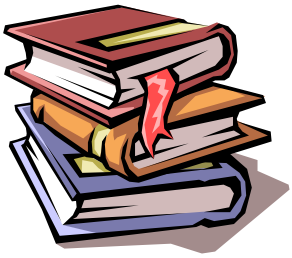
The Chemical Engineering Practice School
Department of Chemical Engineering

Design Project Report Writing

Introduction (taken from *On Technical Writing* by H. M. Ku)



The purpose of technical writing is to report information, often in the fields of science and engineering. Technical writing relays important information to readers. As such, the styles and prose of the documents must be objective, clear, and concise.

Researchers, engineers, and scientists are people who need to communicate their work to others. However, today's students often find themselves in the same boat, as more curricula place more emphasis on writing (as well as oral presentations). It should be stressed that technical writing is different from creative and other styles of writing in many ways. While becoming a successful writer, for example a novelist, requires hard work and some natural gifts, technical writing can be coached. With proper training and some dedication, anyone can become a good technical writer.

Today's engineers and scientists often overlook the importance of writing. In many cases, they did not bother spending the time to master the craft. Technical papers are "serious documents", meaning that a lot depend on them. They need to be concise and specific. An engineer may be passed up for a major promotion because his or her shoddy technical reports fail to convince the management of the significance of the findings. An academician's manuscripts for publications may be rejected on the ground of poor writing. Finally, a scientist's request for a research grant may be denied because the proposal is laden with personal opinions.

The following are some general technical writing tips for success:

1. **Be specific and avoid clutter in your writing.**
   W. Zinsser once wrote: "*Clutter is the disease of American writing … the secret of good writing is to strip every sentence to its cleanest components. Every word that serves no function, every long word that could be a short word, every adverb which carries the same meaning that is already in the verb, every passive construction that leaves the writer unsure of who is doing what – these are thousand and one adulterants that weaken the strength of a sentence. And they usually occur, ironically, in proportion to education and rank.*"

   Technical writing is not literary writing, which serves a completely different purpose. Technical writing must be clear and concise. Short declarative sentences are the easiest to write and read, and they are usually clear. However, too many short sentences in a row can

sound abrupt and monotonous. Good technical writing involves finding the right mix between short sentences and more complex constructions.

2. Write with an active voice.

An active voice is always preferable to a passive voice. Write "*The researchers found a strong correlation between the dosage of the drug and its efficacy.*" instead of "*A strong correlation between the dosage of the drug and its efficacy was found by the researchers.*"

3. Present accurate information and be as precise as possible.

The author of a technical paper uses words to relay information about facts and events that have happened. The author typically does not relay opinions, except in the cases where an unexplained event or phenomenon has occurred. In this case, it is appropriate for the author to render an opinion (an educated one, of course) about the situation. If this is done, it is important that the author make clear that he or she is offering an opinion and not a fact.

4. Use different verb tenses for different expository purposes.

As the writer is usually writing about events which have already happened, the tense of the paper is mainly past tense. For example, "*Smith (1994) found* (not "finds") *that freshmen spend less time" . . .*, or "*The results were*" (not "are"). However, in some parts of the document, it may be appropriate to use the present or future tense. For instance, if the author is covering facts that were, are, and forever shall be true, the facts may be referred to in present tense. The present tense can also be used when you are giving your own ideas, when presenting statements that are well accepted, or when describing your results. For example, "*I believe that maintaining a positive attitude is very useful in helping to beat the cancer scourge.*"; or "*Freud believes that the unconscious determines our behavior.*"; or "*Table 1 shows . . .*". Future tenses are used very sparingly but are more common when writing research proposals. If the author is writing about experiments or activities yet to come, future tense is also appropriate.

5. Try using third-person pronouns.

Technical documents usually do not contain first-person and second-person pronouns such as "I", "you", and "we". However, in recent years the use of first-person pronouns has become more acceptable. Even then, only the first-pronoun "we" is used. When in doubt, stay with third-person pronouns.

6. Use charts, tables, and graphs.

Tables and charts are important components in technical papers. They convey a lot of information in the shortest time and in minimum space. Label all charts, tables, and graphs sequentially, and give them titles. A common mistake among novice writers is to include tables and graphs but somehow fail to discuss them in the report.

(The following is courtesy of the Department of Chemical Engineering at West Virginia University)

Grammar, Punctuation, and Spelling

It is important to write using correct spelling, grammar, and punctuation. Incorrect spelling, incorrect grammar, incorrect word usage, and incorrect punctuation make a poor impression on the reader. They can deflect attention from quality technical work. There is no reason for incorrectly spelled words in any report. Spell checkers identify incorrectly spelled words for you, and they also identify words that are often confused with each other. You still must proofread carefully, since a spell checker will not identify a correctly spelled incorrect word (*e.g.* "too" instead of "two.").

For those of you who are unsure of the correct use of punctuation, grammar, etc., the web site http://grammar.ccc.commnet.edu/grammar is a good reference.

In general, first person (pronouns "I," "we," "me") should be avoided. The passive voice should be used. ("It was done" instead of "I/we did it.") The passive voice will be flagged by your grammar checker unless you disable that option. Others may tell you not to use the passive voice; however, we think it is more formal, and therefore "better," than the alternative. Addressing the reader should also be avoided. ("You should do this." "Seek medical attention.")

The report should be written as a recommendation, not as if the process is already built (unless it is already built!). Therefore, avoid stating "A 10 m^3 reactor was installed." Instead, write "It is recommended that a 10 m^3 reactor be used."

Avoid using active verbs with inanimate objects. For example, "This report optimizes …" is incorrect, because a report, which is inanimate, cannot optimize. Instead, try "This report contains the optimization of …"

The most common punctuation errors are the omission of commas and the misuse of semi-colons.

Commas must be used to separate introductory phrases and subordinate clauses from the subject of the sentence. For example, there must be a comma in the following sentence before optimization: "On the other hand, optimization yielded …" Similarly, conjunctive adverbs (therefore, however, although) at the beginning of sentences must be followed by commas.

Commas precede coordinating conjunctions (and, but, or) if the clause following the conjunction contains a new subject. For example, a comma is needed before "and" in the following sentence: "The reactor was optimized, and the optimum temperature was found to be 100°C." A comma should not be used in the following sentence because what follows the conjunction refers to the original subject of the sentence: "The reactor was optimized and found to require a temperature of 100°C."

When complete sentences are separated by conjunctive adverbs (therefore, however, although), the conjunctive adverb is preceded by a semi-colon and followed by a comma (for example, "A

three-compressor configuration was investigated; however, the two-compressor configuration was found to be the optimum").

Semi-colons are also used to separate two complete sentences that are written as one sentence. This should be used sparingly, mostly for effect (for example, "A three-compressor configuration was investigated; it was found to be incredibly expensive").

It should be observed that the compound adjective "three-compressor" is hyphenated. Another example is high-pressure steam. This only occurs when the compound is used as an adjective (for example, "High-pressure steam was used" but "The steam used was of high pressure").

Group Reports

Group reports must be edited for consistency. Each group member should read every section and provide feedback to the section authors. Simply assembling individually written sections without editing almost always results in a very poor report. One group member should be designated as the editor. This person should make certain that all figures, tables, equations, etc., are numbered consistently, that font types and sizes are consistent, that formatting such as the indentation spacing, paragraph spacing, justification, etc., are all consistent.

Report Format

The suggested report format is as follows:

Letter of Transmittal

This is a memorandum (if internal) or a letter (if external) to the appropriate person identifying the report. The report is actually an enclosure to this letter. Remember to refer to the original memorandum or problem statement. In order to get the reader's attention, writing several sentences summarizing the bottom line is essential. You should always sign or initial this memo or letter. This letter stands alone. It contains no figures or tables, and does not reference any figures or tables contained within the report.

Title Page

This must include the title, names of all contributors to the report, the business name (class number and name will suffice), and the date.

Abstract or Executive Summary

An abstract or executive summary should start on a new page and nothing else should appear on the same page.

An executive summary is essentially a long abstract. Whereas an abstract is usually less than one typed page, an executive summary may be several pages. An executive summary is usually reserved for a very long report, while an abstract is appropriate for shorter reports. Very long

reports may have executive summaries approaching ten pages. It is probably best for the executive summary to be less than 10% of the total report length. For most of our reports, an abstract is appropriate; however, the year-long, senior design project and the third major may be extensive enough to require an executive summary. Some multi-volume reports may contain both an abstract for each volume and an overall executive summary.

At times, an entire report may be an executive summary plus appendices, usually if the report is short. This is essentially a short report without an abstract. In this case, the executive summary should have the same organization as a full report, without separate section headings. It should include key figures and tables, but need not include as much discussion as a full report. The Results section may be abbreviated, with additional tables and figures well organized in the appendix. A key difference between an abstract and an executive summary is that an abstract stands alone. It contains no figures, tables, only rarely contains an equation, and does not refer to any figures (such as references to a PFD – stream numbers, equipment numbers) or tables contained within the report.

Either an abstract or an executive summary should convey to the reader, in a rapid and concise manner, what you did, what you conclude, and what you recommend. This is for the reader who may not read any further or for the reader who is deciding whether or not to read any further. Summarize the bottom line; do not discuss computational details unless they are unique and applicable beyond the report at hand. In an executive summary (but not in an abstract), do not be afraid to use a few well-chosen graphs, pie charts, or histograms to emphasize your important points, but choose these wisely in order to keep the length of the executive summary down.

These instructions suggest that the contents of the abstract and letter of transmittal are similar. Since both sections are supposed to provide a summary of important conclusions, there will be significant repetition of content. The abstract usually contains more information than the letter of transmittal.

Remember the bottom line!

Table of Contents

This is only necessary for longer reports. At the top of the page, the proper title is "Contents," not "Table of Contents." Regardless of whether you include a table of contents, all pages of your report should be numbered, preferably at the top right corner or top center (the latter permits easy two-sided copying). Number, indent, or otherwise indicate sections, subsections, etc.

Introduction

This is for the reader who continues past the abstract. The introduction is a one- or two- paragraph summary of what was assigned, what was done, and (very briefly) how it was done. A summary of the constraints on the problem is appropriate, as well as some perspective on the specific problem in the context of the larger business picture. There should be no results or conclusions in the Introduction section.

Results

The Results section states what was found. It is usually presented without detailed explanations, which are in the Discussion section.

The following are essential components of a results section:

1. Labeled and dated process flow diagram (PFD) – Chemcad PFDs are unacceptable.
2. Stream flow tables – These must include temperature, pressure, phase, total mass flowrate, total molar flowrate, and component molar flowrates for every numbered stream.
3. Manufacturing cost summary – Yearly revenue and expense (income from product sales, expenses for raw materials, utilities [itemized], equipment costs if calculated as an annual cost, personnel, etc.) must be included.
4. Investment summary – The cost to build and install plant now (if appropriate to goals of problem) is required. This should be itemized by piece of equipment.
5. Equipment summary – A listing of equipment to be purchased and installed, with specifications is required. This could be combined with item 4 if the list is not too long.

The above should not simply appear without description. This section is held together by prose that provides the reader with a road map through the tables and figures of item 1 – item 5 above. Whether you use figures or tables for the above is your choice. Generally, a figure is used when the trends or relative relationships are more important than the actual numbers. You must decide whether a figure or a table conveys your intent more efficiently. It is also important not to be redundant – do not have a figure and a table illustrating the same point. Make a choice!

Mention the process flow diagram early in the prose of this section, and refer to it often.

Discussion

The discussion section contains explanations of the results. It explains how the results were obtained and what they mean. However, a detailed log of how calculations were done should be avoided. This section is for the reader who still wants more information and is willing to read still further. Here you discuss the reasons for making choices and the reasons for discarding alternatives. This is where you discuss any optimization that was done. You might also discuss non-routine or unique computational aspects.

For our junior designs, a sub-section pertinent to each class is also appropriate.

Conclusions

Nothing new is presented in this section. You should reiterate your important conclusions, which may have already been stated in the abstract, the executive summary, and/or the letter of

transmittal. Usually these will involve economics and process modifications. Be concise and clear; avoid lengthy paragraphs. Once again, remember the bottom line!

Recommendations

This section includes recommendations for further action and/or further study. If there are few conclusions and recommendations, these two sections can be combined. Avoid recommendations that are "pie in the sky," like finding a better catalyst. Also, avoid recommendations that will clearly be studied in subsequent semesters, such as to study the separation section.

References

There are two ways this section can be presented. If you put it at this location in the report, it should only contain references cited in the sections of the report preceding this section. References may be listed by number, and cited in the text by this number, either as a superscript or as a number in parentheses or in brackets (preferred). Another method is to cite the reference by the author and year. You should consult the end of a chapter or the end of the book in any of your chemical engineering texts for the correct citation format. If you choose this method, then any references to data sources appearing in the Appendix should appear on the page on which that calculation is presented.

No references should appear that are not specifically cited in the report. Software should never be referenced unless you use it as a source of data, as might be the case with Chemcad.

The other alternative is to place the reference section at the very end of the report, and cite all data references in the Appendix in the manner described above for the body of the report.

Figures taken from books or the web must be cited. Failure to do so is considered plagiarism.

Other Sections

Sometimes, especially for longer reports, specialized additional sections are included, such as: Safety, Assumptions, Environmental Concerns, Risks, etc. The author should check with the prospective users of the document to determine the appropriate additional sections and what these sections should include.

Appendix

This section contains your detailed calculations, computer programs, etc. A specific Table of Contents for the appendix is essential so the reader can easily find a particular calculation. Therefore, pages in the appendix must also be numbered. This numbering may be continuous with the main report, or you may start over. You may also choose to start numbering over for each appendix. If you do the latter, be sure to use a letter indicating the appendix in which the page is contained (*e.g.*, page B-5 means page 5 of Appendix B). Calculations may be hand written, but should be legible and easy to follow. Include a copy of the full Chemcad report (including the flowsheet) for your final case at the end.

Other Aspects of the Report

Figures and Tables

Whichever you choose, figures and tables have a specific format. They are numbered in the order in which they appear in the report. They should be embedded in the text where they are cited or appear on the pages immediately following where they are first cited in the prose. Figures and tables are cited by their name, not by a location (above, below). If a figure or table is not cited, it should not appear in the report. Tables have a title at the top. Figures have a caption at the bottom, which, if a graph, should not simply repeat the axes (unacceptable: *y* vs. *x*; good: plot illustrating ...). Nothing should appear at the top of a figure. The fact that most software puts a figure title at the top is not a reason for you to have a title at the top. If you put a title at the top of a figure for an oral presentation, the title should be removed for the version used in the written report. There are only figures and tables. Nothing is labeled a graph, sketch, etc. When you refer to a figure or table, Figure #, Stream #, or Table # should be considered a proper name and, therefore, capitalized. Finally, use something other than colors in figures and tables to distinguish between items (different shading, different symbols), since colors are not copied well. It is also strongly suggested that the default gray background on Excel plots be changed to white. Also, on Excel plots, what looks good in color in PowerPoint looks terrible when copied in black and white. Lines and symbols should be black monochrome.

Figures can be scatter plots, bar charts, or pie charts. Use scatter plots when the independent variable (*x*-axis) is quantitative, *e.g.*, temperature. Use bar charts when a non-quantitative independent variable is being plotted, *e.g.*, cost (*y*-axis) vs. case study number or piece of equipment (*x*-axis). Use pie charts when the relative amounts of quantities are being compared, and the quantities form a whole, *e.g.*, distribution of capital costs between individual equipment.

When pie charts are used, the total quantity (corresponding to the whole pie) should be in a legend or outside the pie. Each slice should contain the percentage of the pie. When graphs are used, do not use "line charts" (where the *x*-axis has tick marks at irregular intervals) when the independent variable is numerical. Instead, use scatter plots. Numbers on axes should all have the same number of decimal places. Increasing magnitude should always be to the right (*x*-axis) and up (*y*-axis). If using grid lines in scatter plots, make sure to use both horizontal and vertical lines. Gridlines help the reader identify the value of data points; however, grid lines should be used sparingly.

Avoid using 3-dimensional bar charts or scatter plots, especially when only two variables are used, *i.e.*, if there is only one independent variable. Three-dimensional figures are very difficult to read. That your software uses 3-d plots as a default option is not a good reason to use them.

For axes, use ranges in appropriately round numbers, *e.g.*, from 0 to 20, not from 3.47 to 19.993. If possible, include zero in your scale for the proper perspective.

For plot axes and tables of figures, use the appropriate number of significant figures. The numbers appearing on a figure axis should all contain the same number of decimal places.

When columns of figures appear in a table (and these should be used sparingly), each figure in the column must have the same units. If a total is shown, it should be the sum of all numbers above it. Columns should be lined up by the decimal point or by where the decimal point would be.

The following terminology is used to define the orientation of a table or figure on a page. "Portrait" refers to the way typed text appears, with the long dimension of the paper vertical. This page is in "portrait." Landscape refers to text, figures, or tables appearing with the long dimension of the paper horizontal. Landscape figures and tables should always be bound facing outward, *i.e.*, the top of the figure or table is closer to the binding.

It is expected that numbers, symbols, and unit abbreviations will be used in the written report. Learn to use the symbols and the equation editor in your word processor, and learn to insert symbols, superscripts, and subscripts in plotting software. For example, use 5°C, not five degrees C. Write $25 million/yr instead of 25 million dollars per year. Include lead zeroes in all numbers less than one, *e.g.*, 0.25 instead of .25. Use 10 m^3 instead of 10 m^3 in both the report and on figures. Items like m^3 are considered unacceptable for reports in this Department.

When reporting large costs, millions of dollars, for example, present no more that three or four significant figures. Just because your spreadsheet reports ten or more significant figures is no reason to present all of them. It is ludicrous to present a preliminary design down to the penny. Remember that people do not expect dollar figures to be in scientific notation. One million dollars should appear as $1 million or $1,000,000.

Equations

Equations may be used in different parts of a report, as needed. The proper format for equations is as follows. Equations are usually centered. All equations are numbered serially, with the equation number, usually right-justified. Only the number appears, either in parenthesis or in brackets. Just as with figures and tables, equations should be cited by number. Similarly, Equation # is a proper name and should be capitalized. It is not usual to refer to an equation by number before it appears. Correct and incorrect examples are presented below.

incorrect:

The relationship for the heat capacity difference is given by Equation 1.

$$C_p - C_v = \frac{\alpha^2 VT}{\kappa_T} \qquad \text{(Equation 1)}$$

For an ideal gas, this reduces to Equation 2.

$$C_p - C_v = R \qquad \text{(Eq. 2)}$$

correct:

The relationship for the heat capacity difference is:

$$C_p - C_v = \frac{\alpha^2 VT}{\kappa_T} \tag{1}$$

For an ideal gas, Equation 1 reduces to:

$$C_p - C_v = R \tag{2}$$

It is also considered improper format to include *, ×, or · to indicate multiplication in an equation or anywhere else in a report, except as noted below for exponents. Therefore, $PV = nRT$ is correct. The following are incorrect: $P \times V = n \times R \times T$, $P \cdot V = n \cdot R \cdot T$, $P*V = n*R*T$. Similarly, these symbols should be avoided in units.

It is also incorrect to use the symbol ^ for an exponent in equations or anywhere else in a report.

The terms and symbols used in all equations must be defined, either immediately after the equation or in a comprehensive nomenclature section appearing either immediately after the table of contents or at the end of the report, following the reference list.

Finally, when using exponents, it is not correct to use E format. So, 6.02E23 is incorrect. 6.02×10^{23} is correct.

How Engineering Reports Are Used

An engineering report is essentially never read in its entirety by a single person. Most of the users of these documents are too busy to sit down and read every word. However, you must assume that each word will be read by someone, sometime, and that you will not be around to explain any ambiguous passages. Your report must be useful to the following types of readers:

1. The person who has only a few minutes to read the report. This is often an intelligent, non-technical person who controls millions of dollars. You must be sure that this person can pick up your report, immediately find the important answers, *i.e.*, the "bottom line," and make the right decision. If the answer is not prominently presented in the Executive Summary or the Abstract, this type of reader will judge your report to be of little value. You cannot afford that judgment.

2. The technical manager. You may assume that this person is a chemical engineer, but you may not assume any specific technical knowledge about the details of your project. This person is busy but may have enough time to read most of the report (but not the appendices). Few engineers will sit down and read a report from beginning to end! One looks for the answers quickly. As soon as these answers are found, one makes a decision and stops reading. Sections might be read in the following order, for example, until the answers are found: Executive Summary, Recommendations, Conclusions, Results, Discussion, Introduction. Different

readers will read the sections in different orders. You must, therefore, take special care to put the information in the correct sections. This is part of the reason why repeating important conclusions in several places in the report (letter of transmittal, abstract, conclusions) is a good idea.

3. The engineer who must use your design. This chemical engineer needs to find details of how you did your calculations and how you reached decisions. The appendices are of special interest to this reader. However, time is of the essence. This reader wants to be able to go immediately to that page or two in your appendices that deals with a specific detail. Without good organization and a good table of contents for the appendices, this is impossible. If this reader cannot find the right information, your effort has been wasted.

4. Others. Many others will try to read your report: mechanical engineers, chemists, environmental activists. Think about these people, too.

What can you do to see if your report meets the needs of these readers? Ask someone who did not author the report to read it, pretending to be one of these readers. A friend, a roommate, or a fellow student might qualify. If they cannot understand what you are trying to say, you have a problem. Remember, if the reader does not find what he or she is looking for or cannot understand what you are trying to say, it really does not matter whether the information is in the report somewhere or not or whether the results are of high quality. And remember, reports written at the last minute will be obvious to an experienced reader. A report with typographical errors, misspelled words, grammar faults, or confusing phrasing is insulting to the reader. That is not the impression that you want to leave with your clients, supervisors, or fellow engineers.