparison of the data—for instance, which location had the highest reading?

On the other hand, if the information in the table can be expressed more simply by words, a graph, or a chart, a table should not be used. A graph, for example, may not give so much data, or such exact data, but it gives the reader an instant picture of the relationships under discussion.

Table Components and Assembly

To discuss what makes a table work well, we need to name its parts (Fig. 2).

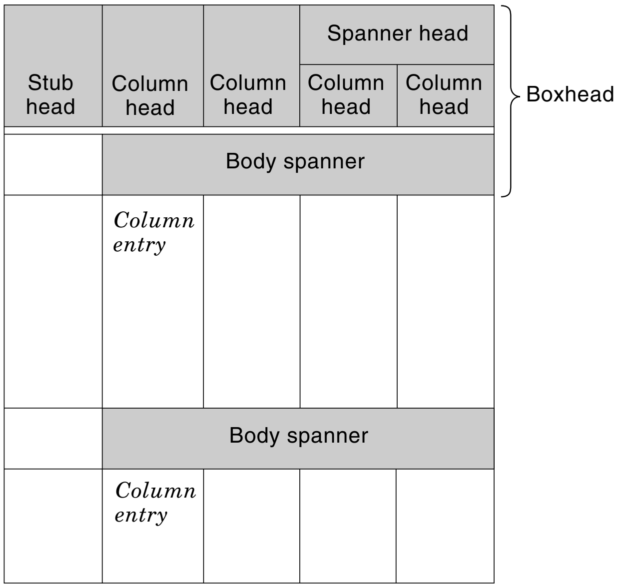


Figure 2. Parts of a table.

Table 1. Example of Unboxed Table

	Meter Reading at Indicated Time (V)		
Test	1 hr	2 hr	3 hr
1	51	60	61
2	78	83	85
3	26	32	33

The following guidelines govern data entry in tables:

- Information always reads *down* from the boxhead, all the way to the end of the table.
- Information reads *down* from the stub head. (That is, the stub head describes information in the stub entry column, not the information in the column heads.)
- Information controlled by the stub head reads *across*.

Note that a table may be *boxed*, as shown in Fig. 2 (that is, have a border around it), or *unboxed* (Table 1). The use of borders and lines is discussed below, under "Table Format."

Like graphs, many tables show a relationship between independent and dependent variables. Usually, the independent variable (time, for example) reads horizontally, across the table; the dependent variable (test number, for example) reads vertically. Care must be taken to ensure that the column and spanner heads describe the column entries exactly. For instance, Table 1 might have this spanner head: "Meter reading at indicated time (hr)." But it would not be accurate because the entries are in volts, not hours.

Units of measurement are just as important to tables as they are to graphs and charts. Every column or spanner head needs a unit of measurement (or some explanation if the values are arbitrary numbers rather than measurements). It is an aid to both clarity and economy to put the unit in the head rather than in the entries:

This is better . . .	**than this . . .**
Boiling point (°C)	Boiling point
100	100°C
197	197°C
290	290°C

Standard practice for use of a dual system of measurement [for example, both SI (metric units) and engineering (English) units] is covered below, under "Metric Conversion."

Spanner heads help to combine data and avoid repetition. Instead of repeating the unit of measurement after the column head *Boiling point* and after *Freezing point,* we can introduce a spanner:

Temperature constants (° C)	
Boiling point	Freezing point

A good question to ask is "How much data does this description apply to, and what is the clearest way to show that?" A lengthy description that applies to a small amount of data could be placed in a footnote.

Sometimes the stub column is hard to define with a stub head because the stub column entries do not seem to be classifiable. Often there is an "umbrella" word that will cover the list, like *parameter* or *function* or *instrument.* If we cannot find any common denominator, we may have to rethink the whole table. Do the data sets truly reference the same parameters? If not, we need to present the data in some other way.

We often see a column of sequential numbers before the stub; that is, the entry rows are numbered from 1 through *n*. Unless these numbers truly describe some feature of the data (such as *item number* or *test number*), or unless there is a real need to refer to certain rows of the table by number designator, this column should be eliminated. In the former case, where the numbers are part of the descriptive data, the column should probably follow the stub rather than precede it.

Using singular nouns to describe column entries is a commonly accepted convention in table construction. Examples are *meter reading, tube diameter,* and *voltage.*

Body spanners are useful ways to divide data sets—for instance, data from the United States, data from Europe, data from Asia. Formatting can also be used to divide data for clarity and ease of comprehension (see "Table Format," below).

The table title should be both descriptive and concise. For instance, instead of titling a table merely "Cumulative use factors," we might call it "Cumulative use factors for various stress ranges."

Tables are also used to summarize sets of nonnumerical data, as shown below:

Component	Location
Heat pump	Area A
Pressurizer	Area B
Cooling tank	Area C

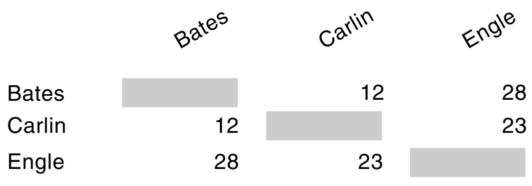
Informal tables are essentially lists. They have no number or title; they may have no stub heads, as shown below:

Advantages	Disadvantages
Low cost	Long lead time
Design simplicity	High consumables requirement

A matrix is a special kind of table in which each item in the stub column interacts with each item in the column heads. The matrix in Fig. 3 shows distances between plants.

Because it is symmetrical (the same parameters are shown in stub column and column heads), certain spaces are blank. That is, there is zero distance between pairs like Bates and Bates. Also, each entry (value) appears twice, since the distance between Bates and Carlin is the same as the distance between Carlin and Bates. The matrix can be read either across and down or down and across.

In a nonsymmetrical matrix, there is no repetition of data. Such a matrix might show currency conversion factors, in which the value for dollars expressed in yen is not the same as the value for yen expressed in dollars.



	Bates	Carlin	Engle
Bates		12	28
Carlin	12		23
Engle	28	23	

Figure 3. Example of a matrix.

It is fairly common to see blank cells in symmetrical matrixes, since most readers understand the principle behind this kind of data presentation. However, some explanation is recommended for missing, inadequate, or negligible data in other tables. We can use the word *none* or N/D (no data), or insert an em dash (—), to show that we have not simply forgotten to fill the cell. N/A is commonly used for *not applicable.* It is good practice to footnote N/A or N/D the first time it is used.

Footnotes are often used to explain a missing or a seemingly anomalous table entry, to qualify an entry for which the conditions varied from those in the remainder of the table, or to expand on an abridged entry. However, if a table accumulates too many footnotes, we again need to rethink the appropriateness of a table in this application. The data may simply not match up well enough for tabular presentation.

Table Placement

If the table is to be used as the document is read, it is best to include it with the discussion. Many tables, however, are supplemental information; that is, the reader can understand the text without referring to them but may want to consult them later. In these cases, tables can be grouped in an appendix (and referred to in the discussion). A third (and recommended) alternative is to summarize the data in a short table in the body of the document and provide the full body of information in the appendix.

When a table is used, it is referred to in the text by number (except for informal two- or three-line tables inserted in text like spot drawings). The necessary amount of explanation or comment is provided. For instance:

> The voltage fluctuations were recorded at 10-minute intervals and entered in column 3 of table 7, which shows that the fluctuations were most marked between 8:15 and 11:20 AM.

Table Entry

Electronic production of tabular material is a task most engineers try to avoid. It is time-consuming and tedious.

However, even if data entry is done by someone other than the document creator, we need to understand how tables are created and formatted. Then, at least we know what to ask for.

It is even better to study the word processing manual to the extent that we can insert a program-generated table into the document. When we "insert table," we are asked how many columns and how many rows the table should contain. Most often, we do not know this exactly at the outset. We can enter an estimate; columns and rows can be added or deleted later.

The table will usually appear in our document extending across the entire page width, divided equally into the number of columns we have specified. If we do not want a full-page table, we can indent it right and/or left. We usually do not want equal-width columns; we typically want a wider column for the stub and narrower columns for the data. Column widths are easily adjusted by highlighting the entire column and entering the desired width when prompted. Then, we can usually tell the computer to take us to the next (or the preceding) column, resize that one, and so on. It may take some arithmetical work and fine adjustment to get the right proportions.

When the table has been set up the way we want it, including formatting (below), we can proceed to enter data. Alternatively, we can give this template (on disk, perhaps) to a typist/word processing operator for the bulk of the data entry task. (Of course, it will be necessary to proofread the result very carefully.)

Tables generated by a spreadsheet or other data analysis program and satisfactory for use as is may be entered electronically. That is, the table can be converted to the word processing program, imported into the word processing program, electronically cut and pasted into the word processing program, or scanned onto frame pages. The caption (table number and title) should be entered on the frame page during document creation; the page number will be entered automatically.

Table Format

Once the content of the table has been sorted out into an accurate representation of the facts we want to present, we can format the table for optimum readability.

We have all seen tables that featured less-than-optimum readability. The type was too small and the lines too crowded; we could not find our way from one side of a line to the other; we forgot what the column heads and footnotes were when we got to the continuation on the next page.

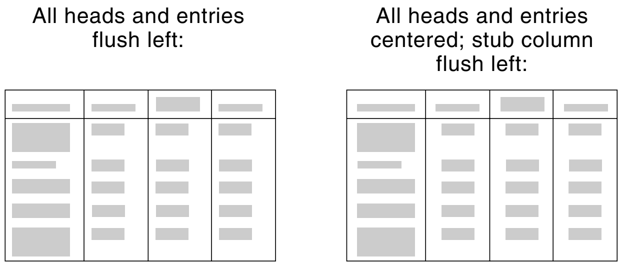
Given that the tabular data we present is very often the heart of the report, it is worth a little time and effort to package tables for maximum effectiveness. The investment pays off especially well when we have a series of similar tables, in which case we can simply *copy* the last one and replace the entries with the current material.

Before we start entering heads and data, we want to give the computer some formatting information. Many word processing programs include a variety of automatic table formats from which to select when entering the table in a document. Otherwise, we must first specify type style and size.

The stub head and column heads need to stand out, so we can make them **bold,** *italic,* or ***bold italic.*** Stub and data entries are usually in regular (that is, not bold, not italic) type style.

All material in a table (heads and body) should be entered in the same size type. The size of the type depends to a large degree on the size of the table. If we must fit a great deal of data into the table, especially if we need many columns, we will have to use a smaller size than the body text. In the body of a document, table type should be no more than 2 points smaller than the body text. Tables that require very small type are probably appendix material. (Note that although 8-point type may be readable, it does not fulfill the legibility requirements for microfilm work.)

Text entered in spanners may be set in **bold,** *italic,* or ***bold italic;*** however, the style chosen should not be the same as that chosen for the stub and column heads. (It should be a degree less emphatic; for instance, if the heads are bold italic, the spanner can be plain italic.) All-capital letters may be used in spanners if the line of type is fairly short (less than the full width of the table).



All heads and entries flush left:

All heads and entries centered; stub column flush left:

Figure 4. Two examples of table entry alignment.

Entries in the columns may be aligned flush left or flush right, centered, or (for numbers) aligned on a decimal point. Heads are often centered in their columns. Stub entries are almost always aligned left. Subcategories of stub entries may be bulleted and/or indented, like regular text. Two examples are shown in Fig. 4.

When column entries consist of one or two words, their alignment matches that of the heads above them. More lengthy text entries are usually entered flush left. Number entries are usually centered on the decimal point, literally or figuratively. In the latter case, when there is no decimal point in the number, we can simply tell the computer to use right alignment. If there is a decimal point (in any or all of the entries), we must set a decimal tab at the desired point in the column, and then press the *Tab* key before each entry.

Text in spanners is aligned left if they span the entire table (including stub column); it may be centered if the spanner covers only the data columns.

Column heads should be ‘flush bottom’—that is, the bottom lines of all head entries should be aligned. This may necessitate adding carriage returns (extra lines of space) before some lines. It is not a good idea to set column heads vertically or at an angle, since type turned on its side is hard to read.

A table is a *box* of data, whether it is enclosed in a visible box (borders) or not. The choice between *boxed* and *unboxed* tables is most often a matter of personal preference. Even in an unboxed table, however, the boxes are there. If the table has been created with the table function of the word processor, the box borders can be seen, faintly, on the computer monitor.

With the word processor, a visible box is created by turning on the borders of the table and the columns and/or rows.

An unboxed table, if it is anything more than the simplest two-by-two or three-by-three arrangement, needs some kind of treatment to guide the readers’ eyes across and down.

At a minimum, there should be a divider between the heads and the body of the table (perhaps a double line). Additional horizontal lines (rules) are needed after (and, preferably, before) spanners. A very long table should be divided by horizontal rules, perhaps every five or ten rows; an additional line of space may be used instead. A rule at the bottom of the table helps to separate it from text.

Vertical rules are optional; they help to divide columns of data, especially very narrow columns.

If desired, tint blocks may be used in place of rules (Fig. 5). A tint block is an area of color or a shade of gray under a segment of text, illustration, or table to highlight it or set it apart. To add a tint block to a row, column, or cell, we turn on the shading feature of the word processor.

Figure 5. Example of use of tint blocks in a table.

Shades for tint blocks should be strong enough to copy easily and light enough so that the text can be read clearly. Finding the best shade (percentage) is often a matter of trial and error; try a low percentage (5% or 10%) first and check it out by printing a sample page. All type set inside a tint block should be boldface.

In a simple two-column table (like a table of contents or index), dotted, dashed, or solid line leaders are sometimes used to guide the readers' eyes from one column to the other. These tables are usually set up with tabs rather than with the table function, and the desired leader can be chosen when the tab is set. Leaders should only be used when they serve an important function; otherwise, they clutter up the page unnecessarily.

The caption (that is, the title plus the designator, such as *Table 4-1*) may be centered over the table or set flush left. It should be in the same size type as body text but may be bold and/or display type. The table number (usually including a chapter or section designator) should be on the first line, with the table title on the second, for easy location and scanning.

For footnote designators, we can use letters since table entries are usually numerical. They should, of course, be set as superscripts. It is best to keep the number of footnotes to a minimum.

Tables frequently spill over onto a second page, or further. The reader needs to see the full caption (number and title) on each continuation page. It is common to put the word *continued* or the abbreviation *cont* in parentheses after the table number.

All the column heads of the table should also appear on continuation page(s). If spanners are used, the most recent spanner should be printed between column heads and data, again followed by *continued* or *cont* in parentheses.

Table footnotes should be repeated on each page of the table to which they apply. Thus, the continuation page of a table might include only notes *b, d,* and *f*, which is all right.

More information on table formatting may be found in the article entitled DOCUMENT/INFORMATION DESIGN in this encyclopedia.

COMPUTER PRINTOUTS

Computers are very good at constructing tables, and in fact, computer printouts are often the source of the data we want to present. This facility tempts us to stuff engineering documents with huge batches of computer printout. Sometimes, this is helpful or even required; more often, it is not. If we must include raw computer data, perhaps we can do it more effectively and/or economically by means of diskette, CD-ROM, or microfiche.

At least, the printouts should be culled from the body of the document, where they are likely to interrrupt the reader's train of thought, and put in an appendix for reference as needed.

However used, these compilations of data need identification, with a caption (table number and title). They usually need to be reduced in size and pasted down on (or scanned onto) the page bearing the caption.

EXPRESSION OF NUMERICAL INFORMATION

Numbers can be expressed in different ways—Roman and Arabic, superscript and subscript, rational and irrational, whole integers or derived to the 12th decimal place. We need to be consistent in expressing numerical information, just as we are with textual matter.

Superscripts and subscripts are common in engineering documentation, but they wreak havoc with line spacing. When used, they should be set in a smaller type size (at least two points smaller), or the numbers thus modified should be displayed like a displayed equation. Super- and subscripts are set with the character format function of the word processor.

The facility of the computer in generating numbers has led to a decline in the consideration of *significant figures.* The computer will keep dividing 11,624,581 by 346, at least until its display capacity has been reached. But do we really want 12 figures after the decimal point? Not just because we have them; these figures may not be significant. When we include figures with no significance, we lead the audience to assume more accuracy than the work provides.

The following guidelines cover most situations:

- The number of significant figures used is a function of the *accuracy of the measuring device.* For instance, when we measure a room with a yardstick, the result is not any more accurate than the eighth-inch marks on the stick. Thus 10 feet, $6\frac{1}{8}$ inches, for instance, would be the accuracy limit of such a measurement. However, in machining, we can use micrometer calipers to measure fractions of a millimeter.
- The number of significant figures used is a function of the *counting method.* If we count every person who enters an arena by means of a turnstile, we are justified in presenting the total attendance as 47,631. However, if we count the number of people standing on a 10-foot-square plot and multiply by the number of plots, the result is a lot fuzzier. We have factors of error in both the randomness of the sample and the proportion of the sample to the whole; the result would probably only be significant to one or two figures—50,000 or 47,000.
- The number of significant figures used is a function of the *data used to create the number* in question. When we divide 20 by 3, our answer is no more accurate than 6.7 (one digit more than the smaller number in the original data). But when we truly have original data to the third decimal place, we can divide 20.000 by 3.000 and present the answer as 6.6667. (Note that a zero to the *right* of the decimal point counts as a significant figure; those to the left generally do not.) If we divide 20.000 by 3, however, our answer is no more accurate than the smaller number in the original data; again the answer is 6.7.

On the other hand, in addition and subtraction, we can use an answer that corresponds to the *higher* or *highest* number of significant figures in the calculation. For instance, 4.327 plus 8 equals 12.327.

- Tolerances, or margins of error, should be expressed to the same level of accuracy as the measurement they qualify. For instance, a machining tolerance may be given as 31.000 ± 0.005, but not 31 ± 0.005.
- We can round off—that is, arbitrarily reduce the number of significant figures presented—if we do it consistently throughout a calculation or series of calculations. Even the Internal Revenue Service permits us to drop cents from our computation as long as we are consistent.

A word of caution about expressions of tolerance, noted above. When we are very sure that our audience is made up entirely of other engineers, the plus-or-minus symbol (±) is acceptable. However, when we require the reader/user to calculate the limits of a tolerance or range, we are creating a potential for error. In a manual or procedure intended for use in the field, this is not acceptable. Thus, we need to give tolerances and limits in immediately recognizable terms, using the format ⟨nominal value⟩ ⟨units⟩ (⟨lower limit⟩ to ⟨upper limit⟩). For example:

125 vdc (115 to 135)

Manual/procedures users should never be required to calculate percentages. For calculations like this, we can provide a graph or table.

Similar considerations for in-the-field users include using the same measurement units that appear on the user's instruments. (That is, we do not write about foot-pounds if the equipment shows inch-pounds.) Also, we use values that are readable on the user's instrument. One-half the distance between markings is about the limit of instrument-reading accuracy.

Scientific notation for the expression of very small or very large numbers involves the use of powers of ten, for instance, 5.7×10^{-8}. These numbers are usually written with no more than one figure to the right of the decimal point unless there is justification for doing otherwise. It is preferable, but not essential, to use a *symbol* font for the 'times' mark, rather than the 'x' in a normal text font. It is not good to use an asterisk (*).

METRIC CONVERSION

More and more often, in today's global community of science, technology, and business, we are asked to furnish measurements in SI (Le Système Internationale d'Unités). SI closely resembles the centimeter-gram-second and meter-kilogram-second metric systems we may have learned many years ago in basic science courses—but tidied up, standardized, and unified. Usually, we must also present the data in standard/British/engineering units.

This requirement can present special problems. The primary principle here is consistency; whatever usage we adopt should remain the same throughout the document (or series) of documents. The following usage is recommended:

- Choose one unit system to be primary and one to be secondary. In engineering documents prepared for U.S. readers, the engineering units are usually primary and the metric secondary. (In this encyclopedia, however, the reverse is true.)
- Express all numbers in the primary system followed by the corresponding value in the secondary system, in parentheses: 6 in. (152.4 mm)
- If the value is already contained within parentheses, change the outer marks to brackets: [The original length was 6 in. (150 mm).] Or change the parentheses to brackets and the outer marks to parentheses.
- Observe the principles given above for matching the number of significant figures between systems. However, it must be noted that the base unit in one system may be a great deal larger or smaller than the base unit in the other system. For instance, in the above example, millimeters are much smaller than inches; for that reason, the conversion (1 inch = 25.4 millimeters) produced a result (152.4 mm) that implied more accuracy than is warranted by the original measurement. Engineering judgment is required here. We might use meters instead of millimeters, with the following (more reasonable) result: 6 in. (0.15 m)

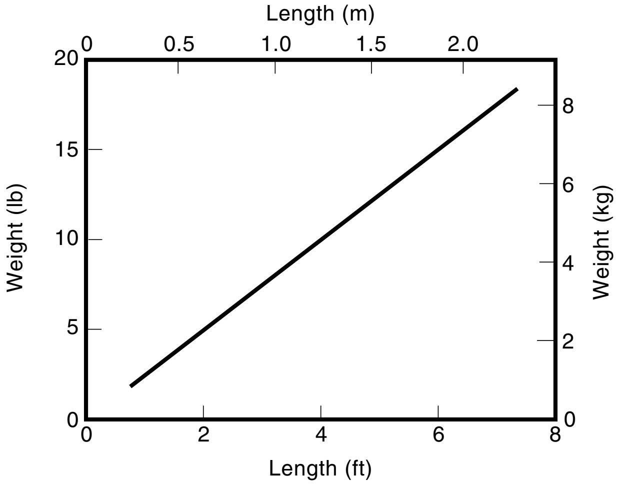
  Here, since a meter is so much longer than an inch, we have added one significant figure to the metric equivalent.
- In table headings, where the unit of measurement is usually given in parentheses following the column head, we again change to brackets and give the secondary unit in parentheses: Temperature [°F (°C)]
- Similar practices are followed in illustrations. In callouts (labels within the illustration) and dimensions, values are expressed in units of the primary system followed by expression in the secondary system, in parentheses. In graphs, units in the primary system are shown in labels at right and at the bottom; units in the secondary system are shown in labels at left and at the top. Alternatively, both values may be shown on the same scales, but this can be confusing. Both these practices are shown in Fig. 6.

The following guidelines apply specifically to the use of SI measurement units:

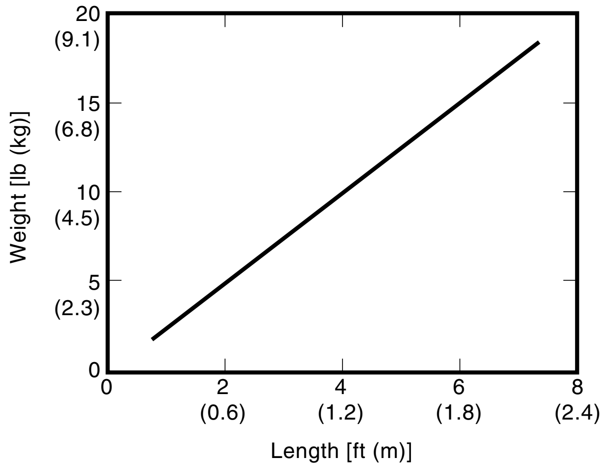
- Unit names are not capitalized even when they derive from the name of a person. Unit symbols are not capitalized unless they derive from a proper name. For example,

Unit	Symbol
meter	m
newton	N
pascal	Pa

  Note that abbreviations for SI units are commonly referred to as *symbols.*
- The plural of an SI unit is formed by adding *s*, except for *hertz, siemens,* and *lux,* which are the same in both singular and plural, and *henry,* for which the plural is *henries.*
- SI prefixes and symbols at various multiplication factors are shown in Table 2.



(**a**) Preferred method



(**b**) Alternative method

Figure 6. Use of dual measurements in graphs.

- The final vowel in the prefix is retained in all but two cases: *megohm* and *kilohm*. No space or hyphen is used between prefix and root.
- Certain conventions govern the use of term:

  The prefixes *hecto, deka, deci,* and *centi* are accepted SI forms, but they are rarely used. (*Centi* does, however, appear frequently in non-SI work.)

  The same unit should be used for all values of the same quantity in tables and discussions of these quantities.

  Specific units are common to different fields and should be used even when the order of magnitude is very large or very small. For example,

kPa	for fluid pressure
MPa	for stress (except in very weak materials, for which kPa may be more appropriate)
GPa	for modulus of elasticity
kg/m^3	for mass density (except for fluids generally measured in liters, for which g/l may be used; the numerical value is the same)

  When it is possible to do so within these conventions, units chosen should result in numerical values between 0.1 and 1000.

  The recommended unit for fluid pressure (barometric pressure, gas pressure, water pressure, and hydraulic pressure) is *kilopascal* (*kPa*). There are two exceptions: in the field of air-conditioning, where pressure differentials in air ducts are measured in *pascals* (*Pa*), and in measurement of high vacuum in terms of absolute pressure, where *Pa* and *mPa* are more convenient.

  The term *bar* is a metric unit but not an SI unit (although accepted internationally for a limited time in special fields because of existing usage).

  Absolute and gauge pressures are specified by using the words, not the abbreviations *a* and *g*; for example,

  at a gauge pressure of 7kPa
  at an absolute pressure of 25 kPa
  or
  7 kPa (gauge)
  25 kPa (absolute)

- The word *per* is used to form the name of a compound that is a quotient, and a slash (/) to form the symbol; for example, kilometer per hour (km/h).

  To avoid ambiguity, use one of the following forms for combinations of symbols: meters per second per second—m/s^2 *or* (m/s)/s.

- A compound unit that is a product is written with a space or hyphen between the words, and a multiplication or product dot (a dot at the center of the line space) between the symbols. For example, newton meter or newton-meter (N · m).

  The product dot can be found on the symbol font of most word processing programs. If it is not available, use a period set as a superscript. In either case, the dot should be set in boldface.

Table 2. SI Prefixes and Symbols for Unit Multiplication Factors

Multiplication Factor	Prefix	Symbol	Term
1,000,000,000,000,000,000	exa	E	one quintillion
1,000,000,000,000,000	peta	P	one quadrillion
1,000,000,000,000	tera	T	one trillion
1,000,000,000	giga	G	one billion
1,000,000	mega	M	one million
1,000	kilo	k	one thousand
100	hecto	h	one hundred
10	deka	da	ten
0.1	deci	d	one-tenth
0.01	centi	c	one-hundredth
0.001	milli	m	one-thousandth
0.000001	micro	μ	one-millionth
0.000000001	nano	n	one-billionth
0.000000000001	pico	p	one-trillionth
0.000000000000001	femto	f	one-quadrillionth
0.000000000000000001	atto	a	one-quintillionth

Table 3. Metric (SI) Units and Conversion Factors

			To Convert to SI . . .	
			Multiply The Value	
Quantity	SI Unit	Symbol	In This Unit . . .	By This Factor . . .
acceleration	meter per second squared	m/s^2	ft/s^2	(3.048×10^{-1})
area	square kilometer	km^2	mi^2	2.590
	square hectometer (hectare)	hm^2	acres	(4.047×10^{-1})
	square meter	m^2	yd^2	(8.361×10^{-1})
			in^2	(6.452×10^{-4})
	square centimeter	cm^2	in^2	6.452
	square millimeter	mm^2	in^2	(6.452×10^{2})
capacitance	farad	F	N/A	
density	kilogram per cubic meter	kg/m^3	lbm/ft^3	(1.602×10^{1})
electric current	ampere	A	N/A	
electric resistance	ohm	Ω	N/A	
electromotive force	volt	V	N/A	
energy, work, or quantity of heat	joule	J	Btu	(1.054×10^{3})
			ft-lb	1.356
	kilojoule	kJ	Btu	(1.054×10^{6})
	megajoule	MJ	Btu	(1.054×10^{9})
	kilowatt hour	kWh	N/A	
force	kilonewton	kN	lbf	(4.448×10^{3})
	newton	N	lbf	4.448
luminous flux	lumen	lm	candle-power	(1.257×10^{1})
mass (commonly, weight)	kilogram	kg	lb	(4.536×10^{-1})
	gram	g	lb	(4.536×10^{2})
	milligram	mg	oz	(2.801×10^{3})
moment of force (torque)	newton meter	N·m	N/A	
plane angle	radian	rad	degrees	(1.745×10^{2})
	degree[a]	°	N/A	
power or heat flow rate	kilowatt	kW	N/A	
	watt	W	N/A	
pressure (or vacuum)	kilopascal	kPa	psi	(6.895×10^{3})
quantity of electricity	coulomb	C	ampere hours	3600
rotational frequency	revolution per second	r/s	N/A	
	revolution per minute	r/min	N/A	
	revolution per hour	r/h	N/A	
sound pressure level	decibel	dB	N/A	
speed (velocity)	meter per second	m/s	ft/s	(3.048×10^{-1})
	kilometer per hour	km/h	mph	1.609
stress	megapascal	MPa	psi	(1.450×10^{6})
temperature *or*	kelvin	K	—[b]	
temperature interval	degree Celsius	°C	°F − 32	(5.555×10^{-1})
viscosity (dynamic)	millipascal second	mPa·s	centipoise	1
			ft^2/s	929
viscosity (kinematic)	square millimeter per second	mm^2/s	ft^2/s	(6.452×10^{2})
volume	cubic meter	m^3	yd^3	(7.646×10^{-1})
	cubic centimeter	cm^3	in^3	(1.639×10^{1})
	cubic millimeter	mm^3	in^3	(1.639×10^{4})

[a] In SI, fractions of a degree are expressed as decimals, not in minutes and seconds.

[b] To convert to degrees kelvin, calculate Celsius value and then add 273. No degree symbol is used with kelvin values.

- The choice of SI unit for weight depends on whether we mean mass or force of gravity. The unit of mass is the *kilogram,* and the unit of force is the *newton.* Whenever the word *weight* or *weigh* is used, the common meaning is mass (especially in expressing capacity ratings, as of a bridge).

  However in some fields, weight is defined as the force of gravity acting on an object; in this case, the SI term *newton* would be used. For example, on earth, the weight of a 10-kilogram mass is about 98 newtons.

A full treatment of SI may be found in ANS/IEEE Standard 268-1872 and ISO 1000-1981. Table 3 lists SI units for various quantities, their symbols, and factors for converting some common engineering units to SI.

DATA EDITING

There is a high potential for embarrassment in the presentation of data. It is so easy to enter a wrong digit, and spellchecking cannot catch it. We must check all statistics, dates, phone numbers, and the like. Words like *maximum* and *minimum* are red flags: is the value referred to truly the maximum or minimum?

Whenever a column of data has been added up and the total presented, we want to check the addition. Particularly, when a column shows a series of percentages, we want to ensure that they add up to 100 (or else explain why not). (However, by custom, the number 100 is not entered in the total line, if any.) In fact, we want to check any mathematical operation for correctness; not only may an arithmetic mistake have been made, but a component may have been changed somewhere along the line, making the original result of the operation incorrect.

Orders of magnitude and other exponents are often entered incorrectly—with the wrong number, or missing a minus sign. Superscripts and subscripts are also sources of error because of their lack of inherent meaning and the fact that they are set in smaller type than text.

In tables, are the stubs and headers complete, correct, succinct, accurate? Are the entries correct, legible?

Equations need to be checked, rechecked, and then rechecked again, especially if they have been entered by clerical personnel. This check is best done by the professional who was originally responsible for inserting the equation.

NONPRINT DOCUMENTS

These editing precautions are especially important in the case of audiovisual aids (overhead projections, slides) shown with oral presentations. Great care should be taken in projecting tables before an audience; only very brief and very, very clearly formatted tables should be used. (More complex data may be given to the audience in the form of a printed handout.) Additional information may be found in the article entitled ORAL PRESENTATIONS in this encyclopedia.

The creation of electronic documents, such as software help files and manuals on the World Wide Web, is a complex process. The computer display is clearly different from a paper book. The ways in which users access, assimilate, and process electronically presented information incorporate an entirely new set of human factor engineering considerations.

It is recommended that those who are involved in production of electronic documents refer to the article ELECTRONIC DOCUMENT PRODUCTION/REVISION in this encyclopedia, or to the evolving literature on this subject, including the first two references (below).

BIBLIOGRAPHY

The material in this article has been compounded from various sections of *Handbook for Preparing Engineering Documents,* written by Joan G. Nagle and published by IEEE Press (Piscataway, NJ, 1996). The book also covers overall design of documentation, creation of text and illustrations, document testing, and document production. It includes tables of recommended usage in such areas as abbreviations, capitalization, compounding, numbers/numerals, punctuation, references, and spelling symbols.

Other references include the following:

S. Carliner, Elements of editorial style for computer-delivered information, *IEEE Trans. Prof. Commun.,* **33**: 1, March 1990.

W. Horton, *Designing and Writing Online Documentation: Help Files to Hypertext,* New York: Wiley, 1990.

R. Krull (ed), *Word Processing for Technical Writers,* Amityville, NY: Baywood, 1988.

The Chicago Manual of Style, 14th rev., Chicago: University of Chicago Press, 1993.

P. Rubens (ed), *Science and Technical Writing—a Manual of Style,* New York: Henry Holt, 1992.

JOAN G. NAGLE

DATA PROCESSING FOR MANUFACTURING. See MANUFACTURING PROCESSES.

DATA PROCESSING FOR REMOTE SENSING. See REMOTE SENSING GEOMETRIC CORRECTIONS.

DATA PROCESSING INDUSTRY. See INFORMATION TECHNOLOGY INDUSTRY; SOFTWARE HOUSES.