West Virginia University
Department of Chemical Engineering

Written Design Reports

The format for presenting a written design report differs from that of a laboratory report. A laboratory report is more of a scholarly endeavor in which a scientific story is told starting with theory, proceeding through results, discussion, and conclusion. It is usually assumed that the reader will read the entire report. In a design report, the most important conclusions should appear early in the report, with more detail presented for the reader who reads further into the report. Such is the way of business, where you must effectively convey the bottom line to someone who may not have the time to read the entire report.

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 rule. Others may tell you to avoid use the passive voice; however, we think it is more formal, and therefore "better" than the alternative.

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://www.ccc.commnet.edu/grammar/ is a good reference.

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 or tables, only rarely contains an equation, and does not refer to any figures 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 following are essential components of a results section:

1. Labeled and dated process flow diagram (PFD) -- Care should be taken to bind oversized PFDs so that they can be easily unfolded and read.
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 #4 above 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 #1-#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.

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 appear on the pages immediately following where they are first cited in the prose. 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.

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. 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).

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, *i.e.*, 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 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.

In more sophisticated designs, like the senior majors, you may evaluate several cases. Graphical or tabular comparisons of these cases are essential. In this instance, components 1-5, above, should be followed for the case you finally recommend unless you are instructed to submit a base-case calculation first.

It is perfectly acceptable to use numbers in the written report. They are expected in a technical report, as are symbols. Learn to use the symbols in your word processor. For example,

use 5°C, not five degrees C. Include lead zeroes in all numbers less than one, *e.g.*, 0.25 instead of .25. When columns of figures are used (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.

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.

Discussion

Now you go into more detail. 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 dollars 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.

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 wit 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.

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:

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

For an ideal gas, Equation 1 reduces to:

$$C_p - C_v = R \qquad (2)$$

Other

In figures, tables, and text, you must use a degree symbol for temperatures in Celsius and Fahrenheit, and you must include subscripts and superscripts where appropriate. It is your responsibility to learn to use the software appropriately.

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.